Government of Nepal
Ministry of Land Reform and Management

National Land Use Project

Mid Baneshwor, Kathmandu
Nepal

FINAL REPORT

on

Preparation of VDC Level Land Resource Maps (Present Land Use Map, Soil Map, Land Capability Map, Land Use Zoning Map, VDC Profile and Superimpose of Cadastral Layers), Database and Reports

PACKAGE–27

GANGOBALIYA VDC

of

Rupandehi District

F/Y: 2073/74

Submitted by:

ADMC Engineering Pvt. Ltd.

Shreenagar Marg, New Baneshwor, Kathmandu, Nepal
P.O. Box No.: 24083, Kathmandu
Phone: 01-4782350, Fax: 977-01-4782350
Email: adm.carto.consult@gmail.com
Web : www.admcengineering.com

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Many difficult hours were poured into this report to make it what it is now and we realize that there is enough room for improvement. However, we are confident that this report will be useful both in its range and extent, not only to National Land Use Project in its planning for future, but also for all the map/data users at large.

ADMC Engineering Pvt. Ltd.

EXECUTIVE SUMMARY

The Preparation of VDC/Municipality Level Land Use Maps, Database and Reports of **Gangobaliya** VDC of **Rupandehi district** has been carried out of which the mapping has been done in 1:10,000 scale. These components have been performed under the project "**Preparation of VDC Level land resource maps (Present Land use Map, Soil Map, Land Capability Map, Risk Layers, Land Use Zoning Map, VDC Profile and Superimpose of Cadastral Layers), database and reports**."

The land use classification has been carried out as per the essence of National Land Use Policy 2072. Based on the Specification, Land Use has been categorized in 11 different classes: Agriculture, Forest, Residential, Commercial, Industrial, Public Service, Mine and Minerals, Cultural and Archeological, Riverine and Lake Area, Excavation Area and Other. The data prepared for the VDC reveals that 89.71% area is covered by agriculture followed by residential with 3.09%. Commercial area covers 0.97% area of the VDC. Public services cover about 1.55%, Riverine and lake cover 2.78%, Industrial cover 1.86%, Cultural and Archeological covers 0.02% and forest cover 0.01% of the area.

USDA Soil classification scheme (USDA 2003) has been followed for classification of soil pits from the category of Order to series linking with world Reference Base for Soil resources (FAO 1998) as per the Specification. In this concern, LRMP has identified seven categories of soils such as entisols, inceptisols, spodosols, mollisols, alfisols, ultisols, and aridisols at order levels, twenty-one at sub-order 3 of each order. Some of them are aquents, aquepts, orthods, aquolls, aqualfs, udults and so on. Similarly, forty-one categories are identified at great-group level representing 2 of each sub-order and 110 categories at sub-group level. The data prepared for soil revealed 5.26% of entisols, 21.05% of inceptisols 5.26% of mollisols and 63.16% of vertisols in the VDC while remaining being the water bodies.

Similarly, Capability Mapping has been done based on the spatial analysis of soil, climate, and topographic parameters, to differentiate the land in arability class and deficiency type and sub-type unit by using GIS tool as per the specification. A multi-criteria evaluation rule has been developed to classify land units based on soil parameter, fertility, erosion susceptibility, terrain constraints and surface drainage (wetness). The data prepared for land capability in terms of arability classified (83.08%) consists of land capability Class I AU/1R, 15.14% land has I Au /1 class and 1.78% of land is II Ah/5sd Class in the VDC.

As per the Updated NLUP 2072, risk layers for evaluation of risk prone areas have been delineated which can supplement in the Land Use Zoning Process. There exist diversities in

Risk type. Land use mapping focuses different types of risk such as fire, flood, landslide, seismic, industrial etc. Similarly, from the view of proximity of occurrences, risk can be hieratically classified as different level: such as High, Medium and Low. Different level have been given to the risk type and its level.

VDC Profile of the VDC has been prepared from the data provided from the VDC office and District Office as well as the data from other relevant sources.

Finally, Land Use Zoning has been performed as per the Updated Specification of National Land Use Policy 2072 under which 11 categories has been mentioned: Agricultural Zone, Residential Zone, Commercial Zone, Industrial Zone, Forest Zone, Public Use Zone, Other Zone, Mine and Minerals, Cultural and Archeological, Riverine and Lake Area and Excavation Area (Construction Materials). The data prepared for Land Use Zoning classified 89.40% is suitable for agricultural activities and hence categorized as agricultural zone. The land under present residential use and potential residential use for future is about 2.85%. The land suitable for commercial activities is about 0.93% only. In this VDC, the forest cover is about 0.01%. Within the agricultural land, most of the land is found suitable for cereal crop, agro-forestry, production, fish farming and cash crop production. For public utility uses, about 4.12% of the land is identified. About 0.20% of land is separated for Industrial development and for existing riverine and lake area, about 2.38% land is identified in the VDC. Also, Cadastral layers as provided by NLUP has been overlaid in Land Use zone.

A. General Background

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List of Abbreviation

Abbreviation	Full Form
DEM	Digital Elevation Model
DGPS	Differential Global Positioning System
DNA	Data Not Available
DOLIA	Department of Land Information and Archive
DTM	Digital Terrain Model
ERDAS	Earth Resources Data Analysis System
FAO	Food and Agricultural Organization
GCPs	Ground Control Points
GDP	Gross domestic Product
GIS	Geographic Information system
GoN	Government of Nepal
GPS	Global Positioning System
Ha	Area in hectare
HQs	Headquarters
IHS	Intensity Hue Saturation
ISRIC	International Soil Reference and Information Centre
IUSS	The International Union of Soil Sciences
KII	Key Informants Interview
Km	Kilometer
LC	Land Cover
LP	Land Policy
LRMP	Land Reform Mapping Project
LU	Land use
LULC	Land use and the land cover
LUTs	Land Utilization Types
m	Meter
MCA	Multi-Criteria Analysis
mm	Millimeter
MMU	Minimum Mapping Unit

MoLRM	Ministry of Land Reform and Management
MSS	Multi Spectral Scanner
MUTM	Modified Universal Transverse Mercator
NDVI	Normalized Difference Vegetation Index
NGOs	Non-Governmental Organizations
NLUP	National Land Use Project
OM	Organic Matter
PAN	Panchromatic
PCA	Principal Component Analysis
PH	Power of Hydrogen
RGB	Red Green Blue
RMSE	Root Mean Square Error
RPC	Rational polynomial coefficient
RS	Remote Sensing
RSM	Rigorous sensor Model
Sil	Silty Loam
SL	Sandy Loam
ToR	Terms of Reference
UNESCO	United Nation Educational, Scientific and Cultural Organization
USA	United States of America
USDA	United States Department of Agriculture & Soil Conservation
UTM	Universal Transverse Mercator
VDC	Village Development Committee
VHRS	Very High Resolution Satellite
WGS84	World Geodetic System 84
WRB	World Reference Base
WRBS	world Reference Base for Soil Resources

1. Background

Land use planning is the systematic assessment of the land and water potential, alternatives for land use and economic and social conditions in order to select and adopt the land use options (FAO, 1993). Land is the only natural resource that is at the centre of all economic activities. The land use/ land cover pattern of a region is an outcome of natural and socio – economic factors and their utilization by man in time and space. Land is becoming a scarce resource due to immense agricultural and demographic pressure. Hence, information on land use / land cover and possibilities for their optimal use is essential for the selection, planning and implementation of land use schemes to meet the increasing demands for basic human needs and welfare. In the context of rapidly growing human population, the demand for land for agriculture, grazing, wildlife, tourism, and urban development, is conflicting and greater than it is available.
About 60% of the active populations of Nepal depend upon the agriculture and related activities like forestry and pasture. These activities constitute about 97% of the total land use area. Since the country is producing insufficient food, the demand for arable land is increasing. In addition, the problem has become much severe due to increased land demand for urbanization, industrial uses, infrastructures and forestry and pasture. The forces that would change their availability like climate change and natural disaster; and need to preserve the land quality and availability for the future generation is challenging task. Therefore, land use planning is required to best utilize the limited land resources based on inherent qualities. This will address the issues of food security, land degradation, forest and wild life protection, hazard mitigation, and physical development. Except sporadic attempts for the urban areas (GoN, 2002), Nepal has not practiced land-use planning for the country as a whole, although attempts were made for balanced use of country's existing natural resources in the past through different polices and national planning efforts. The Ninth and Tenth Five Year plans (2002/03 - 2006/07) of Nepal highlighted on the formulation and implementation of land use policy to discourage to use arable land for non-agricultural purposes. Comprehensive local level (Village or Municipality level) land use planning has been felt necessary by the Government of Nepal to address the issues of food security, land degradation, forest and wild life protection, hazard mitigation, and physical development. In this scale of land use planning, basic information of the current land use, soil characteristics, land capability, land system, land use zoning, and cadastral maps as well as that of people and service are required. In the Tenth Five Year Plan, implementation of land use program was included. So, the National Land Use Project (NLUP) initiated its work to update existing land resources maps, to prepare land zoning data and to prepare profile of district level and to create land use data, to prepare land zoning data, to prepare profile for Village Development Committees/municipalities level and to superimpose cadastral map. This project of selected VDCs of Rupandehi district is a part of the series of functions to achieve the objectives of the NLUP. Analysis and interpolations of high resolution satellite images supported with field observations for the soil data and other related details for the preparation of the VDC level existing land use maps, soil maps, land capability maps, land use zoning maps in large scale using Remote Sensing and Geographic Information System techniques is the present state of art to execute the project. This spatial information is intended to provide valuable insight to the land resources planners, urban/infrastructure planners, environmentalists, foresters, scientific researchers as well as local municipal authority and other agencies to implement effective land use plans.

The National Land-Use Project, (hereinafter referred as ‘NLUP’) under the Ministry of Land Reform and Management, Government of Nepal offered the task to prepare VDC level present land use maps, soil maps, land capability maps, land use zoning maps, land hazard maps, Cadastral Superimpose and profile, and databases and reports for the Package 27’s 17 VDCs; Bagaha ,Basantapur, Bodabar, Chhipagadh, Chhotki Ramnagar, Chilhiya, Dhakadhai, Gangobaliya, Harnaiya, Hatipharsatikar, Hatti Banagai, Mainahiya, Padasari, Pajarkatti, Patkhauli, Pokharbhindi and Siktahan. VDCs of Rupandehi District to ADMC Engineering Pvt. Ltd.

2. Objectives

The broad objective of National Land Use Project (NLUP), Package 27, (2073/074 fiscal year) is to prepare of Village Development Committee (VDC) level Land Resource Maps (present land use map, soil map, land capability map, land use zoning map and preparation of profile for land use zoning and cadastral layer superimpose), Database and Reports Bagaha ,Basantapur, Bodabar, Chhipagadh, Chhotki Ramnagar, Chilhiya, Dhakadhai, Gangobaliya, Harnaiya, Hatipharsatikar, Hatti Banagai, Mainahiya, Padasari, Pajarkatti, Patkhauli, Pokharbhindi and Siktahan VDCs of Rupandehi district of Nepal. In order to fulfill the broad objective, the present study aims to prepare a present land use map of Gangobaliya VDC based on high resolution satellite image (WorldView-2) and detailed field survey. Therefore, the main objective of the study is:

a) Preparation of VDC level present land use maps,
b) Preparation of VDC level soil maps,
c) Preparation of VDC level land systems maps,
d) Preparation of VDC level land capability maps,
e) Preparation of VDC level land use zoning maps,
f) Preparation of VDC profile for land use zoning,
g) Superimposition of cadastral layers with land use zoning maps and
h) Preparation of Land Hazard Mapping for land use zoning.

Details of each of the task are described in respective chapters.

3. Project Area

The project area under this working package consists of seventeen VDCs of Rupandehi District.

VDC Name	Area(Ha)
Bagaha	830.9342
Basantapur	969.4481
Bodabar	1570.11
Chhipagadh	1075.476
Chhotki Ramnagar	947.4018
Chilhiya	854.9348
Dhakadhai	1204.768
Gangobaliya	1285.807
Harnaiya	1106.163
Hatipharsatikar	1001.772
Hatti Banagai	1125.703
Mainahiya	1110.607
Padasari	933.8526
Pajarkatti	735.4455
Patkhauli	980.6107
Pokharbhindi	1036.242
Siktahan	1858.638

Location map of the Gangobaliya VDC in Rupandehi district given below in Figure 1.

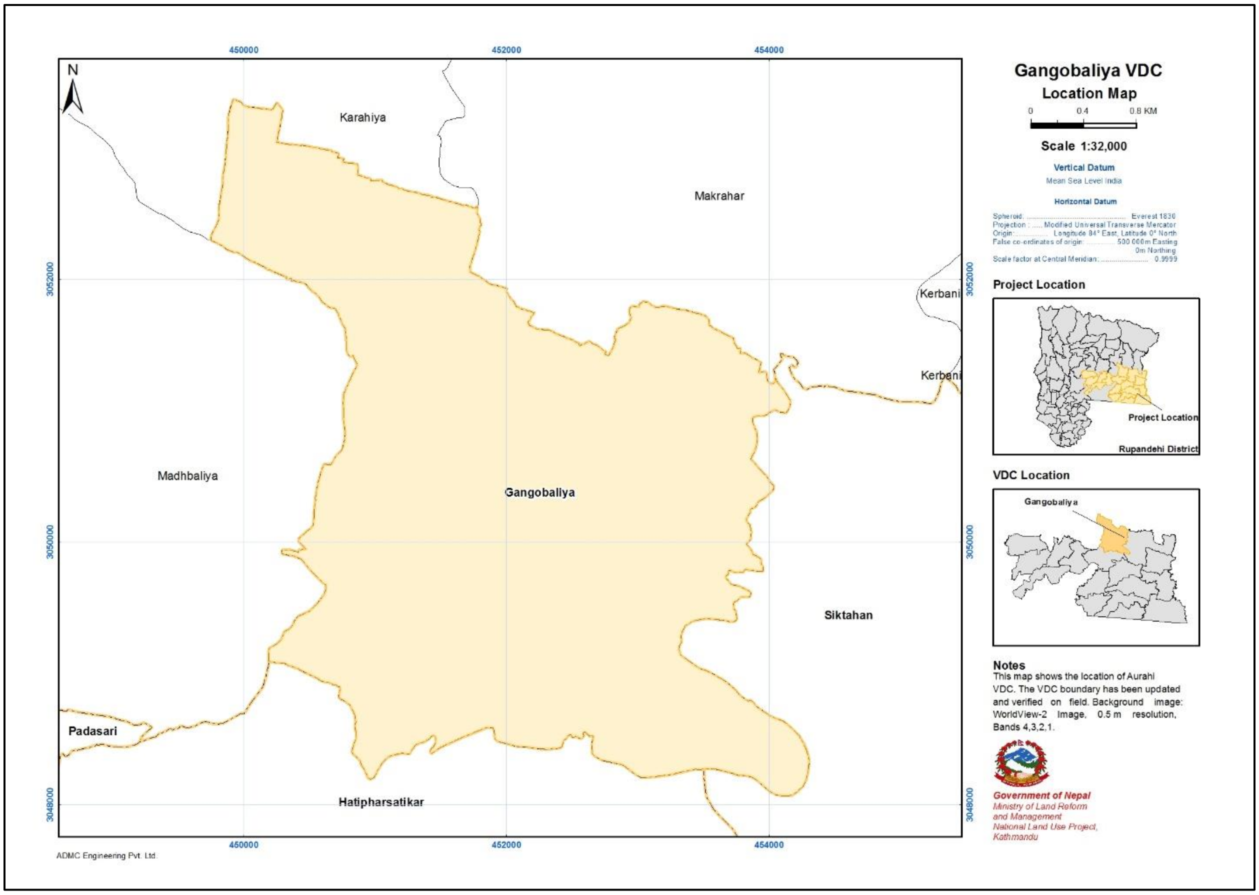

Figure 1: Location Map of Gangobaliya VDC in Rupandehi District

B. Present Land Use

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Chapter -1
INTRODUCTION

1.1. Background and Rationale

Background: Land is the only natural resource that is at the centre of all economic activities. An inventory of land, skillfully classified according to various economic uses, has been an important database for governments, planners and policy makers for a long time. At the country level, these databases are being produced using available resources and reflecting local needs. Studies have shown that there remain only few landscapes on the Earth that is still in their natural state. Due to anthropogenic activities, the earth surface is being significantly altered in some manner and man's presence on the Earth and his use of land has had a profound effect upon the natural environment thus resulting into an observable pattern in the land use/land cover over time.

Land Cover (LC) is defined as the observed bio/physical cover of the earth's surface (Gregorio & Jansen, 2005). It refers to the type of feature present in the land (but not limited to the land because, the dispute about whether it covers the water area or not is normalized by scientific community, who accept, in practice, water area also under land cover) (FAO, 2005). Land use (LU) relates to the human activity or economic function in a specific piece of land. LU demonstrates the economic activities of an area. It can also be considered as to reflect the degree of human activities directly related to land and making use of its resources or having an impact. LC can described in terms of biophysical component of a particular area where as LU is a functional unit of the LC. Many of the LU operations lead to the change in LC, which is the consequence of interactions between the natural environment and the human activities. Land use and the land cover (LULC) are the complex mixture of natural and anthropogenic influences and is the composition and characteristics of land surface elements (Cihlar, 2000). Land is a scarce and precious resource and knowledge of the land use/cover has become increasingly important for the national planning.

Land is one of the most important natural resources of the earth. Conducting developing activities of a nation is not possible without adequate information on many complex interrelated aspects of its activities, particularly land, in order to make appropriate or effective decision by using land in sustainable manner. If a nation cannot make effective decision on particular land, the use may turn into misuse/overuse, which finally results in degradation and deterioration of land. Thus, for the sustainable land resource management is required to overcome the problems of haphazard, uncontrolled development, deteriorating environmental quality, loss of prime agricultural lands, destruction of important wet lands, and loss of fish and wildlife habitat (Anderson, Hardy, Roach, & Witmer, 1976).

Sustainable land resource management requires a systematic approach towards land utilization planning, land use zonation and assessment of land performance when used for specific purpose (Joshi, 2007). Land use data are needed in the analysis of environmental processes and problems that must be understood if living conditions and standards are to be improved or maintained at current levels. Its other application includes residential-industrial-commercial site selection, population estimation, tax assessment, development of zoning regulation etc. (Anderson, Hardy, Roach, & Witmer, 1976).

Rationale: The land use/land cover pattern of a region is an outcome of natural and socio – economic factors and their utilization by man in time and space. Land is becoming a scarce resource due to immense agricultural and demographic pressure. Hence, information on land use / land cover and possibilities for their optimal use is essential for the selection, planning and implementation of land use schemes to meet the increasing demands for basic human needs and welfare. This information also assists in monitoring the dynamics of land use resulting out of changing demands of increasing population. Land use and land cover change has become a central component in current strategies for managing natural resources and monitoring environmental changes. The advancement in the concept of vegetation mapping has greatly increased research on land use land cover change thus providing an accurate evaluation of the spread and health of the world's forest, grassland, and agricultural resources has become an important priority.

Viewing the Earth from space is now crucial to the understanding of the influence of man's activities on his natural resource base over time. In situations of rapid and often unrecorded land use change, observations of the earth from space provide objective information of human utilization of the landscape. Over the past years, data from Earth sensing satellites has become vital in mapping the Earth's features and infrastructures, managing natural resources and studying environmental change.

Remote Sensing (RS) and Geographic Information System (GIS) are now providing new tools for advanced ecosystem management. The collection of remotely sensed data facilitates the synoptic analyses of Earth - system function, patterning, and change at local, regional and global scales over time; such data also provide an important link between intensive, localized ecological research and regional, national and international conservation and management of biological diversity (Wilkie and Finn, 1996).

Therefore, attempt has been undertaken to map out the present status of land use in VDC level for the whole country by the National Land Use Project (NLUP).

Land is one of the important and precious natural resources of the earth surface. The demands for arable land, grazing, forestry, wild-life, tourism and urban development are greater than the land resources available. Hence, land–use planning for making the best use of the limited land resources is inevitable. Land-use planning is the systematic assessment of land and water potential, alternatives for land use and economic and social conditions in order to select and adopt the best land–use options (FAO, 1993). Except sporadic attempts for the urban areas, Nepal has not practiced land-use planning for the country as a whole, although attempts were made for balanced use of country's existing natural resources in the past through different policies and national planning efforts.

Land-use planning can be applied at three broad levels: national, district and local. Local level planning is about getting things done on particular areas of land – what shall be done, where and when, and who will be responsible. It requires detail basic information about the land, the people and services at local level. However, Nepal has only regional level data base on land use, land system and land capability which were produced by Land Resource Mapping Project (**LRMP**, 1983/84). Realizing this fact, the Ministry of Land Reform and Management of Government of Nepal established the **National Land Use Project** (**NLUP**) in 2057/058 fiscal year to generate the necessary data bases on the land resources of the country.

In the first phase, the National Land Use Project of Nepal had initiated several projects at district level and prepared **Land Resource Maps and Database** at 1:50,000 scale for the whole Nepal. It had also prepared same kinds of maps and database for Kirtipur, Lekhnath, Madhyapur Thimi and Bhaktapur municipalities at larger scales. Finally, NLUP was mandated to prepare land resource maps of Village Development Committees (VDCs) of Nepal for local level planning through outsourcing modality. Up to 2068/069 fiscal years, NLUP has completed preparation of land resource maps and database for all VDCs of Chitawan district and Nawalparasi Districts and one VDC each for Kavre (*Panchkhal VDC*) and Tanahu (*Anbu Khaireni VDC*) District as well. These digital data base includes VDC level present land use, soil, land capability, land use zoning, cadastral layers and VDC profile with bio-physical and socio – economic data base.

Previously, on 16th Baisakh 2012, the Government of Nepal approved the **National Land Use Policy, 2069**. It is intended to manage land use according to land use zoning policy of the government of Nepal and outlined six zones such as **Agricultural area, Residential area, Commercial area, Industrial area, Forest area and Public use area**. The policy has defined the respective zones as per the land characteristics, capability and requirement of the lands. Further, for the effective implementation of land use zones in the country, the National Land Use Policy, 2069 has clearly directed for an institutional set up of **Land Use Council** at the top to the **District level** and **Municipality/VDC level** at the bottom. It has added further importance to the NLUP projects on preparation of VDC level maps and database.

During the course of implementation some updating and refinement has felt in NLUP 2069. As a result, GON came up with NLUP 2072. The following land use categories has been designated for present land use mapping or land use zoning task. Following list exhibits the corresponding codes used for each of the classes and the class itself.

- AGR Agriculture
- FOR Forest
- RES Residential
- COM Commercial
- IND Industrial
- PUB Public Service
- MIN Mine and Minerals
- CULARCH Cultural and Archeological
- HYD Riverine and Lake Area
- EXC Excavation Area
- OTH Other

Following NLUP 2073, the National Land Use Project (NLUP) has awarded the project entitled Package 27: Preparation of VDC level land resources maps (Present Land Use Map, Soil Map, Land Capability Map, Land Use Zoning Map and VDC profile for Land Use Zoning Map and Superimpose of Cadastral Layers), Data Base and Reports of 17 VDCs of Rupandehi District to our consultancy for fiscal year 2073/074. The Package 27 covers 17 VDCs; Bagaha ,Basantapur, Bodabar, Chhipagadh, Chhotki Ramnagar, Chilhiya, Dhakadhai, Gangobaliya, Harnaiya, Hatipharsatikar, Hatti Banagai, Mainahiya, Padasari, Pajarkatti, Patkhauli, Pokharbhindi, Siktahan.

The rational for the preparation of VDC level land use maps by NLUP are:

- Classify land into agricultural area, residential area, commercial area, industrial area, forest area, public use area and other lands as per the policy of the government of Nepal;
- Identification of residential area to provide basic facilities conveniently;
- Classification of agricultural land into maximum comparatively advantageous sub areas on the basis of land characteristics;
- Conservation of the natural resources including forest, shrub, wet lands, hazard prone areas, rivers and rivulets.

1.2 Objective of the Study

The broad objective of National Land Use Project (NLUP), Package 27, (2073/074 fiscal year) is to prepare of Village Development Committee (VDC) level Land Resource Maps (present land use map, soil map, land capability map, land use zoning map and preparation of profile for land use zoning and cadastral layer superimpose), Database and Reports for the package 27 covers 17 VDCs; Bagaha ,Basantapur, Bodabar, Chhipagadh, Chhotki Ramnagar, Chilhiya, Dhakadhai, Gangobaliya, Harnaiya, Hatipharsatikar, Hatti Banagai, Mainahiya, Padasari, Pajarkatti, Patkhauli, Pokharbhindi, Siktahan district of Nepal. In order to fulfill the broad objective, the present study aims to prepare a present land use map of Gangobaliya VDC based on high resolution satellite image (WorldView-2) and detailed field survey. Therefore, the main objective of the study is:

i) To prepare Present Land Use Maps, GIS Database and Reports for the Gangobaliya VDCs at 1:10,000 scales.

Scope:

In order to achieve the above mentioned objectives, the scope of this study includes;

- Perform ortho-rectification of the given satellite image.
- Prepare present Land cover/land use maps in different hierarchical levels for the selected VDCs.
- Design appropriate GIS database logically.
- Discuss the accuracy, reliability and consistencies of data.
- Prepare reports describing methodology, existing land use pattern and model of GIS data base.

1.3 Study Area

The Gangobaliya VDC is covered by Siktahan in the East, Madhbaliya in the West, Makrahar in the North and Hatipharsatikar in the South. The rectangular extent of the VDC is 83°32'8''E, 27°35'51''N, 83°29'27''E and 27°33'1''N. The total population of this VDC is 6966, of which male population accounts for 49.14 percent and female population is 50.86 percent (VDC profile, 2011). However, all the wards vary in area and population size. Total number of household in the VDC is 1172.The area of the VDC is 1285.81 hectares.

This VDC is inhabited by different caste and ethnic groups. Tharu predominates the inhabitants of this VDC accounting 44.57 percent of the total VDC Population. Tharu, Brahman hill, Yadav & Mallaha are other dominant caste and ethnic groups of this VDC.

Economic condition of the people of this VDC largely depends on agriculture. Land is main source of income and capital accumulation and also the major source of employment. Economic condition of the people having large landholding size is better than the others.

The location map of the study area has been shown in **Figure 1.1**

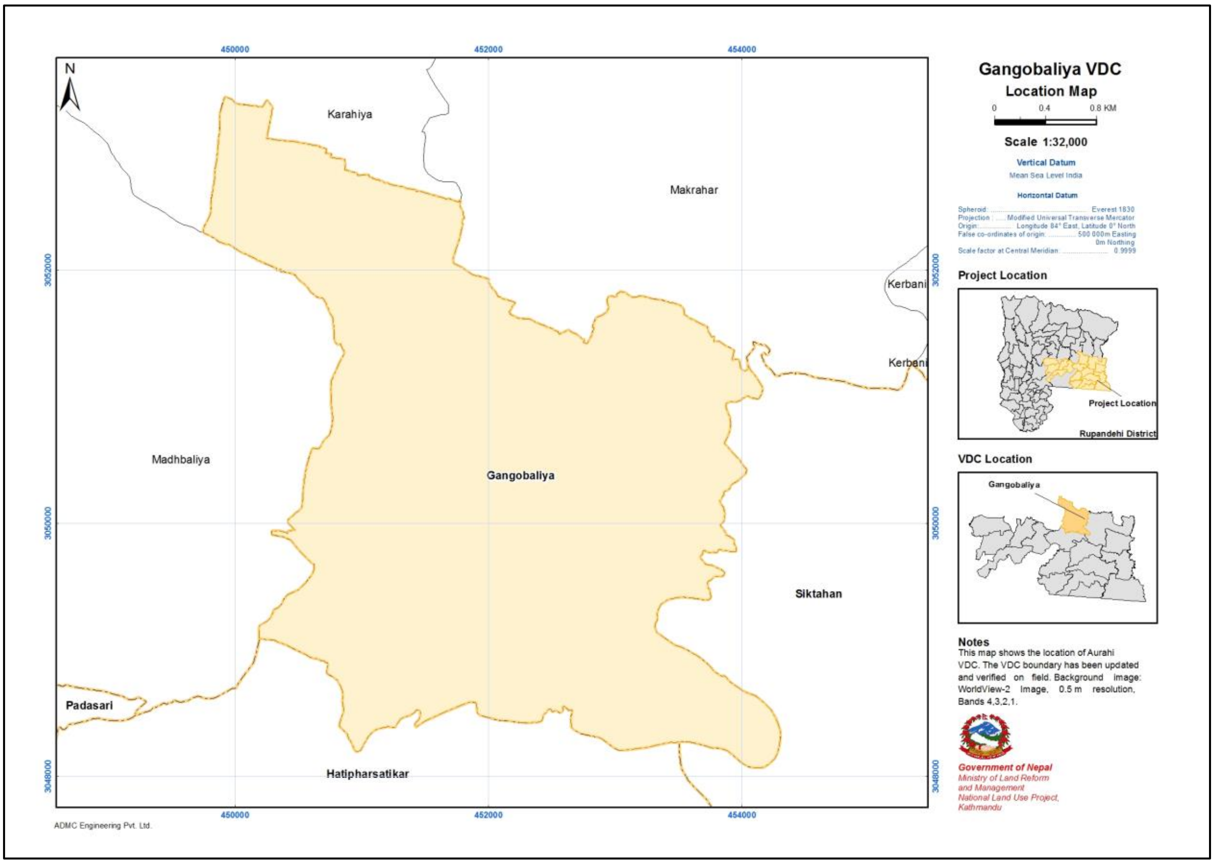


Figure1.1: Location Map of Gangobaliya VDC

Chapter – 2
CONCEPTUAL BASIS OF LAND USE CLASSIFICATION

2.1 Classification System and Criteria

In almost any classification process, it is rare to find the clearly defined classes that one would like. In determining land cover, it would seem simple to draw the line between land and water until one considers such problems as seasonally wet areas, tidal fiats, or marshes with various kinds of plant cover. Decisions that may seem arbitrary must be made at times, but if the descriptions of categories are complete and guidelines are explained, the inventory process can be repeated. The classification system must allow for the inclusion of all parts of the area under study and should also provide a unit of reference for each land use and land cover type (James R. Anderson et el 1976).

There is no one ideal classification of land use and land cover, and it is unlikely that one could ever be developed. There are different perspectives in the classification process, and the process itself tends to be subjective, even when an objective numerical approach is used. There is, in fact, no logical reason to expect that one detailed inventory should be adequate for more than a short time, since land use and land cover patterns change in keeping with demands for natural resources. Each classification is made to suit the needs of the user, and few users will be satisfied with an inventory that does not meet most of their needs. In attempting to develop a classification system for use with remote sensing techniques that will provide a framework to satisfy the needs of the majority of users, certain guidelines of criteria for evaluation must first be established. We have taken the reference of the recently formulated land use policy as guidelines of classification and fit into the model supplied by NLUP.

Land use land cover of an area is largely depend on different factors such as terrain, lithology, soil type, climate, rainfall pattern, socio-cultural practices, relative location etc. land use classification is necessary for the preparation of land use zonation and or for the optimum utilization of a particular land. Classification is an abstract representation of the situation in the field using well-defined diagnostic criteria: the classifiers. It can be defined as: "the ordering or arrangement of objects into groups or sets on the basis of their relationships" (Sokal, 1974). A classification describes the systematic framework with the names of the classes and the criteria used to distinguish them, and the relationship between classes. Classification thus requires the definition of class boundaries, which should be clear, precise, possibly quantitative, and based upon objective criteria (Gregorio & Jansen, 2005).

A classification should be:

- Scale independent, meaning that the classes should be applicable at any scale or level of detail; and
- Source independent, implying that it is independent of the means used to collect information, whether it is through satellite imagery, aerial photography, field survey or using a combination of sources.

Classification systems come in two basic formats, hierarchical and non-hierarchical. Most systems are hierarchically structured because such a classification offers more consistency owing to its ability to accommodate different levels of information, starting with structured broad-level classes, which allow further systematic subdivision into more detailed sub-classes. At each level the defined classes are mutually exclusive. At the higher levels of the classification system few diagnostic criteria are used, whereas at the lower levels the number of diagnostic criteria increases. Criteria used at one level of the classification should not be repeated at another lower level (Gregorio & Jansen, 2005).

Classification system can be a priori or a posterior. In a priori classification system classes are pre-arranged. The use of such a classification assumes that all possible classes can be derived, independent of scale and tools used, from the system. It is the most effective way to produce standardization of classification results among user communities. Posteriori classification system is based upon definition of classes after clustering the field samples that are collected. Since this system depends on the specific area described and is adapted to local conditions, it is unable to define standardized classes.

A land use and land cover classification system which can effectively employ orbital and high-resolution remote sensing image should meet the following criteria (Anderson, Hardy, Roach, & Witmer, 1976). The minimum level of interpretation accuracy in the identification of land use and land cover categories from remote sensing image should be at least 85 percent.

I. The accuracy of interpretation for the several categories should be approximately equal.
II. Repeatable or repetitive results should be obtainable from one interpreter or another and from one time of sensing or another.
III. The classification system should be applicable to extensive areas.
IV. The categorization should permit vegetation and other types of land cover to be used as surrogate for activity.
V. The classification system should be suitable for use with remote sensing image obtained at different times of the year.
VI. Effective use of subcategories that can be obtained from ground surveys or from the use of larger scale or enhanced remote sensing image should be possible.
VII. Aggregation of categories must be possible.
VIII. Comparison with future land use data should be possible.
IX. Multiple uses of land should be recognized when possible.

For land use and land cover data needed for planning and management purposes, the accuracy of interpretation at the generalized first and second levels is satisfactory when the interpreter makes the correct interpretation 85 to 90 percent of the time. For regulation of land use activities or for tax assessment purposes, for example, greater accuracy usually will be required. Greater accuracy generally will be attained only at much higher cost.

2.2 Land Use Hierarchy and Description

Land use practice in any region of the country is governed by physiography, lithology/soil climatic conditions, settlement pattern, cultural practices and socio economic factors. To incorporate diverse land use at the VDC level, comprehensive model should be adopted while making land use inventory. Hierarchical classification system has been recommended in TOR provided by the National Land Use Project (NLUP). This system provides a great flexibility in terms of application through its hierarchical structure. Priori classification system with land use categories as specified in the specification provided by NLUP has been adopted. This ensures the standardization among the classification result. National Land Use Policy 2072 provides the nomenclature of the Land Use classes. The level 1 categories of the land use are:- **Agricultural area, Forest area, Settlement area, Grazing/pasture area, Hydrography Area, Conservation area, Industrial area, Mining and quarry areas, Tourism and recreational area, Wetland area and Cultural heritage.**

2.2.1 Agricultural Land Use

Agricultural land is defined broadly as land used primarily for production of food and fiber. The areas those have been used for agricultural production such as cereals, cash crops, orchards, and so on. Use of land for different agricultural production differs due to physical (e.g. climatic condition, topography, soil) and social/cultural believes of the particular region. LRMP has broadly categorized cultivated land based on physiograpy of Nepal, namely Tarai, Hill, Mountain and Valley cultivation. The Tarai cultivation is further sub divided into Wet land, Dry land and Mix land and Sloping terraces. The Mountain cultivation is further divided into Level terraces, Upland cultivation and Sloppy upland. Similarly, Valley cultivation is divided into Level terraces, Khet land cultivation, Level terraces, Upland/pakho cultivation, Valley slope upland cultivation and Valley riverbeds lower footslope alluvial fans cultivation (alluvial riverbed fans). The Wetland cultivation is further divided into Low khet land cultivation and Upper khet land cultivation-tari khet. Different cropping pattern is presented in level five, whereas cropping intensity is also presented in subsequent chapter. NLUP has provided hierarchy of agricultural land for this study **(Table 2.1).**

Table 2.1: Hierarchy of Agricultural Land Use

Level 1	Level 2	Level 3	Level 4	Level 5 Cropping Pattern	Level 6 Cropping Intensity
				Monsoon- Winter-Dry season	
Agricultural Land Use	**Tarai Cultivation**	• **Wet Land Cultivation**	• **Low Khet Land Cultivation** (Poorly drained with High bond)	As indicated below the table	Intense (75%-100% cultivated) medium(50%-75% cultivated) Light (25%-50% cultivated)
			• **Upper Khet Land Cultivation-TariKhet** (Intermediate land between wet and dry land with well drain soil bonds are lower)		
		• **Dry Land Cultivation** (Upland pakho/ Bhith land Cultivation, Drained, smallest bond height)	Unclassified		
		• **Mixed Land Cultivation** Diyara land cultivation (Commonly found near River where River have change the course)	Unclassified		
			• **Level Terraces Khet Land Cultivation**		

Level 1	Level 2	Level 3	Level 4	Level 5 Cropping Pattern	Level 6 Cropping Intensity
				Monsoon- Winter-Dry season	
	Hill Cultivation	**Level Terraces**	(level khet land with small bond) • **Level Terraces Upland/Pakho Land Cultivation** (level upland with no bond)		
		Slopping Terraces	• **Slopping Upland/ Pakho Land Cultivation** (cultivated on natural slopes		
	Mountain cultivation	• **Level Terraces Upland Cultivation** • **Sloppy Upland**	Unclassified		
	Valley Cultivation	• **Level Terraces Khet Land Cultivation** (Level khet land with small bond) • **Level Terraces Upland/Pakho Cultivation** (Level upland with small bond)	Unclassified	As listed at the end of the table.	
		• **Valley slope upland/Pakho cultivation** (Cultivated on natural slopeS)	Unclassified		

Level 1	Level 2	Level 3	Level 4	Level 5 Cropping Pattern	Level 6 Cropping Intensity
				Monsoon- Winter-Dry season	
		• **Valley Riverbeds(Lower footslope) Alluvial Fans Cultivation** (alluvial riverbed fans)			Light-1 Medium-2 Intense-3

Level 5 for Agricultural Landuse (including cropping pattern)

Maize-Oilseeds-m2	Rice-Potato-r8	Rice-Buckwheat-r14	Barley-Buck Wheat-b1
Maize-Pulses-m4	Rice-Potato-Vegetable-r9	Rice-Wheat-Maize-r15	Fruit-Fruit-f1
Maize-Wheat-m5	Rice-Maize-r10	Bamboo-b3	Fruit-Others-f3
Maize - Vegetable-m6	Rice-Vegetable-Vegetable-r11	Pond for Fish farming-p3	Others-Others-o2
Maize-Millet-m7	Rice-Maize-Vegetable-r12	Beekeepig-b4	Others-Others-others-o3
Maize-Potato-m8	Garlic-Vegetable-v2	Cotton-c3	Maize-Rice-Fallow-m1
Maize-Others-m9	Vegetables-Vegetable-v3	Floriculture-f5	
Pulses-Fallow-p1	Fruit+Potato/ Vegetable/Buckwheat-f2	Barren Cultivable land-b5	
Pulses-Others-p2	Banana-b2	Livestock Grazing area-g2	
Rice-Fallow-r0	Tea-t1	Maize-Rice-Cereal-m3	
Rice-Rice-r1	Coffee-c1	Rice-Others-r13	
Rice-Wheat-r2	Cardamom-c2	Sugarcane-Sugarcane-s1	
Rice-Wheat-Pulses-r3	Amriso-a1	Potato-Vegetable Crops-v1	
Rice-Oilseed-r4	Ginger-g1	Others-o1	

Rice-Pulses-r5	Livestock/Cattle/buffalo Farm-l1	Shrub from non-forest area-s3
Rice-Rice- Vegetable-r6	Turmeric-t2	Vegetables-Others-v4
Rice-Vegetable-r7	Fruits-f4	Sugarcane-Others-s2

2.2.2 Residential Land Use

Residential areas are the built up areas used for housing purposes. Area of sparse residential land use such as farmstead will also be included in this category. This includes annex buildings like cow sheds, garage and farm house etc. This also includes features such as lawn area, well, private path, vegetable farm close to the house etc. The area delineated as residential area by government should also be categorized in this class. Based on density of houses, the residential area is further divided into three categories; dense (> 70%), moderate (40-70%) and sparse (<40%). Similarly, it is also divided in terms of origin of the settlement; old area, newly developed area (unplanned) and planned area such as colony type, parcels plotting area and housing complex etc. Table 2.2 shows the hierarchy of residential land use.

Table 2.2: Hierarchy of Residential Land Use

Level1	Level2	Level3	Level4
Residential	Densely Populated Medium Populated Scarcely Populated (The category were devised based on the local condition; based on the density of houses, dense, moderate and or sparse residential unit areas may be used for > 70 %, 40-70% and < 40% categories respectively)	Old Area, Newly Developed Area (Unplanned) Planned Area (Colony Type, Parcels Plotting Area and Housing Complex, etc.)	Residential cluster-r Apartment/Multi-storeys-a Oldage care place-o Hostel-h Dharashram-d Quarters-q Infracture developed area-i Other-x

2.2.3 Commercial Land Use

Commercial areas are those used predominantly for the sale of goods and services. It consists of the main building, supporting structure and area that serve for commercial purpose. They are often abutted by, residential, agricultural, or other contrasting uses which help define them. It includes shopping centers, hotels, guest houses, shops, private schools, health centers, radio station, petrol pumps etc. Commercial areas are further classified into service areas and business areas. The service areas include public services whereas Business area includes market area where exchange of goods and services occur. Commercial strip are situated along the highway and access route to the highway in this VDC. Table 2.3 shows the hierarchy of commercial land use.

Table 2.3: Hierarchy of Commercial Land Use

Level1	Level2	Level3	Level4
Commercial	Service Areas	Government Service Area(G)	Designated Name
	Business Areas	Market Area with specific categories like Market (M) Hotel (H) Recreation(R) Utility(U) Storage(T) Service (S)	

Commercial Level4

Market Subcategory (M)
Shop - s1
Boutique - b2
Departmental Store - d1
Retail Business - r2
Supermarket - m1

Hotel Subcategory (H)
Hotel - h1
Guest House -g1
Fast-food -f1
Restaurant - r1
Bar - b1
Travel Agency - t1
Other hotel - o1

Hotel Subcategory (H)
Hotel - h1
Guest House -g1
Fast-food -f1
Restaurant - r1
Bar - b1
Travel Agency - t1
Other hotel - o1

Storage Subcategory (T)
Storage house/ area - s3

Recreation Subcategory (R)
Cyber cafe - y1
Cinema Hall - c2
Concert Hall - h2
Theatre - t2
Dance Hall - d2
Night Club - n1
Gaming Hall - g2
Gambling Hall - l1
Exhibition Centre - e1
Gym House - m2
Other Entertaing area - x2

Services Subcategory (S)
Bank/Money Exchange - b3
Private Post office - p1
Private Communication Area - c3
Broadcast Studio - d3
Private School Area - e2
Private Health Service Area - h3
Petrol Pump - m3
Radio Station - r3
Service centre - s2
TV Station - t3
Other Service - o3

Utility Subcategory (U)
Water Reservoir - w1
Hydropower Area - h4
Cable Car - c5
Gas Plant - g3
Oil Storage - o4
Other storage - x3

Government Service Area Subcategory(G)
Agriculture Office - ag
CBS - b5
Civil Aviation - ca
Communication - cm
Court - co
Cultural Office - cu
District Administration office - a1
Doildar - do
Education - en
Electricity office - eo
Forestry office - f2
Health office - h5
Irrigation office - i1
Land Transaction Office -lt
Local Development office - l2
Mining and Geology - mg
Other - o5

Consultancy service area - c4

Business house - b4

Petroleum - pm

Post Office - po

Road Office - r4

Soil Conservation - sc

2.2.4 Industrial Land Use

Industrial areas are the areas where production of goods occurs. It includes a wide array of land uses from light manufacturing to heavy manufacturing plants. It includes area covered by land, house and shed that are used as workshop or processing and manufacturing industry. It consists of factories such as textile, food, brick, timber, vehicle, brewery etc. It is further sub-divided into small scale industry including cottage industry, medium scale industry and large scale industry. Table 2.4 shows the hierarchy of industrial land use.

Table 2.4: Hierarchy of Industrial Land Use

Level1	Level2	Level3	Level4
Industrial	Small Scale Industry(S) Medium Scale Industry(M) Large Scale Industry(L) Special Economic Zone(E) Industrial Estate(I) Other Industrial Category(O)		Designated Name

2.2.5 Forest Land Use

Area covered by vegetation completely or partially and which does not fall under above mentioned category is forest. It consists of area covered by forest, shrub and grazing land/grassland. It is an area with natural or planted trees along with shrubs and grass where the dominant species are trees of various kinds. The forest land are subdivided into level 2 sub types as per the climatic vegetation zone such as tropical (<1000 m), subtropical (1000-2000/2100m), temperate (2000/2100-3000/3100), sub-alpine (3000/3100-4000/4100) and alpine (4000/4100-4500). Similarly the forest land is further subdivided into level 3 categories by cover type as hardwood, coniferous and mixed. On the basis of crown density, forest is classified as dense, sparse, degraded types. Similarly, according to the forest ownership category or use right, it is classified as private, protected, government managed, community, leasehold, collaborative and religious. The hierarchy of forest land use is shown in **Table 2.5.**

Table 2.5: Hierarchy of Forest Land Use

Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
Forest	***Climatic Vegetation Zone:*** **Tropical Forest** (<1000m) **Sub-tropical**	***Cover Type*** **Hardwood** **Coniferous** **Mixed**	***Species Type*** Sal: Shorea R7obusta Or Dalbergla Sissoo etc Pr: Pinus Rosburghii	***Crown Density:*** **Dense** (>70% Crown Density) **Sparse** (40-70% Crown Density)	***Maturity Class*** ***Mature*** To over mature-trees have reached at least estimated	***Forest Ownership Category or Use Rights:*** Private Protected

	(1000-2000/2100 m) **Temperate** (2000/2100-3000/3100 m) **Sub-alpine** (3000/3100-4000/4100 m)		Quercus (Oak) all species Pinus wallchiana) Blue Pine etc	**Degraded** (<40% Crown Density) followed by name of Dominant species (Crown Density/Tree density and Maturity of the forest should be adopted to categorize dense, sparse and degraded forest)	rotation age of saw timber size **Immature** or small timber size materials **Reproduction** New generation to pole size	Government Managed Community Leasehold Collaborative Religious Others
	Alpine (4000/4100-4500m)	**Shrub**				

Shrub or bush has multiple stems and are usually about 5-6m in height. A large number of plants can be either shrubs or trees depending on their growing conditions. Shrubs are generally found in the gardens, narrow gullies, along the river bank as well as on bare unattended land during rainy season. Shrubs are not categorized into lower levels.

2.2.6 Public Services Land Use

Public services are those services which cannot exclude any person from using it under certain terms of condition. Land used for School, College, Hostel, Parks, Airport, Road, Stadium, Picnic spot, and other public service activities are categorized in this class. Public service is further classified on the basis of their functional use into Educational, Security Services, Transportation Infrastructure, Health Service, Recreational facility, Institution and Open Area. School, Colleges and Universities are placed in Educational class. Police station and Fire station are categorized in Security services. Transportation Infrastructure includes Road, Trail, Airport, Bus Park, Railway, Ropeway, etc. Hospital, Health Post, Polyclinic etc are included under Health services. Recreational facility includes Park, Picnic spot, Open Spaces, Stadium, Playground etc. Institutional service includes Government and Public institutions. The hierarchy of public services is presented in Table 2.6

Table 2.6: Hierarchy of Public Service Land use

Level 1	Level 2	Level 3	Level 4
Public Services	Educational	As explained at the end of the table	Designated Name
	Security Services		
	Transportation Infrastructure		
	Health Service		
	Recreational Facility		
	Institution		
	Open Area		

Public Use Level 3

Sub-Category Transportation- T
Highway - h2
Feeder Road - f2
District Road - d3
Local Road - i1
Other Road - o5
Bus park - b1
Airport - a2
Railway - r2
Car Park - c4
Port - p3
Pavement - v1
Cart Track - t3
Other Transportation - x1
Bridge - g3

Sub-Category Education- E
Primary - p5
Secondary - s2
Campus - c5
University - u2
Other educational area- o6

Sub-Category Health - H
Hospital - h3
Nursing Home - n1
Health Centre - c7

Sub-Category Institutional- I
Private Institution - r3
Public Intuition - p6
NGO - n2
INGO - i4
Other intuitional- o8

Sub-Category Recreational- F
Public Theatre- c8
Drama House - d4
Stadium - s3
Playground - g4
Open space - o9
Other - x2
Zoo - z1
Rest-point-Chautari- r4
Museum - m1

Sub-Category Security Service- S
Police Station - p8
Military Area - m2
Armed Force - a3
Other Security- o10

Pharmacy - f3

Polyclinic - i2

Other - o7

2.2.7 Mine and Minerals Area Land Use

The mine and mineral area land use include areas having metallic minerals, non-metallic minerals, gemstones, construction minerals (materials), fuel minerals, decorative and dimension stones and other minerals. The hierarchy of mine and mineral area land use is given below in Table 2.7.

Table 2.7: Hierarchy of Mine and Minerals Land use

LEVEL1	LEVEL2	LEVEL3	LEVEL4	LEVEL5
Mine and Minerals	Metallic Minerals	**Mine_minerals_Construction(Materials) sub_Category (CNSM)**	Licensed	Not Operated So Far
	Nonmetallic Minerals	Sands	Not-Licensed	Currently under Operation
	Gemstones	Cobbles	Reserved	Closed
	Construction Minerals (Materials)	Flaggy quartzite	Banned	Other Operation Status
	Fuel Minerals	Limestone		
	Decorative and Dimension Stones	Pebbles		
	Other Minerals	Quartzite		
		River boulders		
		Schist		
		Slates		
		Other Construction Minerals		
		Mine_minerals_ Decorative and Dimension_sub_Category (DCDEM)		
		Basalt		
		Coloured sandstone		
		Granites		

		Marble		
		Quartzites		
		Other Decorative and Dimension Minerals		
		Mine_minerals_Fuel_Sub_category(FUEL)		
		Coal		
		Hot springs		
		Methane		
		Petroleum		
		Other Fuel Minerals		
		Natural Gas		
		Mine_minerals_GEM_Sub_category(GM)		
		Aquamarine		
		Beryl		
		Garnets		
		Gem		
		Kyanites		
		Quartz crystals		
		Ruby		
		Sapphire		
		Tourmaline		
		Other Gemstone Minerals		
		Mine_minerals_non_metallic_cateory(NM)		
		Clay		
		Dolomite		
		Limestone		
		Magnesite		
		Mica		
		Phosphorite		
		Quartz		
		Silica sand		
		Talc		

		Other Non-Metallic		
		Phyllite		
		Mine_minerals_Metallic_Sub_category(MTL)		
		Iron		
		Copper		
		Zinc		
		Lead		
		Cobalt		
		Nickel		
		Gold		
		Silver		
		Tin		
		Tungsten		
		Molybdenum		
		Uranium		
		Lithium		
		Lepidolite (Mica)		
		Tantalum		
		Bismuth		
		Arsenic		
		Cadmium		
		Chromium		
		Mercury		
		Titanium		
		Other Metallic Minerals		

2.2.8 Cultural and Archaeological Land Use

The Cultural and Archaeological land use include heritage site, durbar square, gadh, archaeological site, cultural site, fort, temple, stupa/monastery, mosque, church, bahal, patis, bihar and other. The hierarchy of Cultural and Archaeological land use is presented in Table 2.8.

Table 2.8: Hierarchy of Cultural and Archaeological Land use

LEVEL1	LEVEL 2
Historical and Archeological	**Historical, Archeological and Religious Sub category**
	Heritage Site (h)
	Durbar Square (d)
	Gadh (g)
	Archeological Site (a)
	Cultural Site (c)
	Fort (f)
	Temple(t)
	Stupa/Monastery(s)
	Mosque(m)
	Church(c)
	Bahal(b)
	Patis(p)
	Bihar(v)
	Other(o)

2.2.9 Riverine and Lake Area Land Use

The Riverine and Lake Area land use include ponds, lakes, canals, glaciers, snow area, wetlands, rivers, spout, wells, kulo, sand and other hydrological area. The hierarchy of Riverine and Lake land use is shown in Table 2.9

Table 2.9: Hierarchy of Riverine and Lake Land use

LEVEL1	LEVEL2
Riverine and Lake Area	Pond (p)
	Lake (l)
	Canal (c)
	Glacier (g)
	Snow Area (s)
	Wetland (w)
	River (r)
	Spout (t)
	Well (e)
	Kulo (k)
	Other (o)
	Sand (d)

2.2.10 Excavation Area Land Use

The Excavation Area land use include areas with cobbles, flaggy quartzite, limestone, pebbles, phyllite, quartzite, river boulders, sands, schist, slates and other excavation materials. The hierarchy of Excavation Area land use is shown in Table 2.10

Table 2.10: Hierarchy of Excavation Area Land use

LEVEL1	LEVEL2	LEVEL3
Excavation (Construction Materials) Area	Cobbles	Licensed
	Flaggy quartzite	Not-Licensed
	Limestone	Reserved
	Pebbles	Banned
	Phyllite	
	Quartzite	
	River boulders	
	Sands	
	Schist	
	Slates	
	Other Excavation Materials	

2.2.11 Others Land Use

Other land use include types of land that does not belong to the above mentioned categories. Such type of lands are: grass land and its various forms. Grass land is further divided into tropical (<1000m), sub-tropical (1000-2000/2100m), temperate (2000/2100-3000/3100 m), sub-alpine (3000/3100-4000/4100m) and alpine (4000/4100-4500m) categories. Table 2.11 presents the hierarchy of other land uses as per Land Use Policy 2072.

Table 2.11: Hierarchy of Other Land use

Level 1	Level 2	Level 3	Level 4
Others	**Grazing Land-G**	***Climatic Vegetation Zone*** **Tropical**, (<1000m); **Sub tropical**,(1000-2000/2100m); **Temperate**,(2000/2100m-3000/3100m); **Sub-alpine**, (3000/3100-4000/4100m); **Alpine**, (4000/4100m-4500m).	
	Others-X		

Chapter – 3
METHODOLOGY

3.1 Data Sources

There are many different sources of information on existing land use and land cover and on changes that are occurring. Local planning agencies make use of detailed information generated during ground surveys involving enumeration and observation. Interpretation of large-scale aerial photographs also has been used widely. In some cases, supplementary information is inferred on the basis of utility hookups, building permits, and similar information. Major problems are present in the application and interpretation of the existing data. These include changes in definitions of categories and data collection methods by source agencies, incomplete data coverage, varying data age, and employment of incompatible classification systems. In addition, it is nearly impossible to aggregate the available data because of the differing classification systems used (James R. Anderson et el 2001).

The primary data source used for the land use classification in this project is high-resolution 0.5m resolution Panchromatics WorldView-2 satellite imagery fused with the 4 band multi-spectral image of 2 meter spatial resolution of the same. Various other vector, raster and imagery data sets were used as ancillary data, which enhanced interpretation and classification of land use classes. This chapter describes, in brief, the sources and characteristics of various datasets used for the study.

Both types of data, primary and secondary, were used for the present land analysis. Maps and their related information of Land utilization, Land Capability, Land System, and Topographical Map prepared by Survey Department, Government of Nepal in different years were used as secondary information. Above maps and their reports was gathered and analyzed before interpretation of satellite imagery and field visit. Three WorldView-2 satellite images (MSS and pan bands) dated on 19th November 2016, of the project area was used for this project. Primary data (e.g., land use types, cropping pattern, and forest types/management) was collected during the field work through observation and discussion with locals using the formatted questionnaires and maps. All data and information obtained from secondary sources related to this theme (land use) were verified during the field work. Major data sources used for this study are as follows.

WorldView-2:
WorldView-2 satellite system is one of the best ground resolution commercial color imaging satellite of the present time. The satellite has extraordinary detail, high accuracy. WorldView-2 satellite simultaneously collects panchromatic imagery at 0.5m and multispectral imagery at 2m at nadir view. The WorldView-2 image was obtained from National Land Use Project (NLUP), Mid-Baneshwor, Kathmandu. A sensor characteristic of WorldView-2 is described in Table 3.1

Table 3.1: Specification of WorldView-2 Image

Package 27	
Product ID:	**055839166080_01_P004**
Image Manufacturer:	Digital Globe, Inc. ("Digital Globe")
Image (sensor Name):	WORLDVIEW-2
Processing Level:	Standard Geometrically Corrected
Cloud cover:	0% in the study area
Image Type:	PAN/MSI
Resolution	Spatial Pan- 0.5 m and MSI : 2m Spectral: 4 bands
Date of Acquisition:	2016-11-19 05:28:54 GMT
Buffering:	Well cross the boundary of the project study area
Sensor Type:	Satellite

Product ID:	**055839166080_01_P006**
Image Manufacturer:	DigitalGlobe, Inc. ("DigitalGlobe")
Image (sensor Name):	WORLDVIEW-2
Processing Level:	Standard Geometrically Corrected
Cloud cover:	0% in the study area
Image Type:	PAN/MSI
Resolution	Spatial Pan- 0.5 m and MSI : 2m Spectral: 4 bands
Date of Acquisition:	2016-11-19 05:28:41 GMT
Buffering:	Well cross the boundary of the project study area
Sensor Type:	Satellite

Product ID:	**055839166080_01_P008**
Image Manufacturer:	DigitalGlobe, Inc. ("DigitalGlobe")
Image (sensor Name):	WORLDVIEW-2
Processing Level:	Standard Geometrically Corrected
Cloud cover:	0% in the study area
Image Type:	PAN/MSI
Resolution	Spatial Pan- 0.5 m and MSI : 2m Spectral: 4 bands
Date of Acquisition:	2016-11-19 05:27:58 GMT
Buffering:	Well cross the boundary of the project study area
Sensor Type:	Satellite

The WorldView-2 image used in the study area are shown in Figure 3.1.

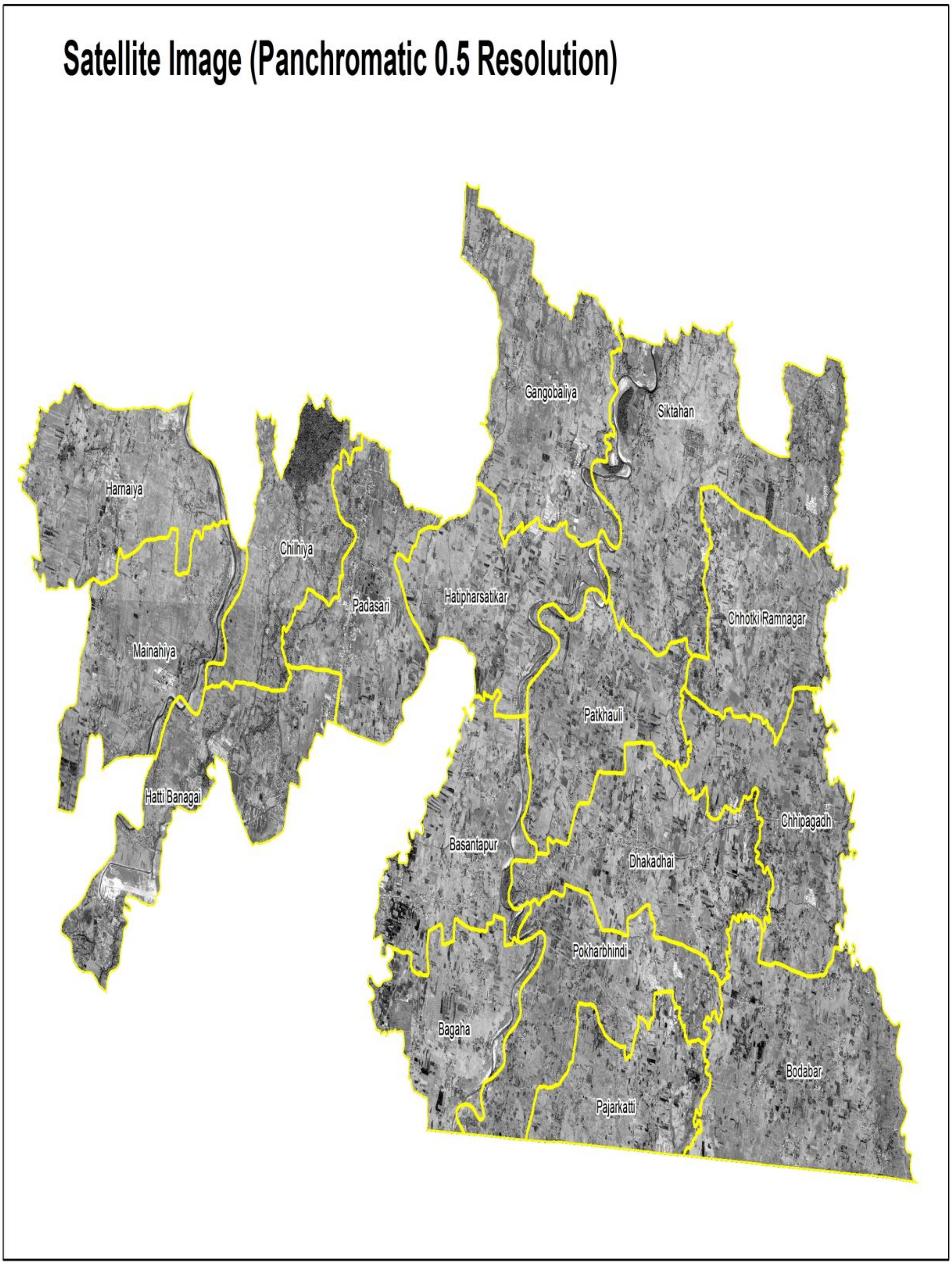
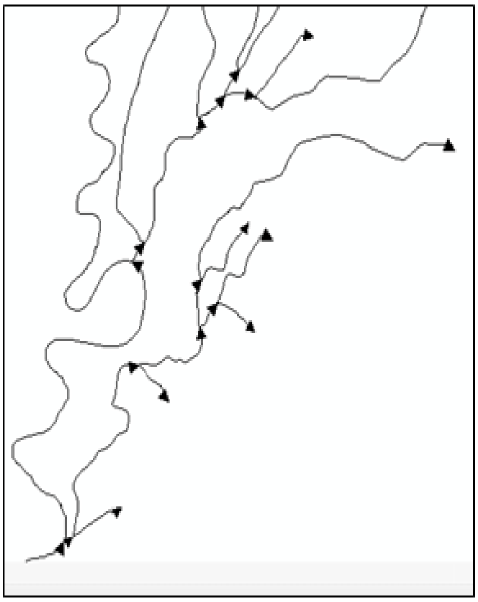


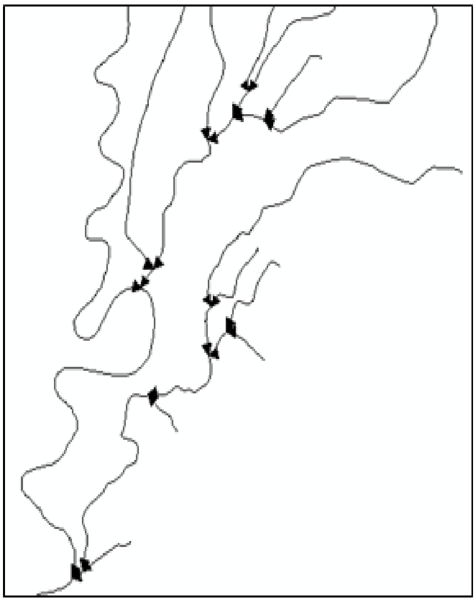
Figure 3.1: WorldView-2 Images of the Package 27 VDCs Rupandehi District

Topographical Map: The Topographical base maps collected from NLUP as bellow:
Map Sheet No. 278306C, 2783-06B, 2783-07C, 2783-10B and 2783-11A in the scale of 1: 25000 bearing supplementary contour of interval 10m and in some areas even 5m. These maps are published in 1996 and are compiled from 1: 50000 scale aerial photography of December, 1990 and field verification done in December, 1991. Both hard copy and soft copy covering the project VDCs and its surrounding was obtained from Survey Department of Nepal. The Topographical Maps were used for planning process of GCPs collection with DGPS survey and also used for feature extraction of dataset such as drainage network, VDC boundary, location name, etc and additional data for GIS based analysis.

Digital Elevation Model: Digital Elevation Model was prepared from the spot height and contour data of Topographic map of study area prepared by Department of Survey. The DEM was used for the orthorectification of the image and to derive information such as slope, aspect, relief intensity surface etc. for performing different terrain analysis. The DEM prepared from contours of topographical map is overlaid with VDC boundary of respective VDC of this project.



Topologically erroneous survey data



Topologically rectified survey data during the project task

Digital Elevation Model has been prepared from the spot height and contour data of Topographic map of Department of Survey. However, an intensive task was required to be performed for correcting the hydrographic data as the given river line data do not match with the geographic behavior. The DEM was created in ArcGIS using topo to raster feature tool. The DEM was used to derive information such as slope, aspect, relief intensity surface etc. for performing different terrain analysis.

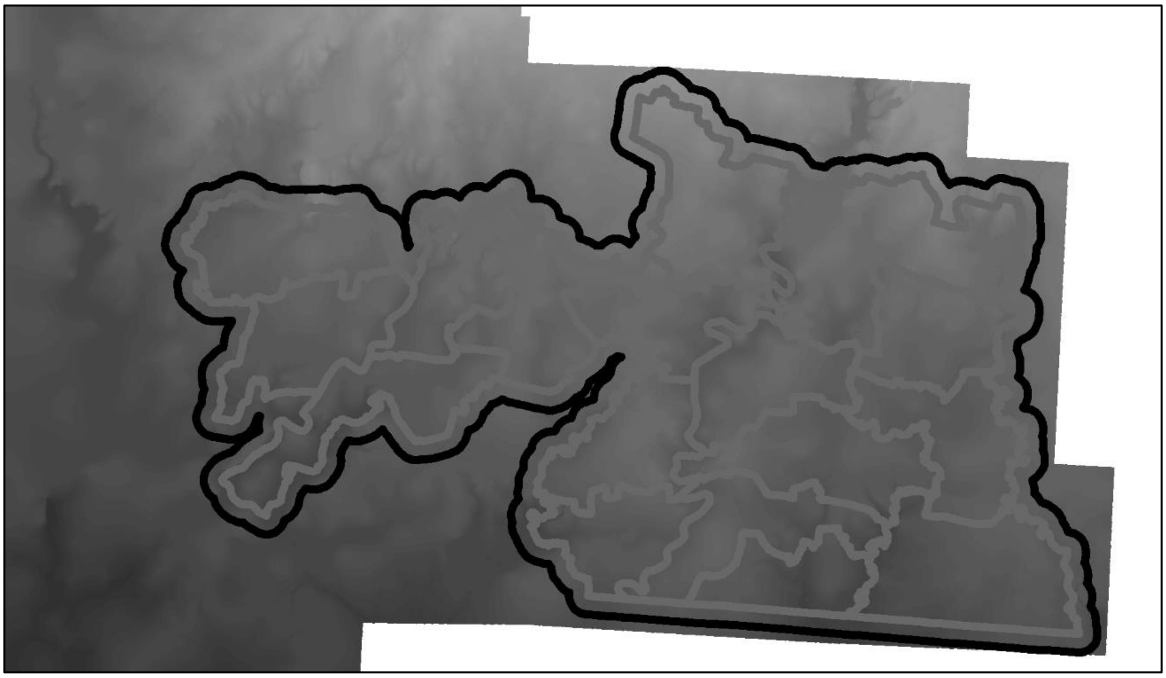


Figure 3.2: DEM for package 27 of Rupandehi District

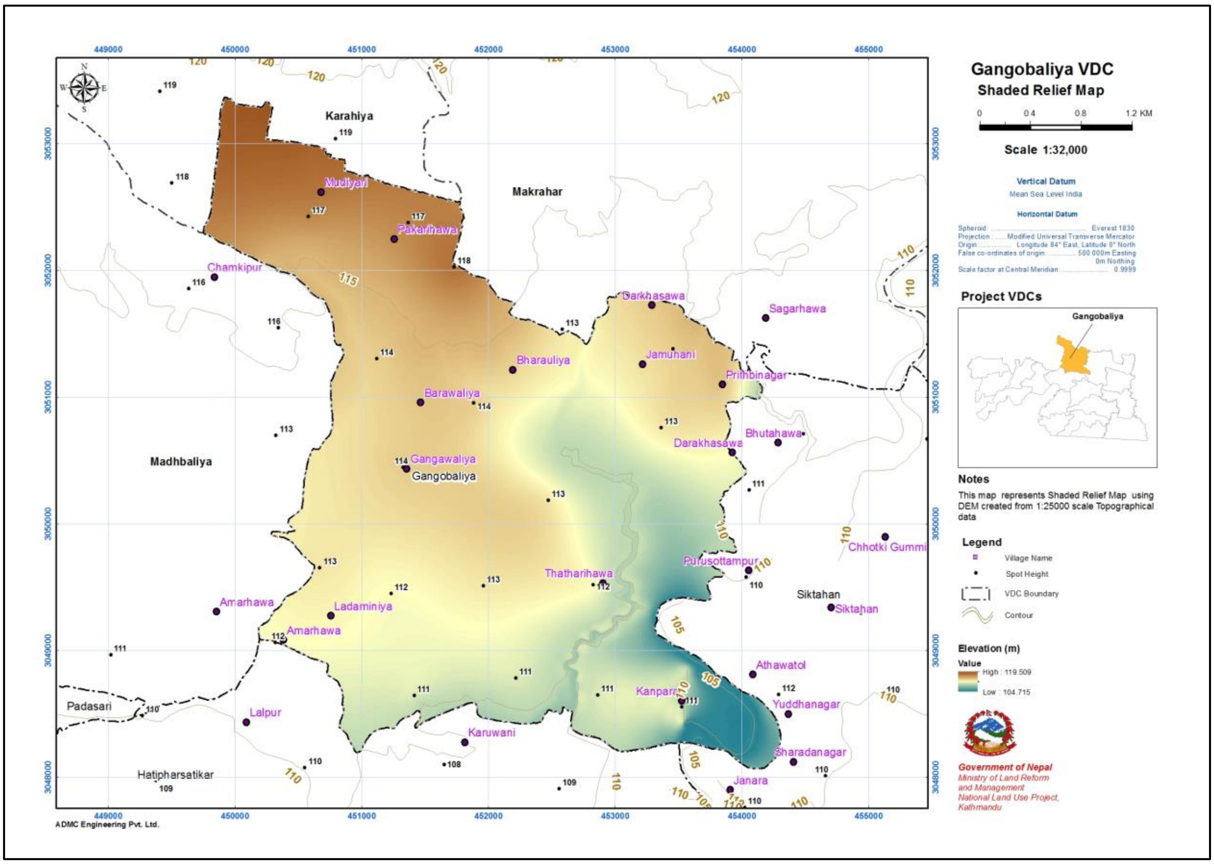


Figure 3.3: DEM map of Gangobaliya VDC

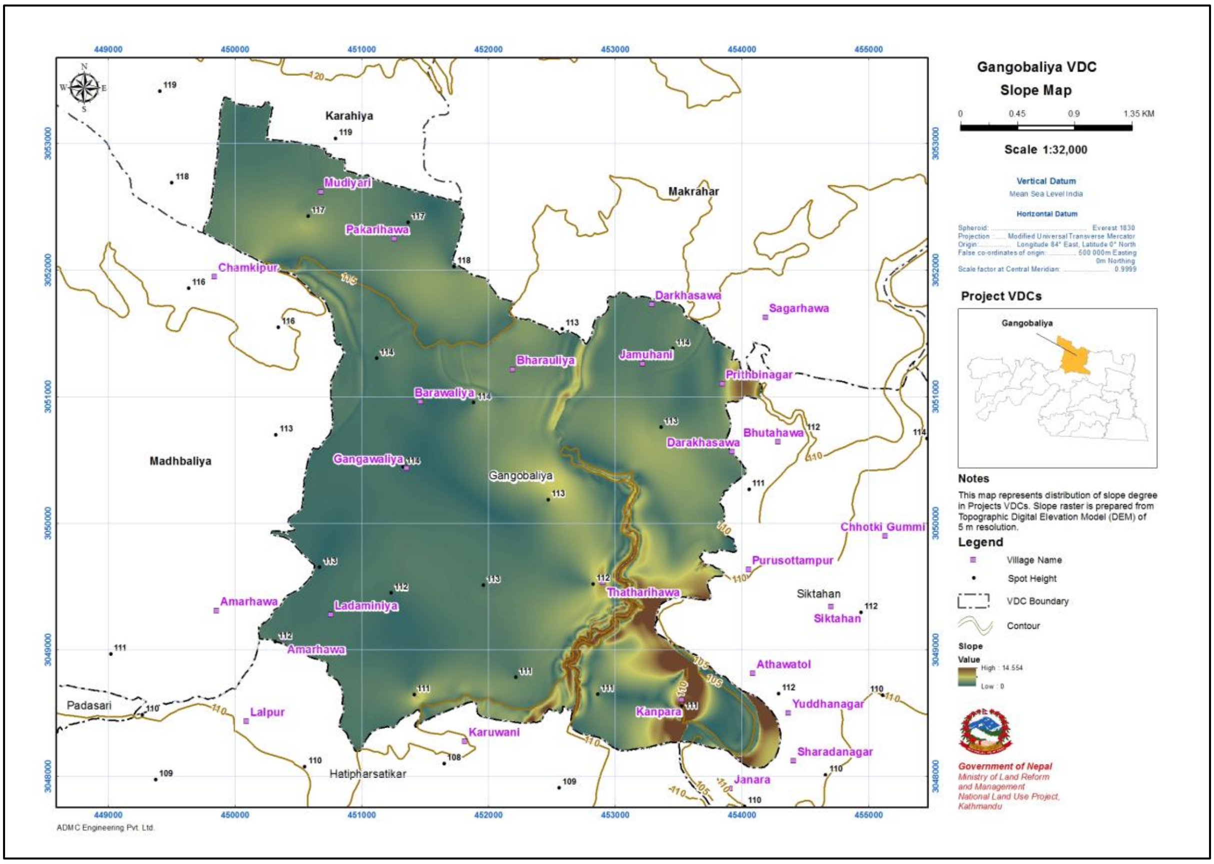


Figure 3.4: Slope map of Gangobaliya VDC

LRMP Maps/Reports: Land Utilization, Land System and Land Capability maps and reports prepared by Land Resource Mapping Project (LRMP), 1986 were used as references for getting insights into existing land use classification and zonation system of Nepal. These maps are used to aid the classification process in the study.

Land Use Policy 2072: Land Use Policy (2072) was the main basis for the classification of the land use categories. The policy was reviewed. The major land use categories ascribed by the policy were adopted in classifying the existing land use of the study area.

Key Informants Interview (KII): KII conducted interviewing selected individuals for their knowledge and experience in land use, forests (species and management) and cropping pattern and their related issues. Interviews were qualitative, in-depth, and semi-structured. The interviews were guided by a checklist of topics/issues or open-ended questions.

Formal and Informal Consultation, Discussion and Observation: Formal/informal discussion with VDC members, local stakeholders and people of different backgrounds and social identities was conducted to identify key actors and agents of the project and to explore the underlying socioeconomic, cultural and bio-physical situation that have shaped the optimum utilization of resources and land use practices. Observation was made for confirm the land use pattern and their practices.

Ground Control Point: Differential global positioning system (DGPS) survey was carried out for the collection of ground control points (GCPs) including check points. The DGPS survey for this package VDCs was carried out during the month of December. The works includes establishment of 16 Ground control points (GCPs) in the project area with an observation time of at least forty five minutes in all the points and 8 hours in one main GCP on the vicinity of the project area. The DGPS stations were established on the locations identifiable in the WorldView-2 imagery as well as on the ground with well distributing for covering entire study area and three sets of Geomax Zenith 25 Series were used in which one is used as base station and the remaining were used for collection ground control as rover station. DGPS readings were later processed using post processing software (Geomax Geo-Office) to get adjusted co-ordinates of GPS points. Then, these adjusted co-ordinates were transformed into national co-ordinate system. The co-ordinate list of GCPs used in the study is shown in Table 3.2. The distribution of GCPs location overlay on WorldView-2 imagery is shown in Figure 3.5.

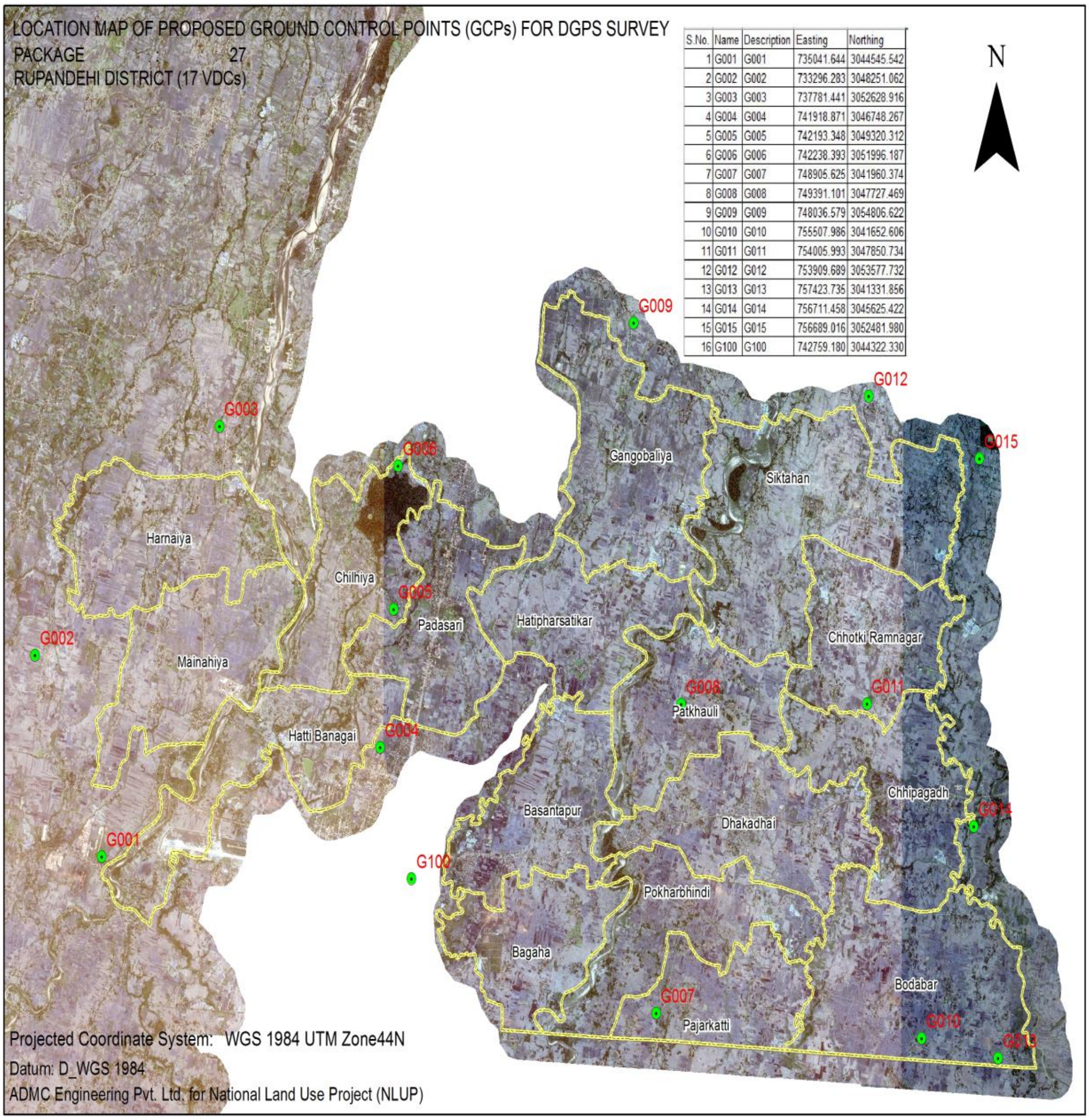


Figure 3.5 Distribution of GCPs locations on Imagery

Table 3.2: Coordinate list of GCPs

Station	WGS84			UTM 45N Zone			MUTM CM84		
	Latitude	Longitude	Ellipse Ht.	Easting	Northing	Ortho Ht.	Easting	Northing	Ortho Ht.
GCP-001	27° 30' 15.40834"N	83° 22' 45.55442"E	39.358	438893.841	3043075.01	102.669	735041.644	3044545.542	102.669
GCP-002	27° 32' 16.82047"N	83° 21' 44.56524"E	42.077	437239.219	3046820.435	104.859	733296.283	3048251.062	104.859
GCP-003	27° 34' 36.17147"N	83° 24' 31.05408"E	52.339	441827.56	3051086.861	114.319	737781.441	3052628.916	114.319
GCP-004	27° 31' 22.58467"N	83° 26' 57.58103"E	43.832	445819.822	3045109.952	106.714	741918.871	3046748.267	106.714
GCP-005	27° 32' 45.92418"N	83° 27' 09.43279"E	46.761	446156.363	3047673.595	109.228	742193.348	3049320.312	109.228
GCP-006	27° 34' 12.78203"N	83° 27' 13.00622"E	51.433	446266.193	3050346.544	113.457	742238.393	3051996.187	113.457
GCP-007	27° 28' 42.57733"N	83° 31' 08.49842"E	42.733	452685.883	3040156.541	106.254	748905.625	3041960.374	106.254
GCP-008	27° 31' 49.50843"N	83° 31' 30.44800"E	48.992	453310.439	3045907.659	111.634	749391.101	3047727.469	111.634
GCP-009	27° 35' 40.25524"N	83° 30' 46.34943"E	58.627	452128.404	3053014.433	120.114	748036.579	3054806.622	120.114
GCP-010	27° 28' 28.17566"N	83° 35' 08.61579"E	40.446	459275.812	3039689.524	103.915	755507.986	3041652.606	103.915
GCP-011	27° 31' 50.42799"N	83° 34' 18.62033"E	46.588	457924.833	3045919.153	109.155	754005.993	3047850.734	109.155
GCP-012	27° 34' 56.43419"N	83° 34' 19.44753"E	58.108	457967.311	3051644.066	119.739	753909.689	3053577.732	119.739
GCP-013	27° 28' 16.46108"N	83° 36' 18.10659"E	40.476	461182.305	3039322.757	103.957	757423.735	3041331.856	103.957
GCP-014	27° 30' 36.34547"N	83° 35' 55.45396"E	45.06	460574.352	3043630.132	107.931	756711.458	3045625.422	107.931
GCP-015	27° 34' 18.97161"N	83° 35' 59.87896"E	54.134	460717.907	3050481.808	115.917	756689.016	3052481.98	115.917
GCP-016	27° 30' 03.27289"N	83° 27' 26.43465"E	59.465	446600.885	3042665.356	122.705	742759.18	3044322.33	122.705

3.2 Methods Adopted

The specific approaches and methods adopted to generate the VDC level land use map of the project VDC area is explained briefly with the flow diagram in **Figure 3.6.**

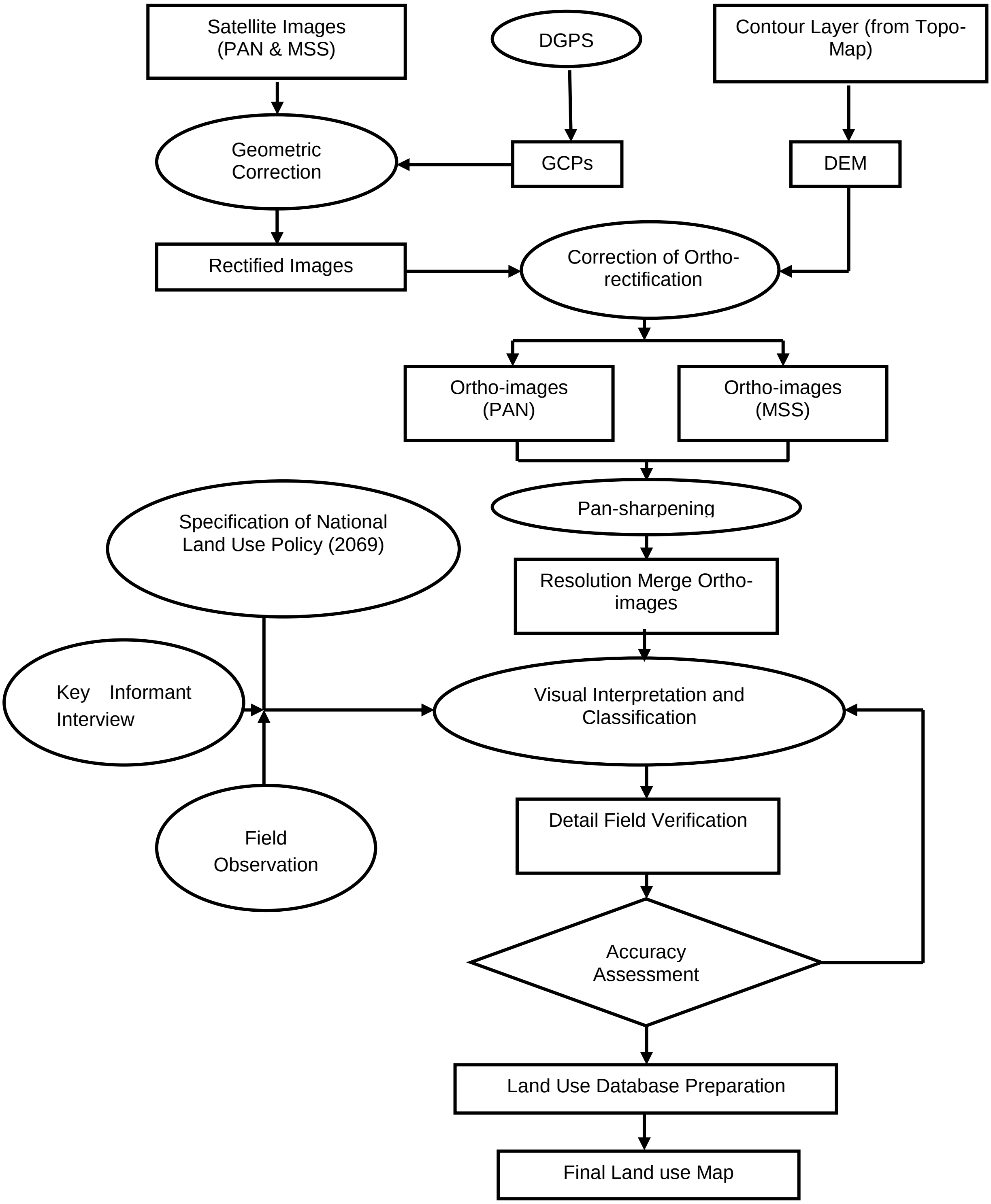


Figure 3.6 Schematic Work Flow Diagrams

The stepwise procedure adopted to generate the land use map of the area is following:

- Geometric Correction and Ortho-rectification
- Pan-sharpening (Image Fusion)
- Visual Image Interpretation and classification
- Detail Field Verification
- Mapping and Accuracy Assessment
- Land Use Geo-database Creation

3.2.1 Ortho-rectification of Satellite Images

Radiometric Correction

Rectification of the imagery consists of the Geometrical, radiometric aspects. Firstly, the images are radiometrically corrected in which basically we focus in the sun angle correction and haze correction. However, we could not ascertain about the Skylight correction from the very beginning as it can be only said after the observation of the actual dataset and other acquisition parameters (date and time of day of the observation, type of the satellite imagery itself etc.) After the application of radiometric correction, we apply the geometric correction of the satellite imagery where it is geo-referenced and re-sampled. The process was conducted in the ERDAS Imagine software. Part of the originally supplied imagery has been shown as follows.

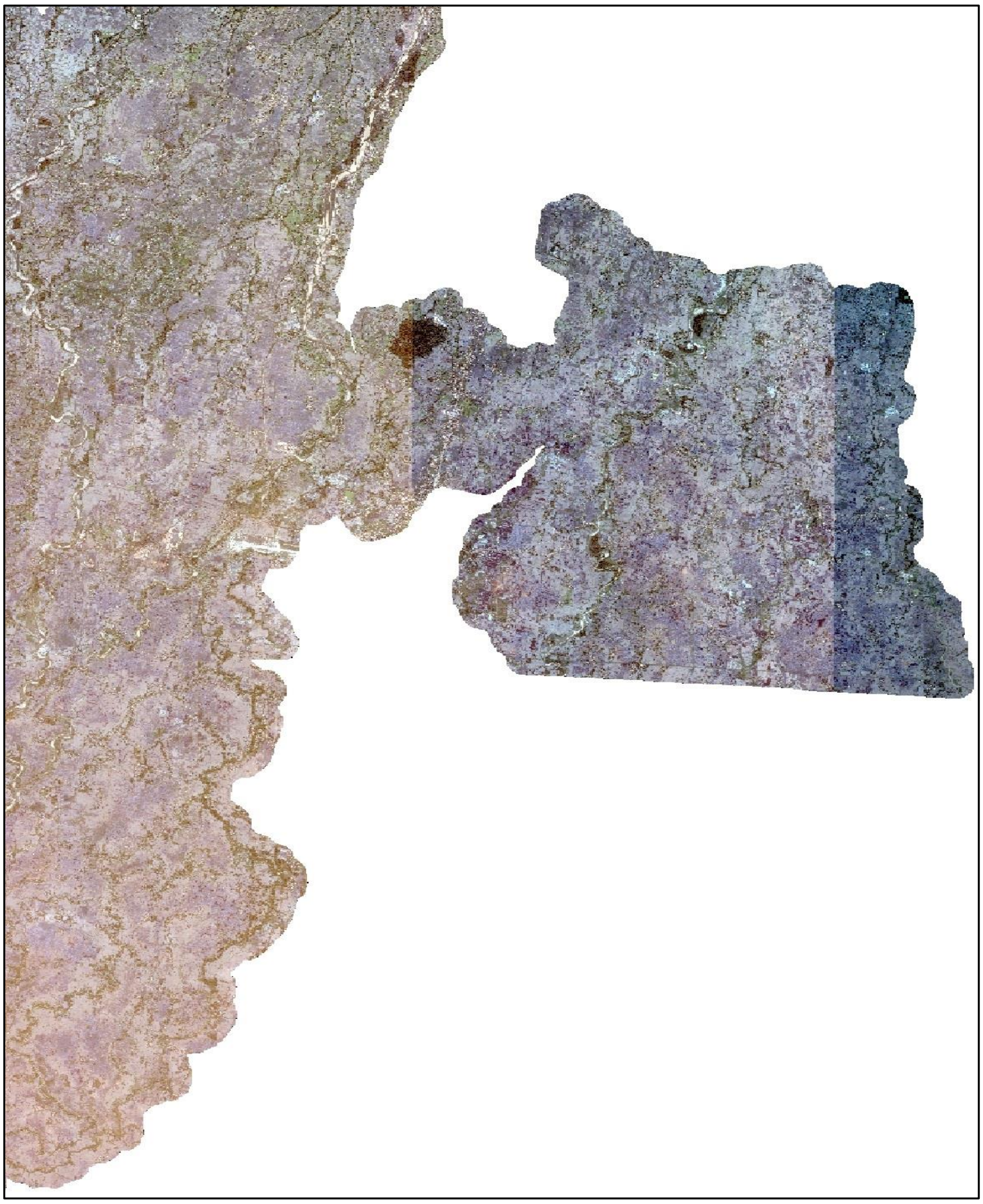


Figure 3.7 Radiometric Correction Work Diagram

Ortho-Rectification

For an image taken with very high resolution satellite (VHRS) with push broom sensor in which each image line is taken at a different instance of time, i.e. each scan line has its own perspective projection model. On satellite board, there is GPS receivers which are used for determining satellite ephemeris, i.e. camera position with respect to time. Star trackers and gyros on board measure the camera attitude angle (roll, pitch and yaw) as a function of time (Grodecki and Gene, 2003). The sensor camera position and attitude angle most essential to geo-rectification of VHRS optical images. Geometric corrections include correcting for geometric distortions due to sensor-earth geometry variations, and conversion of the data to real world (Tempfli, Bakker, & Kar, 2001). Geometric correction was done to compensate for errors caused by variation in altitude, velocity of sensor platform, rotation of the earth and earth curvature etc.

For the geometric correction of optical images, there are two mathematical approaches commonly used. The first is rigorous sensor model (RSM) which is parametric based on satellite orbital parameters; is used in direct geo-referencing techniques which describes physically the image generation process from the focal plane location of an instrument pixel to an earth surface location in terms of earth coordinate system i.e. this model is established relationship between the point on the image and the correspondent point on the ground (Kaveh and Mazlan, 2011) using model as;

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = kM_aM_b\left[\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} - m\begin{bmatrix} 0 \\ 0 \\ f \end{bmatrix} - \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix}\right] \quad (3.1)$$

The second is rational polynomial functions (RPFs) which are non–parametric or generic or universal sensor models which provide a standardized and easy to use mathematical model to map object coordinates to image column and row values of the original image. Exterior and interior orientation can be implicitly encoded in the form of RPFs using third order polynomials for numerator and denominator. The universal sensor model provides the transformation of object space coordinates to image space coordinates, which is available in standard format for a lot of remote sensing satellite systems (Reinartz.P.et al, 2010) and each of the RPFs for a row and column is given by the ratio of two polynomials of third order with normalized ground coordinate (λ, Φ and h) with 20 coefficients. The advance form of RPF is the rational polynomial co-efficient (RPC) which has universally used for interior and exterior orientation of each satellite images for transformation of image column and row values of the original image to object ground co-ordinates using third order polynomials for numerator and denominator of at least 80 coefficients.

In order to improve the geometric accuracy of the original RPCs, these has to be corrected using GCP collected from ground survey technique of DGPS survey and geometric adjustment has done using least square adjustment with affine transformation for estimate the error occurring between the satellite scene and the reference scene. The corrected image coordinates are computed based on the affine transformation and given by;

$$row = a_0 + a_1 \cdot rpc_r + a_2 \cdot rpc_c$$
$$col = b_0 + b_1 \cdot rpc_r + b_2 \cdot rpc_c \quad (3.2)$$

Where rpc_r and rpc_c are the originally rational polynomial coefficients provided by satellite image provider or vendors. The RPCs mathematical model are widely used for geo-referencing the images (Lehner et al., 2005).

Ortho-rectified images are the most popular product from high spatial resolution satellite sensors and digital image for the accurate representation of the earth planimetric features or objects as a map (Toutin, 2004). So, it is a map like geometric properties i.e. orthogonal projection with earth reference terrestrial (geographic) coordinate system which preserves the shape of the earth surface and makes the distance measurements possible across the entire

image accurately. It is used for the measurements and analysis where a high positional accuracy is required. Nowadays, it is possible to represent the earth surface accurately by DEM, which is useful for environmental planning; monitoring and decision support system and plays an important role in impact of environment and the associated human, cultural, and physical landscape.
Satellite images do not represent the real world features/objects in its actual geometric position due to perspective geometry. The effect of object height, terrain relief, and curvature of the earth, systematic error in aircraft flight or satellite system and object displacements introduces geometric error in the image. Due to the perspective projection of the satellite sensor, scale distortion, effect of the tilt and relief displacement is more prominent in outward direction from the nadir point causes the non-uniform scale over the different part of the image (Schenk, 1999). In ortho-rectification process, oriented image and elevation data are used for differential rectification to transfer perspective projection to orthogonal projection in oriented image and re-sampling process is used for computing the new geometric and radiometric properties of the image of each location after ortho-rectification (Schenk, 1999). Without performing ortho-rectification, the scale of the photograph/image is not constant and uniform over the entire scene as well there is not possibility of accurate measurements of distance and direction. In order to ortho-rectify a transformation model is required which takes into account the various sources of image distortion mainly caused by elevated objects and its relief displacement at the time of photograph/image acquisition. These distortions is eliminated or reduced by ortho-rectification using high quality DEM, but only DEM is not sufficient to eliminate the effect of elevated objects and occlusion caused by it completely.

The present project used geometric correction of satellite images using RPCs mathematical model with RPCs file and GCPs collected with DGPS technique in national co-ordinate system as reference co-ordinate system. Details of Nepalese co-ordinate system of central meridian 84^0 E is as following:

Spheroid	: Everest 1830
Semi-major Axis	: 6377276.345
Semi-minor Axis	: 6356075.413
Inverse Flattering	: 300.8017
Projection	: Modified Universal Transverse Mercator (MUTM)
Origin	: Longitude 84^0 E, Latitude 0^0 N (Equator)
False Co-ordinate	: 500000m Easting, 0m Northing
Scale Factor	: 0.9999 at Central Meridian

Ortho-rectification was done based on geometrically corrected images and DEM generated from topographical contours. The minimum and maximum residual errors are shown in Appendix-2. The ortho-rectification process has been presented below:

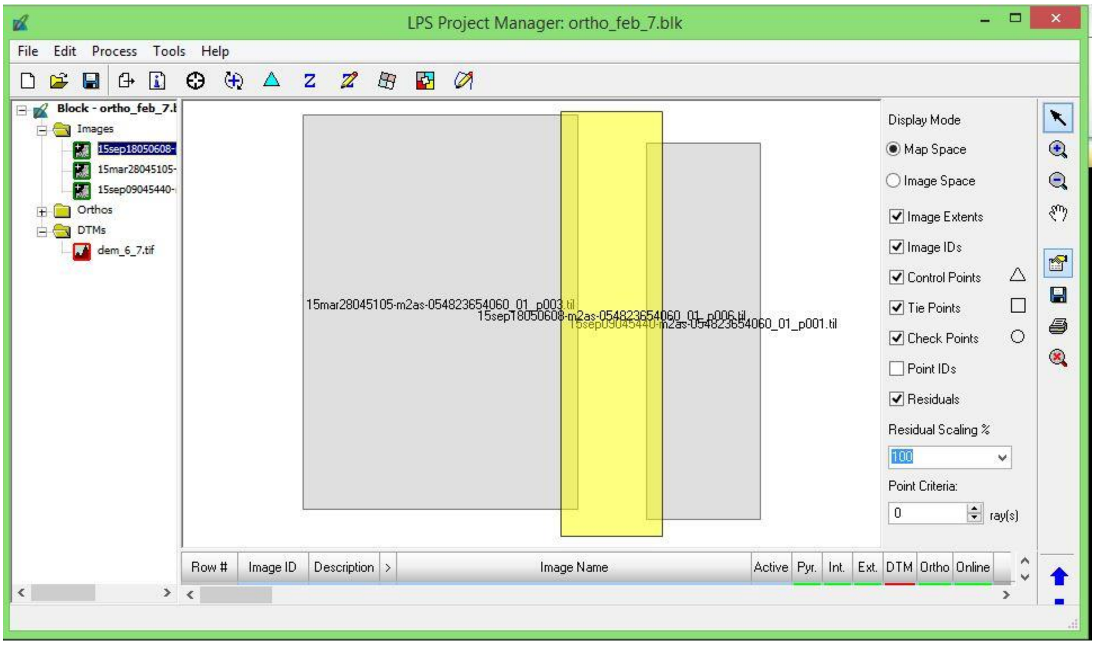


Figure 3.8 Ortho-rectification work diagram

Visulisation of different Color Composite

Enhancing of the spatial resolution was carried out by fusioning the multi-spectral images among themselves (i.e. generating color composite). In this way, Intensity of panchromatic image is utilized to get the better detail view. As the date and time of the acquisition of these two sets of satellite imagery do not vary that much, we also conducted the image fusion. The process is conducted in the ERDAS Imagine software.

Application of Filters

The original image consisted of spatial disturbance abundantly. To solve this problem, low pass filter was applied to smoothen the spatial quality of the image.

Cloud Removal

As the image originally given by NLUP was of cloud-free, we did not have to carryout any operation for cloud removal.

Pan-sharpening

Pan-sharpening (resolution merge or image fusion) technique has used to create a high resolution multispectral data set by the fusion process of high resolution panchromatic data with lower resolution multispectral data. Now-a days in image processing several methods of pan-sharpening are used such as Brovey transform, Multiplicative technique, Principal Component Analysis (PCA), Intensity Hue Saturation (IHS) transform, Wavelet transform, Euler’s technique, Gram-Schmidt transform etc. For present project, the pan-sharpening was carried using Brovey transform to visually increase contrast in the low and high ends of an image’s histogram (i .e. to provide contrast in shadows, water and high reflectance areas such as urban features). Pan-sharpening was done using Multiplicative technique to increase presence of the intensity component and involved in urban or suburban studies, city planning, and utilities routing roads and cultural features (which tend toward high reflection) to be pronounced in the image. Pan-sharpening was done using PCA technique for better spatial and spectral resolution. Similarly, it also used IHS transform for stretching the contrast so that it has approximately the same variance and mean as intensity image and substituted the intensity of image for high resolution image. Pan-sharpening was done with Gram-Schmidt

transforms that gives more accurate due to it uses the spectral response function to estimate as panchromatic data as look like. Pan-sharpening was done using wavelet transform technique to analyze signal in time domain and frequency domain respectively and the multi-resolution analysis is similar with Human Vision System. Pan-sharpening was done using Euler's technique to preserves the spectral characteristics of the lower spatial resolution multispectral images for single-sensor, multi-sensor, and multi-temporal fusion. The requirement for pan-sharpening is that the both images are registered or rectified with an accuracy of 0.25 pixels; otherwise pan-sharpening images may not give the better results. In this study, pan-sharpening was done with Brovey transform technique.
The following figure shows the pan-sharpening process.

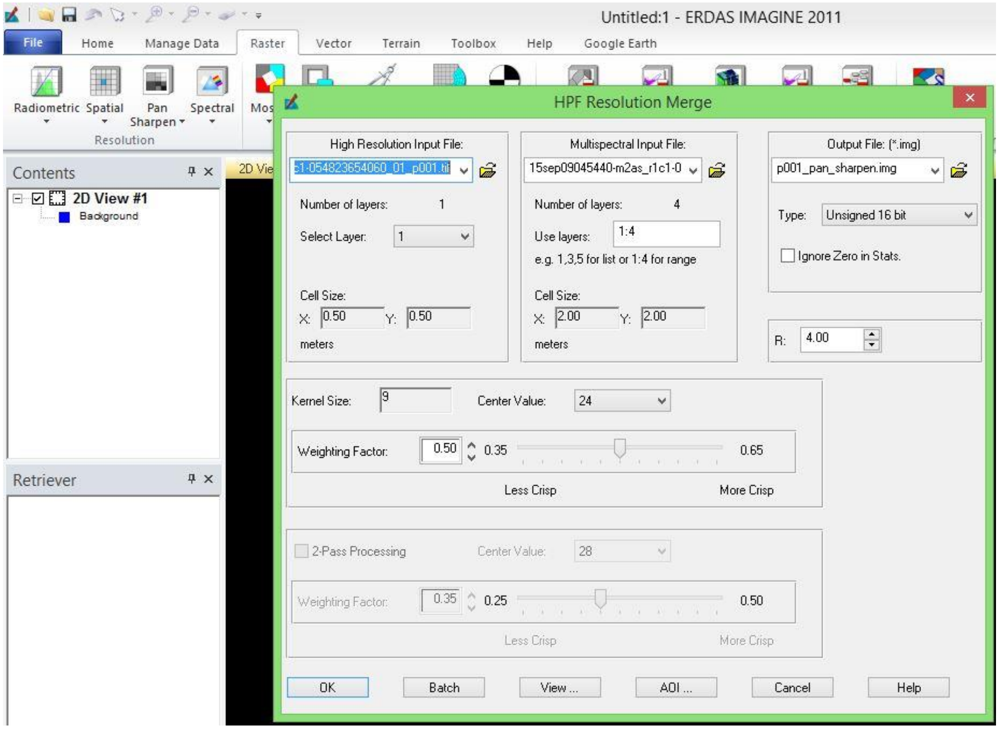


Figure 3.9 Pan sharpening Work Diagrams

3.2.2 Classification

Initially the radiometrially and geogmetricall rectified satellite Imagee was classified using the supervised classification method adopting the maximum likelihood classifier algorithm. Training samples were collected during the field visit, at the time when soil samples were being collected. Samples for the specified thematic classes were fed in the required number to enhance the higher precision of the classified result. The process was conducted using in the ERDAS Imagine software. However, this classification did not render the good result. Theory has already been established in the context of the result of the satellite imagery. Since spectral information based classification renders mixed result, it was found not suitable to directly use as the basis for the land use mapping. Error matrix was generated to see the level of the error in classification. Subjective judgement is always essential over this result. Hence we only applied the classification over the agricultural area to extrac different level of cropping pattern in the field.

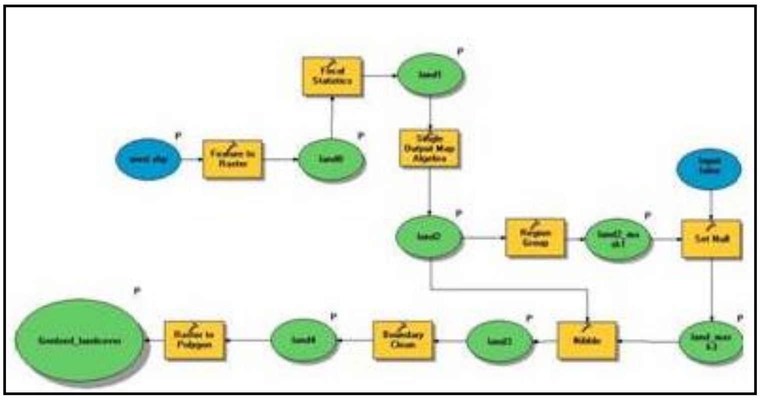
Therefore, multiple image processing techniques were performed to extract the information from the satellite imagery. Subsets of information were extracted from one type of processed product whereas the other subsets were extracted from the other product. Techniques such as Intensity, Hue and Saturation separation, Principal Component Analysis and NDVI calculation were carried out, the product of which were the main inputs for the final classified result.

Later these individual classes were then merged using conditional scripts in ArcGIS Map Algebra into single feature class. Reclassification was also made to merge differently named raster polygon of the same feature types into one. Reclassification was carried out using ArcGIS Spatial Analysis. Samples of the script used are as follows:

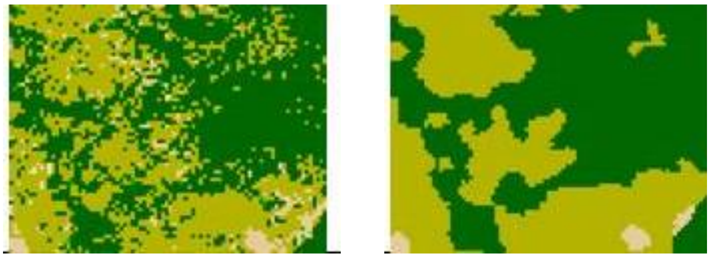
- CON (isnull (class1), (Class2), Class1)
- CON (class2 GE 4, class3, Class4)

Model generation and generalisation of the image extracted information

Howsoever and whatsoever techniques are applied to get the classified image, one always acquire speckles in the classified result. Hence, generalisation must be carried out to clean these speckles and disturbance from these raw outputs. A highly complex model was generated using the model builder for this purpose, which is given below:



Result before and after the application of the above model is shown in the following diagram:



Classified Image before and after the application of model

3.2.3 Visual Interpretation

Visual interpretation is the process of identification and classification of land cover classification. Most intuitive way to extract information from the satellite imagery is visual image interpretation (Tempfli, Bakker, & Kar, 2001). Visual image interpretation assisted by extensive field visit was used to derive the land use classes from the imagery. The main basis for the land use mapping is the extensive field visit with satellite imagery at 1:5000 scale where different ancillary layers such as NDVI, simple ratio, DEM were used in support while performing this task.

Two extremely important issues must be addressed before undertaking task of image interpretation for delineating land use classes. The first is the definition of the criteria to be

used to separate the various categories of features occurring in the photographs. For example, in mapping land use the interpreter must fix firmly in mind what specific characteristics determine if an area is residential, commercial, public service or industrial. This was guided by the definition of land use classes defined by Land Use Policy (2072). The second important issue in delineation of discrete areal units on photographs is the selection of the minimum mapping unit (MMU) to be employed in the process. This refers to the smallest size areal entity to be mapped as a discrete area. The minimum mapping unit for delineating of land use category was 0.25 hectare. However, important and essential features smaller than the MMU were also mapped.
Interpretation elements such as tone, texture, shape, size, pattern, site and association were used for digitizing, editing and assigning land use classes. The size of an object is one of the most distinguishing characteristics and one of the most important elements of image interpretation. Many natural and man-made features on the ground have very unique shapes that can be referenced in photo and image interpretation. For example, Schools and Colleges can be identified by their peculiar L shape.

Tone of the imagery is important while classifying land cover categories. The tonal variation among different land use is a basis for demarcating land use boundary. Each color is caused by the mixture absorbing some wavelengths of light and reflecting others. We may use color-combining techniques to create color composite images. Knowledge of the bands other than the visible range of spectrum increased the quality of the interpretation. For example Vegetation appears red in standard false color composite. Texture is the characteristic placement and arrangement of repetitions of tones or color in an image. For instance Sugarcane was identified by their peculiar texture. Pattern is the spatial arrangement of objects in the landscape. Site refers to the topographic and geographic location. Some parameters of site are elevation, slope, aspect, type of surface cover, value of the land, adjacency to water etc. We can classify agricultural land into sub classes using these parameters. Association refers to the fact that combination of object makes it possible to infer its function or meaning. School can be identified by using the combination of elements shape and association. Peculiar L- shaped building with associated ground confirms that the object is school.

Vectorization and Coding

The Classified agricultural Raster Polygons were then turned into Vector using the conversion tools. Vector generalisation techniques were carried out to comply with the minimum size of the polygon as specified in the TOR. There was the necessity of assigning codes for the vector output. The database model provided by NLUP was then used to load the data so geneated.

3.2.4 Accuracy Assessment

Validation of classification results is an important process in the classification procedure. It allows users to evaluate the utility of a thematic map for their intended applications using accuracy assessment. Accuracy assessment is a feedback system for checking and evaluating the objectives and the results. It determines the correctness of the classified image. It is a measurement of the argument between a standard that is assumed to be correct and a classified image of unknown quality. If the image classification corresponds closely with the standard, it is said to be accurate (Bhatt, 2008). Classification is not complete until its accuracy is assessed (Lillesand et al., 2008). There are several methods of evaluating the accuracy assessment. In general, one method is compared the classified image to a reference image and a random set of points are generated for the comparison of the classification result with the true information classes in the reference image. A second method is used to perform accuracy assessment involves using a GPS and again a random set of points are generated over the classified image with ground truth has performed by going into the field at the location of each randomly generated point (Bhatt, 2008). These methods are used for sample schema and evaluation process is done with generating confusion matrix and its test statistics with kappa coefficients for the test statistics and kappa index of agreement (KIA) for each category of class.

In this study, validation of classification results were done for the quantification and evaluation of error using confusion matrix (error matrix) which compares the class-by-class based on the training samples with visual interpretation of original images and classification result classes at Level-1. The size of interpretation unit and number of polygons that belong to the unit do not influence the number of points. The total area covered by one legend unit is not taken into account for other legend unit. The confusion matrix was generated based on the comparison between the classified image and the existing ground using GCPs collected from visual interpretation i.e. the matrix depicts the land cover classification categories versus the field observed land cover type. This matrix was an N x N matrix of “classified” and “observed” cells corresponding to N land cover class. Classification result is given as rows and reference (ground truth) is given as columns for each sample. The diagonal elements in this matrix indicate numbers of sample in which classification results has agreed with the reference data. Off-diagonal elements in each row present the sample that has been misclassified by the classifier at classification process (Bhatt, 2008). These error matrices were evaluated by computing the user accuracy, producer accuracy and overall accuracy which was tested statistically with the KIA (Kappa statistics). The KIA was calculated with the following formula (Congalton 1991).

$$K = \frac{N \sum_{i=1}^{r} X_{ii} - \sum_{i=1}^{r} (X_{i+} * X_{+i})}{N^2 - \sum_{i=1}^{r} ((X_{i+} * X_{+i}))} \quad (3.3)$$

Where:

r = is the number of rows in the matrix
X_{ii} = is the number of observations in rows i and column I (along the major diagonal)
X_{i+} = the marginal total of row i (right of the matrix)
X_{+i} = the marginal totals of column i (bottom of the matrix)
N = the total number of observations.

The summary of error matrices of classified images is shown in Table 3.3.The overall accuracy represents the percentage of correctly classified pixels; it is achieved by dividing the number of correct observations by the number of actual observations. The overall accuracies with KIA (kappa statistics) were found 94.37% and 0.93 respectively for the classified objects of the Package-27.

Table 3.3: Summary of Accuracy Assessment

	Agriculture	Industry	Commercial	Residential	Forest	Pond	Road	Total	Comission Error	Users Accuracy
Agricultural	39	0	0	0	2	0	0	41	2.5	97.5
Industry	0	7	0	0	0	0	0	7	0	100
Commercial	0	0	5	0	0	0	0	5	0	100
Residential	0	1	0	35	0	1	0	37	5.405405	94.59459
Forest	2	0	0	0	20	0	0	22	9.090909	90.90909
Pond	2	0	0	0	0	10	0	12	16.66667	83.33333
Road	0	0	0	0	0	0	18	18	0	100
Total	43	8	5	35	22	11	18	142		
Omission Error	9.302326	12.5	0	0	9.090909	9.090909	0		Overall Accuracy	94.3662
Producer's Accuracy	90.69767	87.5	100	100	90.90909	90.90909	100			

	Agriculture	Industry	Commercial	Residential	Forest	Pond	Road	Total	Kappa Statistics
Agricultural	39	0	0	0	2	0	0	41	0.929375
Industry	0	7	0	0	0	0	0	7	
Commercial	0	0	5	0	0	0	0	5	
Residential	0	1	0	35	0	1	0	37	
Forest	2	0	0	0	20	0	0	22	
Pond	2	0	0	0	0	10	0	12	
Road	0	0	0	0	0	0	18	18	
Total	43	8	5	35	22	11	18	142	

Chapter – 4
PRESENT LAND USE PATTERN IN THE GANGOBALIYA VDC

The chapter describes the present land use pattern of the Gangobaliya Village Development Committee. General land cover pattern shows that agricultural land dominates land use of this area. This chapter presents land use assessed in different levels of hierarchy.

4.1 Land Use Pattern

General land use of the Gangobaliya VDC at first hierarchical level of classification is provided in Table and Figure below. Out of total 1285.80 hectare land, 89.71% area is covered by agriculture followed by residential with 3.09%. Commercial area covers 0.97% area of the VDC. Public services cover about 1.55%, Riverine and lake cover 2.78% and forest cover 0.01% of the area. Similarly, Industrial covers 1.86% and Cultural and Archeological covers 0.02% of the area. However there are no Mine and Minerals, Excavation and Other Landuse area in this VDC.

Table 4.1: General land use of Gangobaliya VDC

S. No.	Landuse Class	Area(sqm)	Area(ha)	Percentage
1	AGRICULTURAL	11534919.57	1153.49	89.71
2	RESIDENTIAL	397946.50	39.79	3.09
3	RIVERINE AND LAKE AREA	357979.69	35.80	2.78
4	INDUSTRIAL	238648.60	23.86	1.86
5	PUBLIC USE	199140.86	19.91	1.55
6	COMMERCIAL	125187.33	12.52	0.97
7	CULTURAL AND ARCHEOLOGICAL	2801.58	0.28	0.02
8	FOREST	1446.63	0.14	0.01
	Grand Total	**12858070.75**	**1285.81**	**100.00**

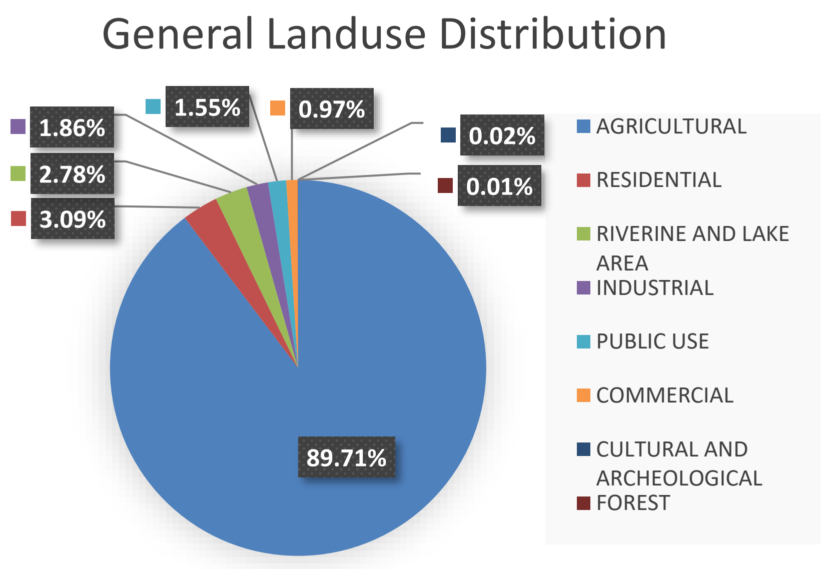


Figure 4.1: General land use of Gangobaliya VDC

Agricultural Land Use: Almost all agricultural land of the Gangobaliya VDC is classified as Terai cultivation based on the physiographic region.

Agriculture level 3 is further divided into wet land cultivation, mixed land cultivation and Dry land Cultivation. About 95.19% of level 3 of agriculture are on Mixed land cultivation category.

Table 4.2: Agriculture land use level 3

S. No.	Agricultural Landuse (level 3)	Area(sqm)	Area(ha)	Percentage
1	Mixed Land Cultivation-X	10980446.92	1098.04	95.19
2	Dry Land Cultivation-D	442000.96	44.20	3.83
3	Wet Land Cultivation-W	112471.69	11.25	0.98
	Grand Total	**11534919.57**	**1153.49**	**100.00**

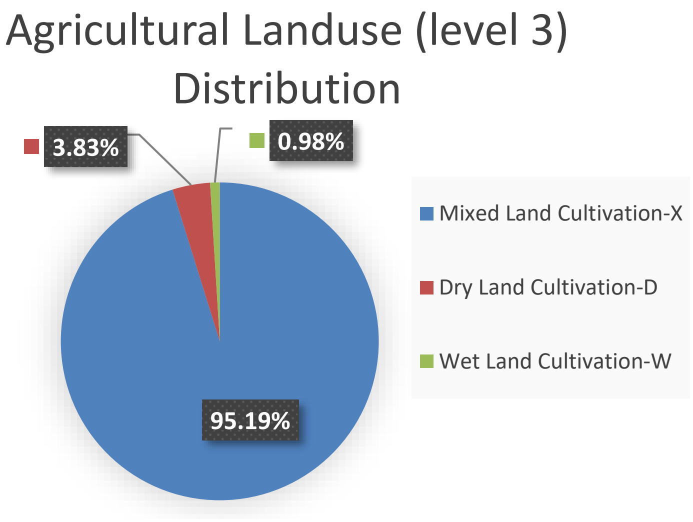


Figure 4.2: Agriculture land use level 3

Table 4.3: Agriculture land use level 4

S. No.	Agricultural Landuse (level 4)	Area(sqm)	Area(ha)	Percentage
1	Unclassified-000	11422447.88	1142.24	99.02
2	Upper Khet Land Cultivation-TariKhet-Uk	112471.69	11.25	0.98
	Grand Total	**11534919.57**	**1153.49**	**100.00**

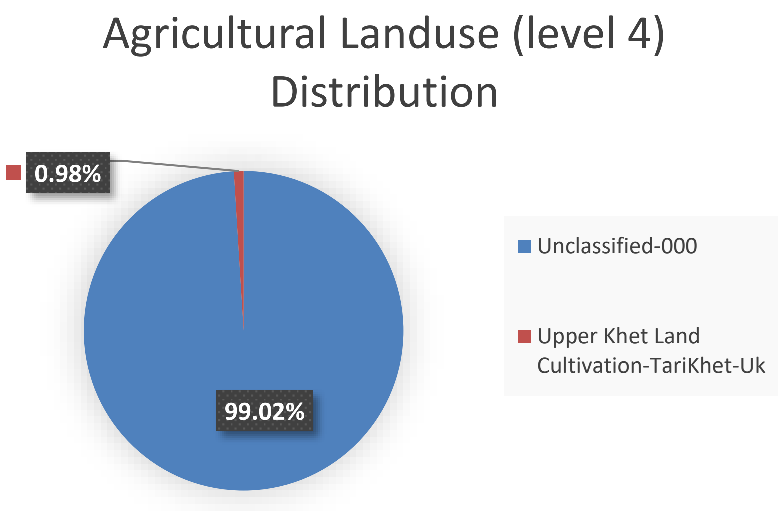


Figure 4.3: Agriculture land use level 4

The cropping pattern of the VDC varies according to agricultural land types, irrigation and precipitation. The wetland cultivation comprises of crops such as rice, wheat, maize, fruits, oilseeds, pulses, pond for fish farming and vegetables. Rice is the dominant summer crop. The table below presents the cropping pattern of the Gangobaliya VDC.

Table 4.4: Cropping pattern

S. No.	Cropping Pattern	Area(sqm)	Area(ha)	Percentage
1	Rice-Wheat-r2	10000906.01	1000.09	86.70
2	Rice-Others-r13	548131.30	54.81	4.75
3	Rice-Rice- Vegetable-r6	406367.76	40.64	3.52
4	Fruit-Others-f3	358904.42	35.89	3.11
5	Pond for Fish farming-p3	127101.98	12.71	1.10
6	Barren Cultivable land-b5	67951.47	6.80	0.59
7	Fruit-Fruit-f1	16602.64	1.66	0.14
8	Fruits-f4	8711.34	0.87	0.08
9	Vegetables-Vegetable-v3	242.65	0.02	0.002
	Grand Total	**11534919.57**	**1153.49**	**100.00**

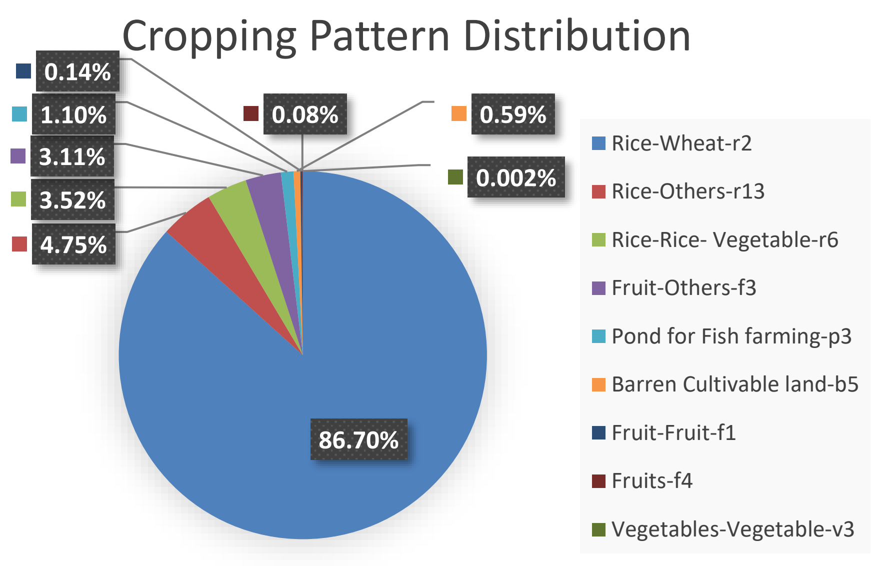


Figure 4.4: Cropping Pattern in Agricultural land

The VDC witness 52.92% of agricultural land having high cropping intensity, 38.52% of arable land of medium cropping intensity and 8.56% of land as of light intensity. Although, pond for fish farming areas do not directly relate themselves with cropping intensity, these have been included in the table as they also bear some degree of agriculture area related production. The following figure shows the distribution of cropping intensity including pond for fish farming.

Table 4.5: Cropping intensity

S. No.	Cropping Intensity	Area(sqm)	Area(ha)	Percentage
1	Intense-3	6104074.91	610.41	52.92
2	Medium-2	4443533.58	444.35	38.52
3	Light-1	987311.09	98.73	8.56
	Grand Total	**11534919.57**	**1153.49**	**100.00**

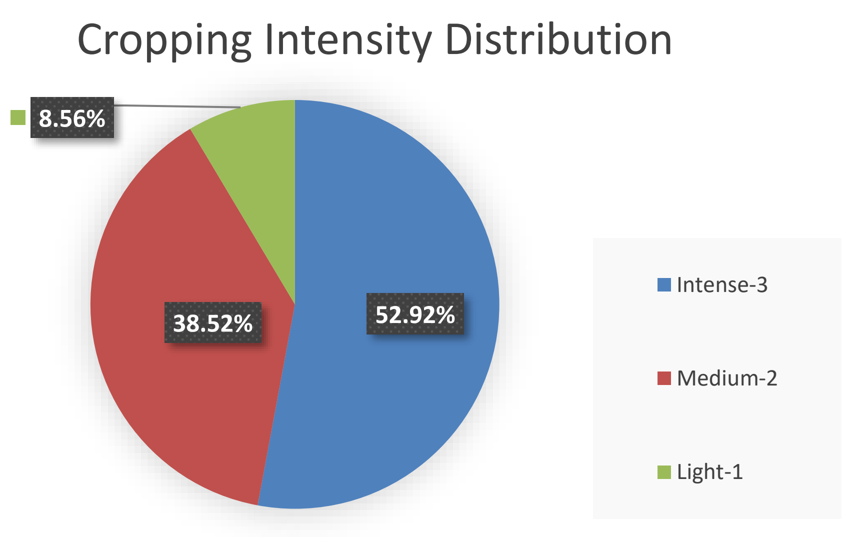


Figure 4.5: Cropping Intensity

Residential Land Use: Gangobaliya VDC has 3.09% residential area. Residential areas of this VDC is categorized as moderately populated and sparsely populated having the majority of the Moderately. The distribution of these categories has been given in the following table.

Table 4.6: Residential Land use level 2

S. No.	Residential Landuse (level 2)	Area(sqm)	Area(ha)	Percentage
1	Moderately Populated-M	298349.82	29.83	74.97
2	Sparsely Populated-S	99596.67	9.95	25.03
	Grand Total	**397946.49**	**39.79**	**100.00**

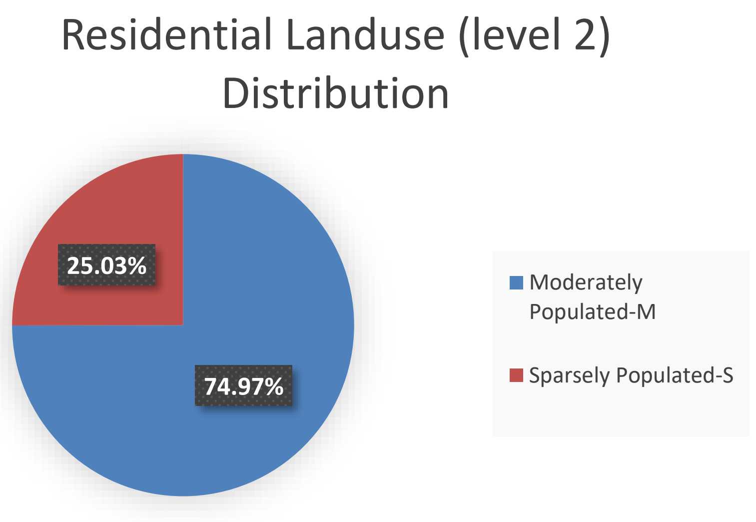


Figure 4.6: Residential Land use level 2

Most of the residential unit of Gangobaliya VDC are old areas i.e. 99.47%. Similarly, 0.53% residential area of the VDC is newly developed area.

Table 4.7: Residential Land use level 3

S. No.	Residential Landuse (level 3)	Area(sqm)	Area(ha)	Percentage
1	Old Area-O	395822.63	39.58	99.47
2	Newly Developed Area-N	2123.86	0.21	0.53
	Grand Total	**397946.49**	**39.79**	**100.00**

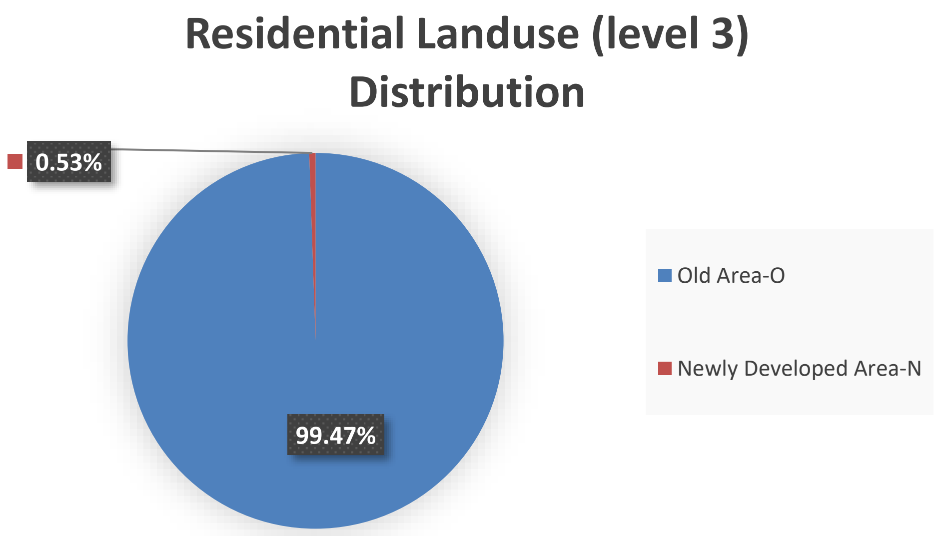


Figure 4.7: Residential level 3 land use

Public Services: Public services which include Educational services such as school, college, recreational facility includes playground, open space, Park etc; road and trail in transportation Infrastructure and health services. About 97.63% public services areas are of Transportation Infrastructure. The educational service comprises 1.60% of the public service area. Detail of the public services is presented in table and figure below.

Table 4.8: Public services level 2 land use distribution

S. No.	Public Services (level 2)	Area(sqm)	Area(ha)	Percentage
1	Transportation Infrastructure (T)	194412.25	19.44	97.63
2	Educational (E)	3194.75	0.31	1.60
3	Security Service (S)	996.93	0.09	0.50
4	Health Service (H)	536.92	0.05	0.27
	Grand Total	**199140.85**	**19.91**	**100.00**

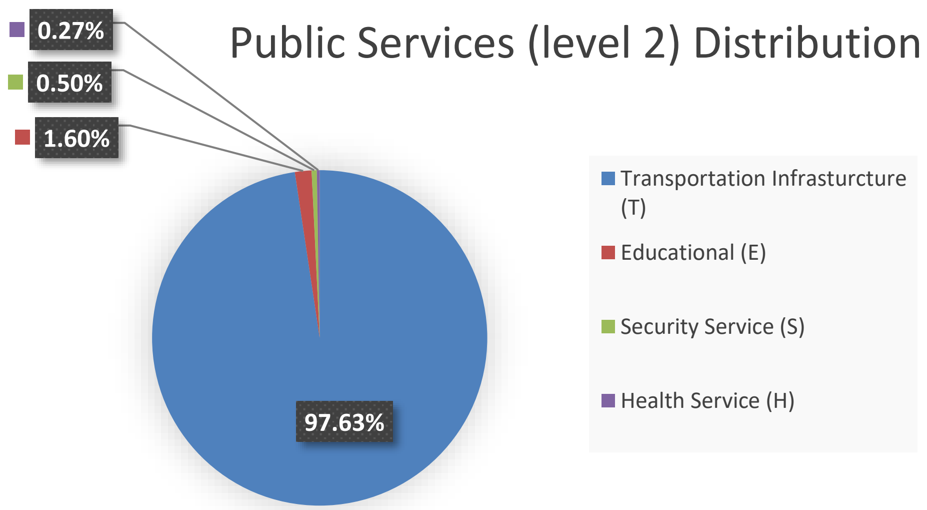


Figure 4.8: Public services level 2 land use distribution

The Public service level 3 has been classified further into Health Centre, School, police Station, Local Road and other road which has been presented below.

Table 4.9: Public services Level 3 land use distribution

S. No.	Public Services Landuse (level 3)	Area(sqm)	Area(ha)	Percentage
1	Local Road - i1	74661.85	7.46	37.49
2	Cart Track - t3	71194.56	7.11	35.75
3	District Road - d3	48004.60	4.80	24.11
4	Primary - p5	2055.65	0.20	1.03
5	Secondary - s2	1139.09	0.11	0.57
6	Police Station - p8	996.93	0.09	0.50
7	Feeder Road - f2	551.23	0.05	0.28
8	Health Centre - c7	536.92	0.05	0.27
	Grand Total	**199140.85**	**19.91**	**100.00**

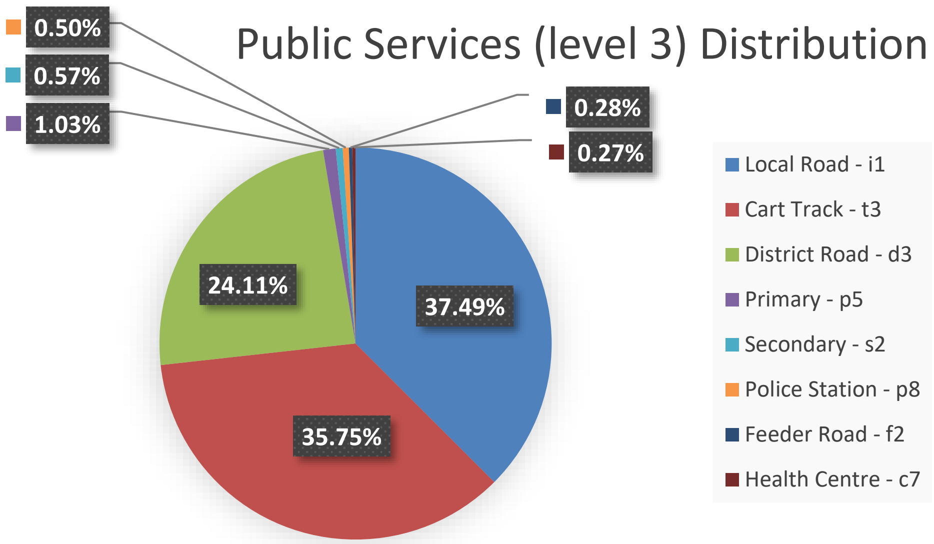


Figure 4.9: Public services level 3 land use distribution

Commercial level 2 is classified as business area and service area in this VDC out of which there are only business area of 12.38 hectare area and into market subcategory.

Table 4.10: Commercial Level 4 land use distribution

S. No.	Commercial Landuse (level 4)	Area(sqm)	Area(ha)	Percentage
1	Consultancy service area - c4	113263.35	11.32	90.48
2	Shop - s1	7072.39	0.70	5.65
3	Market Subcategory (M)	2166.06	0.21	1.73
4	Open Market - o2	1348.12	0.13	1.08
5	Bank/Money Exchange - b3	666.23	0.06	0.53
6	Local Development office - l2	496.95	0.04	0.40
7	Telecommunication Office - tc	174.20	0.01	0.14
	Grand Total	**125187.32**	**12.51**	**100.00**

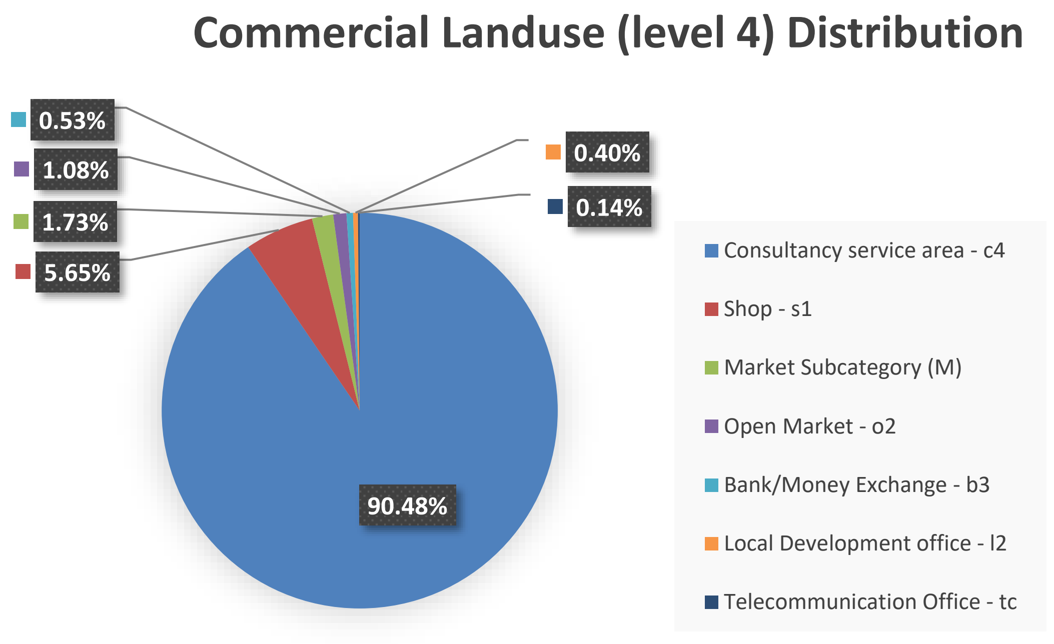


Figure 4.10: Commercial level 4 landuse distribution

Riverine and lakes cover 2.78% land of this VDC out of which 38.72% is river, 3.61% Canal and 57.67% are categorized under kulo.

Table 4.11: Riverine and Lake level 2 land use distribution

S. No.	Riverine and Lake (level 2)	Area(sqm)	Area(ha)	Percentage
1	Kulo (k)	206429.74	20.64	57.67
2	River (r)	138621.51	13.86	38.72
3	Canal (c)	12928.43	1.29	3.61
	Grand Total	**357979.69**	**35.79**	**100.00**

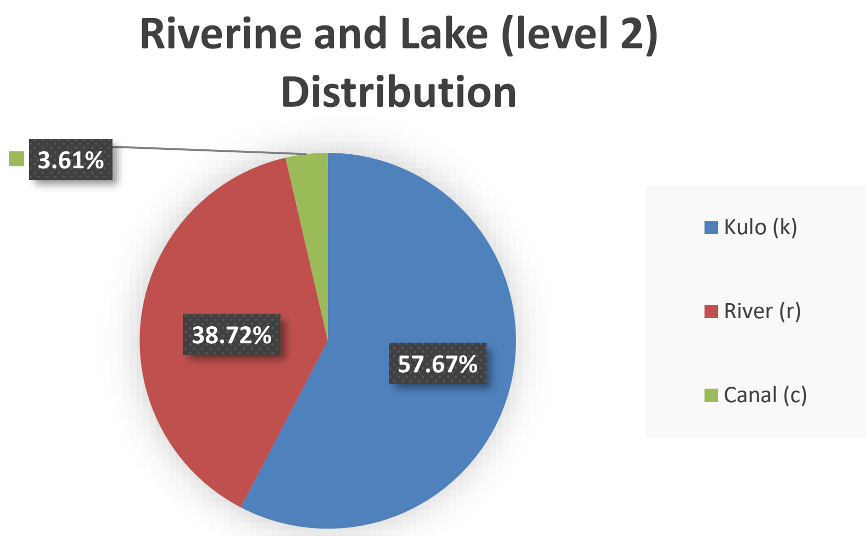


Figure 4.11: Riverine and Lake level 2 land use distribution

4.2 Land Use GIS Database

Present Land Used database prepared for this study is strictly followed as Geo-database provided by NLUP for this project as specification. All data related to land use prepared for this study have been submitted in digital format with this report to NLUP office.

Table 4.12: Database for present land use

Field	Data Type	Description	Remarks
FID	Feature Id	Feature	FID
SHAPE	Geometry	Geometric Object type	SHAPE
ID	Long	Unique Object ID	ID
LEVEL 1	String	Land Use Class	LEVEL 1
LEVEL 2	String	Land Use Class	LEVEL 2
LEVEL 3	String	Land Use Class	LEVEL 3
LEVEL 4	String	Land Use Class	LEVEL 4
LEVEL 5	String	Land Use Class	LEVEL 5
LEVEL 6	String	Land Use Class	LEVEL 6
LEVEL 6	String	Land Use Class	LEVEL 6
AREA	Double	Area in Square meter	AREA
AREA_HA	Double	Area in Hectare	AREA_HA

Chapter – 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The present land use pattern of the VDC under study is classified using remotely sensed image with the help of ground based information. The VDC showed different degree of variability in land use pattern, maximum with agriculture and minimum on forest (although plantation).

Lack of clear guidelines on the classification system has posed a level of difficulty in assigning the classes of different hierarchy in land use, especially in differentiating forest category. The system does not say in which category the plantation should be kept as neither it belong to the category of Forest nor is it explicitly on agricultural use. This has posed a degree of ambiguity to assign the proper land use codes.

Hierarchical classification system helped in incorporation of complex land use pattern of this VDC. Priori classification system used in the study attribute to standardization in the land use result among different VDCs. Visual image interpretation incorporated with extensive field visit and use of ancillary data such as LRMP map, slope map, DEM, NDVI, Google earth was used to generate land use map. For mapping at scale 1:10000 combinations of different levels are used. The accuracy of the results was assessed and overall accuracy was obtained to be 94.37% with Kappa coefficient 0.93.

The land use classes yield better accuracy because the classes are designated manually based on ground knowledge and visual interpretation rather than automatic classification. These land use data and map can be used to formulate land use and other plans for the VDC under study. Further it can also be used for management activities and regulating land use activities in the VDC.

Out of total 1285.81 hectare land, 89.71% area is covered by agriculture followed by residential with 3.09%. Commercial area covers 0.97% area of the VDC. Public services cover about 1.55%, Riverine and lake cover 2.78%, Industrial cover 1.86%, Cultural and Archeological covers 0.02% and forest cover 0.01% of the area.

5.2 Recommendation

Based on the constraints faced on this project following recommendation has been made for future undertaking of similar projects.

- For better result satellite imageries of the study area should be of individual bands. It would be better if there were individual bands supplied which then would be undergone for different image analysis techniques. Further, the study also felt the strong need of real time satellite imageries as problem was faced during field visit because the total change occurred in some of the land use (e.g. farmed land).
- Comprehensive land use database model provided by NLUP facilitated in establishing the physical model very much but if proper criteria of defining the land use polygon in an objective sense is provided, then it would further enhance the consistency of the final product.

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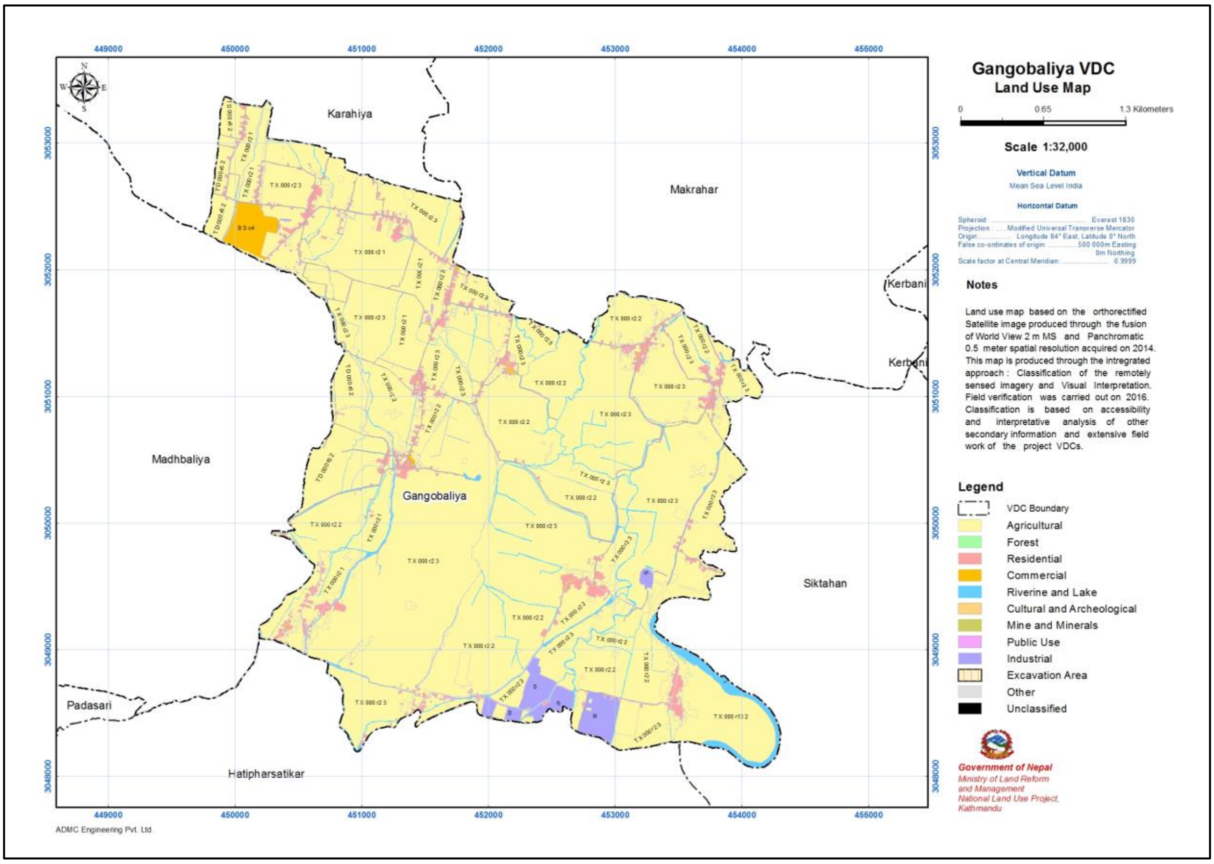
Appendix 1: Land Use Map Gangobaliya VDC, Rupandehi



Appendix 2: RMSE Error Assessment of DGPS

The RMSE error is found to be less than 2 meter.

Appendix 3: Accuracy Assessment of Land Use Classification

	Agriculture	Industry	Commercial	Residential	Forest	Pond	Road	Total	Comission Error	Users Accuracy
Agricultural	39	0	0	0	2	0	0	41	2.5	97.5
Industry	0	7	0	0	0	0	0	7	0	100
Commercial	0	0	5	0	0	0	0	5	0	100
Residential	0	1	0	35	0	1	0	37	5.405405	94.59459
Forest	2	0	0	0	20	0	0	22	9.090909	90.90909
Pond	2	0	0	0	0	10	0	12	16.66667	83.33333
Road	0	0	0	0	0	0	18	18	0	100
Total	43	8	5	35	22	11	18	142		
Omission Error	9.302326	12.5	0	0	9.090909	9.090909	0		Overall Accuracy	94.3662
Producer's Accuracy	90.69767	87.5	100	100	90.90909	90.90909	100			

	Agriculture	Industry	Commercial	Residential	Forest	Pond	Road	Total	Kappa Statistics
Agricultural	39	0	0	0	2	0	0	41	0.929375
Industry	0	7	0	0	0	0	0	7	
Commercial	0	0	5	0	0	0	0	5	
Residential	0	1	0	35	0	1	0	37	
Forest	2	0	0	0	20	0	0	22	
Pond	2	0	0	0	0	10	0	12	
Road	0	0	0	0	0	0	18	18	
Total	43	8	5	35	22	11	18	142	

C. Soil

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CHAPTER - 1

INTRODUCTION

1.1 Background and Rationale

Background: Land use planning has been defined as "The systematic assessment of land and water potential, alternative patterns of land use and other physical, social and economic conditions, for the purpose of selecting and adopting land-use options which are most beneficial to land users without degrading the resources or the environment, together with the selection of measures most likely to encourage such land uses." (Food and Agriculture Organization).

Land use planning is fundamental to the process of natural resource management and ecological sustainable development. It demands an integrated and strategic approach at national, regional and local levels to meet all needs. Land use planning should consider the sustainability, social impact and an assessment of what the land is capable of supporting and sustaining into the future and in the interests of the wider community. The demand on the use of our land to achieve many objectives requires the application of a rigorous process of planning. For example, some areas of land can support a wide range of uses whereas other areas support a small range of uses or certain types of uses. Effective planning involves anticipation and an understanding of land use and land management practices, and the participation by land users, planners, the public and decision makers in the planning process.

Soil surveys most commonly are made for areas that have more than one kind of important land use and for users who have varied interests and needs. These needs may be few and noncomplex in areas of extensive land use where change is not expected or they may be many and complex in areas of intensive land use where changes are expected. The predictions of soil surveys serve as a basis for judgment about land use and management and provide information about soil resources needed for planning development of new lands or conversion of land to new uses. This is important in planning specific land use and the kind and intensity of land management needed, including those operations that must be combined for satisfactory soil performance. Soil surveys are also useful in helping to locate possible sources of sand, gravel, or fertile topsoil for cultivation. Thus, intended land use and its economic feasibility can be determined with the soil surveys and ultimately by land use planning.

Agriculture is the major sector in the country Nepal, which provides employment to the more than 65 percent of the people, contributing 33 percent in the national GDP. The production of major cereal crops plays an important role in agriculture production. The production of major cereals was reduced by 8 percent (Economic Survey, 2012/13). Low agriculture production is the major problem in Nepalese agriculture posing food security problem in the country. The major cause of low agriculture production is the cultivation of crops and soil management without scientific land resource data. Thus, land resource inventory data is necessary for environment friendly agriculture sustainability.

In this context, the Government of Nepal has recently formulated the 20 year Agriculture Development Strategy emphasizing to increase agriculture production to solve the food and nutritional security problems of the country safeguarding the environment. Also, the National Land Use Policy-2072 has been declared, which is focused to increase the productive capacity of land.

Rationale: Land-use planning can be applied at three broad levels: national, district and local. For local level planning, information regarding the natural resource, socio-economic and demography of that are is necessary for effective planning which gives guideline for selection of land and what activities can be performed, when and who is responsible for those activities. However, Nepal has only regional level data base on land use, land system and land capability which were produced by Land Resource Mapping Project (LRMP, 1983/84). Realizing this fact, the Ministry of Land Reform and Management of Government of Nepal established the National Land Use Project (NLUP) in 2057/058 fiscal year to generate the necessary data bases on the land resources of the country.

In the first phase, the National Land Use Project of Nepal had initiated several projects at district level and prepared Land Resource Maps and Database at 1:50,000 scale for the whole Nepal. It had also prepared same kinds of maps and database for Kirtipur, Lekhnath, Madhyapur Thimi and Bhaktapur municipalities at larger scales. Finally, NLUP was mandated to prepare land resource maps of Village Development Committees (VDCs) of Nepal for local level planning through outsourcing modality.

The National Land Use Policy 2072, has emphasized to manage land use in accordance with the land zoning policy of Government of Nepal which categorizes 11 land zones such as Agricultural area, Residential area, Commercial area, Industrial area, Forest area and Public use area, Mine and Minerals, Cultural and Archeological, Riverine and Lake area, Excavation area and others. The policy has mentioned the land characteristics, capability of the each category of land zones. In addition, the policy has pointed to form Land Use Council at the top of district and Municipality/VDC level at the bottom which also highlighted the importance of preparation of Municipality and VDC level maps and databases on natural resources.

In this regards, the National Land Use Project (NLUP) has awarded to conduct the project entitled Package 27: Preparation of VDC level land resources maps, Data base and Reports (Present Land Use Map, Soil Map, Land Capability Map, Risk Layers, Land Use Zoning Map and VDC Profile for Land Use Zoning Map and Superimpose of Cadastral Layers) of Rupandehi District to our consultancy for fiscal year 2073/2074. The Package 27 covers 17 VDCs; Bagaha ,Basantapur, Bodabar, Chhipagadh, Chhotki Ramnagar, Chilhiya, Dhakadhai, Gangobaliya, Harnaiya, Hatipharsatikar, Hatti Banagai, Mainahiya, Padasari, Pajarkatti, Patkhauli, Pokharbhindi and Siktahan

1.2 Objectives

The objectives of the study are as follows:

1. To prepare map specifications for preparation of Land Resources Maps at the scale of 1:10000
2. To prepare standards for different steps of the preparation of land resources maps
3. To maintain uniformity and to follow the standards and norms for the preparation of land resources maps of specified areas
4. To identify the supplementary data and information necessary for the preparation of profile of the specified area. In order to achieve the objective, the study team shall carryout the following activities:

a. Prepare Geological Maps of the selected VDCs at 1:10000 scales.
b. Prepare Land System Maps for the selected VDCs at 1:10000 scales.
c. Prepare maps of sample pits covering each land unit/land type of the VDC with coordinate points to be identified in the field.
d. Carry out extensive field survey for field verification of land system maps and to collect soil samples from the pits and fill up of the soil profile description form.
e. Analyze the physical and chemical characteristics of soils including nutrients based on the field survey as well as detailed Laboratory test of the soil samples.

f. Prepare Soil Maps from order to family level following United States Department of Agriculture & Soil Conservation (USDA) system for the selected VDCs at 1:10000 scales.
g. Design appropriate GIS database logically for detailed field survey and Lab test analysis data.
h. Discuss the accuracy, reliability and consistencies of data.
i. Prepare reports describing methodology, distribution of different soil types and model of GIS data base.
j. Prepare A4 size Maps of N, P, K, Boron, Zinc, OM, Texture, and pH to attach in the soil reports of the VDCs.

1.3 Study area

The Gangobaliya VDC is covered by Siktahan in the East, Madhbaliya in the West, Makrahar in the North and Hatipharsatikar in the South. The rectangular extent of the VDC is 83°32'08"E, 27°35'51"N, 83°29'27"E and 27°33'01"N. The total population of this VDC is 6966, of which male population accounts for 49.14 percent and female population is 50.86 percent (VDC profile, 2014). However, all the wards vary in area and population size. Total number of household in the VDC is 1172.The area of the VDC is 1,285.81 hectares.

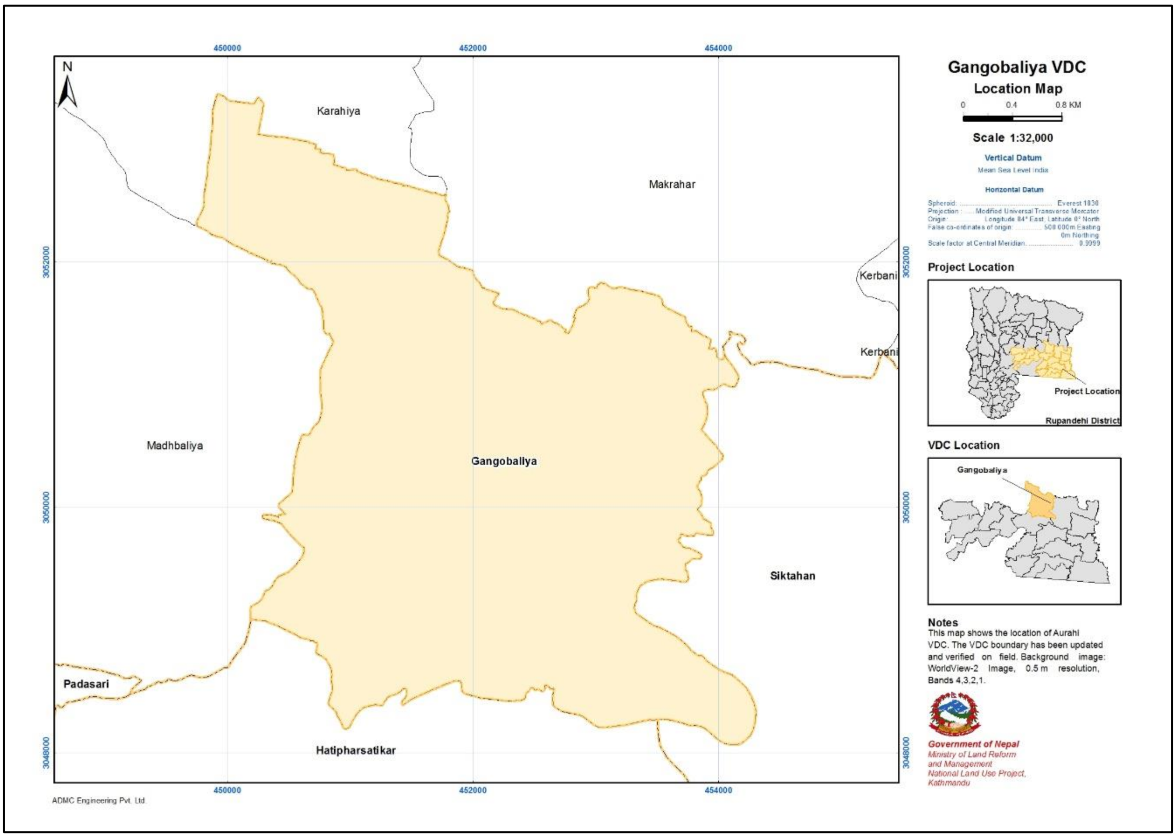


Figure 1.1: Location Map of GangobaliyaVDC of Rupandehi District.

CHAPTER - 2

BIO-PHYSICAL CONDITION OF THE STUDY AREA

2.1 Physiographic region

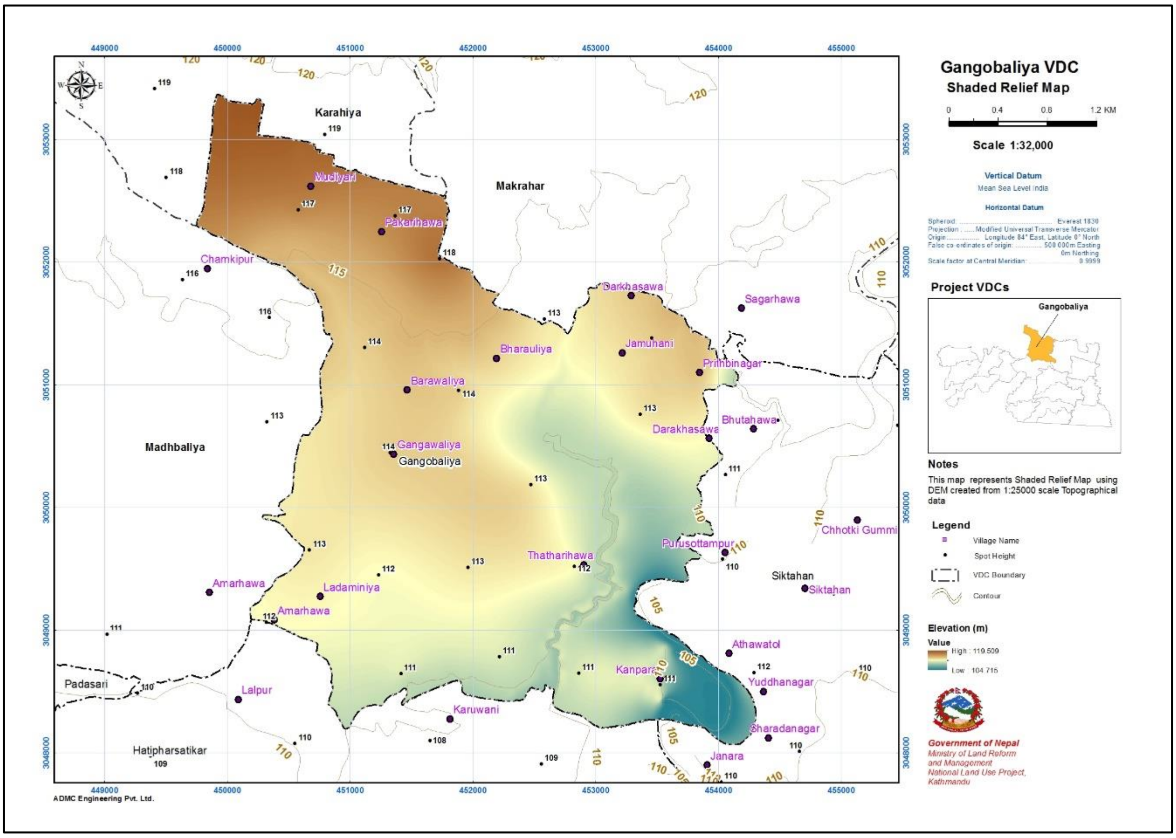
The study area falls within the terai physiographic region which covers the southern part of the country and northern rim of the Gangetic plain. The Elevation of the Basahiya ranges from 65 m to 73 m having the land almost flat with minor relief.

2.2 Elevation

The elevation is an important topographic element affecting the soil formation. Elevation influences the soil formation by affecting the type of vegetation and soil type along with the climatic factors. The Elevation of the Gangobaliya VDC ranges from 104.357 m. to 119.125 m.

2.3 Slope

Slope is influences the soil formation controlling soil erosion and water movement in the soil along with the other soil forming factors and affecting the soil characteristics. To delineate the soil boundary, slope is used as the physiographic variation. Besides this, slope of the project area was used as the basic tool for the demarcation of landform, land types and land units. The slope of Gangobaliya VDC ranges from 0º to 14.56º and covering the major portion of this VDC is less than 1^0.



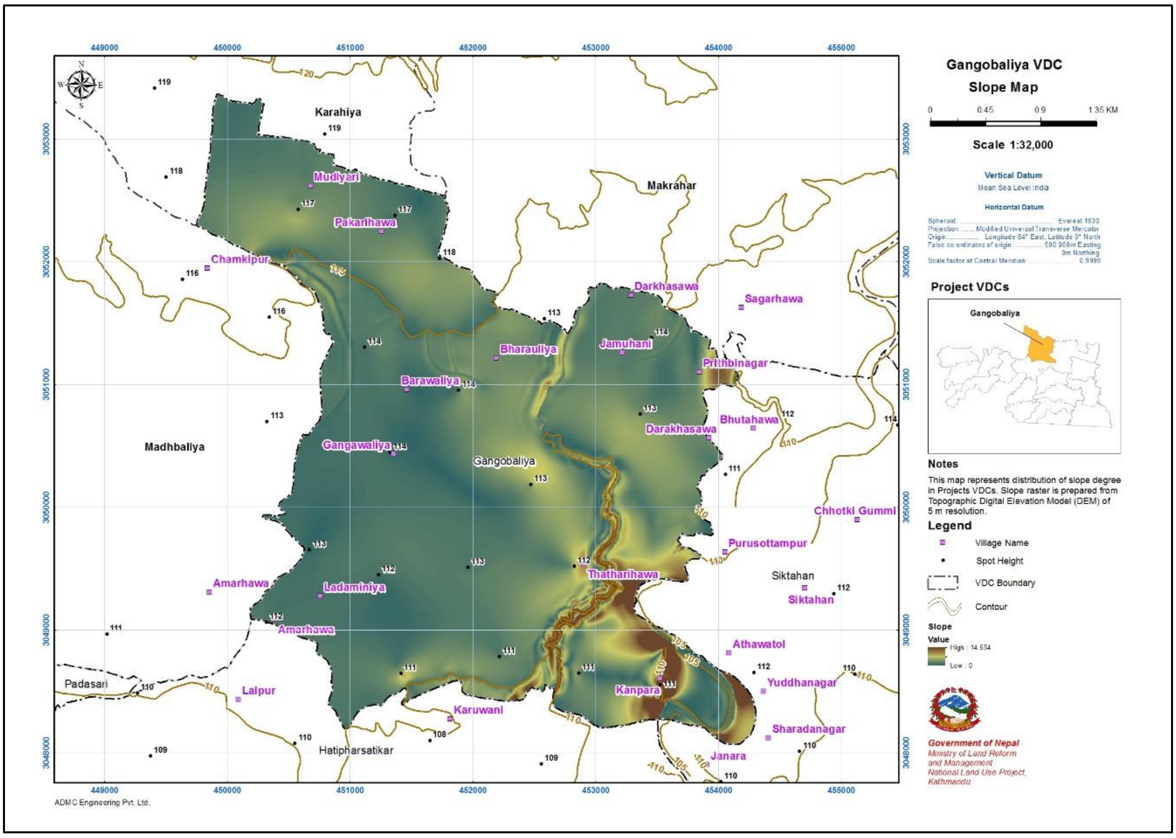


Figure 2.1 Elevation and Slope Distribution Map of GangobaliyaVDC

2.4 Geology

The project area lies within the Terai Plain of Eastern Nepal. It represents end of hill and start of plain lands of Terai and is a continuation of Indo-Gangetic trough. The Terai plain is covered by recent alluvium. The recent alluvium is deposited by rivers coming from mountains and hills.

Alluvium Deposits are distributed on both sides of the rivers and streams as well as immediately at the southern foot slope of the Lower Siwalik in the south belt with low gradient and open valley. Alluvium Deposits are characterized by river terrace deposits and are of unsorted, rounded to sub rounded pebbly and gravely materials mixed together with fine sand, silt as well as clay giving rise to the development of the fertile top fine soil usable for the cultivation. Active Alluvial Fan is locally deposited debris as fan derived from landslides and brought down by tributaries to the main streams.

Flood Plain Deposits (River Bed Deposit): It occurs along the riversides and on the flood plain (present river channel) itself which also contain the water during the winter season and cover the area as high as the water level rises during the heavy rainy season. In other words this is the area that is covered by the flooding river and left barren during the dry season after depositing the various materials carried at flood time. It has alluvial loose sediments consisting of boulders, cobbles, pebbles, coarse sand and gravels mainly of sandstone, siltstone and claystone with silt. When mixed with clay it gives rise to the fertile top fine soil usable for the cultivation. The aggregates thus derived and deposited by the river often provide an excellent source of building and construction materials.

Of the Lower, Middle and Upper divisions of the sequence of the Siwaliks only its Lower part is found in the area. **Lower Siwaliks** comprises the colourful bedded sedimentary rocks like fine grained sandstone, mudstone, siltstone and clay. Siwaliks is the erosinal detritus consisting of thick piles of fresh water molasse sediments deposited and lifted during the rising of the Himalayas. Strong and deep weathering is common throughout the area and particularly severe on spurs and slopes where the rocks are often converted into a soft powdery mass totally different from the original rock.

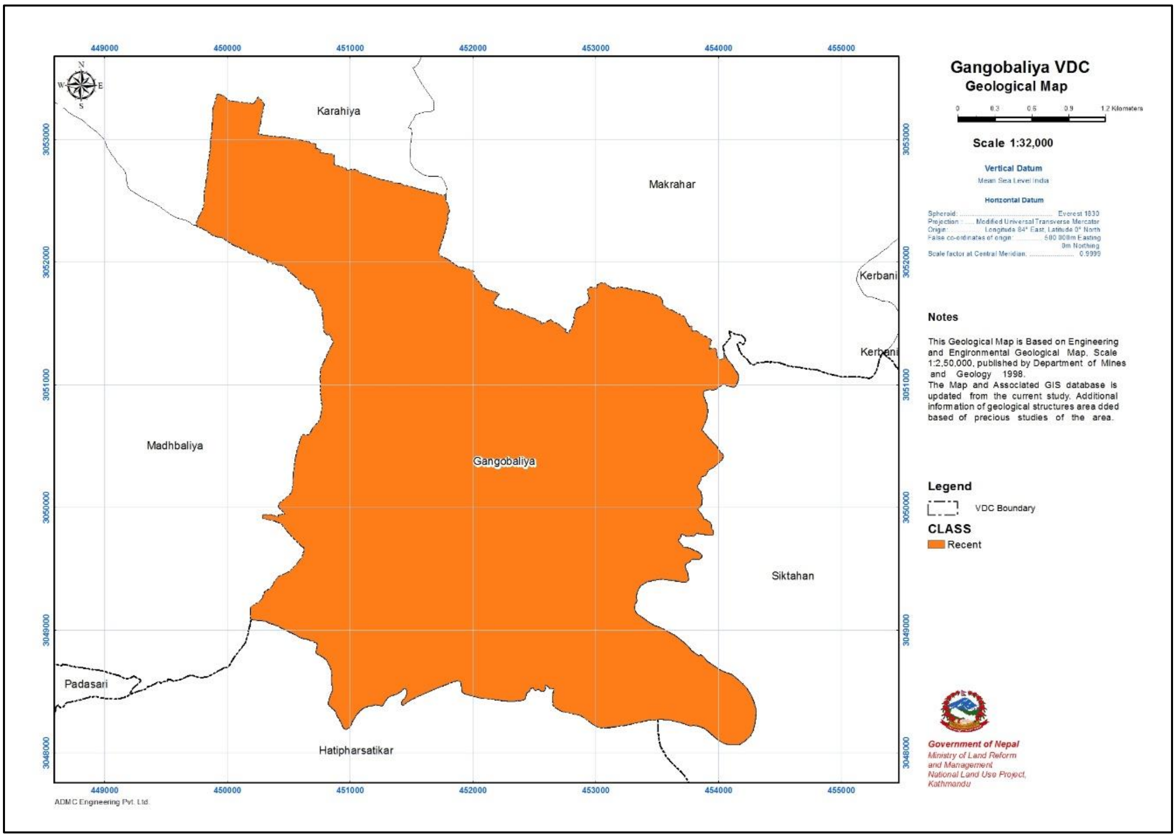


Figure 2.2: Geological Map of Project Area with VDC boundary

2.5 Streams and Canals

The VDC is endowed with rivers among which major river is Tinahu Nadi and Rohini Nadi. No major Canal system is available but many small local canal system exists.

2.6 Climate

The climatic condition of this VDC is as usual as of other Terai Districts, i.e. subtropical monsoon type. The VDC is represented by meteorological station at Bhairahawa Airport. According to Bhairahawa Airport station, the mean yearly minimum temperature is lowest (8.55^{0}C) in the month of January and it slowly rises from the month of February and attains highest (26.17 ^{0}C) in the month of July. Similarly, the mean yearly maximum temperature is lowest (20.52 °C) in the month of January and maximum recorded temperature is 37.05 °C in Bhairahawa Airport. Table 2.1 shows the Yearly Mean Minimum Temperature and Yearly Mean Maximum Temperature in ^{0}C at Bhairahawa Station (1995-2015).

Table 2.2 shows the Yearly Mean Rainfall at Bhairahawa Airport, Rupandehi station. It is seen that the rainfall is intensified within four months i.e. June to September, of the year. Highest rainfall (584.84 mm) is obtained in the month July and lowest rainfall is in November.

Table 2.1: Yearly Mean Minimum Temperature in ^{0}C at Bhairahawa Station (1995-2015)

Temperature of Bhairahawa Airport, Rupandehi (1995-2015)												
Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Average	14.54	18.09	22.78	27.84	30.25	30.72	29.88	29.82	29.16	26.64	22.16	17.11
Max (avg.)	20.52	25.55	31.40	36.34	37.05	35.79	33.60	33.61	33.43	32.59	29.36	23.87
Min (avg.)	8.55	10.63	14.16	19.34	23.45	25.66	26.17	26.03	24.89	20.70	14.96	10.35

Source: Department of Hydrology and Meteorology

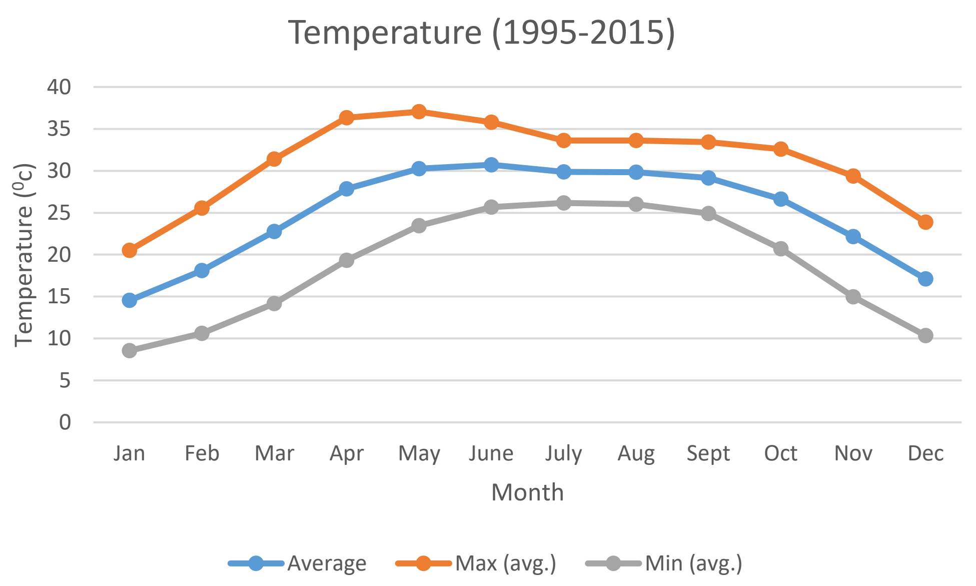


Figure 2.3: Yearly Mean Temperature at Bhairahawa Airport Station (1995-2015)

Table 2.2: Yearly Mean Rainfall (in mm) at, Bhairahawa Airport, Rupandehi (1995-2015)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm.)	18.9	25.3	17.17	26.74	98.5	285.85	584.4	441.7	221.5	73	6.605	9.679

Source: Department of Hydrology and Meteorology

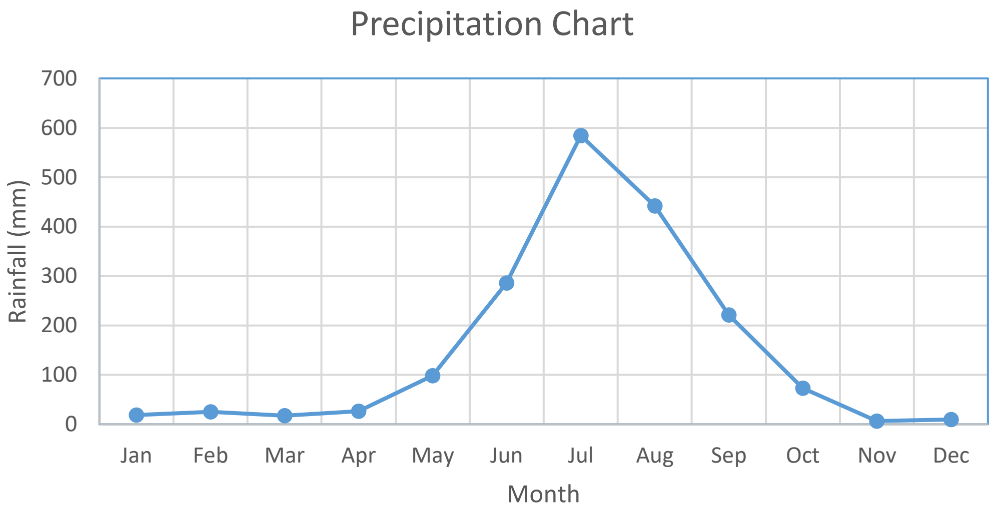


Figure 2.4: Yearly Mean Rainfall at Bhairahawa Airport Station (1995-2015)

Between the months June and September of every year, the highest total rainfall is recorded i.e. 1533.45 mm and the lowest total rainfall of 53.879 mm is recorded between the months of December and February. (Table: 2.3) shows Yearly Mean Seasonal Rainfall (in mm) at, Bhairahawa Airport, Rupandehi (1995-2015)

Table 2.3: Yearly Mean Seasonal Rainfall (in mm) at, Bhairahawa Airport, Rupandehi (1995-2015)

Season	Duration	Total Rainfall
Winter	Dec-Feb	53.879
Pre-Monsoon	Mar-May	142.41
Monsoon	June-Sept	1533.45
Post-Monsoon	Oct-Nov	79.605

2.7 Vegetation/Land Use-Land Cover

The majority the land (89.71 %) is used for the agriculture purpose. The remaining area of land is used for Residential, public use, industrial use, commercial, Cultural and Archeological, Excavation Area and forest. The small patches of private forest are seen in the area.

Table 2.4: Land use Class

S. No.	Landuse Class	Area(sqm)	Area(ha)	Percentage
1	AGRICULTURAL	11534919.57	1153.49	89.71
2	RESIDENTIAL	397946.50	39.79	3.09
3	RIVERINE AND LAKE AREA	357979.69	35.80	2.78
4	INDUSTRIAL	238648.60	23.86	1.86
5	PUBLIC USE	199140.86	19.91	1.55
6	COMMERCIAL	125187.33	12.52	0.97
7	CULTURAL AND ARCHEOLOGICAL	2801.58	0.28	0.02
8	FOREST	1446.63	0.14	0.01
	Grand Total	**12858070.75**	**1285.81**	**100.00**

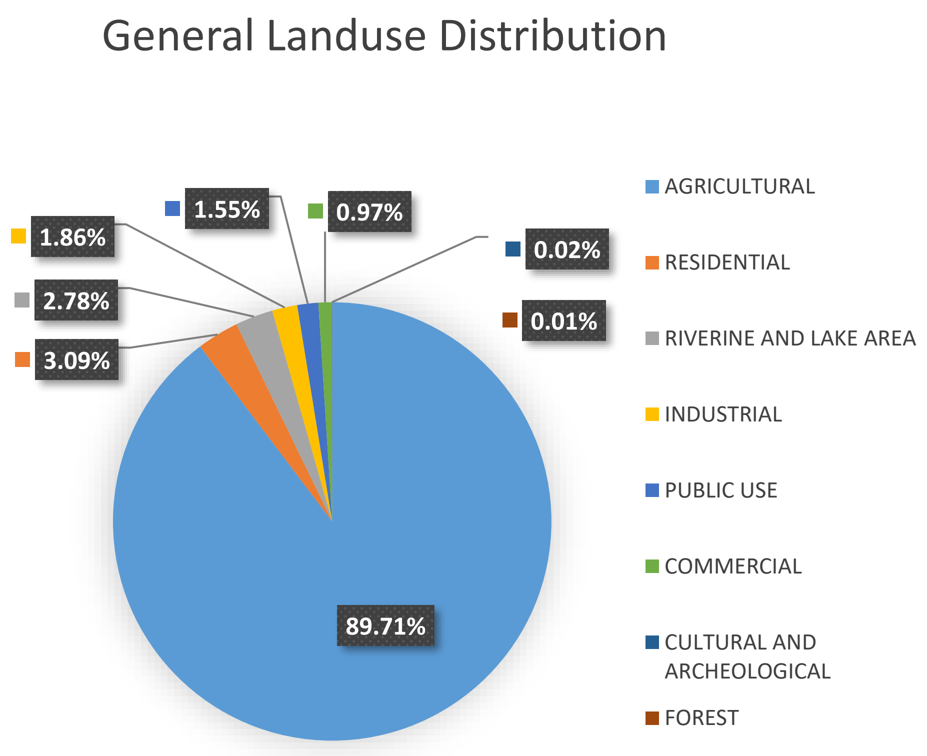


Figure 2.5: Land use Class

CHAPTER - 3

METHODOLOGY OF SOIL SURVEYING

3.1 Review of Soil survey methods

Soil survey includes study and mapping of soils in their natural environment. It is the systematic examination, description, classification and mapping of soils of an area. Soil survey consists of group of activities which are:

- Field work to study the important characteristics of soils and the associated external land features such as landforms, natural vegetation, slope etc.
- Laboratory analysis to support and supplement the field observations.
- Correlation and classification of soils into defined taxonomic units.
- Mapping of soils that is establishing and drawing soil boundaries of various kinds of soils, on standard topographical base map.
- Soil survey interpretation, that is making prediction about the potential of soils for alternative uses, like agricultural crops, grasses, fruit, forestry or plantation crops and Ascertaining their management requirements for sustained production.

The study methodology of soil map preparation can be divided in to two parts, i.e. 1) desk study as secondary information collection, analysis and report preparation and 2) field study as primary information collection with verification of secondary information with observation by the team of expert. In case of desk study, the secondary information was collected from various sources such as published and unpublished reports, various maps and other sources. The primary information of soil was collected using field sampling with strong support from GIS and RS analysis and other remote sensing techniques. However, the soil survey was comprised of identification, examination, classification and mapping of the soil and land units with characterization of both the physical and chemical properties of the soil units.

There are basically two approaches commonly used in other parts of the world for soil mapping using satellite remote sensing data which is available in both format as digital (softcopy) and imageries (hard copy).

A) **Computer aided digital analysis approach:** Digital analysis of remote sensing data utilizing the computers has been developed to meet the requirement of faster analysis and extract information from the large quantities of data based on the utilization of the spectral variations for classification.

B) **Visual image interpretation:** Visual interpretation is based on shape, size, tone, shadow, texture, pattern, site and association. This has advantage of being relatively simple and inexpensive. Soil mapping needs identification of a number of elements, which are of major importance for soil survey. They are land type, drainage pattern and drainage condition, vegetation, land use, slope and relief.

In these contexts, soil survey methods based on the visual image interpretation are reviewed here.

3.1.1 General Traversing

Studying and mapping of soils in the field are the two most important activities of the soil survey. The advancement of technology and technical knowledge has made change in the trend soil survey as if the basic means and methods remained same. The surveyor analyses the landform, geology, climate and vegetation and their relationship with morphological properties of soil by using aerial photo and satellite imagery before going to the field. After that, surveyor goes to the field to identify the points to be studied based on the intensity of mapping. Then, he observes the morphological characteristics such as texture, color, horizons, soil depth, moisture status, structure etc. of the soil at that point through field method and put these observed data on the map.

3.1.2 Grid survey

Grid survey is the field observations at fixed intervals in both directions. The setting of legend before, during and after the field observation is performed in this survey. In very steep terrain, water body, limited budget and large number of soil pit, the grid survey is difficult to perform. If it is necessary to reduce the number of sample site, we can do this by modifying the grid system considering the pedogenesis, water body, and slope, and land use, degree of difficulties, research objectives and research budget producing accurate and sufficient data.

3.1.3 Free survey

The free survey is suitable for small scale survey where large areas of inaccessible terrain must be covered in a short time within a limited budget. The soil sampling points are maintained on the basis of changes in physiography interpreted through satellite imagery and other surface features such as soil colour, vegetation and land use. Number of sampling points depends on the uniformity of soil and mapper concentrates of inferred boundaries within the boundary. On small scales, the inferred boundaries are often accepted as oil boundaries and very limited efforts are made to find soils within the physiographic boundaries. On large scales, however, within the physiographic boundaries are recognized depending on the scale of mapping. Based on the differences in physiography, parent material, drainage class and profile development the grouping of soils of an area into defined soil map units.

3.1.4 Geo-statistical Sampling

In geo-statistical sampling method, systematic sampling of accurate interpolation by krigging producing spatial pattern maps and for accurate estimation of semi-variogram are two primary concerns. A regular grid with square, triangular or hexagonal elements is most often used and placement of sample locations is in the center of each grid cell. Sample spacing for these grid cells should be less than 1/2 of the range for the semi-variogram as a useful tool for modeling spatial structure in a measured soil property.

The methodology adopted for the present soil survey was based on integrated use of visual interpretation and computer aided technology and integrated use of GI Science technology. The entire methodology comprises three- tier approach furnished below in detail.

3.2 Desk Study

Before the field visit, WorldView-2 satellite imagery (MSS and pan bands) dated 18 November, 2015, Topographical Maps and map of land resources; Land System, Land Capability, Land Utilization and their related reports prepared by Land Resource Mapping Project (LRMP) published in 1984/86 were employed to identify the landforms and land units of survey area. All these layers and satellite images were made compatible for overlay analysis by geo-rectifying and geo-referencing them in same projection system prescribed by NLUP. Standard False Color Composite (RGB:432) of the project area at the scale of 1:10000 were produced. These imagery sheets are visually interpreted for lithological (parent material) units which are initially delineated based on available geological maps. It is followed by delineation of broad physiographic units based on relief information available in topographical maps. Topographic information, such as relief and slope, were also produced by interpreting drainage features, drainage density exhibited on imageries. GIS based digital elevation model, relief and hill shade map were produced for the visualization of virtual 3D terrain surface for delineating the land type units that was used for detailed soil survey. The soil mapping units were interpreted and delineated on the imagery with the aid of bio-physical-soil relationship such as topography, geology, drainage and land use. The physiographic units are further sub-divided based on land use/land cover as revealed in the image.

After delineating the land forms/units through available thematic maps and satellite images, pit location for soil sampling were fixed. Pit location was determined in the geo-referenced images covering at least each land forms/ units as identified in the images with the help of Land resource Map of LRMP. The major considerations while selecting the pits were 1) representation of similar characteristics of land form and soils, 2) priority for the cultivated and plain area, 3) discarded or less priority for the rock-out and very steep slope areas etc. Then, maps with pits were prepared at the scale of 1:10000 for field work. Altogether six soil pits were delineated for sampling the soil for this VDC. The spatial distribution of pit locations of Gangobaliya VDC is shown in Fig 6.1.

3.3 Field Survey

The landform and associated soil properties of the project area were identified through conducting preliminary reconnaissance survey during the pre-field visits. The preliminary survey was very useful for recognition of soil mapping units and selecting the appropriate soil pit to study the morphological characteristics and soil sample collection for the physical and chemical determination in various landform/unit. Physiography, landform and their associated soil properties were studied during the field work which was conducted 2073/10/03 to 2073/10/10 the selected soil pits. It is assumed that the soil sampled fro/m the pits covers all units of delineated landform which was demarcated by using land system map, land use map, topographical map and WorldView-2 Satellite imagery for this project. At the time of field work, soil profile was observed as mentioned methods and procedure of specification and Terms of Reference of project. The soil profile of pit was described following the Soil Survey Manual of United States Department of Agriculture (USDA) and FAO guidelines 1998. The soil properties were observed based on the form of soil survey provided by NLUP. The soil sampling was done from each horizon for the chemical and physical analysis of soil to know the fertility status of soil. Besides the topographical map, standard false color composite (FCC), land system maps for the basic information, the following equipment were used during the soil profile observation and sample collection:

a. Soil sample airtight plastic bag with Tag
b. Measuring Tape and Scale
c. Standard Soil description form
d. GPS (1m accuracy)
e. Digital Camera
f. Abney Level
g. pH and moisture meter
h. soil thermometer
i. Marker pen (Permanent)
j. Spade or Shovel

k. Knife
l. Munsell Color Chart

The soil information observed and recorded in *Standard soil profile description form* includes the following morphological and physical characteristics of each soil pit at different horizon. These characteristics include the information as below:

a. Soil Pit Number
b. Satellite Imagery
c. Higher category classification
d. Date of examination
e. Authors of description
f. GPS Location: Easting and Northing
g. Elevation (in meters of feet)
h. Micro-topography
i. Physiographic unit
j. Localities where pit is dug
k. Slope on which profile is sited (direction and degree)
l. Land use /land cover or Vegetation
m. Climate
n. Cropping pattern

1. General Information on the soil

a. Parent Material
b. Drainage class
c. Moisture conditions in the Soil
d. Depth of Ground Water Table (in meters)
e. Presence of Surface Stones or Rock outcrops
f. Evidence of Erosion status
g. Presence of Salt or Alkaline.
h. Human Influence
i. Classification
j. Local name of soil
k. Series name
l. Pans
m. Depth of ground water

2. Description of Individual Soil Horizon

a. Horizon symbol
b. Depth of top and bottom of horizon (in centimeters)
c. Matrix Color (Moist/ Dry)
d. Mottling color
e. Texture
f. Coarse fragments
g. Structure
h. Consistency
i. Clay cutans (Clay Skin)
j. Pores
k. Features of Biological Origin
l. Content of roots
m. Nature of Boundary with Horizon below
n. PH Value
o. Number of Sample taken for Analysis
p. Porosity

The standard soil profile description form was slightly modified considering the information required reflecting ground realities and such form was attached in Appendix. Soil samples are collected from profiles with digging standard size for analysis in the soil laboratory.

3.4 Laboratory Soil Analysis

Soil Profile Data Analysis: The information containing in standard soil description form also known as spatial data includes physical and morphological attributes of soil pit brought from intensive field survey. Such information associated with the information of site characteristics, soil characteristics and horizon characteristics of each soil pit at different horizon level were converted into digital tabular format in order to join with the spatial location of soil pits. All spatial locations of each soil pit were transferred into the same scale of geo-referenced base map projected on MUTM parameters.

Soil Physical-chemical Analysis: The soil sampled from the top horizon of each soil pit were analyzed to determine the physical and chemical properties including soil texture, pH, Nitrogen(N), Phosphorus(P) and Potassium(K) , Organic matter(OM), Boron(B), and Zinc(Zn). These properties were analyzed to assess the fertility status and to assist in the soil classification. Laboratory Work was done in the Central Laboratory of Soil Management Directorate, Department of Agriculture, Hariharbhawan, Lalitpur, Nepal. In the laboratory the following methods were used to analyze the physical and chemical properties of sample pits:

Table 3.1: Methods followed in Laboratory to determine Chemical and physical properties of soil

Parameters	**Analysis methods**
Soil texture	Hydrometer method (Gee and Bauder, 1986).
Soil pH	Beckman electrode pH meter (Cottenie*et al.,* 1982)
Organic matter content	Graham's colorimetric method (Graham, 1948)
Nitrogen	Kjeldahl distillation (Bremner, 1982)
Phosphorous	Modified Olsen's (Olsen *et al.,* 1954)
Potassium	Ammonium acetate extraction method (Pratt, 1965) using flame photometry
Zinc(Zn)	Spectrophotometric Method (Extraction with 10% Sodium Acetate pH 5.2
Boron (B)	Azomethine–H method (Wolf, 1971)

A good correlation was found between routine test in the field and those carried out in the laboratory. Thus field determined pH and texture were found considerably reliable.

GIS Data Analysis: After completing the field study, different thematic layers such as contour, spot height, drainage and VDC and ward, land system and land use were made compatible by transforming into the same projection system (MUTM) adopted by Survey Department. The soil pits location was transferred into base map and image. Vector to raster conversion of line segment were made for preparation of digital surface model required for Digital Terrain Model and Hill shade.

Soil Mapping: Based on shape, size, tonal and color variation and relative height, the landform and land types of the project area were identified on, WorldView-2 satellite imagery and Digital Terrain Model. The color variation ranging from light to dark represents the soil difference identifying dry soil differentiated from wet soil. The Anaglyph Stereo Pair

Visualization of MSS WorldView-2 satellite image was made to get the 3-Dimensional perspective of terrain relief, land use practices associated with the soil in entire project area. It helps in identification of boundaries of soil mapping units in 3 dimensional views because soil is 3 dimensional natural bodies. Soil association which is universally accepted for soil mapping and classification was adopted in order to correlate the soil pit and soil mapping units because these two spatial entities are geometrically different. One soil pit is enclosed by one soil mapping unit. Thus, classifications were made based on soil association. Based on morphological characteristics and chemical properties derived from Lab analysis is used to classify the soil following Soil Taxonomy (USDA/SCS, 1998).

CHAPTER – 4

LAND SYSTEM, LANDFORM AND LAND TYPES

Soils are considered as the integral part of the landscape and their characteristics are largely governed by the landforms in which they are developed. Physiography influences soil formation affecting the climate, vegetation of an area as if it is considered as passive factor of soil formation. Moreover, there is a close relationship between physiography and soil development which ultimately affects the availability of nutrients (Verma et al., 2005). The physiography has influential role in soil formation through slope and exposure. The flat topography has more depth of soil as compared to the steep slopes because the steep slopes are more prone to the erosion (Sehgal, 2002).

Soil properties like profile development, texture, structure, color, acidity, cation exchange capacity, base saturation etc. are related to land form. There is a close relationship between physiography and soils. The formation of the diverse group of soils can be attributed to the variation in topography causing erosion, leaching, sedimentation and other pedogenic processes modified by water table (Mini *et al.,*2006). Thus, physiographic influence of soil properties has been recognized which ultimately leads to evolution of the soil-landscape relationship. Topographic maps, aerial photographs stereo-capability and remote sensing data provide useful tool for geomorphic analysis of the region and help in soil survey and mapping.

The present investigation is based on the physiographic-soil relationship approach assuming the physiographic controlled landform as the basic spatial and structural entities of forming soil mapping units (Table 4.1). Physiography in study area is further divided into land system according to recurrent pattern of landforms, geology and slope and arable agriculture limits and then land units based on map able land surface significantly from some user oriented point of view for delineation (LRMP 1986). Within the land units, land types were delineated based on position, slope, direction, drainage of landscape features which is especially important for local level project design (Carson 1985). The soil properties within the land types further subdivided based on the cropping pattern were determined by detailed field soil survey. These observations were further studied on *Soil Association* for classification. Digital Terrain Model (DTM) is employed for delineation of landform, land units and land types for detailed soil survey at local level planning.

4.1 Land System

The project area lies in the Terai physiographic region. It encompasses land system units of 1, 2 and 3 basically differentiated based on geology and geomorphology. Physiography is further subdivided into landforms basically defined by the position of land surface in landscape and it is characterized by slope and its direction, elevation, rock exposure and soil type.

4.2 Land form

Landform is further subdivided into land units basically defined by the mapable size of land surface for demarcation in landscape by the user. And it is characterized by landscape features. The land units in the project area are shown as below:

- Intermediate position level.
- Depressions
- Khola, sandbar and flood plain

Among the land units defined by LRMP Land System, land types are demarcated considering the local situation of land units representing micro-relief differences based on the local slope and elevation and its orientation.

Landform affects soil formation and its profile development in association with the steepness of land and slope direction. The slope classes are required for land type classification.
The soil classes based on their texture are sand, clay and loams with intermediary class such as sandy loam. The texture is the relative proportion of sand, silt and clay particles in the soil. Soil texture of top layer is used for land system classification, soil suitability and classification of soil at family level. The soil textures found in project area are given with symbol in Table 4.3.

Table 4.1: Soil texture and symbol

Texture Classes	Symbol
Clay	Cl1
Clay Loam	Cl2
Loam	Lo1
Loamy Sand	Lo2
Sand	Sa1
Sandy Clay Loam	Sa2
Sandy Loam	Sa3
Silt	Si1
Silty Clay Loam	Si2
Silty Loam	Si3

4.3 Description of Individual Land Type Units (GangobaliyaVDC)

The land units defined by LRMP are further subdivided based on local field variation associated with the different land use practices. Altogether four land units identified in the project are associated with the local micro-relief variations. The spatial extent covered by the VDC area is presented in Table 4.2 and distribution of the land units are shown in figure 4.1 and 4.2.

Table 4.2: Land System/ Land type

Region	Land system	Landform	Description	Land Unit	Dominant Slope	Area (ha.)	Total (%)
Terai	1	Active Alluvial Plain (depositional)	1a. present river channel	1a	-	35.87	2.79
	2	Recent Alluvial Plain lower piedmont (depositional and erosional)	2a. depressional	2a	<1/2	388.14	30.19
			2b. intermediate position level	2b	<1/2	769.66	59.86
	3	Alluvial Fan complex, upper piedmont (erosional)	3c. undulating	3c	1 to 3	92.14	7.17

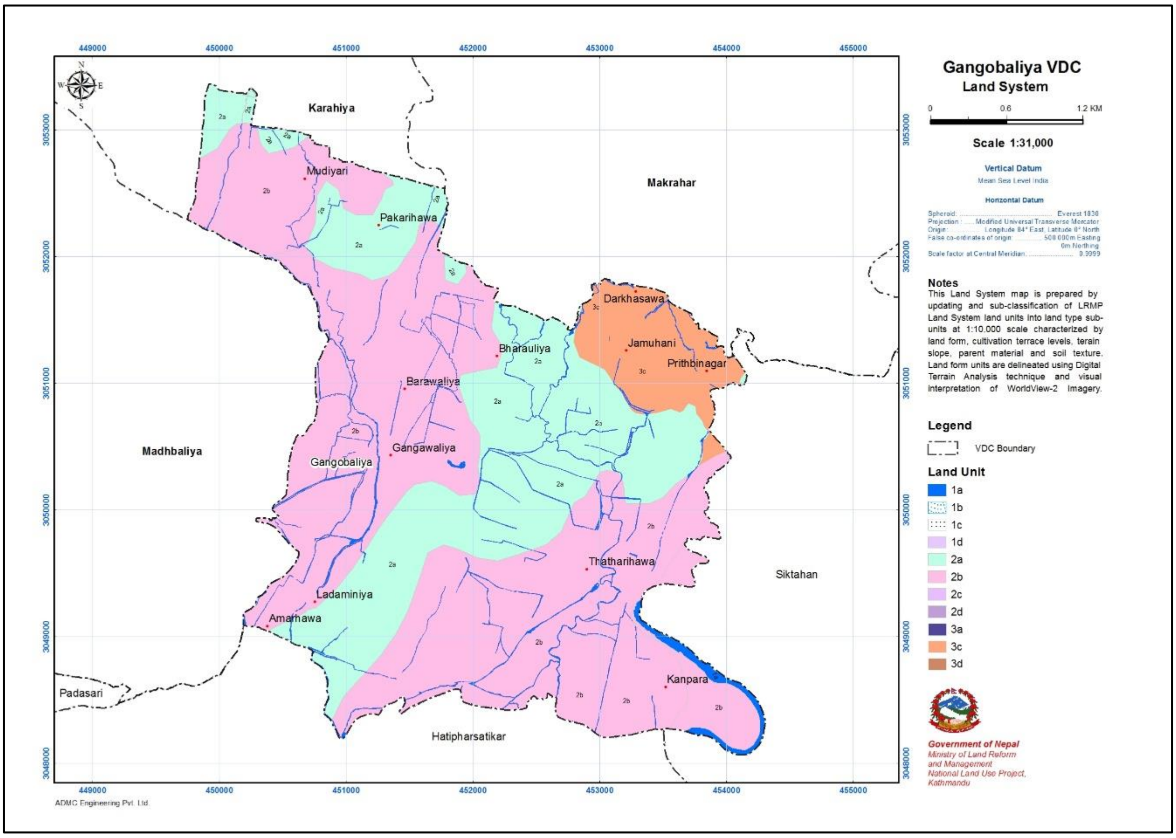


Figure 4.1: Spatial Distribution of Land Units

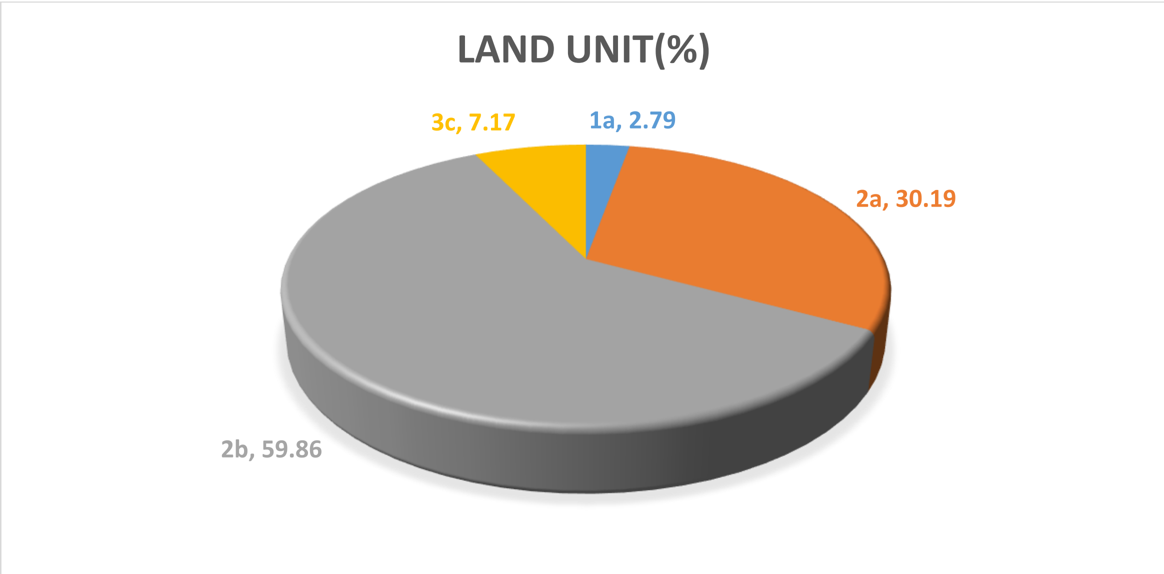


Figure 4.2: Distribution of Land Units

CHAPTER - 5

SOIL CLASSIFICATION SCHEME

Soil classification is the grouping of soils based on their properties for the purpose of studying and identifying them. The most widely used and accepted system of classification is the soil taxonomy developed by United States Department of Agriculture. Soil taxonomy provides a hierarchical grouping of natural bodies. The system is based on soil properties that can be objectively observed or measured, rather than on presumed mechanisms of soil formation. The system uses a unique nomenclature that gives a definite connotation of the major characteristics of the soils in question. It is truly international because it is not based on any one national language. Soil taxonomy is based on the properties of soils as they are found today which the outcome of the soil genesis is.

5.1 Soil Diagnostic Horizons

5.1.1 Diagnostic Surface Horizons

The diagnostic horizons that occur at the soil surface are called epipedons (from the Greek epi, over, and pedon, soil). The epipedon includes the upper part of the soil darkened by organic matter, the upper eluvial horizons, or both. It may include part of the B horizon if the latter is significantly darkened by organic matter. Eight are recognized, but only five occur naturally over wide areas. The other two, anthropic and plaggen, are the result of intensive human use. They are common in parts of Europe and Asia where soils have been utilized for many centuries.

Mollic: The mollicepipedon (Latin mollis, soft) is a mineral surface horizon noted for its dark color associated with its accumulated organic matter (>0.6% organic C throughout), for its thickness (generally >25 cm), and for its softness even when dry. It has a high base saturation greater than 50%. Mollicepipedons are moist at least three months a year when the soil temperature is usually 5° C or higher to a depth of 50 cm. These epipedons are characteristic of soils developed under grassland.

Umbric: The umbricepipedon (Latin umbra, hade; hence, dark) has the same general characteristics as the mollicepipedon except the percentage base saturation is lower. This mineral horizon commonly develops in areas with somewhat higher rainfall and where the parent material has lower content of calcium and magnesium.

Ochric: The ochricepipedon (Greek ochros, pale) is a mineral horizon that is either too thin, too light in color, or too low in organic matter to be either a mollic or umbric horizon. It is usually not as deep as the mollic or umbricepipedons. As a consequence of its low organic matter content, it may be hard and massive when dry.

Melanic: The melanicepipedon (Greek melas, melan, black) is a mineral horizon that is very black in color due to its high organic matter content (organic carbon >6%). It is character-istic of soils high in such minerals as allophane, developed from volcanic ash. It is more than 30 cm thick and is extremely light in weight and fluffy for a mineral soil.

Histic: The histicepipedon (Greek histos, tissue) is a 20 to 60 cm-thick layer of organic soil materials6 overlying a mineral soil. Formed in wet areas, the histicepipedon is a layer of peat or muck with a black to dark brown color and a very low density.

5.1.2 Diagnostic Subsurface Horizons

Many subsurface diagnostic horizons are used to characterize different soils in Soil Taxonomy each diagnostic horizon provides a characteristic that helps place a soil in its proper class in the system. We will briefly discuss a few of the more commonly encountered subsurface diagnostic horizons.

Argillic: The argillic horizon is a subsurface accumulation of silicate clays that have moved downward from the upper horizons or have formed in place. Examples are shown in Figure 3.4 and in Plate 1 between 50 and 90 cm. The clays often are found as coatings on pore walls and surfaces of the structural groupings. The coatings usually appear as shiny surfaces or as clay bridges between sand grains. Termed argillans or clay skins, they are concentrations of clay translocated from upper horizons.

Natric: The natric horizon likewise has silicate clay accumulation (with clay skins), but the clays are accompanied by more than 15% exchangeable sodium on the colloidal complex and by columnar or prismatic soil structural units. The natric horizon is found mostly in arid and semiarid areas.

Kandic: The kandic horizon has an accumulation of Fe and Al oxides as well as low-activity silicate clays (e.g., kaolinite), but clay skins need not be evident. The clays are low in activity as shown by their low cation holding capacities (<16 cmol c/kg clay). The epipedon that overlies a kandic horizon has commonly lost much of its clay content.

Oxic: The oxic horizon is a highly weathered subsurface horizon that is very high in Fe and Al oxides and in low-activity silicate clays (e.g., kaolinite). The cation-holding capacity is <16 cmol c/kg clay. The horizon is at least 30 cm deep and has <10% weatherable minerals in the fine fraction. It is generally physically stable, crumbly, and not very sticky, despite its high clay content. It is found mostly in humid tropical and subtropical regions.

Spodic: The spodic horizon is an illuvial horizon that is characterized by the accumulation of colloidal organic matter and aluminum oxide (with or without iron oxide). It is commonly found in highly leached forest soils of cool humid climates, typically on sandy-textured parent materials.

Sombric: The sombric horizon is an illuvial horizon, dark in color because of high organic matter accumulation. It has a low degree of base saturation and is found mostly in the cool, moist soils of high plateaus and mountains in tropical and subtropical regions.

Albic: The albic horizon is a light-colored eluvial horizon that is low in clay and oxides of Fe and Al. These materials have largely been moved downward from this horizon. A number of horizons have accumulations of salt like chemicals that have leached from upper horizons in the profile.

Calcic: calcic horizons contain an accumulation of carbonates (mostly $CaCO_3$) that often appear as white chalklike nodules.

Gypsic: Gypsic horizons have an accumulation of gypsum ($CaSO_4 \cdot 2H_2O$), and salic horizons have an accumulation of soluble salts. These are found mostly in soils of arid and semiarid regions. In some subsurface diagnostic horizons, the materials are cemented or densely packed, resulting in relatively impermeable layers called pans (duripan, fragipan, and placic horizons). These can resist water movement and the penetration of plant roots. Such pans constrain plant growth and may encourage water runoff and erosion because rainwater cannot move readily downward through the soil.

In the morphometric approach of classification, observable soil properties such as structure, form, color of soil matrix and mottling of the soil at different horizons, horizon designation and arrangement, structure, moisture condition and temperature condition, structure, translocation of carbonates, iron, manganese and clay are used. These properties are studied on the soil profile which is performed by digging the soil pit. Soil profile is the vertical section exposing the set of horizons in the wall of soil pit. The morphological attributes of each horizon is identified for the classification of soil. A soil scientist correlates these observed soil properties with the morphological properties of already existing classification system. The soil is taken from the soil profile for laboratory analysis to determine of physical and chemical properties of soil which assist in soil classification.

Soil classification of the Gangobaliya VDC was carried out by studying the morphological properties of soil through soil profile. After that, these morphological properties were correlated with soil types of USDA Soil taxonomy system of soil classification which is based on the observed and measurable properties of soil that exist today. In addition to this, world Reference Base for Soil Resources (WRBS) and indigenous soil classification system was also performed for soil classification.

5.2 Local Classification System

It is known that local farmers are considered as best engineers because of the fact that they know everything and they have local knowledge derived from their ancestors and historical practices. Local classification helps the farmers to know the soil properties benefited to agriculture. Ethnopedology is another branch of soil science dealing with the indigenous knowledge of local people regarding soil naming and management in Nepalese society, local farmers use to naming the soil base on color, texture and fertility of top soil.

Table 5.1: Local name of soil texture given by the local communities.

Texture	Local Terminology
Sand	Baluwa
Loam	Domat
Silt	Pango
Clay	Bangru
Sandy soil	baluwamitti

5.3 USDA Soil Taxonomy

There are six hierarchical categories of classification in Soil Taxonomy: (1) order, the highest (broadest) category, (2) suborder, (3) great group, (4) subgroup, (5) family, and (6) series (the most specific category). The lower categories fit within the higher categories. Thus, each order has several suborders, each suborder has several great groups, and so forth.

Order

Each of the world's soils is assigned to one of 12orders, largely on the basis of soil properties that reflect a major course of development, with considerable emphasis placed on the presence or absence of major diagnostic horizons. As an example, many soils that developed under grassland vegetation have the same general sequence of horizons and are characterized by a mollicepipedona thick, dark, surface horizon that is high in non-acid cations. Soils with these properties are thought to have been formed by the same general genetic processes, but it is because of the properties they have in common that they are included in the same order: Mollisols. The names and major characteristics of each soil order are shown in Table 5.2.

Table 5.2: Names of Soil Orders in Soil Taxonomy with Their Derivation and Major Characteristics

Name	Formative Element	Derivation	Major characteristics
Alfisols	alf	Nonsense symbol	Argillic, natric, or kandic horizon; high-to-medium base saturation
Andisols	and	Jap, ando, black soil	From volcanic ejecta, dominated by allophane or Al-humic complexes
Aridisols	id	L. aridus,dry	Dry soil, ochricepipedon, sometimes argillic or natric horizon
Entisols	ent	Nonsense symbol	Little profile development, ochricepipedon common
Gelisols	ell	Gk. gelid,very cold	Permafrost, often with cryoturbation (frost churning)
Histosols	ist	Gk. histos,tissue	Peat or bog; >20% organic matter
Inceptisols	ept	L. inceptum, beginning	Embryonic soils with few diagnostic features, ochric or umbricepipedon, cambic horizon
Mollisols	oll	L. mollis,soft	Mollicepipedon, high base saturation, dark soils, some with argillic or natric horizons
Oxisols	ox	Fr. oxide, oxide	Oxic horizon, no argillic horizon, highly weathered
Spodosols	od	Gk. spodos, wood ash	Spodic horizon commonly with Fe, Al oxides and humus accumulation
Ultisols	ulf	L. ultimus,last	Argillic or kandic horizon, low base saturation
Vertisols	ert	L. verto,turn	High in swelling clays; deep cracks when soil is dry

Sub-order

Soils within each order are grouped into suborders on the basis of soil properties that reflect major environmental controls on current soil-forming processes. Many suborders are indicative of the moisture regime or, less frequently, the temperature regime under which the soils are found. Thus, soils formed under wet conditions generally are identified under separate suborders (e.g., Aquents, Aquerts, and Aquepts), as being wet soils.

Great Groups

The great groups are subdivisions of suborders. More than 400 great groups are recognized. They are defined largely by the presence or absence of diagnostic horizons and the arrangements of those horizons.

5.3.1 Soil Classification at Soil Sub-group Level

Subgroups are subdivisions of the great groups. More than 2500 subgroups are recognized. The central concept of a great group makes up one subgroup, termed Typic. Thus, the Typic Hapludolls subgroup typifies the Hapludolls great group. Other subgroups may have characteristics that intergrade between those of the central concept and soils of other orders, suborders, or great groups. A Hapludoll with restricted drainage would be classified as an Aquic Hapludoll. One with evidence of intense earthworm activity would fall in the Vermic Hapludolls subgroup. Some intergrades may have properties in com-mon with other orders or with other great groups. Thus, soils in the Entic Hapludolls sub-group are very weakly developed Mollisols, close to being in the Entisols order. The sub-group concept illustrates very well the flexibility of this classification system.

5.3.2 Soil Classification at Soil Family Level

Within a subgroup, soils fall into a particular family if, at a specified depth, they have similar physical and chemical properties affecting the growth of plant roots. About 8000 families have been identified. The criteria used include broad classes of particle size, mineralogy, cation exchange activity of the clay, temperature, and depth of the soil penetrable by roots.

Series

The series category is the most specific unit of the classification system. It is a subdivision of the family, and each series is defined by a specific range of soil properties involving primarily the kind, thickness, and arrangement of horizons. Features such as a hard pan within a certain distance below the surface, a distinct zone of calcium carbonate accumulation at a certain depth, or striking color characteristics may aid in series identification.

5.4 World Reference Base for Soil Resources (FAO)

The **World Reference Base for Soil Resources (WRB)** is the international standard taxonomic soil classification system endorsed by the International Union of Soil Sciences (IUSS). It was developed by an international collaboration coordinated by the International Soil Reference and Information Centre (ISRIC) and sponsored by the IUSS and the FAO via its Land & Water Development division. It replaces the previous FAO soil classification.

The WRB borrows heavily from modern soil classification concepts, including USDA soil taxonomy, the legend for the FAO Soil Map of the World 1988, the Referential Pedologique and Russian concepts. The classification is based mainly on soil morphology as an expression pedogenesis. A major difference with USDA soil taxonomy is that soil climate is not part of the system, except insofar as climate influences soil profile characteristics. As far as possible, diagnostic criteria match those of existing systems, so that correlation with national and previous international systems is as straightforward as possible.

The WRB is meant for correlation of national and local systems. The level of detail corresponds to USDA soil taxonomy subgroups, without the soil climate information.

Comparisons of the United States and FAO-UNESCO Classification System

The structure, concepts and definitions of the WRB are strongly influenced by (the philosophy behind and experience gained with) the FAO-UNESCO Soil Classification System. A tabulation of the FAO system is given as the basis for comparing the systems: FAO and the 1975 US system (table 5.5). These comparisons are only approximate because the systems are very different. The great group of the US 1975 system is most accurately related to the first sub-unit level of the FAO system. The meanings of most of the FAO sub-unit names and adjectives are identifiable from the formative elements given in the table.

Table 5.3: Comparison of the FAO and the U.S. Systems of Soil Classification

FAO System and Name Meanings	US Systems (1975)
ACRISOLS Latin acris = very acidic, low base status. Subunits: Orthic, Ferric, Humic, Plinthic	ULTISOLS Hapl-ults Pale-ults Hum-ults Plinth-ults
ANDOSOLS Japanese an = black, do = soil. Subunits: Ochric, Mollic, Humic, Vitric	ANDISOLS Several suborders and great groups
ARENOSOLS Latin arena = sand. Subunits: Cambic, Luvic, Ferralic, Albic	Psamments. Several subgroups
CAMBISOLS Latin cambiare = change Subunits: Eutric, Dystric, Humic, Gleyic, Golic, Calcic, Chromic, Vertic, Ferralic	INCEPTISOLS Many Ochrepts
CHERNOZEMS Russian chern = black, zemlja = earth. Subunits: Haplic, Calcic, Luvic, Glossic	MOLLISOLS Several Borolls OXISOLS Most suborders
FERRALSOLS Latin ferrum = iron and aluminum. Subunits: Orthic, Xanthic, Rhodic, Hemic, Acric, Plinthic	Fluvents
GELOSOLS Greek gelid = very cold, permafrost in part	Gelisols
GLEYSOLSRussiangJey = mucky soil mass. Subunits: Eutric, Calcaric, Dystric, Mollic, Humic, Plinthic, Gelic	Aquents, Aquepts, Aquolls
GREYZEMS English grey and Russian zemlja = earth. Subunits: Orthic, Gleyic	MOLLISOLS Borolls, Aquolla
HISTOSOLS Greek histos = tissue. Subunits: Eutric, Dystric, Gelic	HISTOSOLS
KASTANOZEMS Latin castanea = Chestnut, Russian zemlja = earth. Subunits: Haplic, Calcic, Luvic	MOLLISOLS Ustolls, Borolls
LITHOSOLSGreeklithos = stone shallow to rock. Subunits: none	Lithic subgroups
LUVISOLS Latin Juo = to wash, Iliuvial clay layer.	ALFISOLS Many suborders

Subunits: Orthic, Chromic, Calcic, Vertic, Ferric, Albic, Plinthic, Gleyic Brown Wooded, Acid Brown Forest soils	
NITOSOLS Latin nitidus = shiny, shiny ped surfaces. Sub-units: Eutric, Dystric, Humic	Paleudalfs, many Udults, Tropohumults
PHAEOZEMS Greek phaios = dusky, Russian zemlja = earth. Subunits: Haplic, Calcaric, Luvic, Gleyic	Udolls and Aquolls
PLANOSOLS Latin planus = flat, level, poorly drained. Sub-units: Eutric, Dystric, Mollic, Humic, Solodic, Gelic	Pale-alfs, Albaquults, Aqualfs, Albolls
PODZOLS Russian pod = under, zola = ash, white layer. Sub-units: Orthic, Leptic, Ferric, Humic, Placic, Gleyic	SPODOSOLS Orthods, Humods, Aquods
PODZOLUVISOLS From Podzol and Luvisol. Sub-units: Eutric, Dystric, Gleyic	MOLLISOLS Udalfs, Boralfs, Aqualfs
RANKERS Austrian rank = steep slope, shallow soils. No Sub-units	Lithic Haplumbrepts
REGOSOLS Greek rhegos = blanket, thin soil. Sub-units: Eutric, Calcaric, Dystric, Gelic	Orthents, Psamments
RENDZINAS Polish rzedzic = noise, stoney soil. No Sub-units	Rendolls
SOLONETZ Russian sol = salt, affected by salt. Sub-units: Orthic, Mollic, Gleyic	Salids
SOLONETZ Russian sol = salt, affected by salt. Sub-units: Orthic, Mollic, Gleyic	Natr-alfsNadurargids
VERTISOLS Latin verto = turn, self-mixing. Sub-units: Pellic, Chromic	VERTISOLS Pell-erts Chrom—erts
XEROSOLS Greek xeros = dry areas. Sub-units: Haplic, Calcic. Gypsic, Luvic	ARIDISOLS CalcidsGypsids –argids
YERMOSOLS Spanish yermo = desert areas. Sub-units: Haplic, Calcic	ARIDISOLS Cambids Argids

5.5 Rating of soil fertility and Crop suitability analysis

Each crop requires specific soil and environmental conditions for proper growth. However, some plants grow in various soil conditions under extreme agro-ecological conditions. The plants growth is controlled by the availability of nutrients and soil moisture which are governed by the soil characteristics. The soil suitability analysis for crop growth was performed by establishing the suitability criteria for growing crops, forest and plantation crops. The land is delineated based on the suitable soil attributes. The land is classified into following categories based on the limitations for crop growth.

Highly Suitable (S1): Land has no limitations for the crop growth.

Moderately Suitable (S2): Minor physical limitations affecting either productive land use and/or risk of degradation. Limitations overcome by careful planning.

Marginally Suitable (S3): Moderate physical limitations significantly affecting productive land use and/or risk of degradation. Careful planning and conservation measures required.

Almost unsuitable (N1): High degree of physical limitation not easily overcome by standard development techniques and/or resulting in high risk of degradation. Extensive conservation measures and careful ongoing management required.

Unsuitable (N2): Severe limitations. Use is usually prohibitive in terms of development costs or the associated risk of degradation.

5.5.1 Suitability analysis based on available soil nutrient and crop requirement

Soil suitability analysis is carried out by determining the nutrient content present in the soil sampled from the soil pit through laboratory analysis and these results are correlated with the crop nutrient requirement for proper growth.

5.5.2 Rating of soil fertility status

The soil fertility rating is performed by categorization of top soil parameters that encompasses top-soil rooting depth, workability (soil texture), soil drainage (permeability), alkalinity and acidity, content of organic matters, nitrogen, available phosphorus and, available potassium. After that, overall Soil fertility status is rated by the categorization of rooting depth, organic matter, soil texture, acidity and alkalinity, phosphorous content, potash content and nitrogen content. Soil fertility ratings based on chemical and physical properties of soil and their rating is presented in Table below. The Soil nutrients distribution of this VDC is shown in map figure 5.1

Table 5.4: Soil Depth Rating

Soil Root Depth		
>200	Very Deep	High Suitability
1100-200	Deep	
50-100	Moderately Deep	
25-50	Shallow	
<25	Very Shallow	Low Suitability

Table 5.5: Workability Rating

Soil Texture (Workability)		
(Loam)	Good	High Suitability
sit (Silt Loam)	Good	
sI (Sandy Loam)	Good	
sil+l(Silt Loam + Loam)	Good	
cI (Clay Loam)	Moderate	
cl+l/sit (Clay Loam + Loam over Silt Loam)	Moderate	
sicl (Silty Clay Loam)	Moderate	
sl+sicl (Silt Loam + Silty Clay	Moderate	

sicl+sl (Silty Clay Loam + Silt	Moderate	
sic (Silty Clay)	Fair	
sl + sc (Silt Loam + Silty Clay)	Fair	
c (Clay)	Poor	Low Suitability

Table 5.6: Soil Alkalinity and Acidity Rating

Soil Alkalinity & Acidity		
< 5.0	Very high acidic	Low Suitability
5.1– 5.5	High acidic	
5.6 – 6.0	Medium acidic	
6.0 – 6.5	Low acidic	High Suitability
6.6 – 7.3	Neutral	Most Suitable
7.4 – 7.8	Low alkaline	High Suitability
7.9 – 8.4	Medium alkaline	
8.5 – 9.0	High alkaline	
>=9	Very high alkaline	Low Suitability

Table 5.7: Soil Organic Matter Content Rating

Organic Matter (%)		
>5	High	High Suitability
2.5 – 5	Medium	
1.0 -2.5	Low	
<1	Very low	Low Suitability

Table 5.8: Soil Total Nitrogen Rating

Total Nitrogen (%)		
>0.2	High	High Suitability
0.1 – 0.2	Medium	
0.06 – 0.1	Low	
<0.06	Very Low	Low Suitability

Table 5.9: Soil Available Phosphorous Rating

Available P_2O_5 (kg/ha)		
>110	Very High	High Suitability
55 -110	High	
30 – 55	Medium	
16 – 30	Low	
< 16	Very Low	Low Suitability

Table 5.10: Soil Available Potassium Rating

Available K_2O (kg/ha)		
>550	Very High	High Suitability
280 – 550	High	
110 – 280	Medium	
55 –110	Low	
<55	Very Low	Low Suitability

Table 5.11: Soil Drainage Rating

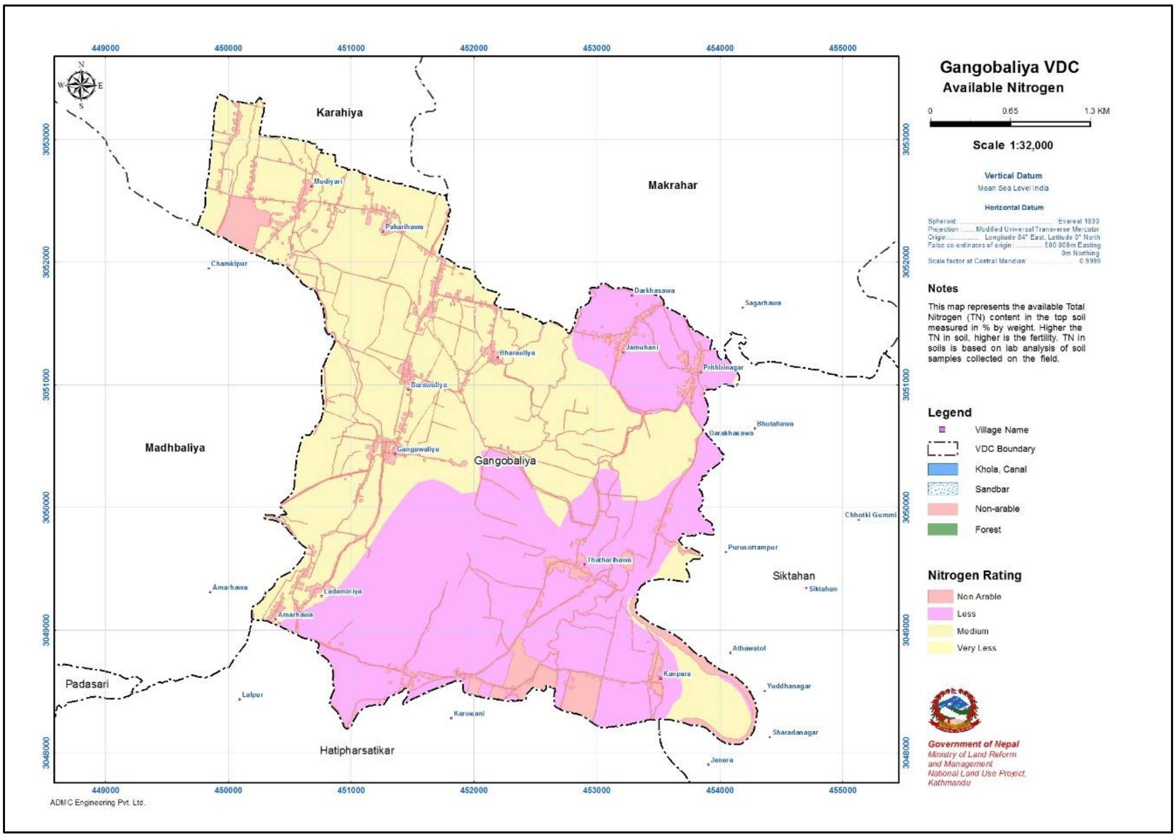
Soil drainage			
Well drained			High Suitability
Moderately well drained			
Somewhat poorly drained			
Somewhat excessively drained			
Poorly drained			
Excessively drained			
Very poorly drained			
Very excessively drained			Low Suitability

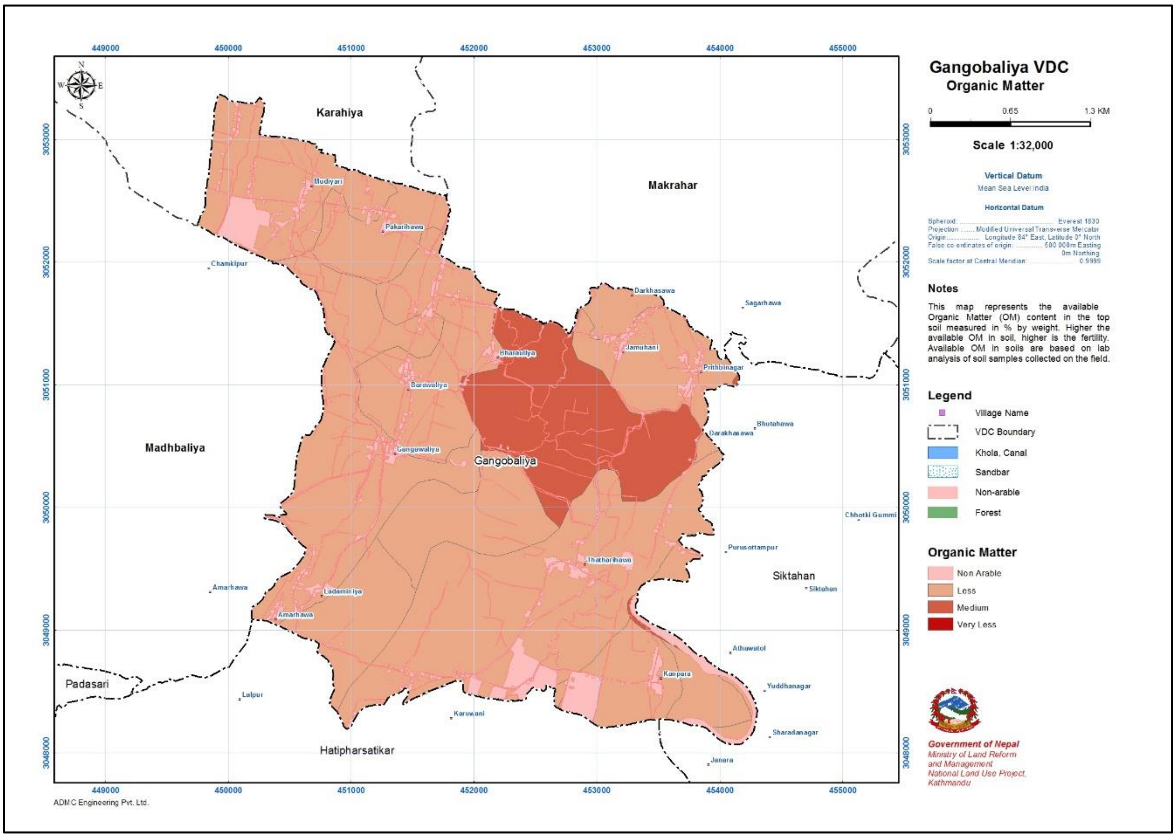
Table 5.12: Soil Available Zinc Rating

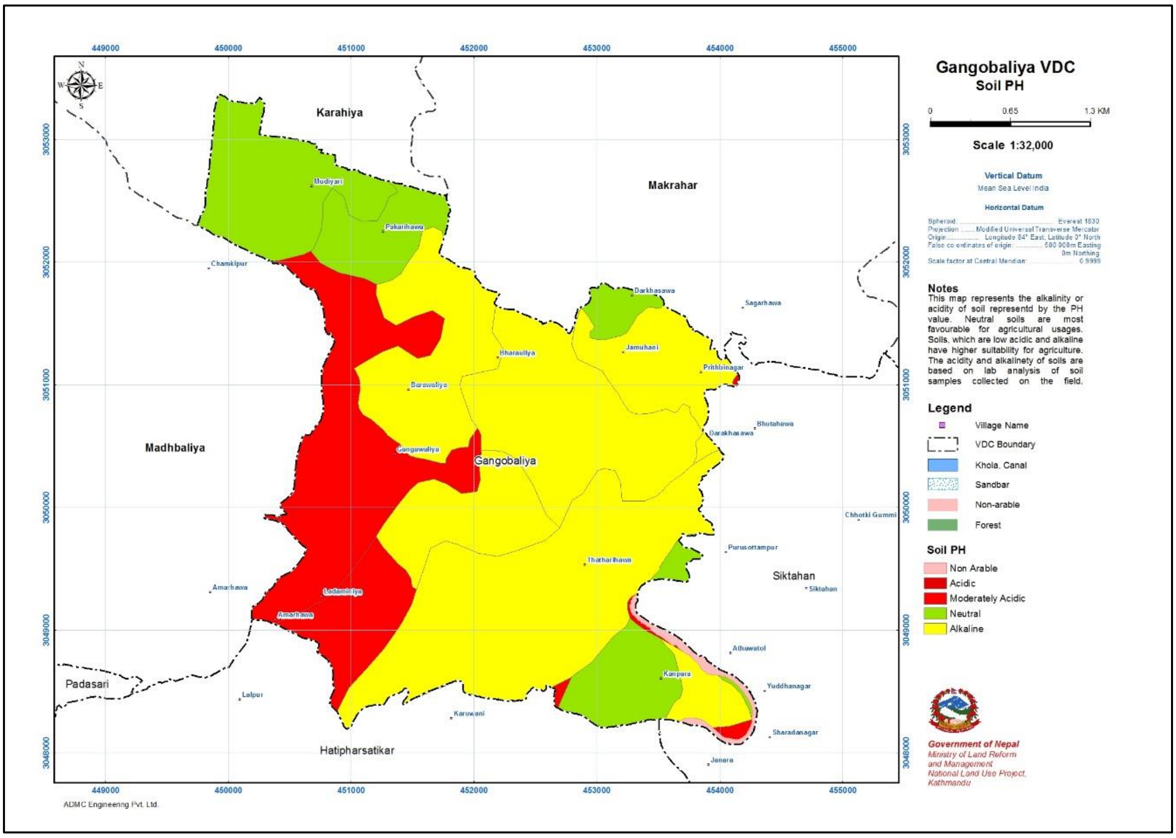
Zinc (ppm)		
>2.0	High	High
0.2-2	Medium	Suitable
<0.2	Low	Low

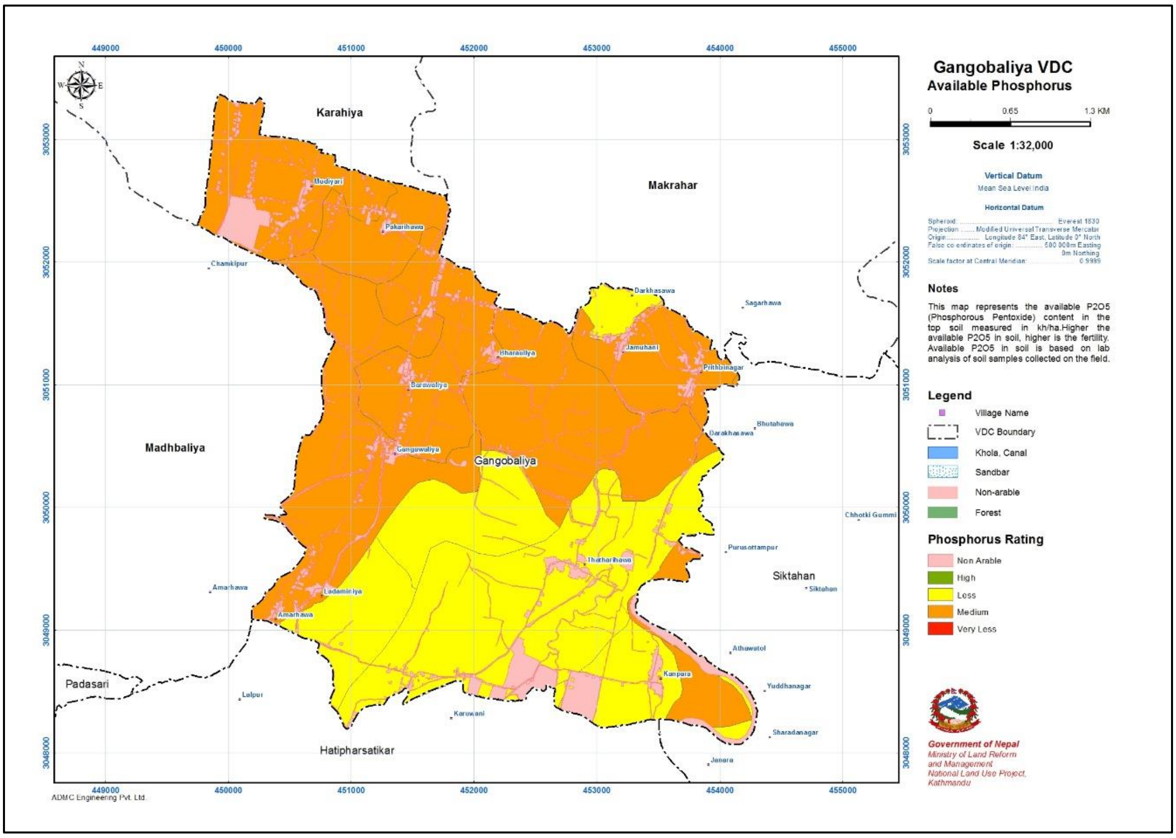
Table 5.13: Soil Available Boron Rating

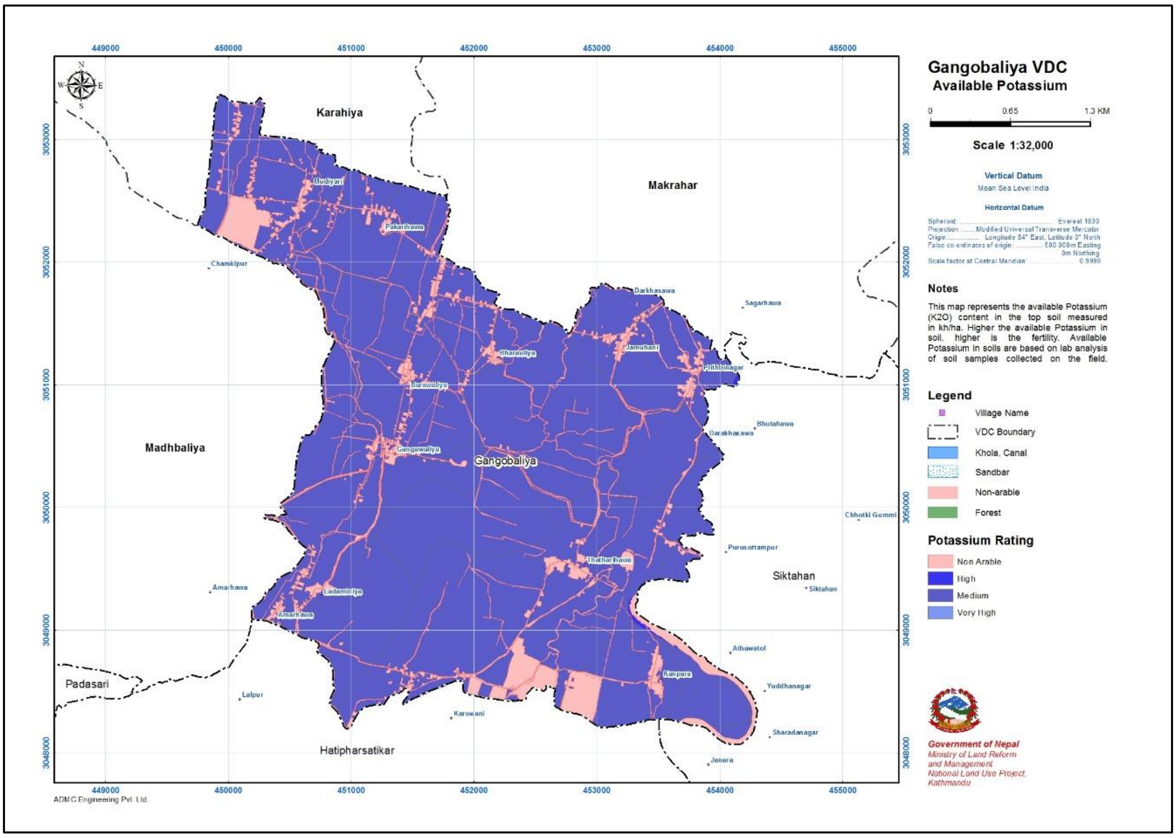
Boron (ppm)		
>2.0	High	High Suitability
0.5-2	Medium	
<0.5	Low	

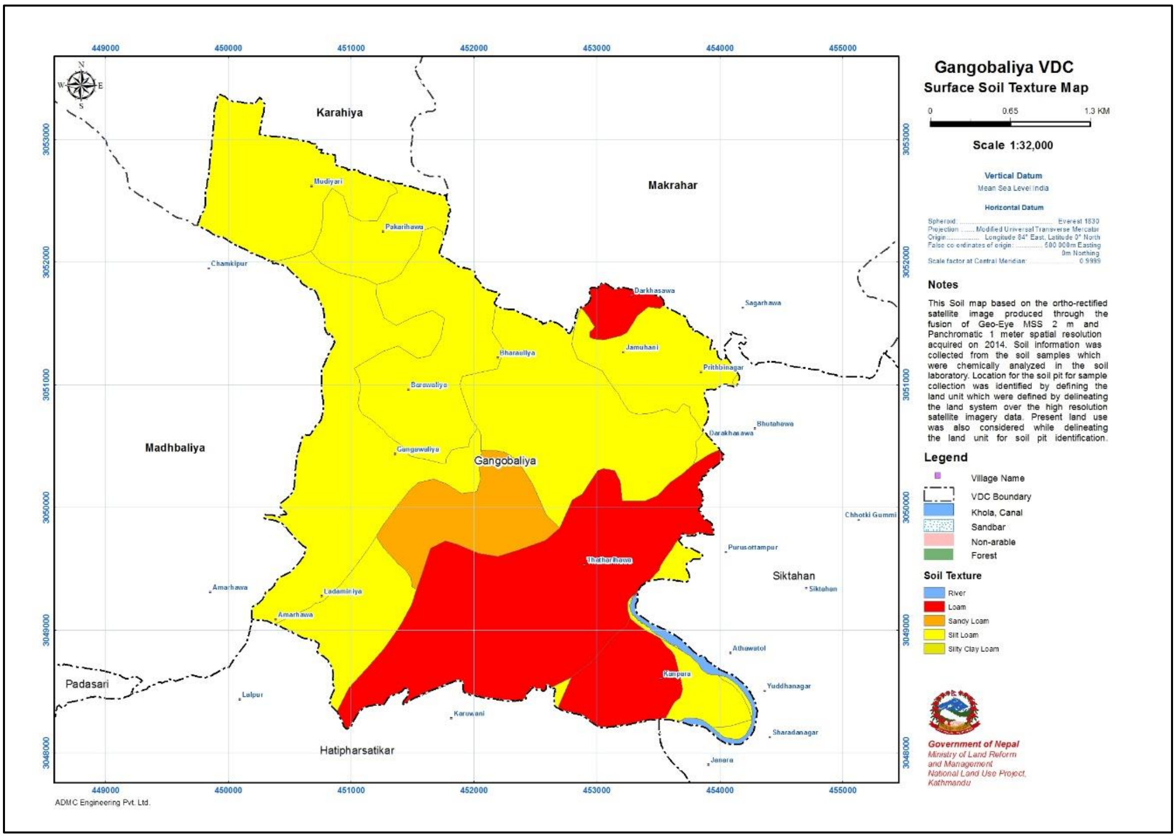

Gangobaliya VDC
Available Nitrogen
0 0.65 1.3 KM
Scale 1:32,000
Vertical Datum
Mean Sea Level India
Horizontal Datum
Spheroid: Everest 1830
Projection: Modified Universal Transverse Mercator
Origin: Longitude 84° East, Latitude 0° North
False co-ordinates of origin: 500 000m Easting 0m Northing
Scale factor at Central Meridian: 0.9999
Notes
This map represents the available Total Nitrogen (TN) content in the top soil measured in % by weight. Higher the TN in soil, higher is the fertility. TN in soils is based on lab analysis of soil samples collected on the field.
Legend
Village Name
VDC Boundary
Khola, Canal
Sandbar
Non-arable
Forest
Nitrogen Rating
Non Arable
Less
Medium
Very Less
Government of Nepal
Ministry of Land Reform and Management
National Land Use Project, Kathmandu
Karahiya
Makrahar
Madhbaliya
Gangobaliya
Siktahan
Padasari
Hatipharsatikar
ADMC Engineering Pvt. Ltd.

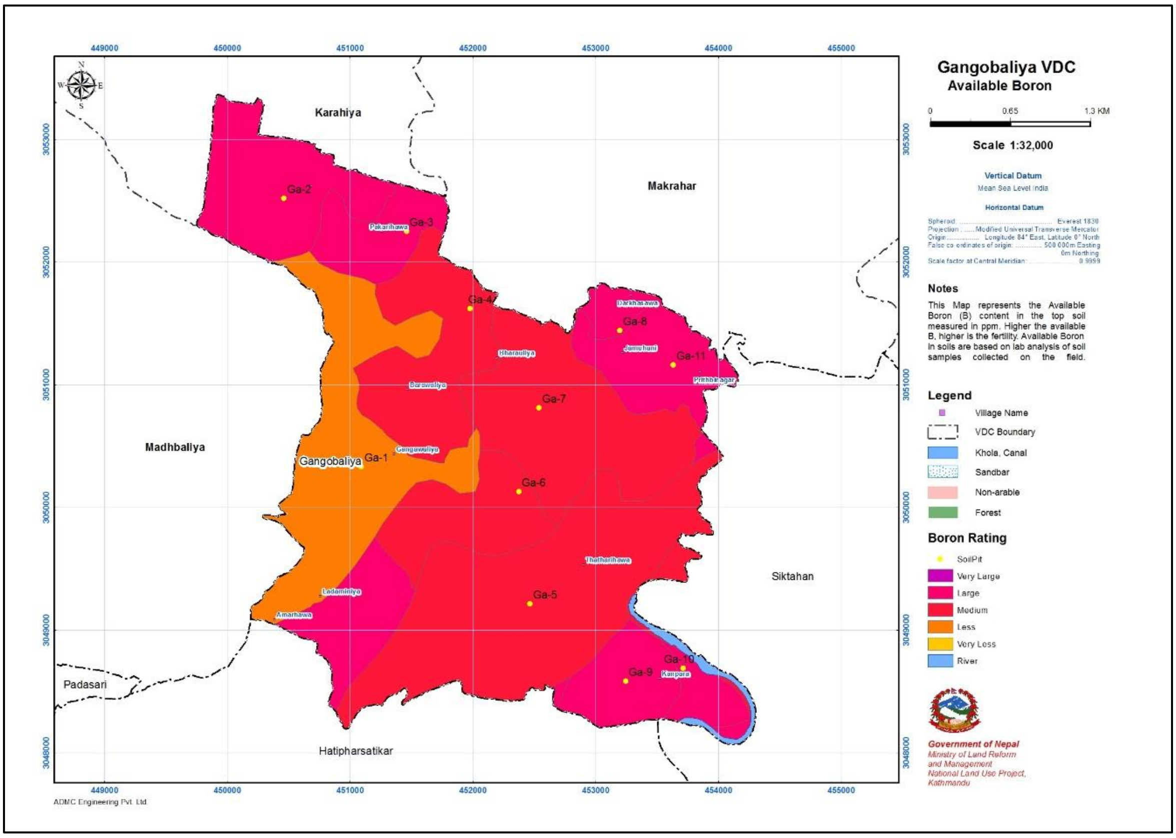

Gangobaliya VDC
Organic Matter
0 0.65 1.3 KM
Scale 1:32,000
Vertical Datum
Mean Sea Level India
Horizontal Datum
Spheroid: Everest 1830
Projection: Modified Universal Transverse Mercator
Origin: Longitude 84° East, Latitude 0° North
False co-ordinates of origin: 500 000m Easting 0m Northing
Scale factor at Central Meridian: 0.9999
Notes
This map represents the available Organic Matter (OM) content in the top soil measured in % by weight. Higher the available OM in soil, higher is the fertility. Available OM in soils are based on lab analysis of soil samples collected on the field.
Legend
Village Name
VDC Boundary
Khola, Canal
Sandbar
Non-arable
Forest
Organic Matter
Non Arable
Less
Medium
Very Less
Government of Nepal
Ministry of Land Reform and Management
National Land Use Project, Kathmandu
Karahiya
Makrahar
Madhbaliya
Gangobaliya
Siktahan
Padasari
Hatipharsatikar
ADMC Engineering Pvt. Ltd.


Gangobaliya VDC
Soil PH
0 0.65 1.3 KM
Scale 1:32,000
Vertical Datum
Mean Sea Level India
Horizontal Datum
Spheroid: Everest 1830
Projection: Modified Universal Transverse Mercator
Origin: Longitude 84° East, Latitude 0° North
False co ordinates of origin: 500 000m Easting 0m Northing
Scale factor at Central Meridian: 0.9999
Notes
This map represents the alkalinity or acidity of soil representd by the PH value. Neutral soils are most favourable for agricultural usages. Soils, which are low acidic and alkaline have higher suitability for agriculture. The acidity and alkalinety of soils are based on lab analysis of soil samples collected on the field.
Legend
Village Name
VDC Boundary
Khola, Canal
Sandbar
Non-arable
Forest
Soil PH
Non Arable
Acidic
Moderately Acidic
Neutral
Alkaline
Government of Nepal
Ministry of Land Reform and Management
National Land Use Project, Kathmandu
Karahiya
Makrahar
Madhbaliya
Gangobaliya
Siktahan
Padasari
Hatipharsatikar
Chhotki Gummi
ADMC Engineering Pvt. Ltd.


Gangobaliya VDC
Available Phosphorus
0 0.65 1.3 KM
Scale 1:32,000
Vertical Datum
Mean Sea Level India
Horizontal Datum
Spheroid: Everest 1830
Projection: Modified Universal Transverse Mercator
Origin: Longitude 84° East, Latitude 0° North
False co ordinates of origin: 500 000m Easting 0m Northing
Scale factor at Central Meridian: 0.9999
Notes
This map represents the available P2O5 (Phosphorous Pentoxide) content in the top soil measured in kh/ha.Higher the available P2O5 in soil, higher is the fertility. Available P2O5 in soil is based on lab analysis of soil samples collected on the field.
Legend
Village Name
VDC Boundary
Khola, Canal
Sandbar
Non-arable
Forest
Phosphorus Rating
Non Arable
High
Less
Medium
Very Less
Government of Nepal
Ministry of Land Reform and Management
National Land Use Project, Kathmandu
Karahiya
Makrahar
Madhbaliya
Gangobaliya
Siktahan
Padasari
Hatipharsatikar
Chhotki Gummi
ADMC Engineering Pvt. Ltd.


Gangobaliya VDC
Available Potassium
0 0.65 1.3 KM
Scale 1:32,000
Vertical Datum
Mean Sea Level India
Horizontal Datum
Spheroid: Everest 1830
Projection ...... Modified Universal Transverse Mercator
Origin: Longitude 84° East, Latitude 0° North
False co ordinates of origin: 500 000m Easting 0m Northing
Scale factor at Central Meridian: 0.9999
Notes
This map represents the available Potassium (K2O) content in the top soil measured in kh/ha. Higher the available Potassium in soil, higher is the fertility. Available Potassium in soils are based on lab analysis of soil samples collected on the field.
Legend
Village Name
VDC Boundary
Khola, Canal
Sandbar
Non-arable
Forest
Potassium Rating
Non Arable
High
Medium
Very High
Karahiya
Makrahar
Madhbaliya
Gangobaliya
Siktahan
Padasari
Hatipharsatikar
Government of Nepal
Ministry of Land Reform and Management
National Land Use Project, Kathmandu
ADMC Engineering Pvt. Ltd.


Gangobaliya VDC
Surface Soil Texture Map
0 0.65 1.3 KM
Scale 1:32,000
Vertical Datum
Mean Sea Level India
Horizontal Datum
Spheroid: Everest 1830
Projection ...... Modified Universal Transverse Mercator
Origin: Longitude 84° East, Latitude 0° North
False co ordinates of origin: 500 000m Easting 0m Northing
Scale factor at Central Meridian: 0.9999
Notes
This Soil map based on the ortho-rectified satellite image produced through the fusion of Geo-Eye MSS 2 m and Panchromatic 1 meter spatial resolution acquired on 2014. Soil information was collected from the soil samples which were chemically analyzed in the soil laboratory. Location for the soil pit for sample collection was identified by defining the land unit which were defined by delineating the land system over the high resolution satellite imagery data. Present land use was also considered while delineating the land unit for soil pit identification.
Legend
Village Name
VDC Boundary
Khola, Canal
Sandbar
Non-arable
Forest
Soil Texture
River
Loam
Sandy Loam
Silt Loam
Silty Clay Loam
Karahiya
Makrahar
Madhbaliya
Gangobaliya
Siktahan
Padasari
Hatipharsatikar
Government of Nepal
Ministry of Land Reform and Management
National Land Use Project, Kathmandu
ADMC Engineering Pvt. Ltd.



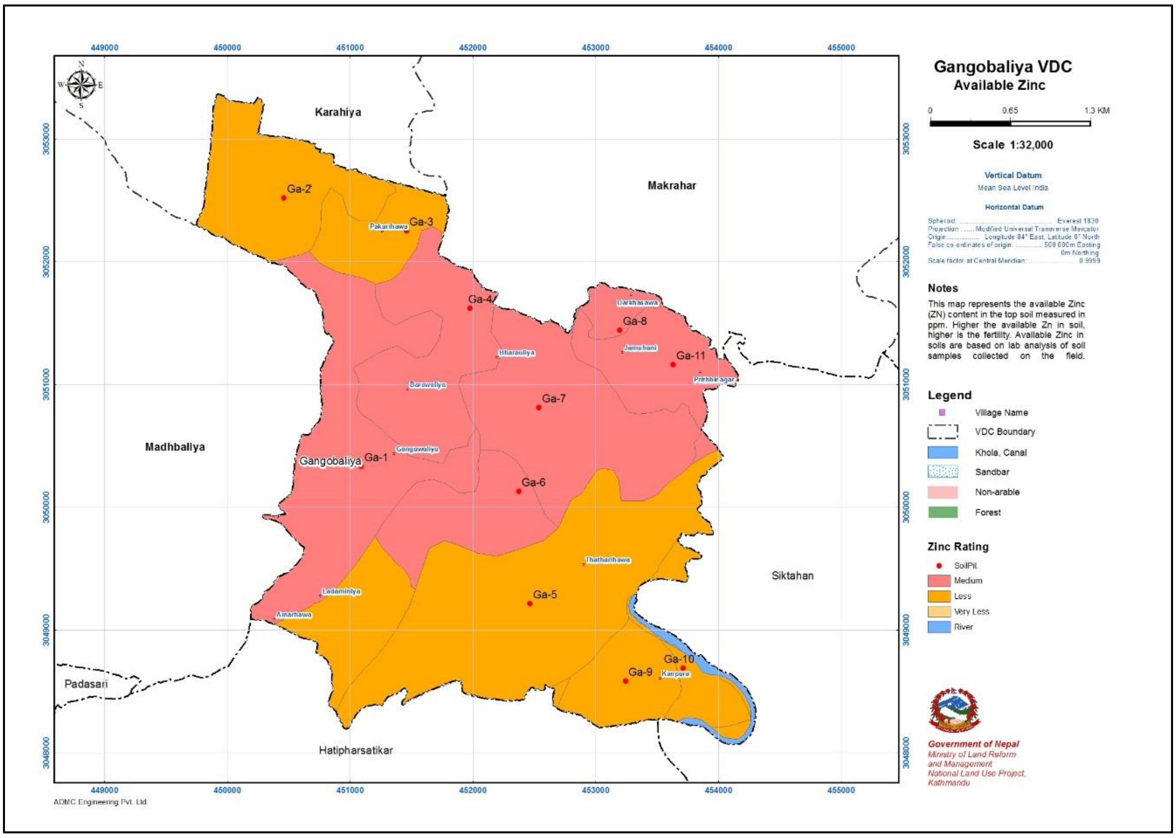


Figure 5.1: Soil Nutrients Distribution of GangobaliyaVDC

CHAPTER - 6

SOIL TYPES AND GIS DATABASE

6.1 Soil Types

The soil types in the Gangobaliya VDC was categorized into order, sub-order, great-group, sub-group, family and series level by following the USDA soil taxonomy system of classification.

6.1.1 Soil types from order to sub-group level

The soils of Gangobaliya VDC of Rupandehi district are classified based on the morphological, chemical and physical properties of soil acquired from the soil profile study by digging the soil pit and soil mapping unit level. USDA soil taxonomy system of soil classification was adopted for the classification of soil in which soils are classified into order, sub-order, great group, sub-group, family and series levels. The soil classification of VDC is presented in the table 6.1.

The Gangobaliya VDC has four soil orders, four sub-orders, five great groups and five sub-groups were found from the survey of the soils. The detail descriptions of soil category are explained as below.

Table 6.1: Soil Taxonomy Classification of GangobaliyaVDC

VDC	Order	Sub order	Great group	Sub group	Area (ha.)	Percentage (%)
River					1285.80	5.26
Gangobaliya	Entisol	Fluvents	Ustifluvents	Typic Ustifluvents	1285.80	5.26
	Inceptisol	Ustepts	Dystrustepts	Fluventic Dystrustepts	5143.22	21.05
	Mollisol	Ustolls	Argiustolls	Vertic Argiustolls	1285.80	5.26
	Vertisols	Usterts	Dystrusterts	Typic Dystrusterts	5143.22	21.05
			Haplusterts	Typic Haplusterts	10286.45	42.105
Total					**24430.33**	**100.00**

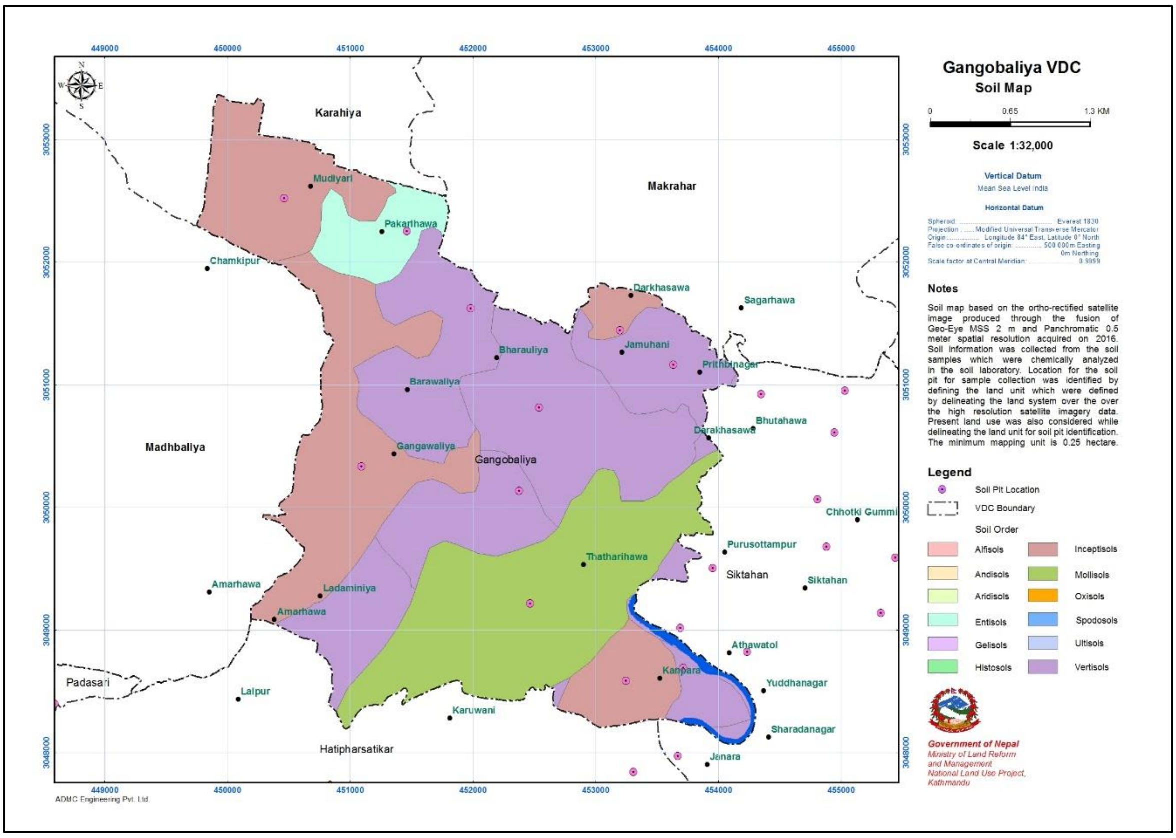


Figure 6.1: Soil Types and Spatial Distribution of Pit Locations of GangobaliyaVDC

Entisols: The central concept of Entisols is that of soils that have little or no evidence of the development of pedogenic horizons. Most Entisols have no diagnostic horizons other than an ochric epipedon. Very few have an anthropic epipedon. A few that have a sandy or sandy-skeletal particle-size class have a horizon that would be a cambic horizon were it not for the particle-size class exclusion. Very few Entisols have an albic horizon. In coastal marshes some Entisols that have sulfidic materials within 50 cm of the mineral soil surface have a histic epipedon. These are very recently developed mineral soils with no diagnostic horizonation other than an ochric or umbric epipedon. The main feature of Entisols is a very slight degree of soil formation, either because of limiting time available for development or because of exceedingly unfavorable conditions. These soils have too thin, dry and too little organic carbon and massive and hard when dry. These soils are found on young geomorphic surfaces such as flood plains and also on steep slopes where erosion removes soil materials as it is formed.

Fluvents: This group of Entisols do not have densic, lithic or paralithic contact within 25 cm of mineral soil surface and the sediments are fluvitile in nature with varying texture and low organic matter content, and stratification is its common feature. These are mostly brownish to reddish soils that formed in recent water-deposited sediments, mainly on flood plains, fans, and deltas of rivers and small streams but not in back-swamps where drainage is poor. The age of the sediments in humid regions commonly is a few years or decades or a very few hundred years. In arid regions it may be somewhat more. Many Fluvents are frequently flooded unless they are protected by dams or levees. Stratification of the materials is normal. Most of the alluvial sediments are derived from eroding soils or streambanks and contain an appreciable amount of organic carbon, which is mainly in the clay fraction. Strata of clayey or loamy materials commonly have more organic carbon than the overlying more sandy strata. Fluvents can have any vegetation and any temperature regime. They can have any moisture regime that does not meet the criteria for Aquents.

Ustifluvents: These are the Fluvents that have an ustic moisture regime and a temperature regime warmer than cryic. These soils are on flood plains along rivers and streams in areas of middle or low latitudes. Flooding can occur in any season but is most common in summer in the middle latitudes and during the rainy season in the Tropics. A few of the soils are flooded regularly in summer because of melting snow in high mountains, even though the summer is rainless.

Typic Ustifluvents: These are the Ustifluvents that have good or moderately good drainage and that do not have a fine particle-size class and clay of a swelling type in a major part of the upper 125 cm. These soils occur in relatively high areas on flood plains, and the water table is deeper than 100 cm, except for very brief periods. There are no redox depletions with chroma of 2 or less or aquic conditions within 50 cm of the mineral soil surface and no chroma of 0 or hue bluer than 10Y or aquic conditions within a depth of 100 cm. There normally is little or no evidence of alteration of the fine stratification in the alluvium. In some Typic Ustifluvents that have a fine-silty or fine particle-size class, however, stratification cannot be easily identified. Typic Ustifluvents are extensive along streams in the sub humid or semiarid parts of the Great Plains in other countries. Many of these soils are used as cropland, with or without irrigation. Others are used for summer grazing.

Inceptisols: The central concept of Inceptisols is that of soils that are of cool to very warm, humid and subhumid regions and that have a cambic horizon and an ochricepipedon. Inceptisols have many kinds of diagnostic horizons and epipedons. They can have an anthropic, histic, mollic, ochric, plaggen, or umbric epipedon. Only a very few Inceptisols, however, have a mollicepipedon. The mollicepipedon is restricted to soils with low base saturation below the epipedon. The most common diagnostic horizons are ochric and umbricepipedons, a cambic horizon, and a fragipan. Some Inceptisols have an umbricepipedon overlying a cambic horizon, with or without an underlying duripan or fragipan. A calcic or petrocalcic horizon or a duripan is common in sub-humid areas. All soils that have a plaggenepipedon are Inceptisols, and any soil underlying the plaggenepipedon is considered to be buried.

Ustepts: Ustepts are mainly the more or less freely drained Inceptisols that have an ustic moisture regime. They receive dominantly summer precipitation, or they have an isomesic, hyperthermic, or warmer temperature regime. Most Ustepts have an ochricepipedon and a cambic horizon. Many are calcareous at a shallow depth and have a Bk or calcic horizon. A few have a duripan or an umbric epipedon.

Dystrustepts: These are the acid Ustepts. They developed mostly in Pleistocene or Holocene deposits. Some of the soils that have steep slopes formed in older deposits. The parent materials generally are acid, moderately or weakly consolidated sedimentary or metamorphic rocks or acid sediments. The vegetation was mostly forest. Most of these soils have a thermic or warmer temperature regime. A common horizon sequence in Dystrustepts is an ochric or umbric epipedon over a cambic horizon. Some of the steeper soils have a shallow densic, lithic, or paralithic contact.

Fluventic Dystrustepts: These soils are on flood plains along rivers draining regions that have acid soils. They formed in Holocene or recent alluvium. They are subject to occasional flooding but receive little fresh alluvium.

Mollisol: The mollisols have dark colored, base rich, granular or crumb structure due to high organic matter content and swelling type clays. These soils have mollicepipedon and may have argillic, natric, albic or cambic subsurface horizon but not an oxic or spodic horizon. They are mostly developed under grassland vegetation in semi arid to sub humid condition and considered as best agricultural soils of the world.

Ustolls: Ustolls are the more or less freely drained Mollisols of sub-humid climates. In addition to the mollicepipedon, these soils may have a cambic, calcic, natric, or argillic horizon. They formed mainly in late-Pleistocene or Holocene deposits or on surfaces of comparable ages. Their temperature regime is frigid or warmer, and their moisture regime is ustic. Where slopes are not too steep, nearly all of these soils are cultivated. Maize and soybeans are the major crops.

Agriustolls: These are the Ustolls that generally have aargillic horizon below a mollic epipedon. There may be a Bk horizon below the argillic (Bt), and a few of the soils have enough secondary carbonates for a calcic horizon.they are formed from base rich sediments and rocks in which there has been accumulation and decomposition of large amounts of organic matter at the surface.

Vertic Argiustolls: These soils have a clayey particle-size class in a significant part, have expanding clays, and in normal years have deep cracks. They formed mostly in material weathered from smectite-rich shale or in material weathered from limestone. They are associated on the landscape with Usterts and with other Ustolls. Vertic Argiustolls occur throughout the Great Plains in the United States and are moderately extensive soils. The natural vegetation was mostly grasses. Slopes generally are gentle, and most of these soils are used as cropland.

Vertisols: The vertisol soils are dominantly observed in sub-humid to semiarid climate where rainfall varies from 500 to 1500 mm per year with pronounced dry season. This soil mostly develop on parent materials of basaltic composition. The soil solum is thick (at least 50 cm), dark coloured cracking clay mineral soils that have high content (>30%) of clay. These soils swell on wetting and shrink on drying that induce the development of wide, deep craks.Theyare dominantly observed on flat terrain and strong swelling and shrinking action of smectite clays are observed. Before the advent of modern classification systems, these soils were already well known for their characteristic color, the cracks they produce during the dry season, and the difficulty of their engineering properties.

Usterts: These are the Vertisols in temperate areas that do not receive high amounts of rainfall during the summer, in areas of monsoonal climate, and in tropical and subtropical areas that have two rainy and two dry seasons. Cracks open and close once or twice during the year. This group of soil have cracks in normal years that are 5 mm or more wide, through a thickness of 25 cm or more within 50 cm of the mineral soil surface, for 90 or more cumulative days per year. These soils are basically very productive, provided they are managed well and with irrigation they can be cultivated for two crops in year.

Dystrusterts: These are the Usterts that have a dominant pH value of 5.0 or less and an electrical conductivity of less than 4.0 dS/m within 50 cm of the soil surface. These soils commonly formed in acid clays and are underlain by more alkaline parent materials. They commonly are derived from alluvial sediments.

Typic Dystrusterts: The Typic subgroup of Dystrusterts is centered on deep or very deep soils that do not have a soil moisture regime that borders on udic or aridic. These soils do not have aquic conditions for significant periods within 100 cm of the soil surface. In addition, they do not have a layer with less than 27 percent clay or light colored surface layers.

Haplusterts: Haplusterts are the most common of the Usterts. They are derived from a variety of parent materials, including sedimentary rocks, alluvium, marl, and basic igneous rocks. Slopes range from nearly level to strongly sloping. This usterts soil have throughout one or more horizons with a total thickness of 25 cm or more within 50 cm of mineral soil surface. They do not have calci or gypsic horizon.

Typic Haplusterts: The Typic subgroup of Haplusterts is centered on deep or very deep soils that do not have significant amounts of salts or sodium. In addition, these soils do not have a petrocalcic horizon, soil moisture regimes that border on aridic or udic, a calcic or gypsic horizon within a depth of 150 cm, a layer with less than 27 percent clay, or light colored surface layers.

6.1.2 Soil types at Great-Group and family level

Differences in texture, mineralogy, temperature, and soil depth are primary bases for family differentiation. They meet the need for making practical prediction of landuse planning of a large area. In the present context, soil texture is used as descriptive criteria of soil family.

6.2 Soil GIS Database

Soil GIS database was prepared by the information gathering from soil pit and soil mapping unit. Soil Mapping Units were demarcated based on integration of Land System, Landform and Land units along with micro relief variation. Individual pit level information was gathered at soil mapping units because it contains multi-pits or pedons. The physical, chemical and morphological characteristics of soil profile at horizon level were contained in soil pit. The framework of entire soil database was presented in **figure 6.2**

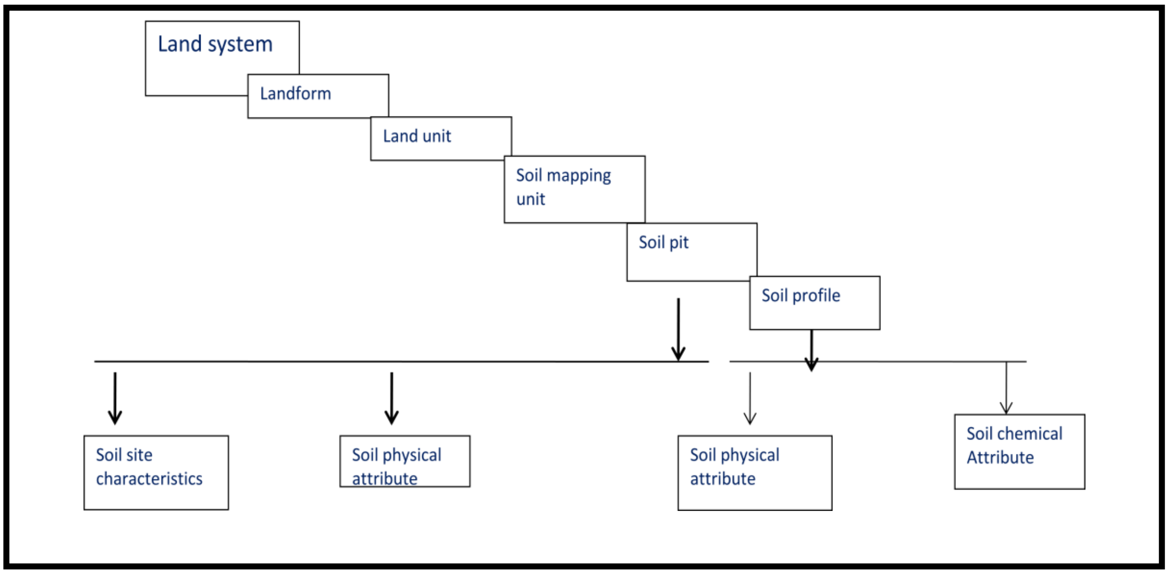


Figure 6.2: Identification of Soil Sampling Unit

The soil GIS database is stored and maintained relating with geo-database linking shape file to its attribute in attribute table. It contains soil unit GIS database, soil pits GIS database including soil profile horizon information. Furthermore it contains soil chemical (lab) test database table. GIS “shape” files and “dbf” are also maintained for comprehensive use. The description of field containing in soil GIS database has been given in Table 6.2 and 6.3.

Table 6.2: Data Field of Soil Pit GIS Attribute

Data Field	Description
Pit_No	Soil pit number
Easting	Easting
Northing	Northing
Elevation	Elevation of land (m)
Physio_uni	Physiographic unit
Imagery	World View 2 satellite
Date_Exam	Date of digging soil pit or examination
Location	Location of pit in ward of VDC
Physio	Physiographic (local relief)
LU_Veg	land use and vegetation
slope_dire	Slope direction
crop_ptrn	Cropping pattern
Slope_degr	Slope degree
Climate	Climate
Classifica	High order of Soil classification
Pt_Materia	Parent material
Drain_Clas	Drainage class
Moist_cond	Moisture condition
Depth_gw_m	Depth of ground water
Hum_Influ	Human Influence
Total_Hor	Total number of horizon
First_Hor	First horizon or Top layer or epipedon
Second_Hor	Second horizon or Sub surface first or indopedon
Third_Hor	Third horizon or sub surface second
Fourth_Hor	Fourth horizon or sub surface third
Depth_FH	Depth of first horizon
Depth_SH	Depth of second horizon
Depth_TH	Depth of third horizon
Depth_4H	Depth of fourth horizon
Boundrs_FH	Boundaries of first horizon
Boundrs_SH	Boundaries of second horizon
Boundrs_TH	Boundaries of third horizon
Boundrs_4H	Boundaries of fourth horizon
DigstHR_FH	Diagnostic horizon of first horizon
DigstHR_SH	Diagnostic horizon of second horizon
DigstHR_TH	Diagnostic horizon of third horizon
DigstHR_4H	Diagnostic horizon of fourth horizon
MxtColr_FH	Matrix color of first horizon
Munsell_FH	Munsell color of first horizon
Mottl_FH	Mottling of first horizon
Mottl_SH	Mottling of second horizon
Mottl_TH	Mottling of third horizon
Mottl_4H	Mottling of fourth horizon
Texture_FH	Texture of first horizon
Texture_SH	Texture of second horizon
Texture_TH	Texture of third horizon
Texture_4H	Texture of fourth horizon
CoaFrag_FH	Coarse fragment of first horizon
CoaFrag_SH	Coarse fragment of second horizon
CoaFrag_TH	Coarse fragment of third horizon

CoaFrag_4H	Coarse fragment of fourth horizon
Structu_FH	Structure of first horizon
Structu_SH	Structure of second horizon
Structu_TH	Structure of third horizon
Stuctu_4H	Structure of fourth horizon
Porosit_FH	Porosity of first horizon
Porosit_SH	Porosity of second horizon
Porosit_TH	Porosity of third horizon
Porosit_4H	Porosity of fourth horizon
Consist_FH	Consistence of first horizon
Consist_SH	Consistence of second horizon
Consist_TH	Consistence of third horizon
Consist_4H	Consistence of fourth horizon
Root_FH	Roots of first horizon
Root_SH	Roots of second horizon
Root_TH	Roots of third horizon
Root_4H	Roots of fourth horizon
S_Order	Order of soil Classification
S_subOrder	Sub-Order of Soil Classification
Grate_group	Grate group of Soil Classification
S_Group	Group of Soil Classification
S_Family	Family of Soil Classification

Table 6.3: Data Field of Lab Test of Soil Pit

Data Field	**Description**
PIT_NO.	Pit No.
LAB_NO.	Lab No.
HORIZON	Horizon
PH_	PH (1:2.5%) H2O
TOTAL_N	Total Nitrogen (N %)
N-STATUS_	Nitrogen Status Ranking
P2O5	Available Phosphorous (P2O5) Kg/ha
P-STATUS_	Phosphorous Status Ranking
K2O	Available Potassium (K2O) Kg/ha
K-STATUS_	Potassium Status Ranking
OM	Organic Matter (OM)%
OM_STATUS_	OM Status Ranking
SAND	Sand%
SILT	Silt%
CLAY	Clay%
S_TEXTURE	Soil Texture
Zinc	Soil available zinc(ppm)
Zinc_STATUS	Soil available zinc status ranking
Boron	Soil available boron(ppm)
Boron_STATUS	Soil available boron status ranking

CHAPTER - 7

CONCLUSIONS

7.1 Conclusions

For the preparation of Soil Map of Gangobaliya VDC of Rupandehi District, the Geo-Science Technology including Remote Sensing (RS), Geographic Information System (GIS) and Geographic Positioning System (GPS), visual interpretation and computer aided technology were used in integrated way. The soil sampling pit was selected covering at least one land unit considering the unique physiography and soil association. The parameters such as slope, land form and land type were used for the delineation of soil boundary.

The VDC is dominated by the slope less than one percent with alluvial deposits and therefore, relief has been less important factor for soil development, however, its effect has been seen at local level with variation in land configuration i.e land form. Considering the river sediments and land form, the entire VDC has been represented with 1a, 2a, 2b, 3c land units. A total 11 pit was surveyed in the VDC. Based on land type/unit, soil survey revealed that the entire VDC is comprised of 4 land units in which most of area (90.05%) of this VDC falls under the recent alluvial plain lower piedmont comprises of depositional and erosional area level. 2.79% of VDC falls under active alluvial plain comprises of depressional area level. 7.17% of VDC falls under Alluvial Fan complex, upper piedmont of erosional. The soil types found was, Vertisols, Inceptisols, Entisols, and Mollisols respectively in decreasing order of spatial extent. Among these, Vertisolsl order was dominantly (63.16 %) found followed by Inceptisols (21.05%), then Entisols (5.26%) and Mollisols (5.26%). 5.26% of River falls under this VDC. Considering genetic horizons and soil properties, altogether 5 types of soil was found in the VDC at the sub group level as per USDA system. Based on soil properties such depth, genetic horizons, and fertility characteristics, soils found in VDC are highly suitable for intensive agriculture.

7.2 Recommendations

Integrated use of Visual interpretation, computer aided technology and Geo-Science technology including Remote Sensing (RS), Geographic Information System (GIS) and Geographic Positioning System (GPS) was used successfully and found satisfactory for this project so that this technique for soil mapping and land use planning can be applied to other places of the country. However, there is need of criteria for soil fertility assessment by the project to create uniformity in data resources. The database of soil resources, landforms, land systems and units would be very useful for the country to formulate planning to cope with the low agriculture production, land degradation problem and climate change induced disaster. The crop suitability assessment is urgent need for improving soil and crop productivity in the VDC. These databases play vital role in sustainable use of natural resources safeguarding the environment. Thus, there is need of such study on other areas, dissemination of these data bases to local level and local and national planning on agriculture, industrial, forest, urban etc. sectors based on these databases.

D. Land Capability

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CHAPTER - 1

INTRODUCTION

1.1 Background and Rationale

Background:

Land use planning has been defined as "The systematic assessment of land and water potential, alternative patterns of land use and other physical, social and economic conditions, for the purpose of selecting and adopting land-use options which are most beneficial to land users without degrading the resources or the environment, together with the selection of measures most likely to encourage such land uses." (Food and Agriculture Organization).

Land use planning is fundamental to the process of natural resource management and ecological sustainable development. It demands an integrated and strategic approach at national, regional and local levels to meet all needs. Land use planning should consider the sustainability, social impact and an assessment of what the land is capable of supporting and sustaining into the future and in the interests of the wider community. The demand on the use of our land to achieve many objectives requires the application of a rigorous process of planning. For example, some areas of land can support a wide range of uses whereas other areas support a small range of uses or certain types of uses. Effective planning involves anticipation and an understanding of land use and land management practices, and the participation by land users, planners, and the public and decision makers in the planning process.

The land capability classification is the grouping of a land units into defined classes based on its capability. It is a broad grouping of soils based on their limitations and designed to emphasize the hazards in different kinds of soils. It serves as a guide to assess the suitability of land for arable crops, grazing and forestry. The capability class is determined on the basis of soil properties such as soil depth, soil texture, permeability, organic matter, N, P, K content, pH of soil, erosion hazard, topography and severity of climate. The land capability classification provides necessary data that helps to find the combination of agricultural and conservation measures which would permit the most rigorous and proper use of the land without safeguarding the soil environment.

The large spatial and temporal variability in land capability can, thus, be studied only by the use of technologies that include the spatial and temporal properties. Remote Sensing (RS) and Geographic Information System (GIS) provide with new tools for analyzing the variation in space and time and help in decision making. In addition an efficient approach to management of resources can be formulated and implemented in relatively short time period.

Agriculture is the major sector in the country Nepal, which provides employment to the more than 65 percent of the people, contributing 33 percent in the national GDP. The production of major cereal crops plays an important role in agriculture production. The production of major cereals was reduced by 8 percent (Economic Survey, 2012/13). Low agriculture production is the major problem in Nepalese agriculture posing food security problem in the country. The major cause of low agriculture production is the cultivation of crops and soil management without scientific land resource data. Thus, land resource inventory data is necessary for environment friendly agriculture sustainability.

In this context, the Government of Nepal has recently formulated the 20 year Agriculture Development Strategy emphasizing to increase agriculture production to solve the food and nutritional security problems of the country safeguarding the environment. Also, the National Land Use Policy-2072 has been declared, which is focused to increase the productive capacity of land.

Rationale:

Land-use planning can be applied at three broad levels: national, district and local. For local level planning, information regarding the natural resource, socio-economic and demography of that are is necessary for effective planning which gives guideline for selection of land and what activities can be performed, when and who is responsible for those activities. However, Nepal has only regional level data base on land use, land system and land capability which were produced by Land Resource Mapping Project (LRMP, 1983/84). Realizing this fact, the Ministry of Land Reform and Management of Government of Nepal established the National Land Use Project (NLUP) in 2057/058 fiscal year to generate the necessary data bases on the land resources of the country.

In the first phase, the National Land Use Project of Nepal had initiated several projects at district level and prepared Land Resource Maps and Database at 1:50,000 scale for the whole Nepal. It had also prepared same kinds of maps and database for Kirtipur, Lekhnath, Madhyapur Thimi and Bhaktapur municipalities at larger scales. Finally, NLUP was mandated to prepare land resource maps of Village Development Committees (VDCs) of Nepal for local level planning through outsourcing modality.

Then, the National Land Use Policy 2069, had emphasized to manage land use in accordance with the land zoning policy of Government of Nepal which categorizes six land zones such as Agricultural area, Residential area, Commercial area, Industrial area, Forest area and Public use area. The policy had mentioned the land characteristics, capability of the each category of land zones. In addition, the policy had pointed to form Land Use Council at the top of district and Municipality/VDC level at the bottom which also highlighted the importance of preparation of Municipality and VDC level maps and databases on natural resources.

During the course of implementation some updating and refinement had been felt in NLUP 2069. As a result, GON came up with **National Land Use Policy 2072**. The following land use categories has been designated for present land use mapping: Agriculture, Forest, Residential, Commercial, Industrial, Public Service, Mine and Minerals, Cultural and Archeological, Riverine and Lake Area, Excavation Area & Other.

In this regards, the National Land Use Project (NLUP) has awarded to conduct the project entitled Package 27: Preparation of VDC level land resources maps (Present Land Use Map, Soil Map, Land Capability Map, Land Use Zoning Map and VDC Profile for Land Use Zoning Map and Superimpose of Cadastral Layers), Data Base and Reports of Rupandehi District to our consultancy for fiscal year 2073/074 but in multi-year project scheme. The Package 27 covers 17 VDCs; Bagaha ,Basantapur, Bodabar, Chhipagadh, Chhotki Ramnagar, Chilhiya, Dhakadhai, Gangobaliya, Harnaiya, Hatipharsatikar, Hatti Banagai, Mainahiya, Padasari, Pajarkatti, Patkhauli, Pokharbhindi and Siktahan.

1.2 Objectives

The broad objective of National Land Use Project (NLUP), Package 27, (2073/074 fiscal year) is to prepare of Village Development Committee (VDC) level Land Resource Maps (present land use map, soil map, land capability map, land use zoning map and preparation of profile for land use zoning and cadastral layer superimpose), Database and Reports for Package 27 covering 17 VDCs; Bagaha ,Basantapur, Bodabar, Chhipagadh, Chhotki Ramnagar, Gangobaliya, Dhakadhai, Gangobaliya, Harnaiya, Hatipharsatikar, Hatti Banagai, Mainahiya, Padasari, Pajarkatti, Patkhauli, Pokharbhindi, Siktahan district of Nepal. In order to fulfill the broad objective, the present study aims to prepare a present land capability map of Gangobaliya VDC based on high resolution satellite image (World-View2) and detailed field survey. Therefore, the main objective of the study is:

i) To prepare Land Capability Maps, GIS database and Reports for the VDC at 1:10,000 scales.

Scope

In order to achieve the above mentioned objective, the following activities were conducted:

(a) Study the existing relevant maps, documents and database of the project area.
(b) Prepare Land capability maps for the selected VDCs at 1:10,000 scales by analyzing relevant data, maps, field samples and information of soil laboratory test analysis.
(c) Design appropriate GIS database logically.
(d) Discuss the accuracy, reliability and consistencies of data.
(e) Prepare reports describing methodology, existing land capability types and model of GIS data base.

1.3 Study area

The Gangobaliya VDC is covered by Siktahan in the East, Madhbaliya in the West, Makrahar in the North and Hatipharsatikar in the South. The rectangular extent of the VDC is 83°32'8"E, 27°35'51"N, 83°29'27"E and 27°33'1"N. The total population of this VDC is 6966, of which male population accounts for 49.14 percent and female population is 50.86 percent (VDC profile, 2011). However, all the wards vary in area and population size. Total number of household in the VDC is 1172.The area of the VDC is 1285.81 hectares.

This VDC is inhabited by different caste and ethnic groups. Tharu predominates the inhabitants of this VDC accounting 44.57 percent of the total VDC Population. Tharu, Brahman hill, Yadav & Mallaha are other dominant caste and ethnic groups of this VDC.

Economic condition of the people of this VDC largely depends on agriculture. Land is the main source of income and capital accumulation and also the major source of employment. Economic condition of the people having large landholding size is better than the others.

The location map of the study area has been shown in **Figure 1.1**

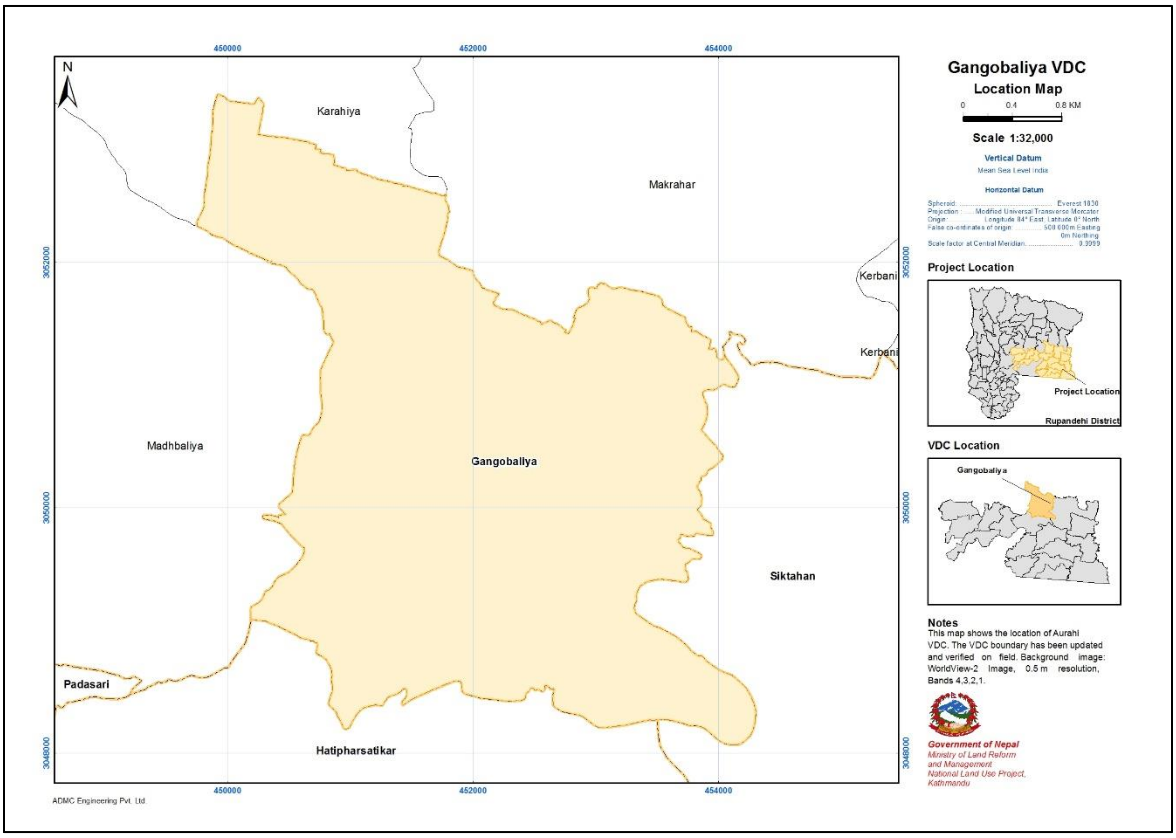

Figure 1.1 Location Map of Gangobaliya VDC of Rupandehi District.

CHAPTER - 2

CONCEPTUAL BASIS OF LAND CAPABILITY CLASSIFICATION

Land is the basic natural resource and it is limited to human beings. Land has been a matter of life and death, of survival or starvation. In the human life history, most of the sustenance and much of his fuel, clothing and shelter obtained from the land. Land is the basis for habitat and living space for man. The use of land should have been of major importance to man is, therefore, not surprising (Mather, 1986). The agricultural land classification provides a framework for classifying land according to the extent to which its physical or chemical characteristics impose long term limitations on agricultural use. The limitations can operate in one or more of four principal ways: they may affect the range of crops which can be grown, the level of yield, the consistency of yield and cost of obtaining it. To ensure a consistent approach when classifying land the following assumptions are made:

1. Land is graded according to the degree to which physical or chemical properties impose long-term limitations on agricultural use. It is assessed on its capability at a good but not outstanding standard of management.
2. Where limitations can be reduced or removed by normal management operations or improvements, for example cultivations or the installation of an appropriate under drainage system, the land is graded according to the severity of the remaining limitations. Where an adequate supply of irrigation water is available this may be taken into account when grading the land. Chemical problems which cannot be rectified, such as high levels of toxic elements or extreme subsoil acidity, are also taken into account.
3. Where long-term limitations outside the control of the farmer or grower will be removed or reduced in the near future through the implementation of a major improvement scheme, such as new arterial drainage or sea defense improvements, the land is classified as if the improvements have already been carried out. Where no such scheme is proposed, or there is uncertainty about implementation, the limitations will be taken into account. Where limitations of uncertain but potentially long-term duration occur, such as subsoil compaction or gas-induced anaerobism, the grading will take account of the severity at the time of survey.
4. The grading does not necessarily reflect the current economic value of land, land use, range of crops, suitability for specific crops or level of yield. For reasons given in the preface, the grade cut-offs are not specified on the basis of crop yields as these can be misleading, although in some cases crop growth may give an indication of the relative severity of a limitation.
5. The size, structure and location of farms, the standard of fixed equipment and the accessibility of land do not affect grading, although they may influence land use decisions.

Vink (1975) defines land use as the ability of human being to manage their ecosystem in order to produce some of his needs. This indicates the ability of man to preserve or destroy land; i.e. man has a full control over land. Vink (1975) indicated that, as circumscribed by the earth, the area of what is considered to be land is finite and fixed in place. Land uses are subject to control by people, whose numbers are not fixed, who have many needs, and who move easily. According to Davis (1976) some areas of land have certain characteristics that make it more useful than other land areas. These include location and suitability of a particular piece of land.

As Speller berg (1992) noted, large forest areas have been cleared for agriculture and most remaining forests have sadly been damaged in some way. The consequence is increasing erosion and degradation. In addition, in more developed western countries, because of industrialization, the invasion on prime agricultural land was eminent. These problems bring about the need for classification. Dent, (1986) citing Jacks (1946), defines land classification as “the way of grouping of land according to its suitability for producing plants of economic importance”.

The foundation of land classification lies in land resource inventories, starting with major geological surveys during the nineteenth century. The development of land capability schemes during the 1930s in the USA marks the beginning of the second major development in the subject, but the widespread adoption of land capability schemes only began after 1960 (Davidson, 1992).

The assessment of land capability involves an evaluation of the degree of limitation posed by permanent or semi-permanent attributes of land to one to one or more land uses. The American system of land assessment goes back to 1930s, but it came into effect only after 1961 when a comprehensive book was published (Klingebiel and Montgomery, 1961). The Soil Conservation Service of the US Department of Agriculture evolved the technique and it will be referred to as the USDA method. Integral to the assessment procedure is an evaluation of soil erosion hazard, wetness, soil and climatic limitations. Land capability assessment is based on a broader range of characteristics than soil properties. Information on slope, angle, climate, flood and erosion risk as well as on soil properties is required (Davidson, 1992).

Land capability could be the land to sustain a specified land use without insignificant onsite or offsite degradation or damage of land resources (US department of Agriculture & State Planning Commission, 1989). Generally, the land capability classifications refer to the grading of the ability of land. Land capability classification system originally devised by the US Department of agriculture and has been used widely since the 1950s to assess the appropriate use of various type of land for agriculture usages in identifying land uses and management practices that can minimize soil erosion, especially induced by rainfall (Brady & Well, 2002).

Land capability assessment is therefore based on the permanent biophysical features of the land (including climate). Land capability assessment is different to land suitability assessment which, in addition to the biophysical features, does take into account economic, social and/ or political factors in evaluating the best use of a particular area of land for various usages of land (Grose, 1999). Land capability classification gives a grading of land for broad scale agricultural uses, whereas land suitability is for landfill.

FAO Framework of Land Evaluation is most widely used for assessing the suitability of soils for various kinds of Land Utilization Types (LUTs). *Land Suitability* may be defined as “the fitness of a given type of land for a specified kind of land use” (FAO, 1983). Suitability is a measure of how well the qualities of a land unit match the requirements of a particular form of land use. Suitability is assessed for each relevant use and each land unit identified in the study.

Land capability classification at VDC level requires assessment of each individual physiographic land unit for agricultural land use. At the level 1, land capability classification needs to be made for degree of suitability, nature of dominant limiting factors considering management and conservation requirements to tackle the limitations in order to conserve land resources for best productivity. This chapter gives a conceptual basis for the land capability assessment on which the classifications are done at VDC level.

2.1 Review of LRMP Land Capability Classification

In between 1980 and 1985, 266 Land Capability Maps were made by the Land Resource Mapping Project (LRMP) covering entire Nepal. LRMP defines land capability classifications as “a specialized evaluation of the land resource based on interpretative classification considering the slope stability, irrigation, flood hazards etc’’ (Carson, 1986). LRMP Land Capability classification is based on observable biophysical characteristics as delineated by land system, local climatic conditions and empirically derived assessment of existing and potential land use. Lands are grouped into seven classes and five sub-divisions according to their opportunities, limitations and hazards for different sustainable usages in LRMP land capability classification system. Land suitability for arable agriculture and forestry uses are emphasized; thus the class arrangements shows the decreasing suitability/opportunities for use as well as decreasing intensity of use. There are seven classes assigned as “Class I” to “Class VII”, according to the order of opportunity each class offers. For example, Class I land has the very less limitations for arable agriculture or forestry development usages. The categorizations of classes are influenced by the land system and soil units.

The subclasses of land capability are based on distinct temperature regimes according to elevation breaks. The subclasses are categorized into five climatic regime groups’ viz. sub-tropical, warm temperature, cool temperature, alpine, and arctic. These subclasses are further differentiated to represent major climatic moisture regime zones, which are arid, semiarid, sub-humid, humid, and per-humid.

Each land capability unit for Class I and Class II is further designated with irrigation suitability. By applying the United States Bureau of Reclamation (USBR) land classification framework, modified for local conditions, the irrigation suitability classification is done. Irrigation suitability classes are further sub-classified on the basis of deficiency in soil, topography or drainage conditions, which attributes to the arability of land.

Table 2.1 below shows the LRMP Land Capability classification scheme. A brief description of land capability classes are presented in subsequent subsections.

Table 2.1 LRMP Land Capability Scheme

Capability Classes						
Class I	Class II	Class III	Class IV	Class V	Class VI	Class VII

Temperature Regimes	Elevation (m)	Mean Annual Air Temperature (ºC)	Dominant Soil Temp. Regimes
Sub tropical	<1000	20 -– 24	Hyperthermic
Warm Temperature	1000-2000	15 -– 20	Thermic
Cool Temperature	2000-3000	10 -– 15	Mesic
Alpine	3000-4000	3 -– 10	Cryic-frigid
Arctic	>4500	< 3	Pergelic

Sub-Class (Temperature Regimes/ Vertical Zonation)

Sub-Division (Moisture regime)
Arid
Semiarid
`
Humid
Per-humid

Irrigation Suitability Class
Class 1
Class 2
Class 1 R
Class 2 R
Class 5
Class 6

Deficiency Subclass
Soil
Topography
Drainage

2.1.1 Land Capability Classes

Land Capability classes are derived from Land System map units. There are seven land classes grouped on the basis of similar geophysical characteristics, reflecting management option (Maharjan & Joshi, 2007). Descriptions of each of seven classes are given below.

Class I

This land class is characterized as the nearly level (< 1 degree slope) and deep soil stratum. This type of land has very few limitations for arable agriculture or forestry land uses. River bank cutting is rampant. However, mass wasting does not pose any significant problems. Stability of the land is not considerably affected due to engineering works. Sporadic flooding occurs in the Tarai region, depositing large amount of sediment; but these depositional areas are quickly reclaimed. By using traditional, intermediate as well as modern farming practices class I lands are cultivated. To minimize the effects of flooding and subsequent mass wasting, the erosion mitigation and river embanking works are required.

Surface drainage pattern and soil moisture has the effect on land use in this capability class. Well to moderately well drained lands are suitable for a wide range of usages including annual cropping, perennial cropping, and grazing and forestry uses during the monsoon period. Poorly drained areas with high water tables included in class I lands during the monsoon, are highly suitable for rice production. In class I lands, during the dry season, where irrigation water is available, wide range of crops can be grown in various temperature regimes. Moderately well and imperfectly drained areas having sufficient subsoil moisture are producing wheat and other winter crops in dry season, where irrigation water is not available.

The dominant land system units associated with class I are 1d, 2c, 2d, 3a, 4c, 5a, 6a, 9b, 13b. Other land system units associated are 3c, 5c, 6c, 10a, 10b and 13d and about 13.7% of total land of Nepal consists of class I type land.

Class II

Class II is characterized as gently sloping (1-5 degrees) and soil stratum is deep and well to moderately well drained. No limitations exist in this class for well managed forestry for timber, fuel wood and fodder production or pasture development. When land of this class is used for arable agriculture, terracing and contouring are required to control soil erosion and suitable provisions are required for controlling surface runoff and drainage waters. Major hazard often occurring is debris flow though lands are usually reclaimable. Due to soil characteristics and surface gradient, gully erosion is major concern. Using traditional, intermediate or modern farming techniques these lands can be successfully cultivated by considering above factors and implementing appropriate mitigation measures.

Surface and subsurface of it is generally adequate for a wide range of uses including annual cropping, perennial cropping, pasture and forestry during monsoon season. In the areas where the climate is favorable and irrigation water is available, paddy rice may be grown even on coarser textured soil.

Class II land is dominant with land system units associated with 3b, 3c, 5b, 5c, 6c, 9c, 10a, 13c and 13d. Other land system units associated are 2d, 3b, 3d and 5d and about 3.2% of total land of the country is occupied by this land capability class.

Class III

Land in this class is characterized as moderately to steeply sloping (5-30 degrees) slopes. Soils are well drained and more than 50cm deep. These lands only occur in climatically arable regions. Soil erosion occurs constantly due to mass wasting, landslides, slumps, and debris flow and river bank failures.

There are few limitations in this class of land for the forest development for fodder, fuel wood, or timber production. Grazing is restricted due to heavy physical damage to soil by livestock overgrazing. When land is used for arable agriculture, terrace is compulsory to control erosion. Class III land cultivation is done making terraces, which is based on traditional farming practices. However, intermediate farming practices can be adopted for better crop production. Fertility of cultivated land is maintained by fodder, forest litter collection and grazing on non-cropped area in the traditional farming methods. Mostly, large area of Class III land is available for forestry usages for fodder and fuel wood collection. In terrace farming the irrigation water is extensively used wherever available. To prevent slope failure and soil erosion in terrace farming a new irrigation system should be developed.

Land system units dominantly associated with this class are 7, 11 and 14a. Significant land system units 12, 13c and 14b are also prevalent in this class and about 15.2% of the total land in the country consists of Class III land.

Class IV

Class IV lands are characterized by soils more than 20cm deep and well to imperfectly drained lands which are too steep (>30º slopes) to be profitably terraced and cultivated, too cold to be cultivated or prone to gully erosion and flooding. These lands are best suited for all forestry related uses provided that good, permanent vegetation cover is maintained to minimize erosion. Mass wasting is a serious and constant hazard problem for any type of land use in this class.

The major area of class IV land is presently forested which can be used for fuel wood, fodder, forage, litter, medicinal plants and timber production. Degradation of forest due to overgrazing is the main problem in this land class. So grazing must be strictly controlled or prohibited altogether in sensitive areas. Sustainable forest management must be given special attention for forest usages, location and design of access roads and maintenance of ground cover.

The dominant units of land system associated to this class are 3d, 5d, 12, 14b and 15a. Other significant land system units are 1c, 1d, 43b, 6d, 7,8,11, 14a, and 15b. About 25.8 percent of the total land of Nepal is occupied by this class.

Class V

Class V lands are characterized by soils more than 20cm deep and slopes less than 30 degrees. These lands are too frequently flooded, too cold or too dry to support any vegetation cover. However, these lands are very suitable for pasture development provided that the stocking rates are carefully controlled. Alpine regions above 3000 meters, the natural steppe country in the shadow of the Himalayas and active flooding alluvial plains are the three major Class V lands in Nepal. This land occupies about 4.1% of the total land of the country. The dominant land system units are 1c, 13a, 16a, 16b, 16c, and 16d and other significant units are 1b and 15a.

Major parts of Class V lands are flood plains which are subjected to frequent inundation throughout the country. More intensive land uses occur on flood plains and it precludes any other more intensively used land. Coarse grasses native to this land provide for fodder, wildlife habitat and construction materials. Above 3000 meters, alpine pastures are generally found, often along the crest of mountain ridges. The major limitations to production are cold and wetness in this land. The steppe country is the natural habitat of class V land which is used for tourism and recreation (mountaineering and trekking) due to scenic beauty and High Mountain peaks for climbing.

Class VI

Class VI lands are characterized by steep slope (40–50 degrees), severe gully erosion with less than 20 cm soil depth and considered to have severe limitations for food and fiber production. To minimize the risk of erosion hazard on this land vegetation cover should be maintained. The degraded areas are difficult or sometimes impossible to reclaim due to steep slope as well as low soil temperature which restricts the speed of regeneration of any type of vegetation.

Class VI lands are best suited for controlled extraction of fuel wood or timber, watershed protection and wildlife habitat conservations and tourism due to their environmental sensitivity. The dominant land system units are 6d, 8, 15b and 17a. Exactly 18.3 percent of the total land of Nepal falls in this class.

Class VII

Class VII lands are characterized by exposed rock and ice in very steeply sloping mountainous terrain. Outcrop rocks or vegetation is virtually absent in this class. The Class VII lands are best suited for the tourism and recreation (mountaineering and trekking) due to scenic beauty and High Mountain peaks for climbing. The land system units are 17b. 18.3 percent of the total land of Nepal falls in this class.

2.1.2 Irrigation Suitability Class

Irrigation suitability classes are based on systematic appraisal of soils and their designations by categories on the basis of similar physical characteristics and land use opportunities under irrigation. The classification follows the USBR land classification framework modified to suite the local conditions of Nepal. The entire Tarai region, the Dun valleys and lands under Class I and Class II capability are classified according to their suitability for irrigation. A brief description of each of the irrigation classes is presented here.

Class I Diversified Crops-Arable

These lands are highly suitable for irrigated farming and are capable of producing sustained and relatively high yields of climatically suited upland crops as well as paddy.

Class 2 Diversified Crops –Arable

These lands are ranked lower than Class I in production capacity but these lands are moderately to fairly suitable for irrigated farming. The narrow ranges of diversified crops are adapted to these lands. There are some limitations in soil, which can be corrected and cannot be corrected. In this class the land productivity is limited compared to class I.

Class 1R Wet Land Paddy-Arable

These lands are capable to produce sustained and high yields of paddy at reasonable cost and highly suitable for paddy production under irrigated condition.

Class 2R Wet Land Paddy-Arable

These lands are ranked lower than Class 1R in productivity or more costly to farm and land is moderately to fairly suitable for paddy production under irrigation. The soil deficiencies can be corrected or cannot be corrected. These lands may possess poor drainage characteristics that affect winter crop production.

Class 5 Non-Arable

Class 5 lands are tentatively classified as non-arable and generally subjected to seasonal inundation.

Class 6 Non-Arable

Land included in this class is considered as non arable because of their failure to meet the minimum requirements for the other classes of land. Generally, soil of this class land is very shallow or impervious to root or water. The lands are characterized by extremely coarse texture surfaces, low water retaining capacity, overflow and run-off channels, permanent waste and slumps. The land is non-arable also due to complex topography.

2.1.3 Irrigation Suitability Sub-Class

The above mentioned irrigation suitability classes are further sub-divided based on the limitations or deficiency in soil, topography or drainage or the combinations of any of these two. These irrigation suitability rating sub-classes are:

- Soil deficiency
- Topography deficiency
- Drainage deficiency
- The combinations of any of the above two indicate to deficiencies of irrigation of land capability class.

2.1.4 Land Capability Sub-Class

The land capability classes described above are further classified into sub-classes on the basis of distinct climatic regimes with their altitudinal ranges. These sub-class climatic zones are as below:

Climatic Zone		Associated Farming Systems
Subtropical (altitude <1000 meters)	A	Intensive farming (multi-crops and livestock)
Warm temperate (altitude 1000-2000 meters)	B	Farming crops and livestock
Cool temperate (altitude 2000-3000 meters)	C	Livestock, fruits, limited crops farming
Alpine (altitude 3000-4000 meters)	D	Monsoon Grazing, fruit farming, cattle grazing
Arctic (altitude>4500 meters)	E	None

2.1.5 Land Capability Sub-Divisions

Besides categorization of capability classes based on climatic regimes, a sub-division based on the mean annual precipitation in combination with mean annual temperature is also made. The capability sub- divisions of moisture regimes are:

- Arid (a)
- Semiarid (s)
- Sub-humid (u)
- Humid (h)
- Per-humid (p)

2.2 Framework for VDC Level Land Capability Classification

Land capability classification for present study at VDC level, at large scale follows the basic principle of LRMP land capability. The LRMP land capability classification is further elaborated to highlight specific management limitation pertaining to the soil for sustainable agricultural uses in particular land unit. This system has been widely used in US Department of Agriculture & State Planning Commission since 1989 (Grose, 1999) and is adapted to suite the context of present study and the context of agricultural soil management in Nepal as a whole.

The salient features of this classifications system are as follows:

a) It follows LRMP Land capability Classifications system

b) Classifications rating is done for geo-morphological land unit i.e. land system land type unit considering soil characteristics, topography, climate, geology and geomorphology.

c) The classification system contains three tiers viz. class, subclass, and unit.

d) Unlike LRMP Land Capability, in which site specific deficiencies are assigned to the arable land units only (classes 2, 2R, and 5 for Class I and Class II), this system assigns deficiency categories to all the land capability units including (III,IV,V,VI,VII) to highlight specific management limitations in each capability classes and the associated land type units.

e) Climatic parameters viz. climatic regimes and moisture are associated with the capability class itself rather than differentiating them as sub-class and sub-division respectively as in LRMP Land Capability. The reason for this is that the climatic and moisture regimes do not vary significantly at all within a small area/region as VDC, which is the current extent of the study.

2.3 Land Capability Classification Hierarchy

The three hierarchical levels are followed for land capability classification viz. capability class, sub-class and unit. Capability Class gives an indication of the general degree of limitations to use; sub-class identifies the dominant kind of limitation and unit differentiates between lands with similar management and conservation requirements as well as productivity characteristics. The hierarchical levels are shown in **figure 2.1.**

Class						
I	II	III	IV	V	VI	VII
Degree of limitations						

Sub-Class			
Soil	Topography	Erosion	Wetness
Dominant limitation			

Unit					
1	2	3	4	5	Etc
Similar management requirement					

Figure 2.1 Land Capability Hierarchy (adopted from Grose, 1999)

The land capability classification system can be used and applied at various scales by mapping at the class, sub-class and unit levels.

2.3.1 Capability Class

The land capability class comprises seven classes ranked in order of increasing degree of limitation and in decreasing order of adaptability for agricultural use. Class I land is identified as the best suited land and it can produce wider range of crops and pastures at higher levels of production with lower costs and/or with less management requirements and/or less risk of damage to land compared to any other classes of land. Class II is superior to Classes 3 to 7 but less superior to Class I, and so on.

A range of land may occur in any one capability class, but it is often possible to identify good or bad quality land within the same class of land.

Class I to III, are considered as capable of supporting cropping activities on sustainable basis. Class IV is suited for forestry. Class V is suited for grazing pastures and fodder collection. Class VI has severe limitation and considered fragile and suitable for rough seasonal grazing only. Class VII land comprises of rock and snow cover with severe management limitations which cannot be corrected. The description of each capability class is presented in brief as below.

Capability classes associated with plain and terraced cultivation viz. Class I and II are further designated with the irrigation suitability as similar to LRMP irrigation suitability ratings for arability viz, Class 1, Class 2, Class 1R, Class 2R, Class 5, and Class 6 as described in Section 2.1.2 above.

Class I
Class I consists of lands with very few or no physical limitations to use of agriculture purpose. These lands are suitable for wide range of cropping, grazing or forestry. These lands are nearly level (<1^o slope) and soils are deep.

Class II
Class II consists of land with very few physical limitations to use. Terracing or contouring is necessary to control soil erosion when used for diversified agricultural crops and ground cover maintenance is required for forestry and grazing use. These lands are gently sloping (1^o–5^o slope) and soils are deep.

Class III
Class III consists of land with moderate limitations that limit the choice of crops or reduce productivity in comparison to Class I and Class II lands. These lands need careful management and conservation for optimum productivity and uses for agriculture. These lands are gently sloping to moderately steep (3^o-28^o slope) with soils 50-100 cm deep and moderately well to well drained. Terracing is compulsory to control erosion when used for agriculture. There are few limitations to traditional forest use provided adequate ground cover is maintained.

Class IV
Class IV consists of lands with moderately severe limitations that limit the choice of crops and/or require very careful management practices. These lands are either too steep to be terraced and cultivated (>28^o slope) or lie above the altitude limit of agriculture. These lands also include relatively flat to gently sloping lands with shallow soil depths (>20 cm) and well to imperfectly drained. These lands are suitable for forestry uses and require forest cover in the slopes to minimize erosion.

Class V
Class V consists of lands with severe limitations that restrict its use for agriculture and forestry. These lands have slopes (<28^o slope) and soils are more than 20 cm deep and in general are above tree line or are frequently flooded river plains. These lands do not support tree growth but have few limitations when used for fodder collection or grazing.

Class VI
Class VI consists of lands with very severe limitations that restrict its use to rough grazing, forestry and recreation. These lands include areas with 40^o to 50^o slope or steep slopes with soils less than 20 cm deep. These lands are considered as fragile because of extreme erosion hazard and/or poor regeneration potential.

Class VII
Class VII lands consist of rock and perpetual snow and have severe limitations that cannot be rectified.

2.3.2 Sub-Class
Within each class it may be possible to identify a number of limitations which restrict their agricultural use. Limitations may be defined as physical factors or constraints that affect the adaptability of the land and determine its capability for long-term sustainable agricultural production. Where limitations are found a class may also be assigned a subclass code indicating the nature of the dominant limitations or hazards that exists. Sub-class is equivalent to LRMP Land Capability's irrigation suitability subclasses but is assigned to all capability classes whether they are arable or not. Thus, the sub-classes can be further categorized and enabling to discriminate good and bad land within each individual capability class. In general sub-class represents management deficiency and its dominant factor. Deficiency factors may be more than one, thus indicating complex or severe

management limitations. These deficiency factors are related to soil, topography, erosion and wetness.

2.3.3 Unit

Unit helps to differentiate between similar areas that have different management or conservation requirements. They may also be used to separate areas that have slightly different productivity characteristics. This is done by specifically indicating a combination of the factors. These factors pertain to one or more of the capability sub-classes related to soil, topography, erosion susceptibility and wetness. The units are represented by codes associated with each individual deficiency type as presented below:

Table 2.2 Unit code for sub-class soil deficiency

Soil Deficiency	
Soil Depth	s1
Plant Nutrient Availability	s2
Workability	s3
Drainage	s4
Permeability	s5
Acidic	s6
Alkaline	s7

Table 2.3 Unit code for sub-class topography deficiency

Terrain Deficiency	
Steep Slope	t1
Surface channel dissection	t2

Table 2.4 Unit code for sub-class erosion deficiency

Erosion Deficiency	
Sheet erosion	e1
Rill erosion	e2
Rill/Gully erosion	e3
Soil slump/mass movement	e4

Table 2.5 Unit code for sub-class wetness (drainage) deficiency

Drainage Deficiency	
Water logging	Dw
Flooding	Df
High water table	Dwt

CHAPTER 3
METHODOLOGY

The methods applied for land capability classification is explained in this chapter. Based on the spatial analysis of soil, climate, and topographic parameters, to differentiate the land in arability class and deficiency type and sub-type unit by using GIS tool. A multi-criteria evaluation rule was developed to classify land units based on soil parameter, fertility, erosion susceptibility, terrain constraints and surface drainage (wetness). The details of the methodology are discussed in the following sections:

3.1 Methodology Framework

In general, the approach or methodology includes following steps:

i) Review of all the relevant maps of the project area including LRMP maps, Topographical maps and documents prepared by the Survey Department of Nepal as well as relevant products prepared by other agencies. As far as possible, the maps were made compatible to the LRMP products so that both could be used as temporal data by the concerned users for research and other uses.
ii) The VDC level land capability maps were prepared using the data sources such as high resolution satellite images, recent soil map prepared at 1: 10,000 scale, recent land system map prepared at 1: 10,000 scale, present land use map prepared at 1: 10,000 scale and management practices, soil survey data (both information gathered from the field as well as laboratory analysis), geomorphology/geology map, slope map, data on climate, soil erosion and moisture conditions.
iii) The multi-criteria evaluation rule was developed to classify land units based on soil parameters, fertility, erosion susceptibility, terrain constraints and surface drainage (wetness).
iv) The smallest mapping unit for delineation of land capability categories was of **0.25 hectare**, which is**1/4th of a square centimeter** in map scale.
v) The map layout and legends are as specified by National Level specification for the Preparation of VDC Level Land Resource Maps, Database and Reports, 2069.
vi) The VDC level out-put maps are based on Modified Universal Transverse Mercator Projection system and at 1:10,000 scales. The data base and maps are provided as per the specification provided by the NLUP office.
vii) The VDC level out-put maps are based on Modified Universal Transverse Mercator Projection system and at 1:10,000 scales. The data base and maps provided here had prepared as per the specification provided by the NLUP office.
viii) The report covers details of the methodology adopted in preparation of the soil capability maps of the selected VDCs. It covers tables, maps and charts showing the categories of the soils.

3.2 Land Capability Evaluation Criteria

Evaluation criteria for soil fertility, topography, erosion and surface drainage are derived as described in the subsequent sub-sections.

3.2.1 Soil Fertility Criteria

Soil fertility evaluation is derived from soil parameters related to top-soil rooting depth, workability (soil texture), soil drainage (permeability), alkalinity and acidity, content of organic matters, nitrogen, available phosphorus, and available potassium. The ratings of these parameters are presented below.

Table 3.1 Topsoil Root Depth Rating

Soil Root Depth		
>200 cm	Very Deep	High Suitability
100 – 200	Deep	
50 – 100	Moderately Deep	
25 – 50	Shallow	
<25	Very Shallow	Low Suitability

Table 3.2 Workability Rating (considering non-mechanized manual farming tools)

Soil Texture (Workability)		
l (Loam)	Good	High Suitability
sil (Silt Loam)	Good	
sl (Sandy Loam)	Good	
sil+l (Silt Loam + Loam)	Good	
cl (Clay Loam)	Moderate	
cl+l/sil (Clay Laom+Loam over Silt Loam	Moderate	
sicl (Silt Clay Loam)	Moderate	
sicl+sl (Silt Clay Loam + Silt Loam)	Moderate	
sl+sicl (Silt Loam +Silty Clay Loam)	Moderate	
sic (Silty Clay)	Fair	
sl + sc (Silt Loam + Silt Clay)	Fair	
c (Clay)	Poor	Low Suitability

Table 3.3 Soil Drainage Rating

Soil Drainage	
Well drained	High Suitability
Moderately well drained	
Somewhat poorly drained	
Somewhat excessively drained	
Poorly drained	
Excessively drained	
Very poorly drained	
Very Excessively drained	Low Suitability

Table 3.4 Soil Alkalinity and Acidity Rating

Soil Alkalinity and Acidity Rating		
<5.0	Very high acidic	Low Suitability
5.1 – 5.5	High acidic	
5.6 – 6.0	Medium acidic	
6.1 – 6.5	Low acidic	High Suitability
6.6 – 7.3	Neutral	Most Suitable
7.4 – 7.8	Low alkaline	High Suitability
7.9 – 8.4	Medium alkaline	
8.5 – 9.0	High alkaline	
>=9	Very high alkaline	Low Suitability

Table 3.5 Soil Organic Matter Contain Rating

Organic Matter (%)		
>5	High	High Suitability
2.5 – 5	Medium	
1.0 – 2.5	Low	
<1	Very low	Low Suitability

Table 3.6 Soil Total Nitrogen Rating

Soil Total Nitrogen Rating (%)		
> 0.05	Very Low	Low Suitability
0.06 - 0.1	Low	
0.11 - 0.20	Medium	
0.21 - 0.30	Large	
<0.31	Very Large	High suitability

Table 3.7 Soil Available Phosphorous Rating

Available P2O5 (kg/ha)		
>15	Very Less	Low Suitability
16 -30	Less	
31 - 55	Medium	
56 - 110	Large	
<110	Very Large	High suitability

Table 3.8 Soil Available Potassium Rating

Available K2O (kg/ha)		
> 55	Very Less	Low Suitability
56 - 110	Less	
111 - 280	Medium	
281 - 500	Large	
< 501	Very Large	High suitability

Table 3.9 Soil Permeability Rating

Soil Permeability	
<0.15 (Very Slow)	Low Suitability
0.15 -0.5 (Slow)	Moderately Low Suitable
0.5 – 1.5 (Moderately Slow)	Moderate Suitability
1.5 – 5 (Moderate)	High Suitability
5 - 15 (Moderately Rapid)	Moderate Suitability
15 - 50 (Rapid)	Moderately Low Suitable
>50 (Very Rapid)	Low Suitability

Table 3.10 Soil Available Zinc Rating

Zinc(ppm)		
>0.25	Very Low	Low Suitability
0.26 - 0.50	Low	
0.51 - 1.00	Medium	
1.00 - 2.00	Large	
<2.00	Very Large	High suitability

Table 3.11 Soil Available Boron Rating

Boron (ppm)		
>0.20	Very Low	Low suitability
0.21-0.50	Low	
0.51 – 1.20	Medium	
1.2-2.00	High	
<2.0	Very High	High Suitability

3.2.2 Topography Criteria

The topography criteria pertain to management limitations in terrain topography. These limitations are related to the steepness of the terrain slopes and surface dissection, which inhibit the sustainable use of land. The land with these topographic problems requires careful management with terracing and maintaining vegetation cover to mitigate soil degradation.

Table 3.12 Topographic Deficiency Criteria due to Slope

Topographic Deficiency (Slope in degree)		
0 – 3	Flat to gently sloping	High Suitability
3 – 14	Sloping to moderately steep	
14 – 28	Steep	
>28	Very steep	Low Suitability

Irregular surface topography and surface dissection is another form for topographic limitation. The surface dissection may be due to the recent gulling or past-multi-terrace effect of surface erosion. Dissected topography increases difficulty in surface water conveyance for irrigation as well as causes severe erosion (especially gully erosion) due to concentrated run-off in this type of terrain.

3.2.3 Erosion Susceptibility Criteria

Erosion susceptibility criteria affect potential of soil loss due to erosion. The susceptibility rating of different types of erosion is given in the following table.

Table 3.13 Soil Erosion Susceptibility

Soil Erodibility (Erosion Deficiency)		
Sheet erosion	Low	High Suitability
Rill erosion	Medium	
Rill/Gully erosion	High	
Soil slumps/Mass movements	Very High	Low Suitability

3.2.4 Surface Drainage Criteria

Surface drainage (wetness) criteria pertain to the drainage condition of surface. Frequent flooding resulting in land inundation, water logging and high water table are the general problems affecting the productivity and use of land.

Table 3.14 Drainage Deficiencies

Drainage Deficiency (Wetness)	
Water Logging	Dw
Flooding	Df
High Water Table	Dwt

3.3 Land Capability Evaluation Method

Land capability of land unit (i.e. land system land type/soil mapping unit) is evaluated based on above mentioned criteria and rating of the land unit is designated with appropriate land capability class along with its specific management limitations. Figure 3.1 shows the general approach for classification and designation of land capability class to a land unit.

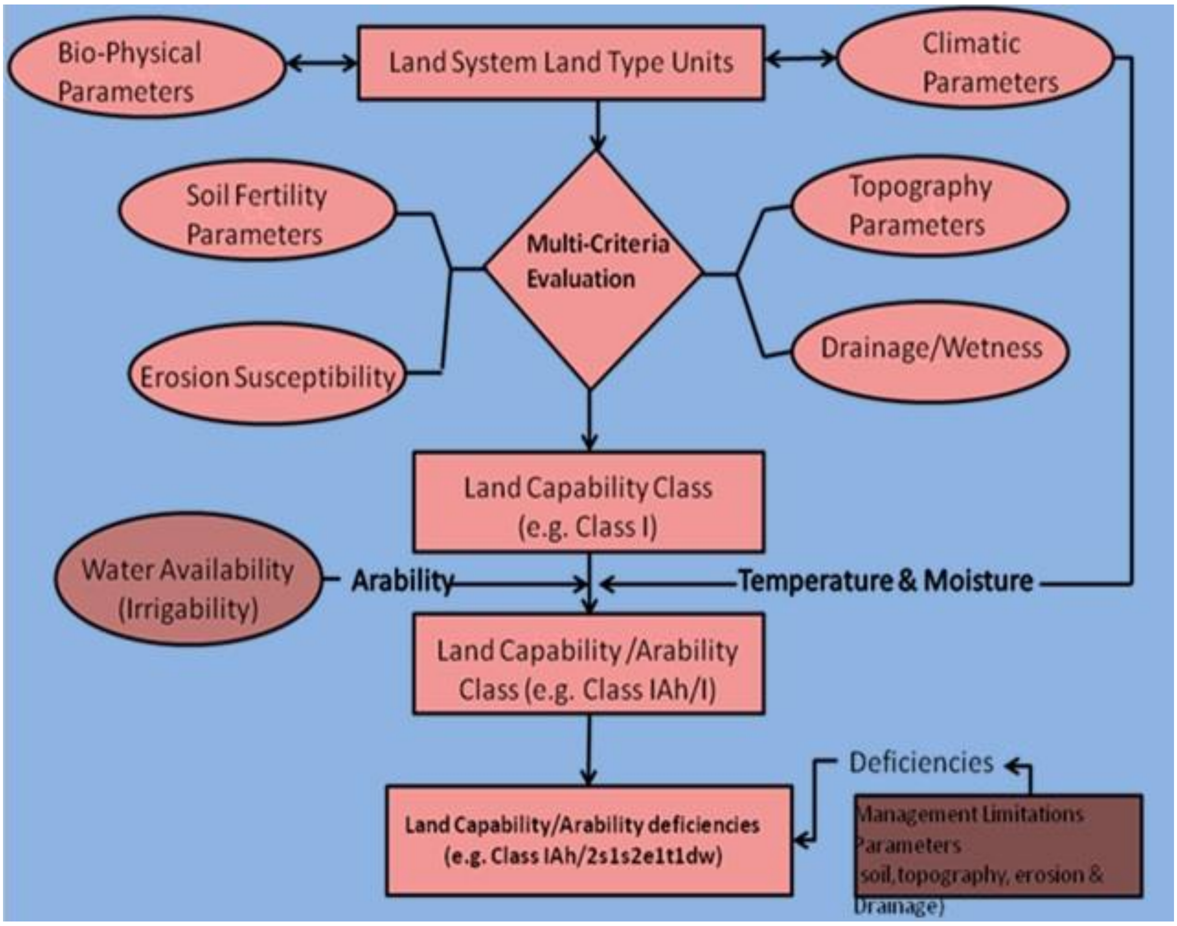

Figure 3.1: Land Capability Classification Method Flow Diagram

CHAPTER - 4

PRESENT LAND CAPABILITY CLASSES OF GANGOBALIYA VDC

Land capability classification of the land type units was conducted on the basis of various criteria of soil and other parameters. This chapter presents the result of land capability class coverage in Gangobaliya VDC. The chapter also presents the summary of each type of management limitations as represented by the capability sub-class and units.

Land Capability of Gangobaliya VDC was conducted on the basis of the soil properties, terrain slope, erosion and drainage characteristics. The land capability class distribution in the VDC is presented in the Table 4.1 and Figure 4.1 and spatial distribution of land capability class of the VDC is shown in the map figure 4.2. Majority of land (83.08%) consists of land capability Class I AU/1R, 15.14% land has I Au /1 class and 1.78% of land is II Ah/5sd Class. These classes are suitable for diversified crops and potential for arable agriculture with minor limitations and requiring low management inputs.

Table 4.1 Land Capability Classes of Gangobaliya VDC.

Capability Class	Area (Sq.m)	Area(Ha.)	percent	Description
Class IAU/1	1746806.462	174.68	15.14%	Lands with very few or no physical limitations to use of agriculture purpose, sub-humid, arable agriculture, diversified crops
Class IAU/1R	9584732.209	958.47	83.08%	Lands with very few or no physical limitations to use of agriculture purpose, sub-humid, wetland rice arable agriculture
Class II Ah/5sd	204827.5155	20.48	1.78%	Land with few physical limitations to use for agricultural purpose, humid moisture regime with soil deficiency

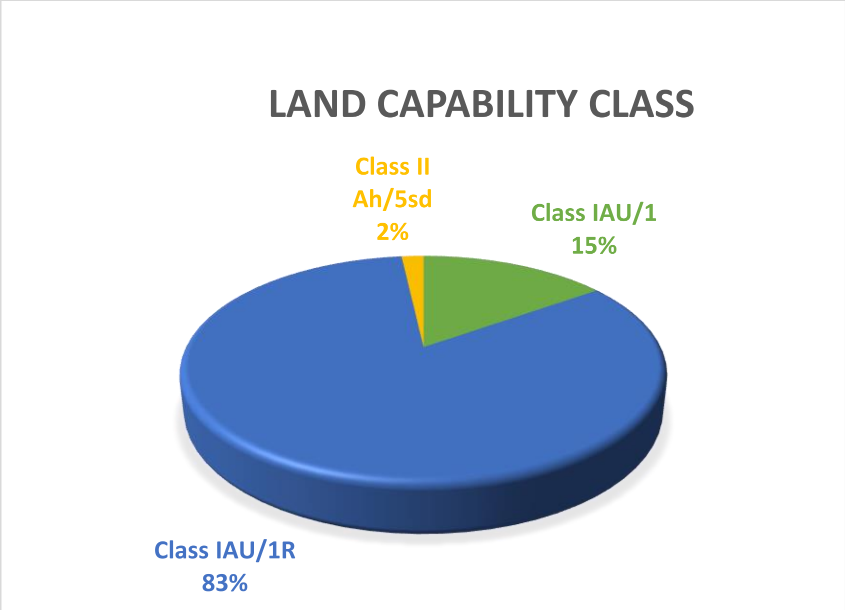

Figure 4.1 Distribution of Land Capability Classes.

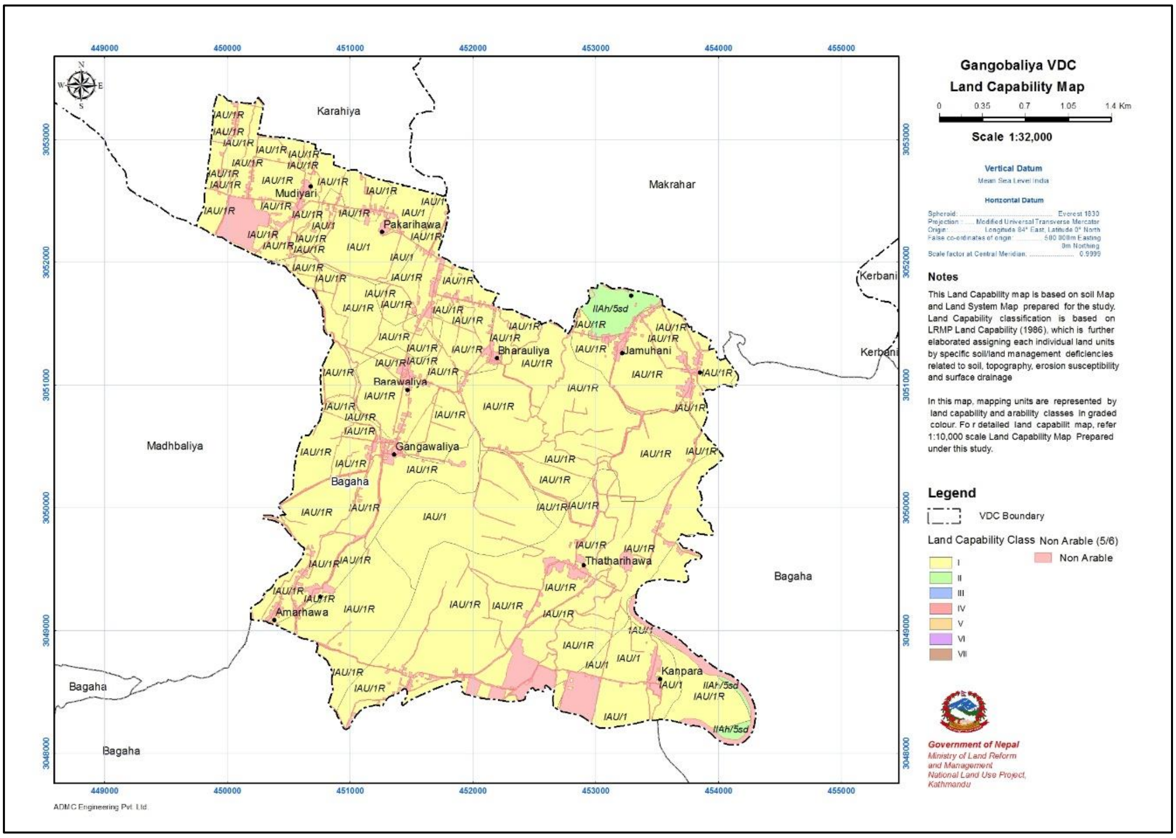

Figure 4.2 Spatial Distribution of Land Capability Classes of Gangobaliya VDC.

4.1 Land Capability GIS Database

The land capability GIS data is stored in vector geo-database and "shape" file formats as a single land unit class which contains a hierarchy of sub-classes that are defined in various attribute fields of vector GIS database. Table 4.2 represents the data model of GIS database.

Table 4.2 Land Capability GIS Attribute Data

S. No.	Attribute	Data Type	Description	Remarks
1	FID	Feature Id	Feature	
2	SHAPE	Geometry	Geometric Object type	
3	OBJECTID	Long	Unique Object ID	
4	CAPABILITY	String	Land Capability Class	
5	ARABILITY	String	Arability Class	
6	AREA	Double	Area in m^2	
7	AREA_HA	Double	Area covered by land capability land unit in ha	
8	SYMB_NUME	Integer	Land Capability mapping symbol	
9	SYMB_DINO	String	Land Capability deficiency mapping symbol	
10	DEFICIENCY	String	Deficiency in land unit (soil, topography,)	
11	CLIMATE	String	Climate Regime	
12	MOISTURE	String	Moisture Regime	
13	ASSO_LS	String	Associated land system	
14	SLOPE_CLS	String	Associated slope class of terrain	
15	SLOPE_DEG	String	Slope description	
16	SOIL_TXT	String	Associated soil texture class	
17	DRAINAGE	String	Associated soil drainage pattern	
18	PH	Integer	Associated soil pH value	
19	PH_RATE	String	Associated soil pH rating	
20	OM_PER	String	Associated soil organic matter percentage	
21	OM_RATE	String	Associated soil organic matter rating	
22	TN_PER	String	Associated soil total nitrogen percentage	
23	TN_RATE	String	Associated soil total nitrogen rating	
24	P_2O_5_ KGHA	String	Associated soil available P_2O_5 in kg/ha	
25	P_2O_5_ RATE	String	Associated soil available P_2O_5 rating	
26	K_2O_ KGHA	String	Associated soil available K_2Oin kg/ha	
27	K_2O_ RATE	String	Associated soil available K_2Orating	
28	FERTILITY	String	Associated soil fertility value (based on different soil parameters)	
29	FER_RATING	String	Associated soil fertility rating	
30	EROSION	String	Erosion susceptibility rating	
31	SOLUM_DPTH	String	Top soil depth in cm	
32	TOPO_DEF	String	Terrain slope type	
33	DRAIN_DEF	String	Surface drainage problem	
34	PERMIABILI	String	Associated soil permeability	
35	SOIL_DEF	String	Associated soil deficiency symbol	
36	ERO_DEF	String	Associated erosion deficiency symbol	
37	TERRA_DEF	String	Associated terrain deficiency symbol	
38	DRAINAGE_D	String	Associated surface drainage deficiency symbol	
39	Class	Short	Subtype for Top Level of Land Capability	
40	LandCap_Subclass	String	Land Capability Sub Class	
41	LandCap_Subdiv	String	Land Capability Sub division	
42	LandcapabilityClass	String	Land Capability of each mapping unit	

CHAPTER - 5

CONCLUSION

5.1 Conclusion

Land capability classification of Gangobaliya VDC was carried out on the basis of topography (slope), soil parameters (depth, texture, drainage, PH, OM, N, P, and K), climate, erosion hazard and land management. The classified lands are ranked best suited for agricultural uses without degrading the soil for long term sustainable basis in class I. The class I land is the most suitable for the agriculture, forestry and grazing with few or no limitations of soil and erosion parameters. The increase in class number of land capability indicates that there are increasing the limitations (e.g. stoniness, poor drainage, salinity/acidity, flooding, erosion, soil depth) for the use of land in sustainable manner. Thus, land capability assessment is therefore based on the permanent biophysical features of the land with existing climate.

Most of the area of this VDC is classified in land capability Class I Au/1R that covers 958.47 ha. It has minor soil limitations. Thus, this land has potential for irrigated farming and are capable of producing sustained and relatively high yields of climatically suited upland crops and for arable agriculture with some management measures taken to overcome the deficiency limitations of the land units.

Classification of land based on its capability or suitability becomes very useful tool to land users and planners to direct their resources to particular type of production in the most suitable area and protect the highly suitable land for crop production from encroachment by non-agricultural practices. Depending on the socio-economic and environmental consequences that can result from the introduction of new practices, suitability classes can provide policy makers with information to make best choice among alternatives.

5.2 Suggestions

There is need of criteria for soil fertility assessment for land capability class by the project to create uniformity in data resources. The database of land capability classes would be very useful for the country to formulate planning to cope with the low agriculture production, land degradation problem and climate change induced disaster. These databases play vital role in sustainable use of natural resources safeguarding the environment. Thus, there is need of such study on other areas, dissemination of these data bases to local level and local and national planning on agriculture, industrial, forest, urban etc. sectors based on these databases.

E. Risk Report

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Chapter 1: INTRODUCTION

1.1 Background and Rationale

The importance of Land Use Planning role in the prevention and the restriction of consequences of major hazard accidents are need to be analyzed. Inversely, Land use planning without due consideration on disaster aspect are not effective. Mainstreaming disaster risk reduction in Land Use Planning can systematically reduce impact of specific hazard. The main objective of this study is to investigate the risk factor associated in land use plan going to be prepared in the study area. Risk assessment, that identifies the severity and spatial distribution of risk and generates the necessary information and data for risk sensitive land use planning is essential for land use zone designation. It discusses the elements of risk, such as hazard (mainly: flood, landslide, seismic, fire and industrial) and vulnerability as a guiding issues for formal land use planning.

Lack of formal planning increases the adoption of informal ways of planning, which may or may not be effective. There is a gap between the formal and informal planning systems. The government is trying to ensure planned future land use to prevent injury, human trauma and loss of life, and to minimize property damage due to diastral events like flood, earthquake landslide etc. In most cases, human response to the hazard is based on the structural measures like construction of protection wall (against landslide), flood defenses, especially levees, storage reservoirs, floodwalls, and diversions (against landslide). Contrary, the approach of land use planning should be largely recognized as the way forward, where development decisions are based on the knowledge of the prevailing and expected future risks.

The recurring heavy losses in Nepal due to diastral events can be reduced by using policies, structural measures and planning tools, such as Land use planning (LUP). A LUP is an essential planning tool for successful and systematic disaster risk reduction like flood. Government of Nepal has already prepared land use plan of flood plain zone in many districts of Terai. In contrary, the area has been seen suffering due to flood recurrently. This triggers for carrying out of such planning task based on the risk layer to ensure risk sensitive land use planning.

1.2 Objectives of the Study

Objective of this risk study is to identify the areas which are more prone to risk events potentially caused by flood, landslide, earthquake, fire and industry within the study area.

1.3 Study Area

GangobaliyaVDC is situated in the eastern Terai region of Nepal which is situated in Central Southern part of Rupandehi district. This VDC is connected with Madhbaliya and Karahiya in the western part, Makrahar and Karahiya in the northern part, Siktahan in the eastern part and Hatipharsatikar in the southen part. The rectangular extent of the VDC is 83°32'8''E, 27°35'51''N, 83°29'27''W and 27°33'1''S. The total population of this VDC is 6966, of which male population accounts for 49.14 percent and female population is 50.86 percent (VDC profile, 2011). However, all the wards vary in area and population size. Total number of household in the VDC is 1172.The area of the VDC is 1285.81 hectares.

This VDC is inhabited by different caste and ethnic groups. Tharu predominates the inhabitants of this VDC accounting 44.57 percent of the total VDC Population. Tharu, Brahman hill, Yadav & Mallaha are other dominant caste and ethnic groups of this VDC.

Economic condition of the people of this VDC largely depends on agriculture. Land is main source of income and capital accumulation and also the major source of employment. Economic condition of the people having large landholding size is better than the others.

The location map of the study area has been shown in Figure 1.

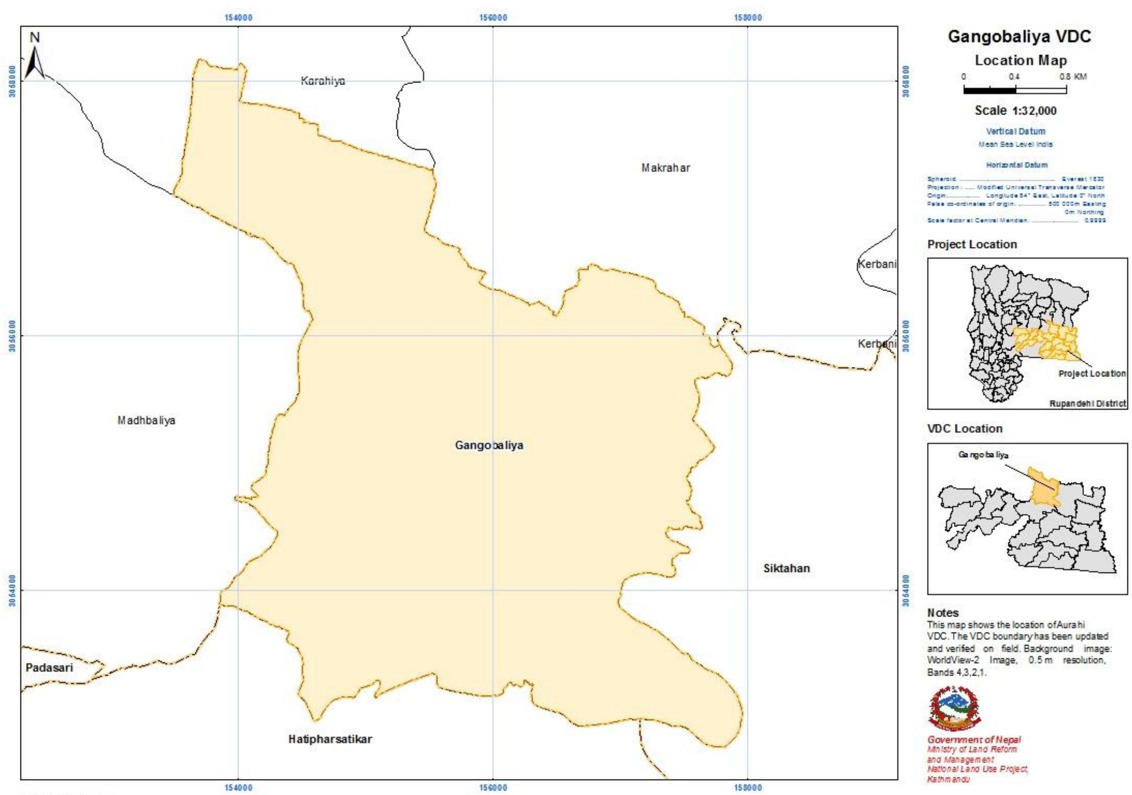


Figure 1: Location Map of GangobaliyaVDC

Chapter 2: CONCEPTUAL BASIS OF RISK MAPPING

2.1 Risk and its relation to Land Use Zoning

The population, buildings and engineering works, economic activities, public services utilities, other infrastructures and environmental values in the area potentially affected by the hazard are deemed as elements at risk. The assets at risk from disaster can be enormous and include private housing, transport and public service infrastructure, commercial and industrial enterprises, and agricultural land.

Risk is a measure of the probability and severity of an adverse effect to health, property or the environment. Risk is often estimated by the product of probability of a phenomenon of a given magnitude times the consequences. However, a more general interpretation of risk involves a comparison of the probability and consequences in a non-product form.

Zoning is the division of land into homogeneous areas or domains and their ranking according to degrees of actual or potential hazard or risk or applicability of certain hazard-related regulations.

2.1.1 Land Use Planning or (Zoning) and Disaster Risk Reduction

Land use planning (LUP) or zoning is an essential planning tool for successful and systematic disaster risk reduction (DRR). It further clarifies that the use of policies, non-structural measures and planning tools like LUP can reduce exposure of vulnerability of communities and assets to hazards. Land use planning can reduce the vulnerability of people and infrastructure identifying appropriate locations for settlement and construction by applying

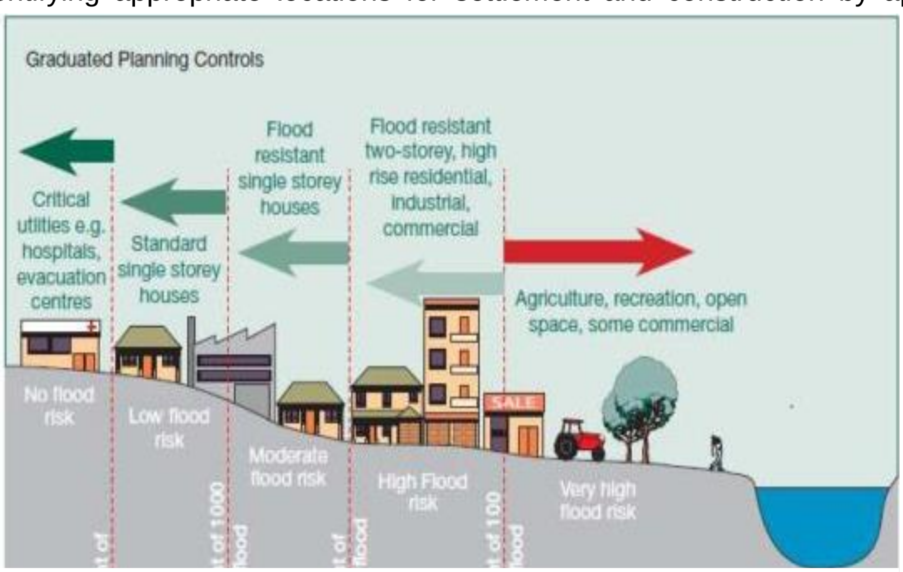


Figure 2: Distribution of land use on floodplain to reduce risk

adequate building standards during implementation of plan. LUP in corporation with DDR ,is a method applied to achieve safer and more sustainable development as it aids in protecting communities, houses, livelihoods, schools, hospitals and other components from disaster(Directorate et al., 2013).Risk-sensitive land use planning is useful for controlling main spatial exposure to risk. The spatial exposure refers to people, property, systems, or other elements present in hazard zones. LUP can reduce exposure of risk hazard and vulnerability as it involves policy and provisions which target, and seek to reduce specific aspects of vulnerability such as poor construction, poor transportation and road access, lack of evacuation routes and evacuation sites, poor drainage systems and waterways etc.

2.2 Relation of vulnerability and hazard with Risk

Hazard: It is a prime component of risk. It is expressed as the probability of a potentially damaging event of a certain magnitude occurring within a certain period of time. Hazards depends on site-specific and seasonal climatic conditions. Hazard is a condition with the potential for causing an undesirable consequence. The description of landslide hazard should include the location, volume (or area), classification and velocity of the potential landslides and any resultant detached material, and the probability of their occurrence within a given period of time. Similarly, other hazard includes corresponding parameters relevant to them.

Hazard is to be understand as a source of potential harm. It poses a threat or condition that may cause loss of life or initiate any failure to the natural, modified or human systems.

The initiating causes of a hazard may be either an external (e.g. earthquake, flood or human agency) or an internal (defective element of the system e.g. an embankment breach) with the potential to initiate a failure mode. Hazards are also classified as either of natural origin (e.g. excessive rainfalls, floods) or of man-made and technological nature (e.g. sabotage, deforestation, industrial site of chemical waste). Regarding hazard identification and estimation, two approaches can be identified based on the ANCOLD Guidelines (2003) and the ISDR principles (2004):

a. Traditional deterministic approach: a first level estimation of the potential adverse consequences, if the hazard occurs, in order to classify the system under threat, identify the necessity or not of further investigation. This approach is also the most comprehensive way of estimating man-induced and /or technological hazards, e.g. a forest fire hazard that cannot be captured by a probability distribution.

b. Probabilistic approach: it is based on the theory of probability and regards hazard estimation as the estimation of the probability of occurrence of a particular natural event with an estimated frequency within a given period of time. It can be applied on hazards of natural origin and it represents a very common method used in most flood plain delineation studies when the potential for loss of life is considered negligible in terms of historical floods. The probabilistic approach tends to assume that events in the future are predictable based on the experience of the past.

Vulnerability: The degree of loss to a given element or set of elements within the area affected by the landslide. It is expressed on a scale of 0 (no loss) to 1 (total loss). For property, the loss will be the value of the damage relative to the value of the property; for persons, it will be the probability that a particular life (the element at risk) will be lost, given the person(s) is (are) affected by the disaster event.

One of the best-known definitions of vulnerability was formulated by the International Strategy for Disaster Reduction (ISDR, 2004), which regards it as “a set of conditions and processes resulting from physical, social, environmental and economic factors, which increase the susceptibility of a community to the impact of hazards”. A basic consensus has emerged, that the concept of vulnerability addresses a double structure consisting of an external side (exposure) (Bohle, 2001), and also that vulnerability is:

- Multi-dimensional and differential (varies across physical space and among and within social groups)
- Scale-dependent (with respect to time, space and units of analysis, such as individual, household, region, system)
- Dynamic (characteristics and driving forces of vulnerability change over time, certainly exceeding that time of the extreme event itself)

Generally, the vulnerability of a system against a certain hazard is not easily assessed.
Three routes for the assessment can be distinguished:

a) Economic
b) Social
c) Cultural

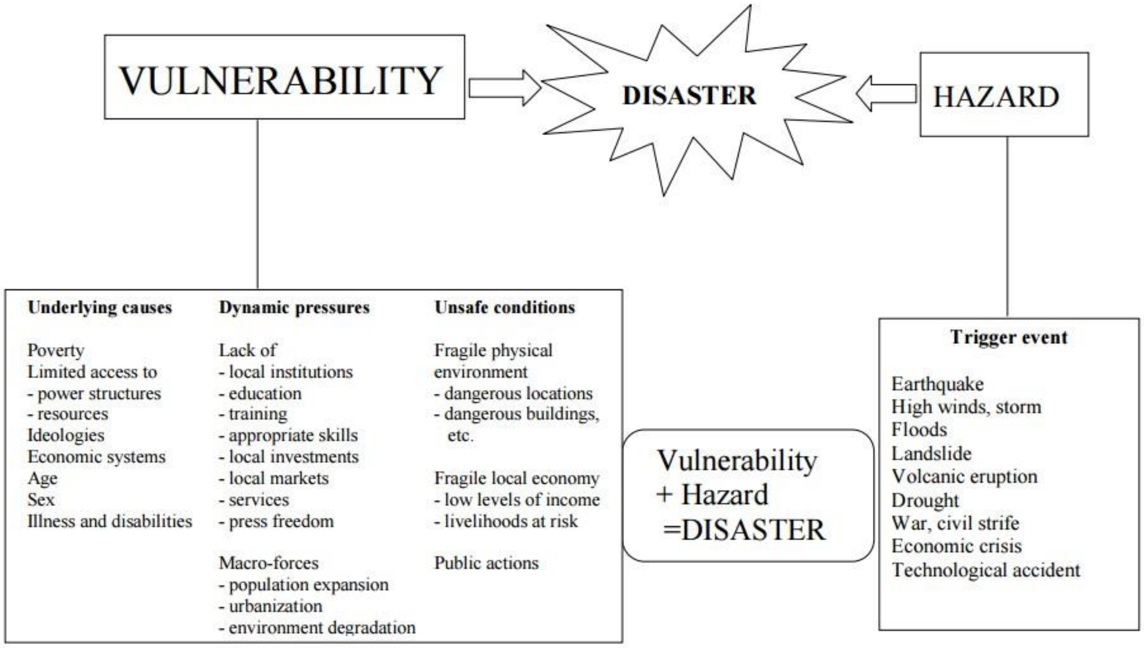


Figure 3: Factors of Disaster

The vulnerability function could be treated as a function between 0 and 1.However, the most appropriate approaches for the case of vulnerability of the society and the cultural heritage are thought to be qualitative. A vulnerability analysis in the event of a hazard like flood considers the population and structures at risk within the affected area. In the start of the analysis, a reference level of the system's vulnerability should be determined that usually refers to existing flood protection systems of the affected area. The vulnerability analysis evaluates the potential costs of disaster event in terms of damages to buildings, crops, roads, bridges and critical infrastructure etc.

It refers to the physical and social elements at risk that lacks the capacity to cope with the negative impact of a hazardous event. The concept of vulnerability not only includes physical or socio-demographic characteristics, but also no tangible factors like lack of knowledge about the hazard, so it is difficult to measure. Common understanding and definition of vulnerability has not yet been found.

The concept of vulnerability describes the characteristics but not the number of people or volume of infrastructure exposed to a hazard. When Hazard and vulnerability meets there occurs disaster.

2.3 Risk types and their Descriptions

Depending upon the types of factor causing an area to expose into vulnerability and hazard associated with it, risk can be classified into various categories. However, for the land use mapping process, risk factors has been specified related to the following event:

- Flood

- Landslide
- Fire
- Earthquake (Seismic event)
- Industrial hazard

2.3.1 Mathematical Understanding of Flood Risk

According to EU Directive (COM, 2006) for flood management, "flood risk" is the likelihood of a flood event together with the actual damage to human health and life, the environment and economic activity associated with that flood event. In this context flood risk can be considered as the actual threat, in other words the real source.

of flood hazard to the affected areas. The quantification of flood risk results either in monetary units or in loss of life units, if the losses are measurable, or in qualitative terms (e.g. allocation in classes) in the case of intangible damages (social, environment, cultural) to the affected areas. In general, risk as a concept incorporates the concepts of hazard {H} (initiating event of failure modes) and vulnerability {V} (specific space/time conditions). It is customary to express risk (R) as a functional relationship of hazard (H) and vulnerability (V).

{R} = {H} □ {V}

in which the symbol □ represents a complex function incorporating the interaction of hazard and vulnerability. Consequently in mathematical terms it can be expressed as:

R = {H} x {V}

Since vulnerability is a dimensionless quantity (Villagran, 2006), risk could be measured in the same units as hazard. In quantitative terms, annualized risk can be estimated as the product of probability of occurrence of the hazardous phenomenon and the actual consequence, combined over all scenarios. According to the methodology of estimating average (annualized) hazard, the expected value of flood risk can be calculated as follows:

$$E(X) = \int^{\infty} x \cdot V(x) \cdot f(x)dx$$

Where, X is the actual flood damage caused by the flood hazardous phenomenon, f(x) is the p.d.f. that describes this phenomenon and V(x) is the vulnerability of the system towards the corresponding magnitude of the phenomenon. It is obvious that such an estimation involves major restrictions such as:

can be applied only on hazards of natural origin due to probabilistic analysis although it abides to a general methodological framework , it is highly case specific

highly dependable on expert's judgment

Chapter 3: METHODOLOGY

3.1 Flood Risk

Flood is a natural event of rising water level in a stream, lake, reservoir or coastal region (Friesecke, 2004). Flood is too much water in the 'wrong' place.(Singh, N, 2013). A flood is caused by heavy rainfall that causes river / oceans to over flow. It can happen at any time. Flood can happen very quickly when lots of heavy rain falls over a short period of time. Such type of flood is called flash flood which can occur with little or no warning. This can cause huge damage on human life than any other type of flooding. Coastal areas are also at risk from sea flooding, as it has been threatened by storms and big waves which bring seawater onto the land. The flooding can be worst if storms, 'spring tides' and low atmospheric pressure occur at a time.(Singh, N, 2013)." Floods can distribute large amounts of water and suspended sediment over vast areas, restocking valuable soil nutrients ruining crops, destroying agricultural land / buildings and drowning farm animals.(Singh, N, 2013).

Natural Hazard and Flood events are part of nature which have always existed and will continue to exist. Floods are climatological phenomenon which is influenced by geology, geomorphology, relief, soil and vegetation conditions. Meteorological and hydrological processes can produce flash floods or more predictable slow developing floods causing riverine floods. In some cases floods are invited by the failure of dam and landslides. Mitigation and non-structural measures are found to be more effective and long term solution for the water related problem. The local flood protection measures create negative effect in both upstream and downstream. Therefore, whole river basin should be taken into account. Flood plain should be identified before assigning any land use in such area("UN/ECE," 2003). The identification of flood plain can be performed by preparing flood hazard maps by the responsible authorities. This can be helpful to stop building development in immediate risk areas.

3.1.1 Data

Data for the Flood Risk Study can be classified into various group as follows:

- Land Use / Land Cover Data
- Elevation Data (Such as Spot height, contour, elevation model)
- Hydrologic parameters such as Catchment area, Cross-section data at defined interval, river bank lines, flow path geometry, stream center line etc.
- Discharge data at strategic points, manning's constant, river boundary information etc.

3.1.2 General Approach and Methodology Framework

Various methodological framework exist in Nepal for flood modeling. It is generally accepted that that the flood risk management framework should be mainly oriented towards non-structural measures (e.g. land use planning, flood warning systems, evacuation plans, insurance policy); that is towards measures that are mainly driven by the need of cultural heritage protection and also by the socioeconomic conditions of the area concerned. In this context the a thorough analysis of the study area is needed before developing a workflow chart, in order to apply the prescribed methodology over flood hazard scenarios to the specific case-study areas of special cultural interest within the same Prefecture. An applied methodological framework for flood risk assessment, in general, is shown in the following page.

The concepts of hazard, vulnerability and risk have been extensively used in various disciplines with a different meaning, impeding cross-disciplinary cooperation for facing hazardous events. Even for natural hazards, such as floods, no unique definitions and assessment procedures have been widely accepted. In this paper we propose a comprehensive way for defining and assessing flood risk and vulnerability in the flood-prone areas. The suggested methodology follows a three-step assessment approach: a) annualized hazard incorporating both probabilities of occurrence and the anticipated potential damages b) vulnerability (exposure and coping capacity) in the flood-prone areas and c) annualized flood risk (estimated on annual basis). The methodology aims to assist water managers and stakeholders in devising rational flood protecting strategies.

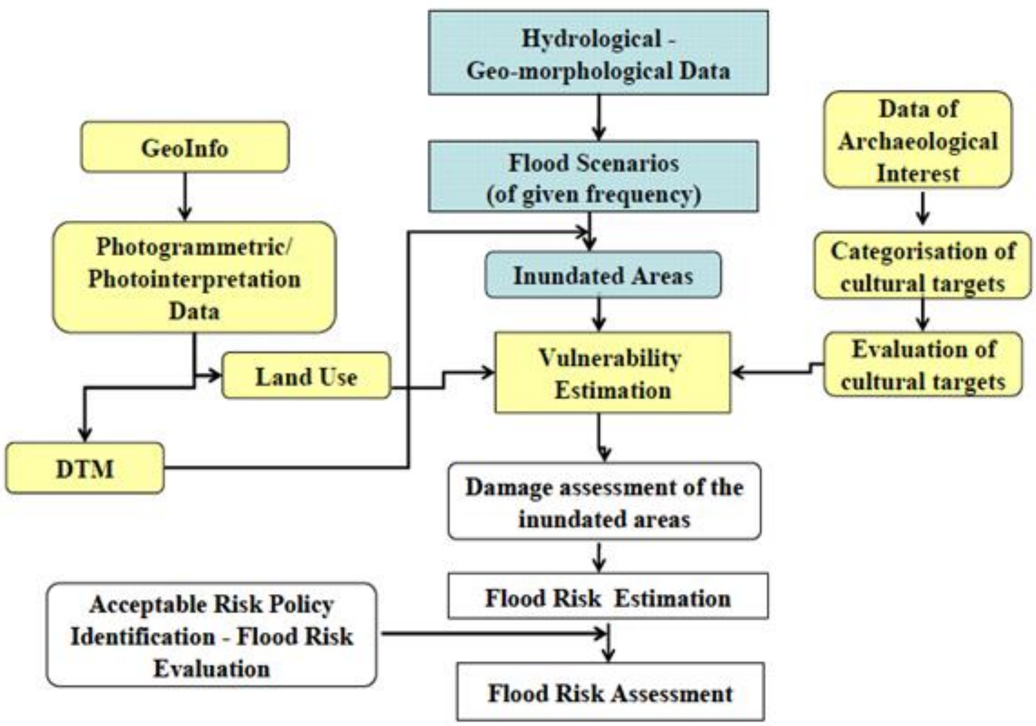


Figure 4: Methodological Framework for Flood Risk Assessment

3.1.2.1 Flood plain

The land that lies next to the river or along the river side during normal river flow and submerged during the flood (Shahiriparsa& Vuatalevu, 2013).

3.1.2.2 Flood hazard map

Flood Hazard Maps refers to the map that provides information on inundation like predicted inundation, inundation depth etc. as well as evacuation routes graphically in understandable format. Flood hazard mapping is one of the good example of non-structural measures for minimizing risk(Map et al., 2003).The flood hazard maps include the information on historical as well as potential future flood events in different probability. This can be the basis for determining land use control, flood proofing of constructions and flood awareness and preparedness. FHM provides information on type of flood, the flood extent; water depths or water level, flow velocity or the relevant water flow direction(Prinos, 2008). Flood Hazard maps should be considered before any investments or implementation of development projects.

3.1.2.3 Flood modelling

It is an engineering tool that provides accurate information regarding flood profile. The governing factor for causing flood are rainfall, run off, catchment characteristics and return period (Kute, Kakad, Bhoye, & Walunj, 2014). The main input data for calculating flood hazard maps is the occurrence probability and the amount of high water discharge in rivers (Prinos, 2008).

Flood discharge calculation is a prominent task for designers of hydraulic structures and river training works. This task is made more difficult as Nepal lacks sufficient hydrological information (Rijal, 2014). To carry out the calculation of flood flow different approaches can be selected based on site condition and available data. There are various methods adopted for calculating flood discharges like Rational Method, Empirical Formula (Modified Dickens's formula), Water and Energy Commission Secretariat (WECS) Approach, Flood - Frequency Method etc.

The rational method is applied for the peak flow calculation of smaller basin that responds to storms as it is simple and requires limited data. In this method it is assumed that intensities of rainfall and infiltration are uniformly distributed in time and space. The smaller basin here refers to the upper limit of 25 km^2(Hua, Liang, & Yu, 2003).

The Empirical Formula (Modified dickens formula) has been derived for northern India. The formula uses the catchment area as a single parameter affecting the flood peak and other factors are constant based on the specific region. This formula is applicable only in the region from which they were developed and when applied to other areas can at best give rough estimates (K. Subramanya, 2006).

Flood frequency method is the statistical method of frequency analysis of flood flow. The method is more time consuming as minimum data of 30 years should be essentially considered. If the length of records is less than 10 years, frequency analysis should not be adopted (K. Subramanya, 2006).

WECS/DHM (1990) method considers whole country as single hydrological region. The regionalization was done for low flows, long term flows and flood flows. It is the modified form of WECS (Water and Energy Commission Secretariat) approach of 1982 which was jointly developed by WECS and DHM (Department of Hydrology and Meteorology) in cooperation with WMO (World Meteorological Organization), WERDP (Water and Energy Resource Development Project, until 1989) and WISP (WECS/NEA Institutional Support Programme) in

1990 (Shrestha ,et al., 2010).The following equations is used for flood flow of any river of catchment area ‘A’ below 3000 m according to the regional hydrological analysis report published by Water and Energy Commission Secretariat cited in (Manandhar, 2010);

$$Q_2 = 1.8767 (A + 1)^{0.8783}$$

$$Q_{100} = 14.63 (A + 1)^{0.7342}$$

Where, the subscript 2 and 100 stand for the return periods innumber of years.

The flows for any other return period ‘R” is then given by:

$$Q_R = \exp (1n\, Q_2 + 3\,\sigma)$$

Therefore from the study of all the methods used for flood discharge, WECS/DHM method is found to be appropriate for the study, so the study has used this method for the calculation of flood discharge for the return periods of 2years and 100 years.

3.1.2.4 Manning’s roughness coefficient (n)

The Manning’s roughness coefficient, n, is commonly used to represent flow resistance(Phillips & Tadayon, 2006).The friction parameters have been considered as the form of Manning's roughness coefficient (n)(Shahiriparsa, Heydari, Sadehian, & Moharrampour, 2013).

3.1.2.5 Applications used for flood modelling

- Geographic Information System (GIS): GIS is computer based system for mapping and analyzing spatial data. GIS is considered to be revolutionary new technology which increases ability to make decision and solve problems. GIS differs from other information system as it integrates common data base operations like query and statistical analysis, unique visualization and geographic analysis benefits offered by maps. This is helpful for explaining events, predicting outcomes and planning strategies. The careful analysis of spatial data using GIS can provide detail information on problem like pollution, deforestation, natural disasters and suggest the way to address them. GIS comprises of five components i.e. hardware, software, data, people, and methods(Is & Of, 2000).

- Hec Geo-Ras: HEC-Geo Ras is an extension for ArcGIS. This extension allows users with limited GIS experience to create an HEC-RAS import file containing geometric attribute data from an existing digital terrain model (DTM) and complementary data sets. Water surface profile results may also be processed to visualize inundation depths and boundaries (Ackerman, 2011). HEC-Geo RAS is a set of procedures, tools, and utilities for processing geospatial data in ArcGIS using a graphical user interface (GUI).

- Hec-Ras: HEC-RAS is numerical analysis software. It is a computer program that models the hydraulics of water flow through natural rivers and other channels (Prinos, 2008). “It is an integrated package of hydraulic analysis programs, in which the user interacts with the system through the use of a Graphical User Interface (GUI)”(Brunner, 2010).This provides the details of flood profiles. This software is easily available and has precise calibration accuracy (Kute et al., 2014).This is the major part of the modeling where flood simulation is done. This program is one-dimensional which means the flow is considered to be uniform from point to point upstream to downstream. It includes numerous data entry capabilities, hydraulic analysis components, data storage and management capabilities, and graphing and reporting capabilities(Prinos, 2008).HEC-RAS system is the composition of four one-dimensional river analysis components viz; steady flow water surface profile computations, unsteady flow simulation, movable boundary sediment transport computations, water quality analysis(Brunner, 2010).

3.1.2.6 Steady Flow water surface profile

This component of modeling system is intended to calculate water surface profiles. The system can handle a single river reach, a dendritic system, or a full network of channels. The component is capable of modeling subcritical, supercritical, and mixed flow regime water surface profiles. The basic computational procedure is based on the solution of the one-dimensional energy equation. Friction (Manning's equation) and contraction/expansion (coefficient multiplied by the change in velocity head) are used for the evaluation of Energy loss while momentum equation is applied in situations where the water surface profile is rapidly varied. These situations include mixed flow regime calculations i.e., hydraulic jumps, hydraulics of bridges, and evaluating profiles at river confluences (stream junctions).The steady flow system is designed for application in flood plain management and flood insurance studies to evaluate floodway encroachments (Brunner, 2010).

3.1.2.7 Unsteady Flow simulation

This component is capable of simulating one-dimensional unsteady flow through full network of open channels. This component was basically designed for subcritical flow regime calculations. However, new releases of the model can now performed mixed flow regime (subcritical, supercritical, hydraulic jumps, and drawdowns). Special features of this component include: Dam break analysis; levee breaching and overtopping; Pumping stations; navigation dam operations; and pressurized pipe systems. Sediment(Brunner, 2010).

Upon discussion with NLUP authorities, it was found that that the study should also aim to evaluate land use plan from disaster (flood) management perspective for which requires the evaluation of flood way encroachment. From the above study it is found that, steady flow analysis is designed to evaluate flood way encroachment .Therefore steady flow analysis has been used for the flood simulation as required for the project. At the same time lack of unsteady flow data has made this project to choose steady flow analysis.

3.1.2.8 Disaster Risk Management in Nepal

Many acts and policies have been formulated for disaster mitigation activities in Nepal. Natural Disaster Relief Act, 1982 is the first Act of Government of Nepal. It has recognized earthquake, fire, storm, flood, landslide, heavy rainfall, drought, famine and epidemics as disaster. This Act defines natural disaster relief work to be carried out in the area affected or likely to be affected by the natural disaster in order to rehabilitate the victims from natural disaster. This Act is defined to control and prevent the natural disasters to prevent loss of life and property(Asia, Seminar, & Mapping,2009).Ministry of Home Affairs is the apex body to deal with disaster management in Nepal. This Ministry functions as:

- Formulation of national policies and their implementation,
- Preparedness and mitigation of disaster,
- Immediate rescue and relief works,
- Data collection and dissemination, Collection and distribution of funds and resources

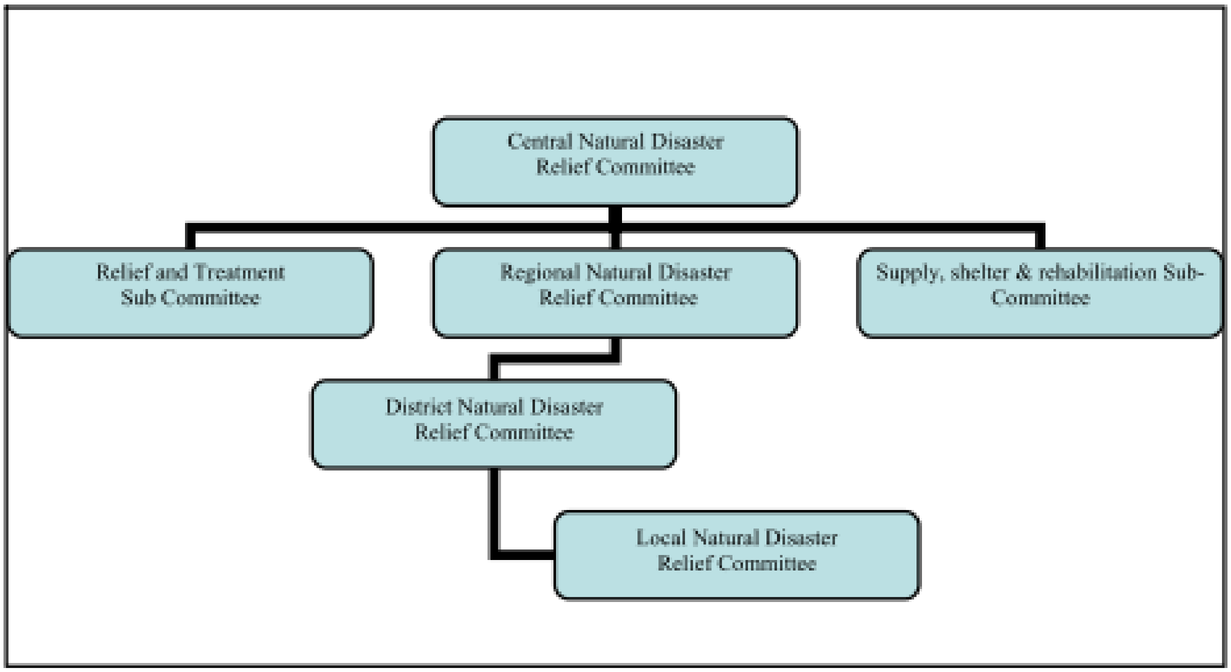


Figure 5: Disaster Relief Committee of Nepal

Some related act and regulation formulated in Nepal for disaster management according to (Asia et al., 2009) are as follows:

• Natural Calamity Relief Act 1982 (Amended in 1982 & 1992)

• Water Resources Act 1992

• National Action Plan on Disaster reduction 1996

• Environmental Protection Act 1996

• Local self-governance act (LSGA, 1999)

• National Water Resource Strategy, 2002

• National Water Plan, 2005

• Three Year Interim Plan (2008-2010)

3.1.2.9 Floods in Nepal

Flood occurs repeatedly in low plains of Nepal causing loss of lives and properties. Nepal has more than 6000 rivers and rivulets (Manandhar, 2010).Major sources of water are glaciers, rivers, lakes, rainfall, ponds, groundwater etc. Mountains are the perennial source of water. Intensity of rainfall with average 1700 mm annually contributes to surface water flow in average annually of approximately 224.7 billion m^3or in terms of flow rate; it is 7,125m^3/sec(Asia et al., 2009). It further adds that Nepal suffers from frequent water induced disaster like flood, landslide, erosion, debris flows, glacial lake outburst, drought and epidemic. This phenomenon occurs mainly in Monsoon. Intense monsoon rainfall causes flooding in many rivers of Nepal. Altogether, water induced disasters causes average annual loss of 309 lives and affects 27654 families (Asia et al., 2009).

3.1.3 Methods

In order to obtain the set objectives defined in TOR regarding flood risk, spatial and non-spatial data were collected. Both Qualitative and Quantitative approach was adopted for data generation. Primary sets of data were acquired using the method of interview with the people, residing in flood prone area and government officials. Secondary data were collected from National Land Use Project. The census of 2011 was obtained from website of CBS.

3.1.3.1 Data Collection

Data-collection is the systematic gathering of information necessary for our study. The information can be of people, objects or phenomena. Haphazard collection of data may create difficulty in answering the set question in a conclusive way (Chaleunvong, 2013).The method applied for collecting data is both qualitative and quantitative. Different techniques applied for the collection of data are: available information, observation, interviewing face to face, written questionnaire and focus group discussion (Chaleunvong, 2013). Among these techniques, this project has applied all techniques except focused group discussion.

3.1.3.2 Primary Data Collection

Primary data was obtained using the method of interview with the people residing in flood prone area to get the answer for the frequency of occurrence of flood and the methods they adopted to cope with. This information was collected through the written questionnaire and interview/conversation with local people. Non-probability, purposive sampling was used. Total sample size of 10 was taken for the interview.

3.1.3.3 Data Analysis

Conversation with local people

From the interview with local people, flood is uncertain in the study area. Bank cutting has been major problem which has created probability of entering flood in many parts along the river. Many agricultural lands have been converted to river bank due to bank cutting. Some dams constructed to check flood are in ruining condition due to the current of water while many has been swept away. According to the local people, flooding which can be controlled with the construction of embankment. Water logging has been a serious problem in the area.

There is a chance of entering flood to the area as bank cutting has found to be serious. Conversion of agricultural land to flood plain due to bank cutting can warn regarding the threat of flood to enter the in the nearby area. Flood has been probable threat for the people in the study area .

Analysis for watershed area determination and calculation of water discharge

In this phase, (Tinahu Nadi and Rohini nadi VDCs of Package 27 of Rupandehi District) was digitized from the WorldView2 image. Digital elevation model, shown in figure as grid model was prepared by using contour and station point from the topographic map. Water discharge for return period 100 years were calculated with the determination of watershed area shown in figure below using Flow direction and Flow accumulation. The process involved is given below:

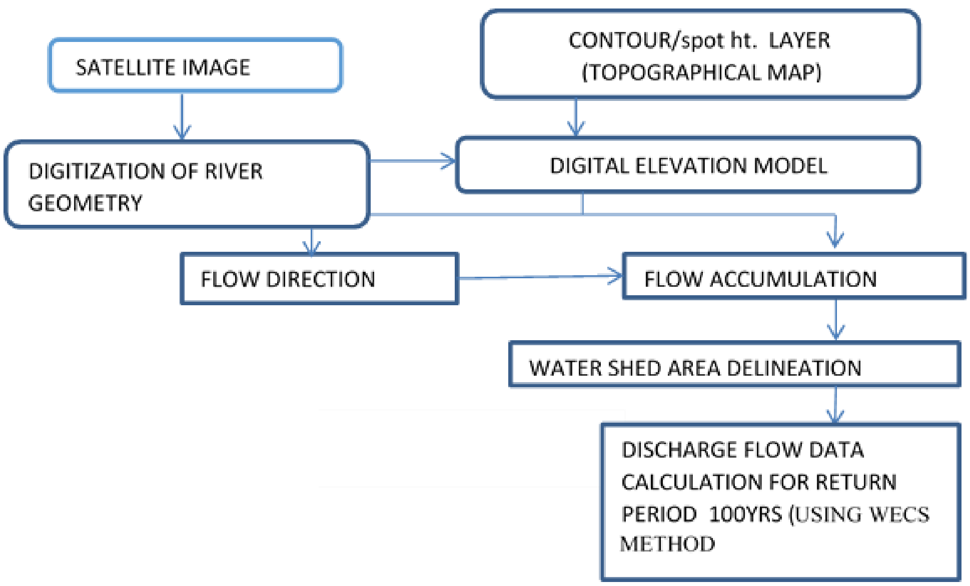
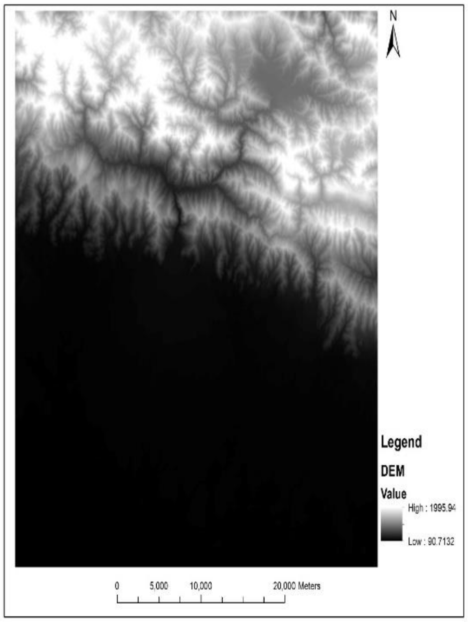


Figure 6: Process for Watershed area determination and discharge calculation



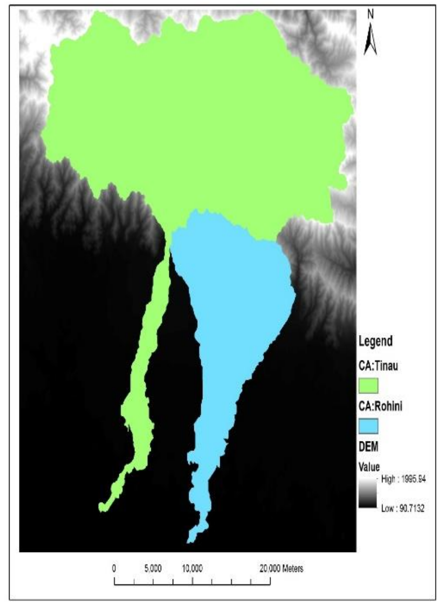


Figure 7 : Digital Elevation Model

Figure 8: Catchment Area

Calculated flow discharge for the given catchment area of return period 100 years is given below:

Table 1: Discharge calculation for given Return Periods

River	Station(m)	Catchment Area (Sq.km)	100 Yrs.
Rohini	124.00	198.02	713.01
Rohini	4042.21	195.15	705.44
Rohini	6970.29	191.85	696.71
Rohini	11476.88	181.66	669.50
Rohini	19118.38	159.71	609.43
Rohini	22508.95	155.42	597.42

Pre-Processing in GIS environment

Here in this part, RAS layers (Stream centerline, river banks, flow path centerlines and cross sections) were created as shown in figure below which was later followed by layer setup and finally RAS-GIS import file was created which was ready for processing in Hec-Ras.

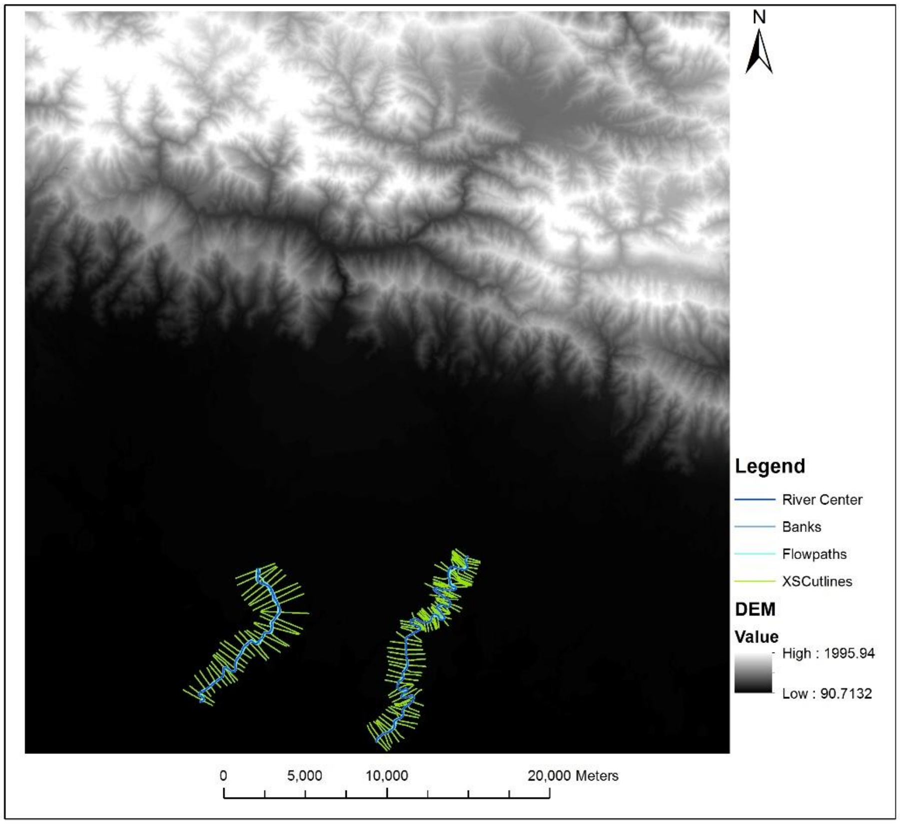


Figure 8: Hec-Georas Layers

HEC-RAS Processing

The import file thus created in HEC-Geo RAS was imported in Geometric Data Editor interface in HEC-RAS. The flood discharge for return periodic 100yrs which we have calculated from WECS/DHM method was entered in steady flow data. Reach boundary conditions were defined as critical depth for both upstream and downstream. Manning's constant for left and right bank was set as 0.04 while 0.035 was set for centre of channel. Mixed analysis was done n steady flow analysis. Then the generated data is exported in GIS format. Process involved here is shown in figure below. Water surface profile for return periods is given in the following figures.

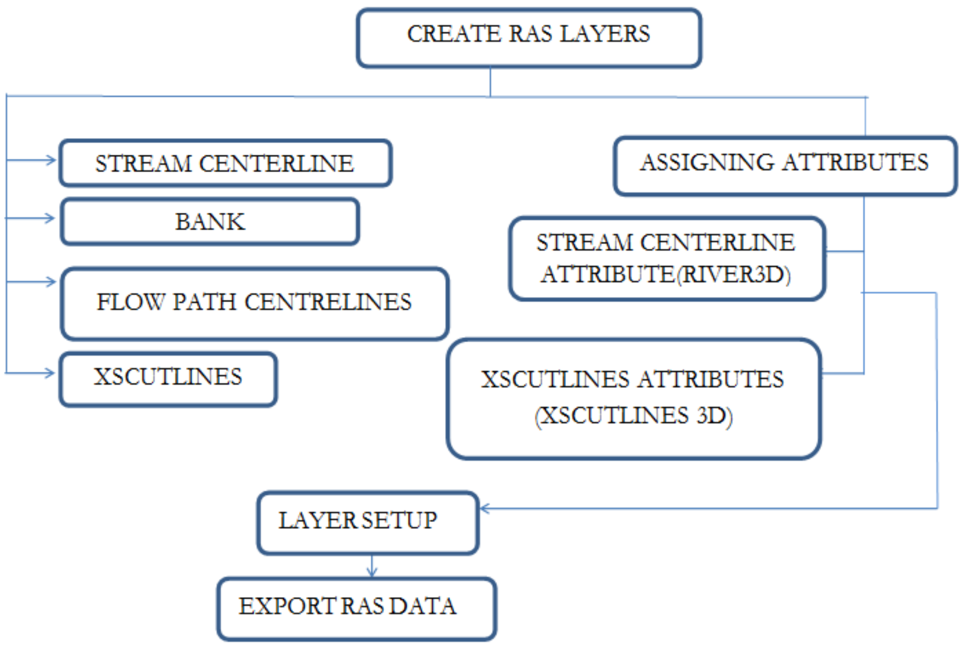


Figure 9: Flowchart for processing in HEC RAS

Processing

In this phase inundation mapping was performed with the generation of water surface which was later followed by flood plain delineation. The process involved is given below and the delineated flood is given in figure 14.

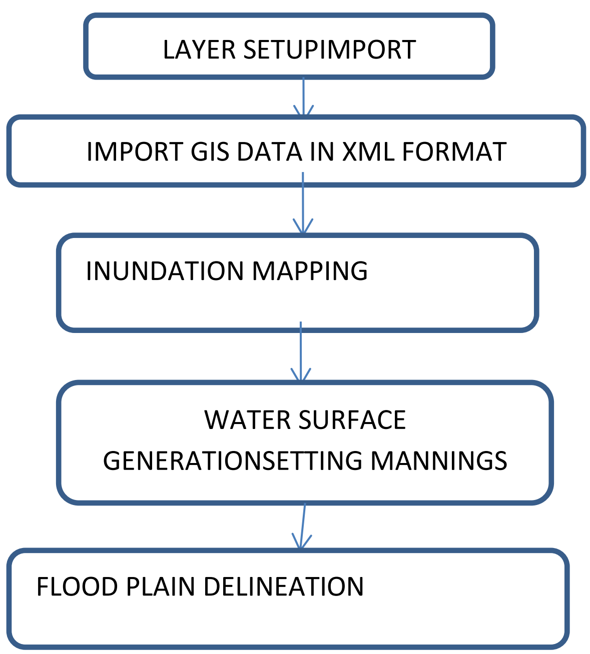


Figure 10: Process Involved in Hec Geo-Ras Processing

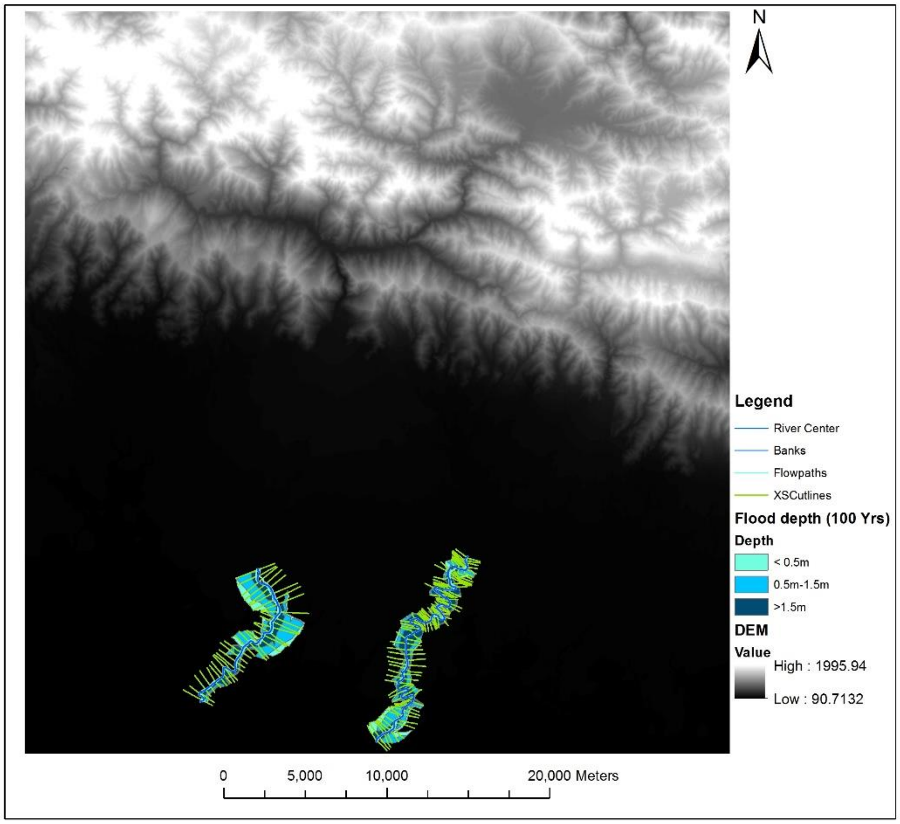


Figure 11: Flood Model for Return Period 100 years

3.1.4 Result

This delineated flood model is later used for the evaluation of land use planning by using overlay analysis in GIS environment. This process is discussed in the following section. The present land use information in the study area renders the following statistics.

Table 2: Present Land Use under Flood Risk

Land Use Type	Area (Sq. m.)	Area (Hectares)	%
AGR	545432.16	54.54	81.65
FOR	1446.63	0.14	0.22
HYD	115093.69	11.51	17.23
PUB	1419.66	0.14	0.21
RES	4630.97	0.46	0.69
Total	**668023.12**	**66.80**	**100.00**

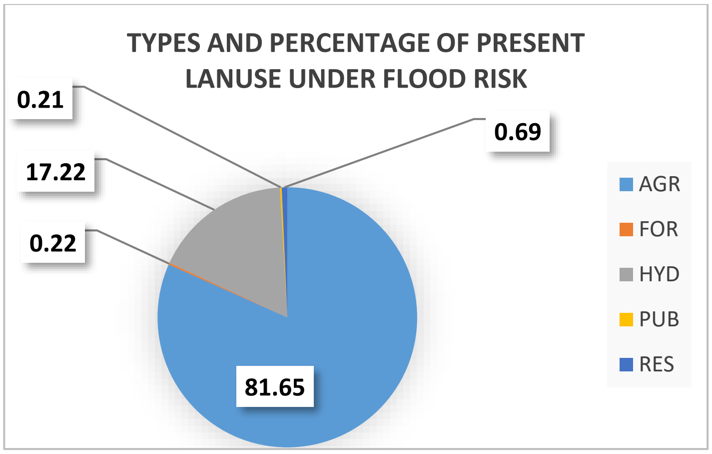


Figure 12: Classified land use under flood Risk

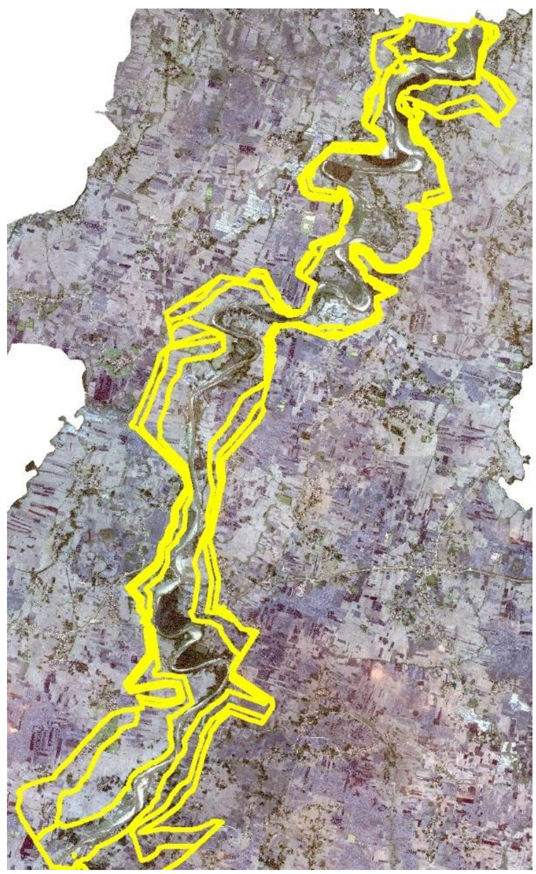


Figure 13: Flood Risk overlaid over satellite Image

Preparing Flood Hazard Map

Flood hazard map was prepared by overlaying land use map with flood area polygon for return period 100 years. This has given clear picture of possible flood that can affect land use of the area. The assessment has been done for period which is represented in given map.

The land use zone that tends to be inundated for return period is represented in figure 3.1.The data obtained for return period 100 years has been graphically represented in Figure above. Flood assessment for return period 100 years has shown that 66.63 hectares of total land use that has been classified by NLUP is in threat of possible flood for the return period of 100 years.

The land use zone classified and the area among the classified zone liable to flood for the return period 100 years is summarized in table below:

Flood Depth for return period 100 years

Overlaying of the flood vulnerability polygon data over the land use data reveals the statistics on hazard. From the analysis of the flood depth, it is found that 8.67% of total flood has the depth less or equal to 0.5m , 16,42% has it depth ranging from 0.5m to 1.5m,and 74.91%has it depth ranging from above or equal to 1.5. From the overlay of flood model with Land use plan of Gangobaliya VDC. This is shown in given bar chart given below;

Vulnerability Class	Area (Sq. m.)	Area (Hectares)	%
Low	57800	5.78	8.67
Medium	109400	10.94	16.42
High	499100	49.91	74.91
Total	**666300**	**66.63**	**100**

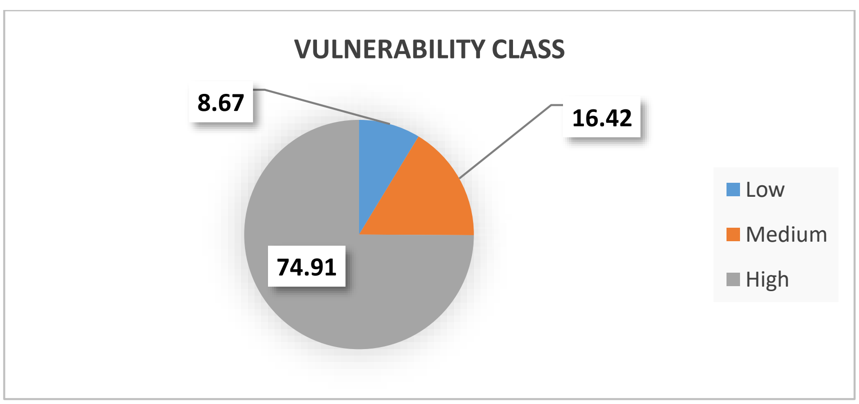
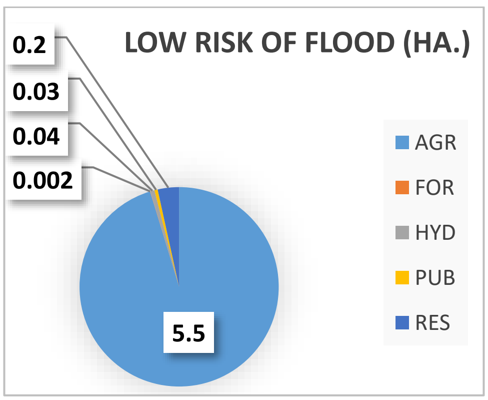
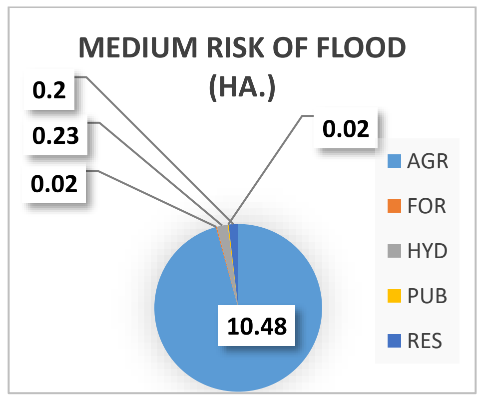


Figure 14: Flood Depth for return period 100 years

Table 3: Land Use Class and Flood Prone Area

Landuse	Low (ha)	Medium (ha)	High (ha)
AGR	5.5	10.48	38.41
FOR	0.002	0.02	0.12
HYD	0.04	0.23	11.24
PUB	0.03	0.02	0.08
RES	0.2	0.2	0.05
Total	**5.78**	**10.95**	**49.91**





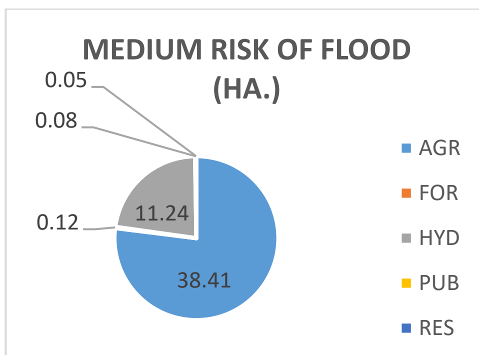


Figure 15: Flood Prone Zone for VDC under Package 27

3.1.5 Discussion

The result acquired through the analysis reveals the fact the study area needs immediate action to take against flood such as river training or embankment or levee construction to protect the given area by flood. Settlement like Kanpara, Darakhasawa and surrounding area are more prone to flood as revealed by the study. The people in such area are at risk of flood hazard so these people needs to be shifted from these area to the area free of flood and other risk.

3.2 Fire Risk

It is common that forest fire occurs every year in Nepal, particularly in the forests of Terai and Churia hills. Government of Nepal has given less priority in managing forest fire due to limited resources. Nepal has adopted various forest management approaches including community forestry, leasehold forestry, protected forestry and government managed forestry. All categories of forests and bamboo plantation are affected by fire albeit the magnitude varies. Forest fire is considered as a problem in forest management systems in Nepal since we have not been able to use it as a management tool. The Fire Management is an important initiation to safeguard forest and other resources by reducing fire damages through mobilizing government, non-government, private sector, civil society and local people.

It is common in Terai during the dry, stormy season between April and June when temperatures exceed 35°C, houses in the region are wooden and have thatched roofs, they are extremely vulnerable to incendiary lighting strikes, suffers from numerous fire outbreaks mainly during the process of cooking. In the winter, the major cause of fires is the short circuiting of electrical appliances, particularly heaters. In urban and other areas, houses are built in close proximity; these too are vulnerable, as fires easily leap from one house to the next. Due to electrical appliances industries area also in high risk of firing. This fires cause great loss of life and property and can have a devastating impact on local economies.

Cause of Firing:

1. Very few fires are naturally caused in Nepal (NBS, 2002). Karkee (1991) observed that 40% of forest fires in the mid-hills are caused by accidents while 60% are started deliberately e.g. Shifting cultivation, forest encroachment.
2. Cattle grazing for new grass and smokers known causes of forest fires.
3. Although it is not common, local communities identified bamboo as a fire igniter. Friction exerted between bamboo culms within the clumps sometimes produce fire.
4. In settlement areas, due to negligence while cooking, firing is common house and shelter.
5. Faulty wiring and electrical equipment, candles, home heating and cooking, children activities, Flammable liquids (fuels, solvents, adhesives, paints, and other raw materials – can ignite or explode if stored improperly) and careless smoking were the main sources of firing in houses and settlements areas.
6. Industrial and chemical fires: These fires occur when hazardous materials such as petrochemicals spill or leak and subsequently explode, technology fails, vehicles collide, and factories catch on fire. Within minutes, an entire industrial area can be

aflame and billions of rupees of property swallowed up. They also take lives and destroy the environment.

Objective of the Study:

1. Assess the status, damages and impacts of firing on forest, settlement and others.
2. Identify fire sensitive areas and causes of fire;
3. Identify preventive and control measures of fire;

3.2.1 Data

The data used for analysis are as follows:

- Forest Area along with its type and maturity
- Hydro meteorological data for DHM (Department of Hydrology and Meteorology)
- Industrial, Settlement, Commercial, Public places, Petro-Chemical station with probable Fire Risk
- Major Transmission line in the study area
- Past Studies, Literature reviews, reports etc. regarding Fire Hazard in the study area

3.2.2 General Approach and Methodology Framework

General Approach: The general approach for the fire risk layer data collection are as follows:

i. For Forest:

- Identification of community forest or other plantation.
- Identification of types of forests other plantation and present management status.
- Identifying nearby settlement areas and foot trail or road along or inside the Community forest other plantation.
- Identification of risk, and its characterization with environmental effects.
- Identification of extend of fire risk area.

ii. For settlement areas and petro-chemical station.

- Identification of settlement areas and others.
- Identification of types of settlement with present status.
- Identifying nearby industries, petro-chemical station and forest.
- Identification of probable risk, its characterization with probable environmental effects.
- Identification of extend of fire risk area.

Methodology Frameworks:

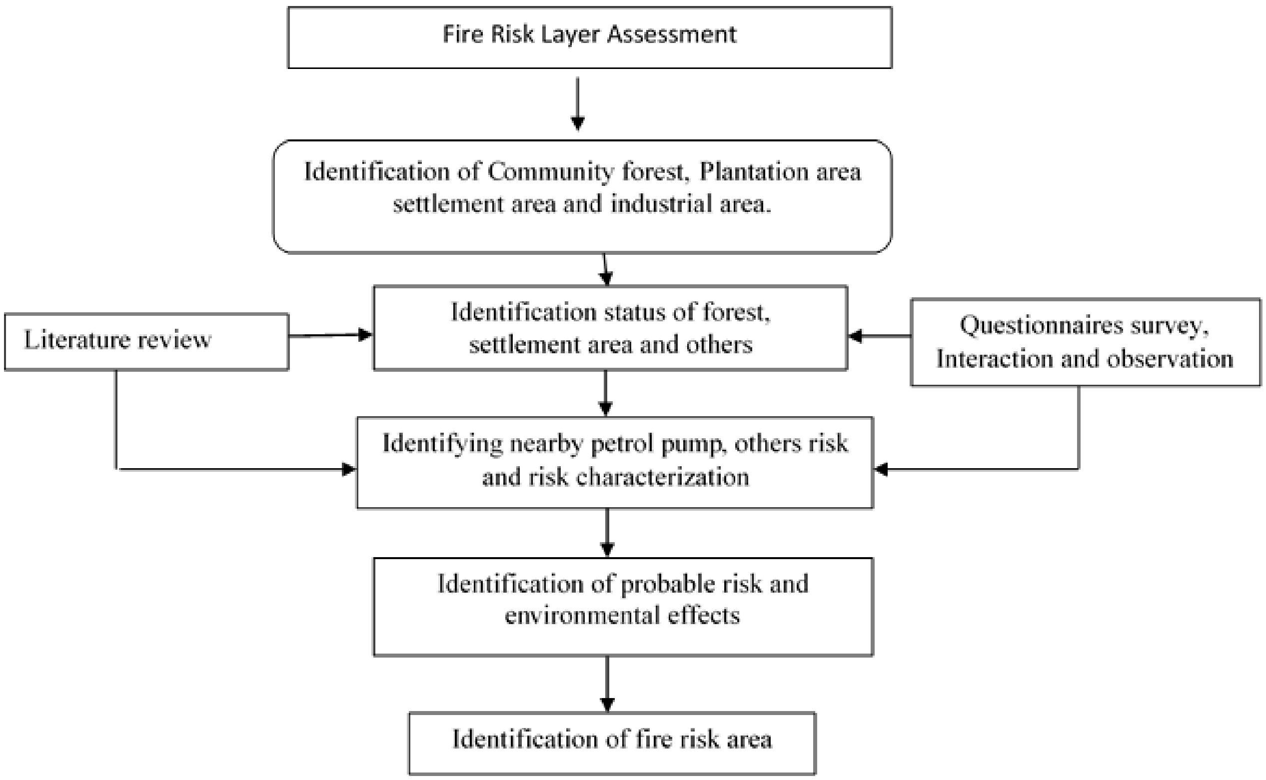


Figure 16: Flowchart for Identification of Fire Risk

3.2.3 Methods

The following methods were adopted for the collection:

- **Literature Review**

The relevant information was collected from various books, publications, journal etc. to access the fire risk. Similarly different types of maps such as topographical map, images were also studied. Required relevant information has been drawn from different internet websites.

- **Field Investigation**

A detailed field investigation was carried out for the data collection. Each VDC was visited during the field visit. The data regarding to community forest, settlement status, industries and Petro-chemical station was taken. Along with this, the probable environmental impact created by past firing was collected.

- **Questionnaires Survey and Interaction approach**

The data were collected through the extensive consultation with government representatives at various levels, experts and professionals, local communities and industrial stockholders. Additionally, interactive methods were adopted to collect the data among local government representatives, community forestry user groups and local communities to find out the impact status and extend of impact.

3.2.4 Result

Since no large forest cover were found in the study area, there is no significant risk of forest fire. But, scattered Bamboo plantations were seen in this package which is fire sensitive too since it produces large amount of leaf litters. Plantation areas nearby the settlements, in general are more fire sensitive than the other areas due to possibility of extending fire from the settlements. So some distance should be maintained to minimize the risk of firing spreading from settlement area. Similarly, possibility of ignition of fire is higher in the forests adjoining trails or roads. So some distance should be maintained to minimize the risk.

Many study suggest that fire occurring in terai region are due to the carelessness of human behavior. Poor handling of fire for cooking and other purposes, electrical short circuits, poor wiring, poor handling of gas cylinders and stoves, throwing cigarette butts carelessly, human negligence and lack of adequate fire safety measures are the major factors contributing to the outbreak of fires. The settlement areas of this package are particularly susceptible to fire hazards due to the heat, the house with thatch roofing, and frequent lightning strikes and windstorms. Most incidences of fires occur in the dry summer season, festivities, crop harvesting, and load-shedding.

3.2.5 Discussion

There is no significant forest cover in this package. Scattered Bamboo plantations were seen in this package which is fire sensitive too since it produces large amount of leaf litters. Bamboo plantation nearby the settlements, in general are more fire sensitive than the other areas due to possibility of extending fire from the settlements. Similarly, On the other hand, the distant plantation is in low risk of fire incidents. Sometimes, because of transmission line, lightening, firing may happens. Planted area encroachment nearby settlement and trail will increase the risk of forest fire, but in community forest these things are managed by community so the risk of firing is also low.

Most of the houses in the study area were constructed from locally available raw material. Houses with straw roofing are very susceptible to fire hazards as the material easily catches fire. In addition, houses for residential purpose are developed in cluster basis which are more susceptible of catching fire and spreading over there immediately due to close connectivity especially in the dry season. In the study area Improper management of straw; use of mechanical threshers; burning straw for heat; feeding cooking stoves with rich husks and packed long cow dung; preparing animal feed on outdoor stove throughout the day and other causes are the main reason for firing. Since the majority of houses were built from stone and wood, there is high risk of firing at any time during cooking and heating. This risk could be reduce if we can give proper attention after cooking and house heating. During site visit, besides few cases we don't find any devastating firing records that have damaged whole settlement area. One good aspect of settlement pattern of the study area is that, scattered settlement area, which will reduce the firing risk in whole settlement areas. But, the settlement area must be built in clumped pattern with good spacing, which will reduce the firing risk. Along with this, artificial pond must be built to control fire if it occurs suddenly at house or at whole settlement area.

Concrete building of sub urban areas as well as rural areas they area also risk to firing because of fault electric wiring and equipment, and LPG gas, but the risk is low. Regular maintenance of those equipment will reduce the risk. Similarly, due to electric short, factories and industries are also in risk of firing. Firing on industries is very hard to control, so the loss on environment and on natural resources will be very high. So, some distant should be kept between two industries and with settlement area too which will reduce spreading of firing from one industries to another industry and on settlement area. Petro-chemical sources station are always at high risk. The impact of firing on petro-chemical station is huge which will destroy live and property and cause huge environmental and economic losses. So, this should be kept at least 1km far from the settlement area.

Finally, fire preparedness activities most be carried out, which includes spreading messages through television, radio, street drama, video, folk songs, drills, posters, pamphlets, and hoarding boards to reduce the risk of firing.

3.3 Landslide Risk

Landslide is defined as "a collapse of a mass of earth or rock from a mountain or cliff" as per Oxford dictionary. Landslides can result in enormous casualties and huge economic losses in mountainous regions. In order to mitigate landslide hazard effectively, new methodologies are required to develop a better understanding of landslide hazard and to make rational decisions on the allocation of funds for management of landslide risk. Recent advances in risk analysis and risk assessment are beginning to provide systematic and rigorous processes to enhance slope management. In recent years, risk analysis and assessment has become an important tool in addressing uncertainty inherent in landslide hazards. (F.C Dai, 2001)

3.3.1 Data

The data used for the analysis are as follows:

- Topographic Data
- Geological Data
- Survey/Questionnaires

3.3.2 General Approach and Methodology Framework

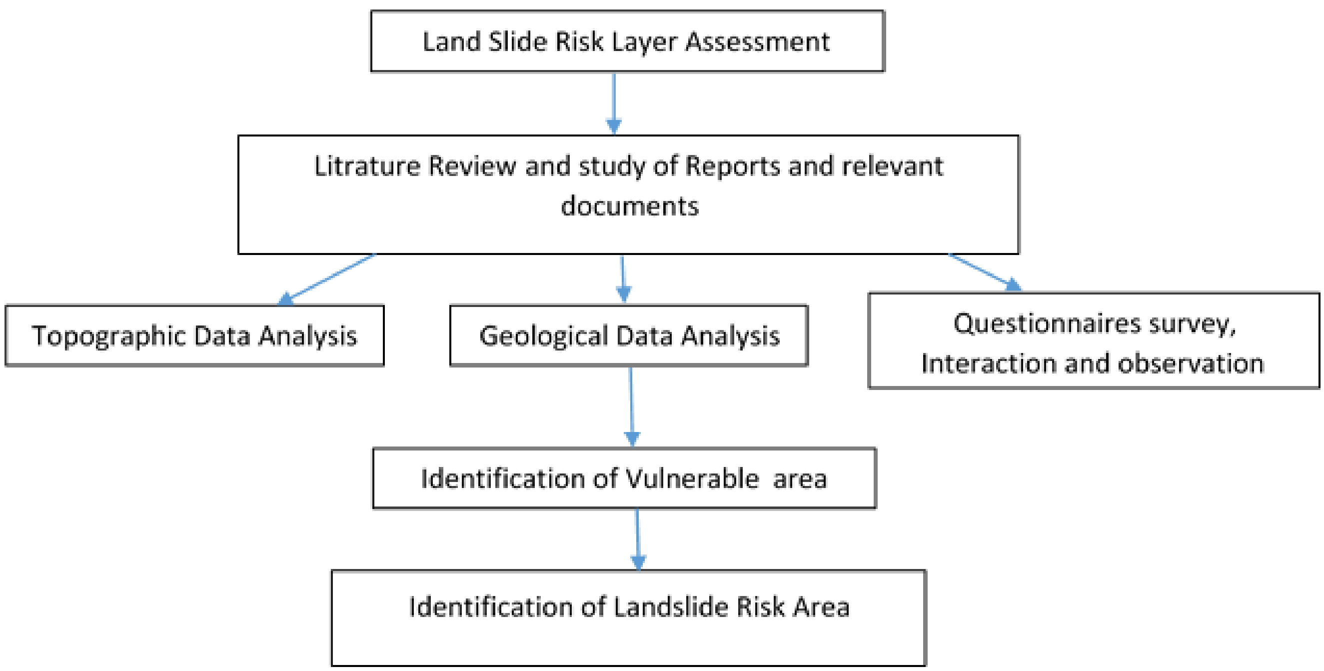


Figure 17: Flowchart for Identification of Landslide Risk

These are the major causes of Landslide.

1. Geological causes
   a. Weak or sensitive materials
   b. Weathered materials
   c. Sheared, jointed, or fissured materials
   d. Adversely oriented discontinuity (bedding, schistosity, fault, unconformity, contact, and so forth)
   e. Contrast in permeability and/or stiffness of materials

2. Morphological causes
   a. Tectonic or volcanic uplift
   b. Glacial rebound
   c. Fluvial, wave, or glacial erosion of slope toe or lateral margins

  d. Subterranean erosion (solution, piping)
  e. Deposition loading slope or its crest
  f. Vegetation removal (by fire, drought)
  g. Thawing
  h. Freeze-and-thaw weathering
  i. Shrink-and-swell weathering

3. Human causes
  a. Excavation of slope or its toe
  b. Loading of slope or its crest
  c. Drawdown (of reservoirs)
  d. Deforestation
  e. Irrigation
  f. Mining
  g. Artificial vibration
  h. Water leakage from utilities

3.3.3 Methods

The following methods were adopted for the collection:

- **Literature Review**

The relevant information was collected from various books, publications, journal etc to access the landslide risk. Similarly different types of maps such as topographical map, images were also studied. Required relevant information has been drawn from different internet websites.

- **Field Investigation**

A detailed field investigation was carried out for the data collection. Each VDC was visited during the field visit.

- **Questionnaires Survey and Interaction approach**

The data were collected through the extensive consultation with government representatives at various levels, experts and professionals, local communities and industrial stockholders. Additionally, interactive methods were adopted to collect the data among local government representatives.

- **GIS Analysis**

The available topographic data were analyzed during the landslide risk assessment.

Result

No significant landslide risk was seen in the study area.

3.4 Seismic Risk

Seismic Hazard is defined as the probabilistic level of ground shaking associated with the reoccurrence of the earthquakes. It is realized by depicting levels of chosen ground motion that likely will not be exceeded in specified exposure of time. (DMG, 2002)

3.4.1 Data

The analyzed data has been used from the secondary data. The data has been produced by maps of Epicenter of the Earthquake in Nepal Himalaya, Probabilistic Seismic Hazard Assessment Map of the Nepal Himalaya (DMG, 2002), and Seismic Risk Zonation Map of the Nepal Himalaya (Bajracharya, 1994).

3.4.2 General Approach and Methodology Framework

The seismicity deals with the preliminary investigation of maximum credible earthquake and seismic coefficient of the project area. The Himalaya seismicity, in general, owes its origin to the continued northward movement of Indian plate after the continental collision between Indian plate and Eurasian plate. The magnitude, recurrence and the mechanism of continental collision depend upon the geometry and plate velocity of Indian plate in relation to southern Tibet (Eurasian Plate). Recent results suggest that the convergence rate is about 20 mm / year and the Indian plate is sub-horizontal below the Sub- Himalaya and the Lesser Himalaya.

The result of micro seismic investigation, geodetic monitoring and morph tectonic study of the Central Nepal has depicted that the more frequent medium sized earthquakes of 6 to 7 magnitude are confined either to flat decollment beneath the Lesser Himalaya or the upper part of the middle crustal ramp. The ramp is occurring at about 15 km depth below the foothills of the Higher Himalaya in the south of MCT surface exposures. Big events of magnitude greater than eight are nucleated near the ramp flat transition and ruptures the whole ramp-flat system up to the blind thrust (MBT) of the Sub-Himalaya (Pandey et. al. 1995).

Preliminary seismic hazard assessment of the country using Gumbel's third asymptotic extremes with the instrumental seismicity database of ISC is carried out by Bajracharya (1994) for different return periods 50, l00, 200 and 300 years, Attenuation model with mean value of McGuire and Oliveira ". (See above) is used for horizontal acceleration.

Return period (years)	Peak horizontal acceleration (g)
50	0.10
100	0.15
200	0.20
300	0.25

Several seismicity studies have been carried out for the various projects in the country during the engineering design phase and seismic design coefficients have been derived for the project. There are several method to convert the maximum acceleration of the earthquake motion into the design seismic coefficient. Generally three methods are commonly used to establish the seismic coefficient. These are:

- Simplest Method
- Empirical Method
- Dynamic Analysis Method using Dynamic Model

The effective design seismic coefficient is determined by using the simplest method, the following equation:

$A_{eff}=R*A_{max}/980$

Where, A_{eff} is effective design seismic coefficient

R=Reduction factor (empirical value R=0.50-0.65).

The result obtained from this method is found to be similar in the recent studies carried out by using the dynamic analysis and the static analysis. Therefore, this method is considered to be the most common method to establish the design seismic coefficient at present.

The third method is the Dynamic Analysis Method using the dynamic model. This method is considered to be te most reasonable method at present. However, to apply the this method parameters like the design input motion, the soil structure model, the properties of the rock materials have to be known, and therefore, it means that a detailed study is required to use this method. Therefore, the Empirical Method is considered to be the best to establish the design seismic coefficient for this level of the study.

3.4.3 Methods

The effective design seismic coefficient is determined by using the simplest method, the following equation:

$A_{eff} = R*A_{max}/980$

Where, A_{eff} is effective design seismic coefficient

R=Reduction factor (empirical value R=0.50-0.65).

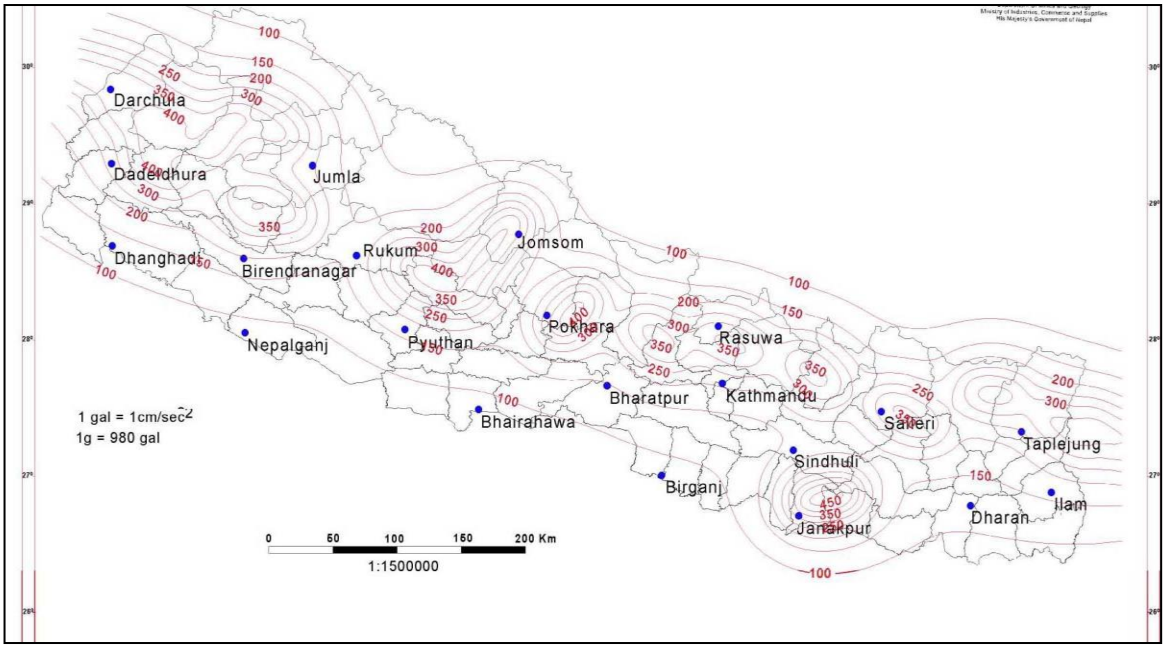


Figure 18: Probabilistic Seismic Hazard Assessment Map of the Nepal Himalaya

The result obtained from this method is found to be similar in the recent studies carried out by using the dynamic analysis and the static analysis. Therefore, this method is considered to be the most common method to establish the design seismic coefficient at present.

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3.4.4 Result

For the minimum acceleration of 100 gal, the calculated effective design seismic coefficient is approximately 0.051.

But the area is composed of fluvial soil so amplification in soil is higher than 20% so the seismic coefficient is considered as 0.061.

3.4.5 Discussion

Bagaha, Basantapur, Bodabar, Chhipagadh, Chhotki Ramnagar, Gangobaliya, Dhakadhai, Chilhiya, Harnaiya, Hatipharsatikar, Hatti Banagai, Mainahiya, Padasari, Pajarkatti, Patkhauli, Pokharbhindi, Siktahan of Rupandehi district areas fall in the seismic zone of 4, high seismic hazard area.

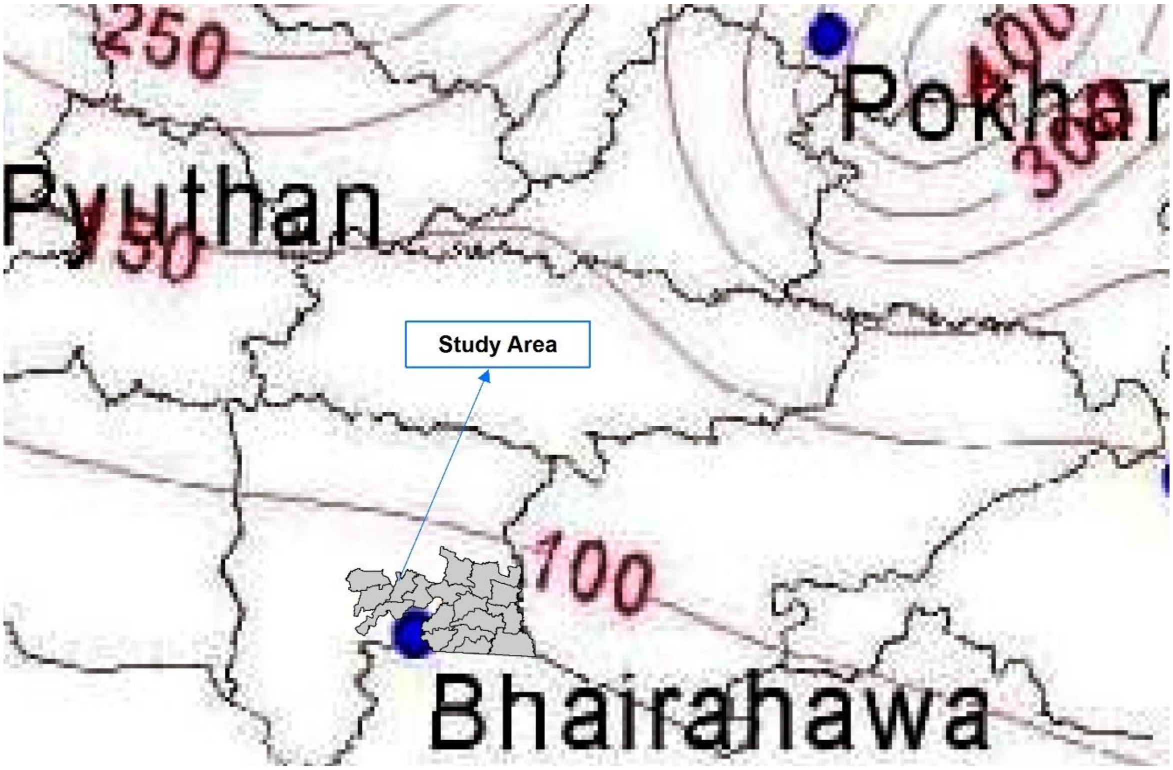


Figure 19: Seismic Hazard Map

The seismic coefficient in bedrock of the VDC area is considered as 0.051. But the area is composed of fluvial soil so amplification in soil is higher than 20% so the seismic coefficient is considered as 0.061.

3.5 Industrial Risk

The basic cause of pollution is industrialization. To fulfill the unlimited demand of population growth, industrialization is going rapidly. As a result, this has led to the environmental changes that have become harmful to all living beings and environment. So, we have to take proper step to reduce the industrial pollution. Both, public and government should take proper step to reduce pollution.

The risk types and their descriptions are discussed below:

1. Flora and fauna

The industrial pollution has impact on the native fauna and flora. It could led to decrease the species diversity of animals, reptiles and amphibians and birds. In addition, a wide range of aquatic creatures and other living organism could be victims of the industrial pollution affecting wetlands, lakes, village ponds, reservoirs, rain water ponds and paddy fields. The by-products of industrial activity, particularly cement sludge, paper sludge and ghee sludge are discharged into rivers without any treatment. This could led decrease in surface and ground water quality near to the industrial sites.

2. Air quality

In Nepal, most of the cement factories do not use regular water sprinklers in order to reduce the negative impact of fugitive industrial emissions. Meteorological parameters such as wind velocity, temperature, humidity, rainfall, cloud coverage and solar radiation determine the dispersion, diffusion and transportation of particulate matter and emissions into the atmosphere.

3. Soil quality

Industrial pollution, has serious impact on soil quality, the soil was found to be alkaline around the industrial area. Beside this, trace amount of metal, plastic, dye, petro-chemical, pesticides were also found around the industrial areas. In Nepal, the soil is also harmed by fugitive effluent from the cement factories. Anecdotal evidence indicates that as a result of the accumulation of dust, crop yields near the industrial site have dramatically decreased compared to the pre-industry era. During the flowering periods, photosynthesis and pollination are disturbed by dust accumulation on plant surfaces and in the soil.

4. Noise levels

In Nepal, Cement manufacturing plants and other industry adjacent to residential, institutional and educational areas use heavy industrial equipment such as fans, engines and generators causing noise pollution.

5. Water Pollution

Water pollution, by the discharge of wastewater from industry (intentionally or through spills) into surface water is in the risk of chemical contaminants. This could lead the impact on ground water too.

6. Others Form of pollution were light, visual, thermal, plastic and pesticides pollution

The adverse impacts caused by industrial pollution and expansion within the zone needs to be identified and assessed to conserve the environment, living organism, as well as the biodiversity of the region for promoting the sustainable development of the surrounding communities in a deliberate and tactful way. The major risk area has to be identified so that the proper planning for settlement and other development activities can be done in planned and sustainable way followed by land use planning. The area nearer to the industries are in high risk in all aspect such as health, environmental, water ecology, agricultural productivity etc.

Objective of the Study:

- Assess the status, cause, damages and impacts of Industrial risk.
- Identify Industrial risk sensitive areas ;

- Identify preventive and control measures of Industrial Pollution.

3.5.1 Data

Data for the Industrial Risk Study has been identified and delineated on the map using field verification.

- Identification of Industrial area
- Industrial type and category
- Criteria for Industrial Hazard Mapping
- Hydrology and Meteorology data obtained from Department of Hydrology and Meteorology (DHM), GoN

3.5.2 General Approach and Methodology Framework

General Approach:

The general approach for the industrial risk layer data collection were as follows:

1. Identification of Industrial area
2. Identification of Industrial type and category
3. Identification of environmental risk, risk characterization and environmental effects.
4. Identification of probable industrial area risk area

Methodology Frameworks:

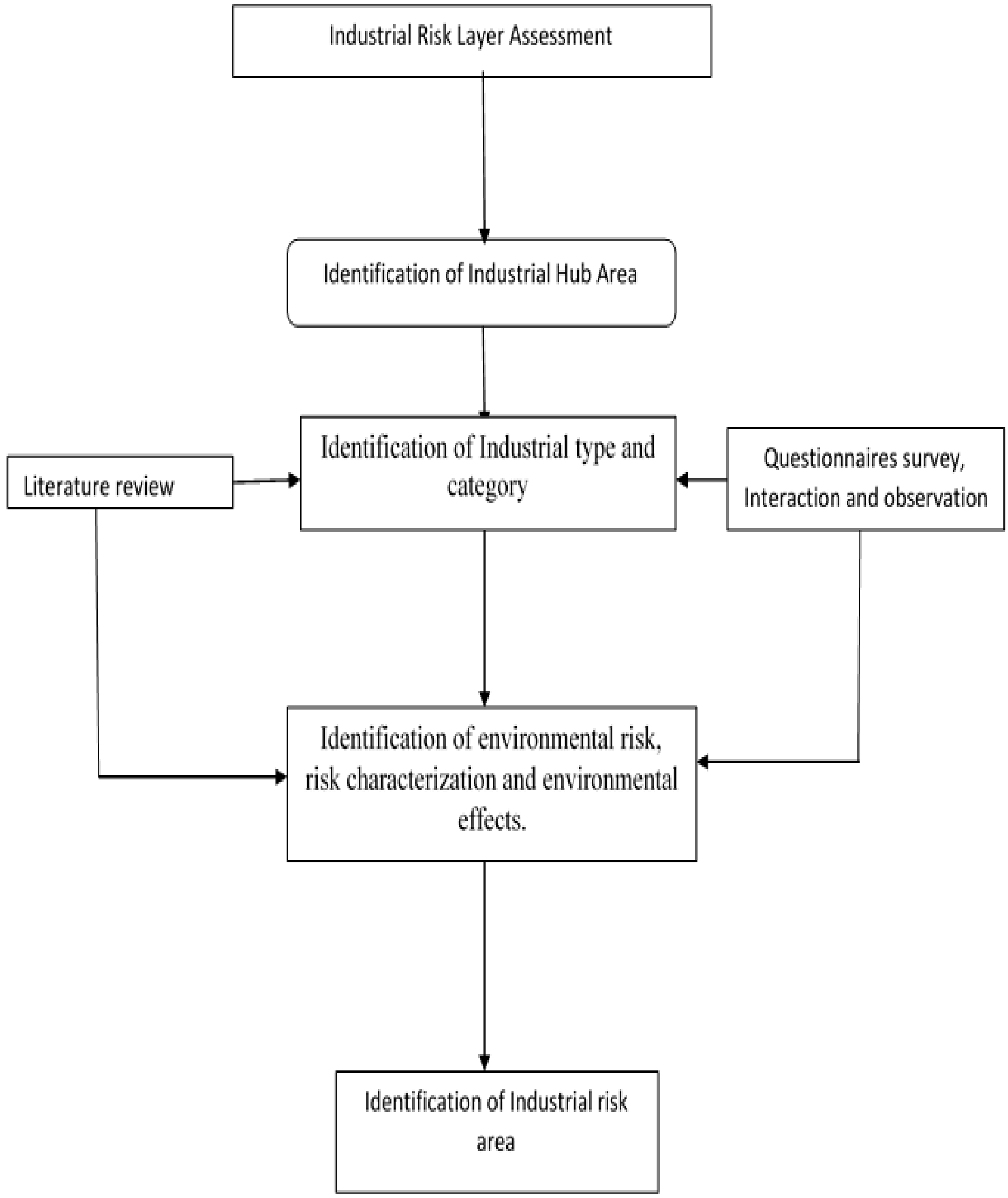


Figure 20: Flowchart for Identification of Industrial Risk

3.5.3 Methods

The following methods were adopted for the collection:

- **Literature Review**

The relevant information was collected from various books, publications, journal etc. to access the fire risk. Similarly different types of maps such as topographical map, images were also studied. Required relevant information has been drawn from different internet Web Pages.

- **Field Investigation**

A detailed field investigation was carried out for the data collection. Each VDC was visited during the field visit. The data regarding to industry type, category, capacity and probable environmental impact created by that environment was collected.

- **Questionnaires Survey and Interaction approach**

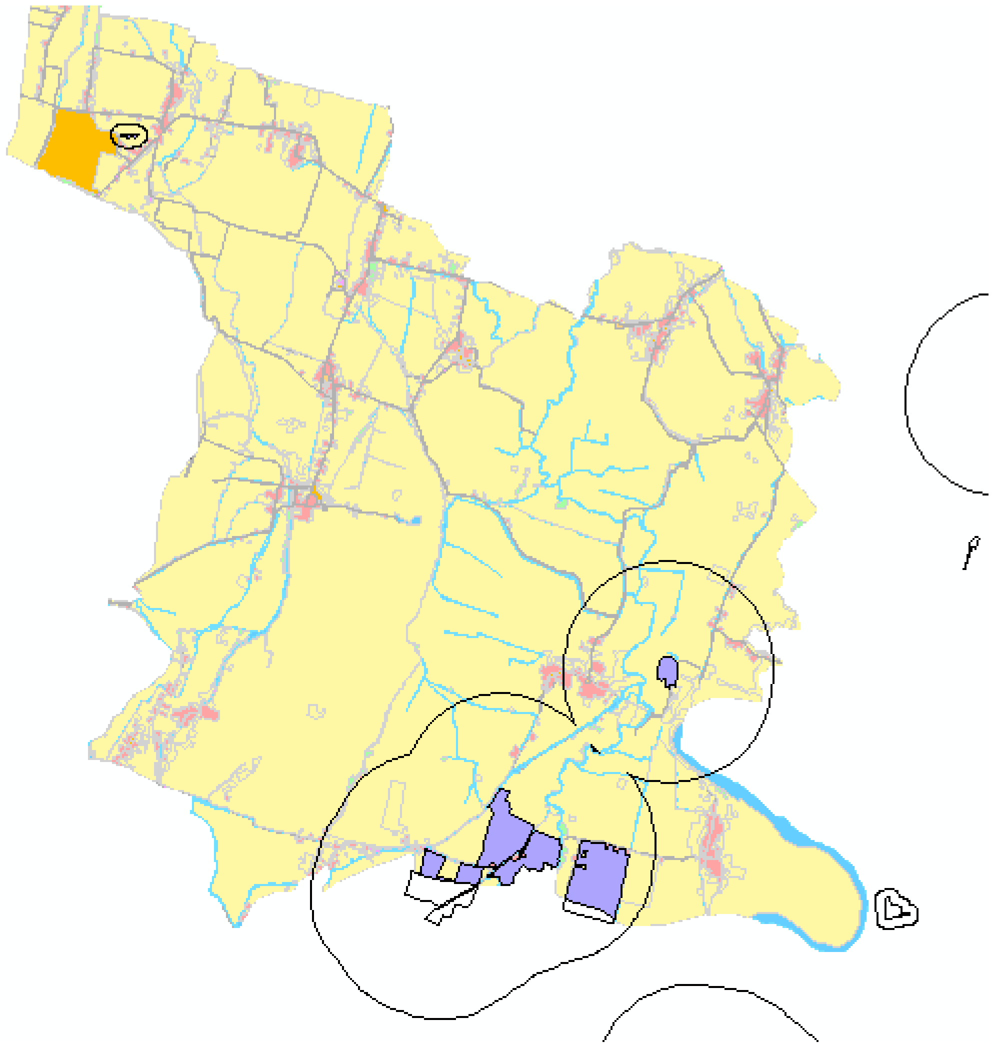
The data were collected through the extensive consultation with government representatives at various levels, experts and professionals, local communities and industrial stockholders. Additionally, interactive methods were adopted to collect the data among local government representatives, community forestry user groups and local communities to find out the impact status and extend of impact.

3.5.4 Result

In this package, mainly on Gangobaliya VDC, few brick industries and Gaddha udyog could be noticed. The list of industriy present in this VDC is given on below table:

Table 4: Industry list with probable Pollution Type

VDC	Industries	Probable Pollution Type	Probable Risk area of some common industries (from center)
Gangobaliya	Industrial	Air pollution	100
	Bindabasini itta udhyog	Air pollution	500
	Gaddha udyog	Sound pollution	50
	Purna itta udhyog	Air pollution	500
	RNC itta udhyog	Air pollution	500



3.5.5 Discussion

Major industries in the area are brick industries and Gaddha udyog which mainly affects the air quality,sound quality and water quality in the surrounding area. The industrial risk will be higher at the nearer site and vice versa. The risk due to air pollution will be increase or decrease depending on the flow of air and also depends on meteorological parameters such as wind velocity, temperature, humidity, rainfall, cloud coverage and solar radiation determine the dispersion, diffusion and transportation of particulate matter and emissions into the atmosphere. The volume of industries present on this VDC is low, although pollution controls measures should be properly installed in order to minimize environmental impact. Furthermore, separate corridor must be made for industrial growth in sustainable and environmental friendly way.

Since this package is nearer to boarder, in future industries could grow in rapid way which could lead further degradation of environment. The proper control measures should be adopted to minimize the risk of industrial pollution in the surrounding area which area as follows.

a. Flora and fauna

- Support community based forest activities to conserve a habitat for flora and fauna.
- Allocated certain money to invest in conservation of biodiversity.

b. Water:

- Maintain and promote water bodies/wetlands and ponds.
- Prohibit polluted water discharge into rivers and any water bodies.
- Develop an irrigation facility in order to increase agricultural productivity of nearer farmers.
- Conduct a community-based watershed/lake management programme.

c. Air Quality:

- Maintain air quality controls in the surrounding areas as per the national standard.
- Prohibit polluted air emission directly into ambient environment.
- Adopt short-term and long-term strategies and equipment to control air pollution by the existing industries in the region.
- Adopt Polluter Pays Principle (PPP) to control the air pollution in the region.
- Monitor the air polluting industries and sources by the concerned authority.

d. Waste pollution and noise pollution:

- Make a green belt on both sides in industrial areas.
- Promote renewable energy for domestic use.
- Encourage 6R of solid waste.
- Adopt noise pollution control measures by the existing industries in the region

e. Soil Pollution:

- Prohibit the discharge of metal, hazardous material, dye, chemical and other into soil.
- Plantation of plants that absorbs pollutant of soil.

f. Legal Framework:

- Ensure that the projects are accompanied by an evaluation of their impact on the environment. Include an alternative projects to minimize the adverse effects (EIA/IEE).

3.6 Other Risk in the study area

No other risks in relation to land use zone is seen in the study area.

Chapter 4: RISK IN THE STUDY AREA

4.1 Existing risk in the study area

The Study area holds major threat of Flood and inundation alongside the rivers. Major rivers flowing though the study area are Tinahu Nadi and Rohini nadi of Rupandehi District of the Study area. Mainly the agricultural area is under high threat from the flood and inundation. Other existing threats include the industrial hazards and Fire Hazards. Some industries in the study area include the brick factories which mainly affect the air quality and soil fertility around the region. No Natural Fire risk is seen in the Study area though there is potential risk of fire due to the thatch roofed houses which easily catches fires and the petrol pumps which need to be operated under the safety regulations. In case of Seismic risk, no fault line passes through the study areas. Some rare occurring of earthquakes as epicentre falling in the area has been seen. No landslide risk is seen in the study area considering the flat landscape although river bank cutting can be a serious concern.

4.2 Potential risk in the study area

The identification of potential risk areas are very difficult task because nature may not follow the hazard model developed by the human beings. However, the modeling of the existing risk areas could be used to estimate or predict the future potential risk areas. Based on the existing risk in the project areas it can be concluded that the existing hazard risk areas are prone to future potential risks as well. Therefore, the existing risk areas identified through the mapping of available hazards are not suitable for future land use zoning for residential, commercial or public use zones. These hazard risk areas could be suggested for forests, plantations or as the open spaces.

4.3 Risk Data Model

The risk developed for Risk data is shown in Table below.

Table 5: Risk Data Model

Field	Data Type	Description	Remarks
OBJECT ID	Object	Feature	
SHAPE	Polygon Geometry	Geometric Object type	
RISK ID	Short	Unique Object ID	
RISK Type	Text	1. Flood Risk	
		2. Fire Risk	
		3. Landslide Risk	
		4. Seismic Risk	
		5. Industrial Risk	

RISK LEVEL	Text	High	
		Medium	
		Low	
VDC	Text	VDC Name	
DISTRICT	Text	District Name	
REMARKS	Text	Any remarks regarding the feature	
SHAPE LENGTH	Double	Meter	
SHAPE AREA	Double	Area in m^2	

4.4 Risk GIS Database

There exist diversities in Risk type. Land use mapping focuses different types of risk such as fire, flood, landslide, seismic, industrial etc. Similarly, from the view of proximity of occurrences, risk can be hieratically classified as different level: such as High, Medium and Low. Different level have been given to the risk type and its level as per **NLUP Specification 2072**. Following is the risk dataset schema:

Table 6: Specification for Risk GIS Database

	LEVEL1	**LEVEL2**	**VDC**	**District**	**REMARKS**
Risk theme types	**Risk type**	**Risk Level**			
Fire	Fire	High, medium, low			
Flood	Flood	High, medium, low			
Landslide	Landslide	High, medium, low			
Seismic	Seismic	High, medium, low			
Industrial	Industrial	High, medium, low			
Other	Other	High, medium, low			

Chapter 5: CONCLUSIONS

5.1 Conclusions

The Study area holds major threat of Flood and inundation alongside the rivers. Major river flowing though the study area is Tinahu Nadi and Rohini nadi Rupandehi District. Mainly, agricultural area is under high threat from the flood and inundation. Other existing threats include the industrial hazards and Fire Hazards. Some industries in the study area include the brick factories which mainly affect the air quality and soil fertility around the region. No Natural Fire risk is seen in the Study area though there is potential risk of fire due to the thatch roofed houses which easily catches fires and the petrol pumps which need to be operated under the safety regulations. In case of Seismic risk, no fault line passes through the study areas. Some rare occurring of earthquakes as epicentre falling in the area has been seen. No landslide risk is seen in the study area considering the flat landscape although river bank cutting can be a serious concern.

5.2 Recommendations

The Study area has been under many potential threat. The bank cutting in the study area has created probability of entering flood into the nearby agriculture land and settlements. Many agricultural lands have been converted to river deposits and Bagar. Therefore, check dam or embankment or spur need to be constructed for the conservation of land resources. Fire preparedness activities most be carried out, which includes spreading messages through television, radio, street drama, video, folk songs, drills, posters, pamphlets, and hoarding boards to reduce the risk of firing. The risk zoning is a very broad and dynamic topic which demands data to be very accurate and must represent the current scenario of the area. The data currently available and used are not sufficient to fully depict the actual picture in regard to risk in the area though it gives possible scenario of existing risk. The present exercise produced preliminary results on the risk areas of the selected hazards. These outputs could be worked for the purpose of the present exercises for delineating the land use zoning of the VDCs. The present risk map and data may be useful for land use planners and environmentalist who uses geospatial tools. It could also be useful for preliminary devising sustainable environmental planning strategies for the rural development of the area. This data can aid in proper zoning of the study area keeping in mind the risk aspect and help to make proper planning for sustainable development.

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F. Land Use Zoning

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Chapter - 1
INTRODUCTION

1.1. Background and Rationale

Land use zoning is assessed based on the suitability of sustainable use for a specific purpose. Land use zoning differs from land capability classification in a sense that land capability is general classification of land based on arability and productivity of soil without degradation or off-site effects for farming. In contrary, land use zoning is the suitability classification of land for various land use purposes. The suitability classes are rated from the most suitable to the least. Each suitability class is therefore designated a zone with suitability ratings. Based on the suitability of land for various land use classes, land use zones are classified into eight broad categories with associated ratings. The zoning is done for agriculture, forest, pasture, industry, settlements, wildlife conservation, tourism and recreational, wetland and parks/natural reserves.

Land is very scarce natural resource on which our life is highly reliant. It is a basis of socio economic development of every country. For sustainable development of society, this resource should be wisely managed. Many countries around the world are nowadays paying their utmost attention to various land management issues for sustainable socio economic development and environmental management.

Land is a basic resource of livelihood for almost seventy five percent of the population in Nepal. Population growth, lack of physical infrastructure, scattered small sized land parcels and haphazard subsistence farming practices have resulted low productivity and food deficit. Similarly, high rate of migration from hilly region to urban and plain fertile land (Terai land) has created unplanned settlement and loss in agricultural production and unsustainable livelihood. There are no any controlling measures for migration and convincing rural development plans for uplifting rural population. This imbalance and unplanned land use has directed towards deterioration of natural setup. Also, due to landless and jobless people's problem, encroachments on public and government lands (like forests) for squatter farming and settlement have been alarming. These are the reasons; the traditional land management is being handicap for implementing community driven sustainable land use planning and zoning programs.

Nepal being a developing nation, massive urban land has been encroached as slums and real estate market has been well flourished since last 2 decades specifically in large municipalities and fringe areas. Almost all economic activities in these areas depend on lands and so is the pivotal for economic development. There has been existed unsystematic and unhealthy real estate business in the absence of effective land use planning and zoning. The utility services are also very poor in the developmental areas due to lack of updated planning and monitoring. All these facts have resulted serious problems on settlement pattern and has deteriorated the urban-rural environment. The state being the guardian, it needs to pay serious attention to face, overcome and tackle the ever growing problem.

In Nepal, the Government is trying to cope with various land related issues in national and local level. The highly fertile agricultural land is getting urbanized haphazardly in many urban/ semi urban areas. In many places, agricultural lands have been left unused and abandoned. The available land is not being used on its optimum level. Crop production is not according as the suitability and capability of the land. In many places, human activities with mountainous land is causing various disasters such as landslides and flooding. Consequently, Nepal has a serious threat of facing problem of food security and hunger in future. Similarly, unplanned settlement and unhealthy habitat, lack of urban infrastructure, natural disaster, and environmental degradation are other serious challenges to be faced in future.

To cope with these challenges, available land should be managed appropriately. Land use planning is one of the tools for getting optimum benefit from scarce land resource. Sustainable socio-economic development of a country is highly dependent on the proper use and utilization of resources available. Land is one of these resources. Therefore, a comprehensive land use plan is highly essential for the national development. The importance of land use plan can be understood from an example of the land use policy formulated during the rule of King Prithivi Narayan Shah (1834 AD), he said as:

- Shift the village situated in the irrigable land to the other high lands
- Shift the houses from the plain plots of lands to the other places; and construct cannels and irrigate those plots
- Shift the villages situated near the mines area to the other places; explore the mines and use the mines

Government of Nepal has identified land use zoning as an important device to design a detailed land use plan and policy. This policy is expected to implement with the help of land use zoning maps. In this context, the Ministry of Land Reform and Management, National Land Use Project has taken an initiative to prepare land use zoning maps of Nepal in different level such as district and VDC level. The main objectives of the land use program are as follows:

- Minimize the ratio amongst the different land use sectors for maintaining the balanced land use from the point of view of population, environment and sustainable development; and classify the land for agriculture, forest, settlement, industrial and commercial areas, etc.
- Identify and classify the sectors based on geographical characteristic, land capability and soil quality which are comparatively more beneficial for arable land for agricultural crop production and the areas for income generation such as fruits, cash crops and herbs production areas.
- Identify and zoning the land for housing, urbanizing, industrialization and other non-agricultural purposes in the existing municipalities and urban oriented rural areas as well as to balance the environment and sustain the system by preserving and developing water, forest and living treasure.
- Identify the main settlements which are in transition zone and develop such areas in a planned and environmentally justifiable way.

  In this context, this study is being carried out for the purpose of preparing land use zoning maps and implementation of land use policy for getting optimum benefits from land in the national and local level. In this project, the land use zoning of Six VDCs of Morang district is under study. The scope of this project is limited to studying the existing relevant maps, documents, and database of the project area

- preparing land use zoning maps of the selected VDCs at 1:10000 scale portraying different zones and sub zones as per the Government's Land Use Policy 2072 BS.

- Designing appropriate GIS database logically on land use zoning for the selected VDCs
- Discussing accuracy, reliability and consistency of data
- Preparing detailed reports, describing methodology, criteria and distribution of different land use zones and sub zones with GIS data models and databases.

1.2. Objectives of the Study

The main objective of the study is to prepare a scientific and comprehensive land resource inventory at VDC level and assess and delineate land use based on land types, associated soils and land capability classes with the main to formulate a sound and sustainable land use planning. The present study aims to fulfill the following major objectives:

- Classify agricultural lands for the purpose of identifying most suitable and lucrative crop production and classify land for non-agricultural purpose based on land types and associated land characteristics
- Classify Hazardous area in terms of Flood, Fire, Landslide, Seismic, industrial and other risks .
- Prepare land use zoning maps of the selected VDCs at 1:10,000 scale portraying different zones and sub- zones as per the Governmental Land Use policy.
- prepare appropriate GIS database on present land use zoning of the selected VDCs; and
- prepare reports on conceptual basis and methodology of land use zoning and Models of GIS database

The specific objectives of this study are:

- To perform landuse zoning of Gangobaliya VDC by using different available data sources by using multi-criteria analysis in GIS.
- To produce land use zoning map at 1:10,000 scale showing different zones and sub-zones as per the Government's Land Use Policy 2072 BS.
- To prepare appropriate GIS database of proposed land use zoning.
- To prepare detailed report containing conceptual basis and methodology, criteria of land use zoning, distribution of different land use zones and data models of GIS database.

1.3. Study Area

The Gangobaliya VDC is covered by Siktahan in the East, Madhbaliya in the West, Makrahar in the North and Hatipharsatikar in the South. The rectangular extent of the VDC is 83°32'8"E, 27°35'51"N, 83°29'27"E and 27°33'1"N. The total population of this VDC is 6966, of which male population accounts for 49.14 percent and female population is 50.86 percent (VDC profile, 2011). However, all the wards vary in area and population size. Total number of household in the VDC is 1172.The area of the VDC is 1285.81 hectares.

This VDC is inhabited by different caste and ethnic groups. Tharu predominates the inhabitants of this VDC accounting 44.57 percent of the total VDC Population. Tharu, Brahman hill, Yadav & Mallaha are other dominant caste and ethnic groups of this VDC.

Economic condition of the people of this VDC largely depends on agriculture. Land is main source of income and capital accumulation and also the major source of employment. Economic condition of the people having large landholding size is better than the others.

The location map of the study area has been shown in **Figure 1.1**

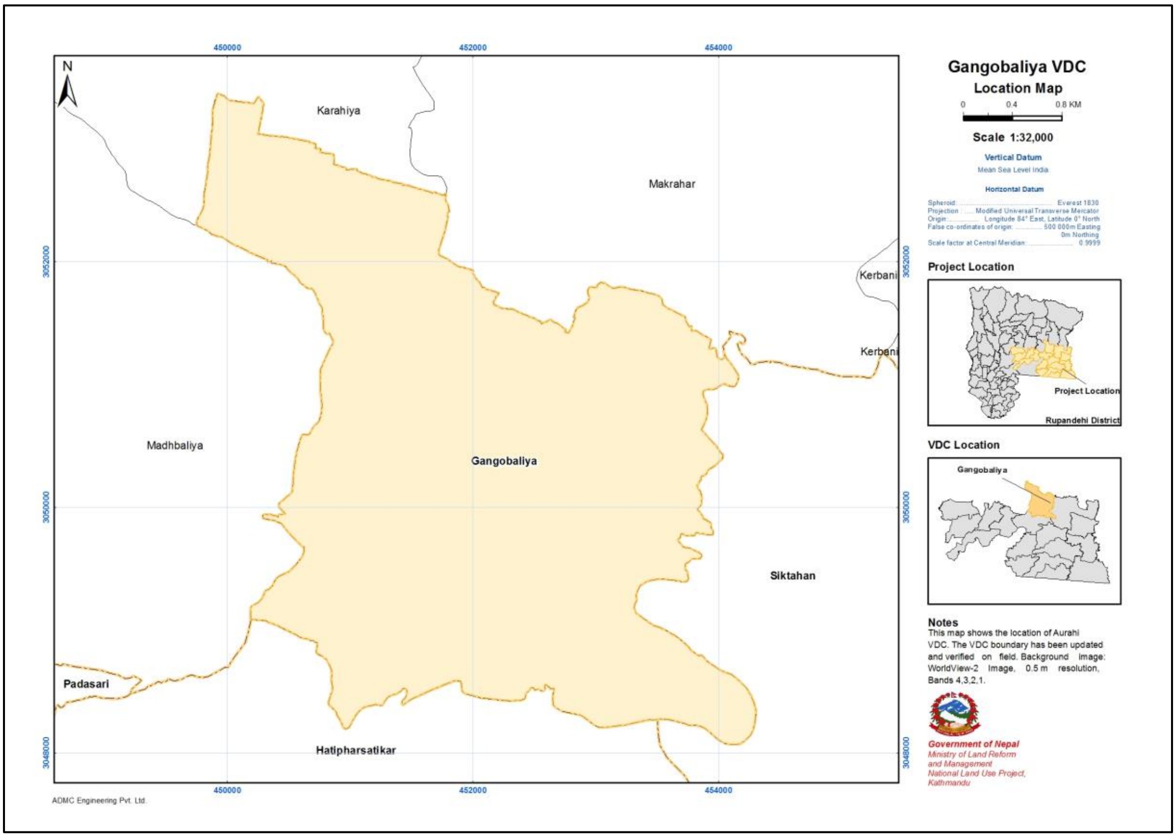

Figure1: Location Map of Gangobaliya VDC

Chapter - 2
CONCEPTUAL BASIS OF LAND USE ZONING

This chapter presents the conceptual basis and principles of land use zoning. Further, it highlights on the parameters and criteria used for land use zoning and finally give detailed description of land use zones identified in the study area.

2.1 Land Use Zoning, Principles and Criteria

Considering the importance of land use zoning, National Land Use Project, Ministry of Land Reform and Management has under laid the following concepts for the land use zoning:

- Classification of land into agricultural area, residential area, commercial area, industrial area, public service area and other uses,
- Identifying areas of potential residential, commercial, industrial and public utility keeping balanced environment.
- Classifying agricultural land into comparatively advantageous sub-areas on the basis quality of land, land capability, irrigation facilities to increase productivity.
- Proper conservation of natural resources including forest, shrub, rivers, rivulets and swampy land etc.
- Multi-Criteria Analysis (MCA) using spatial data pertaining to topography, soil, moisture, drainage, and climate and socio-economic and infrastructures was done.

The Land Use Plan is intended to identify, illustrate and express preferences for use of land in the area based on physical features and constraints, the characteristic of areas and neighborhoods, site suitability for particular types of land use activities, economy and availability of public services and infrastructure. Additionally, the Land Use Plan will provide policy, guidance and assistance in the decision making process relative to land use and land development issues affecting the community.

Zoning is a device of land use planning used by mainly the local governments in most of the developed countries. The word is derived from the practice of assigning permitted uses of land based on mapped zones which separate one set of land uses from another.
Land use zoning determines the types of activities that can occur on the land, such as residential housing or crops harvesting activities. While an area may be zoned for a particular type of use, some or all of that area may not be used as zoned (an example would be an area zoned for residential use that is still partially in agricultural use). As such, the zoning designations the map portrays and reflects both current conditions and anticipated conditions.

Theoretically, the primary purpose of zoning is to separate land uses that are thought to be incompatible to each other. In practice, zoning is used to prevent new development from interfering with existing residents or businesses and to preserve the "character" of a community. Zoning is commonly controlled by local governments such as municipalities or villages, though the nature of the zoning regime may be determined or limited by state or national planning authorities or through enabling legislation. In Australia, land under the control of the Commonwealth (federal) government is not subject to state planning controls. The US and other federal countries are similar. Zoning and urban planning in France and Germany are regulated by national or federal codes. In the case of Germany this code includes contents of zoning plans as well as the legal procedure and zoning usually includes building design, very specific green space and compensation regulations.

Basically, urban zones fall into one of five major categories: residential, mixed residential-commercial, commercial, industrial and special (e. g. power plants, sports complexes, airports, shopping malls etc.) and rural zones are mainly agricultural. Each category can have a number of sub-categories, for example, within the agricultural category there may be separate zones for cereal crops, cash crops, horticulture, agro-forestry and others.

A Zoning Map is a graphic depiction of the boundaries for which a certain set of standards or regulations have been adopted by a government entity. The zoning map typically provides predictability for the residents and development community as to what type of land uses may be expected and allowed within each VDC/ District. Land is divided into zones from the zoning code which describes the intent and regulations of each particular zone category. A typical zone will set forth regulations for permitted land uses.

Land use zoning is assessed based on the suitability of sustainable use for a specific purpose. Land use zoning differs from land capability classification in a sense that land capability is general classification of land based on arability and productivity of soil without degradation or offsite effects of farming whereas land use zoning is suitability classification of land for various land use purposes.

Main principle of land use planning can be listed as

- Land use planning is orientated to local conditions in terms of both method and content.
- Land use planning considers cultural viewpoints and builds up on local environmental knowledge.
- Land use planning takes into account traditional strategies for solving problems and conflicts.
- Land use planning assumes a concept which understands rural development to be a "bottom-up" process based on self-help and self-responsibility.
- Land use planning is a dialogue, creating the prerequisites for the successful negotiation and co-operation among stakeholders.
- Land use planning is a process leading to an improvement in the capacity of the participants to plan and take actions
- Land use planning requires transparency. Therefore, free access to information for all participants is a prerequisite.
- The differentiation of stakeholders and the gender approach are core principles in land use planning.
- Land use planning is based on interdisciplinary cooperation.
- Land use planning is an iterative process; it is the flexible and open reaction based on new findings and changing conditions.
- Land use planning is implementation-orientated.

The concept of land use zoning is come forward to achieve mainly the following specific objectives:

- To provide for a mixture and variety of land uses in appropriate locations throughout the study area
- To identify prime land areas for suitable agricultural crop production.
- To identify and set aside prime land areas for future quality industrial growth and development.
- To create stable, attractive, safe residential neighborhoods which contain a range of supportive commercial, institutional, and public facilities
- To create stable and functional commercial centers based on site suitability and compatibility with adjacent land uses.

- To provide for the appropriate location and distribution of public facilities such as parks and schools throughout the community.
- To promote rehabilitation and improvement of the living environment in older neighborhoods and areas characterized by conflicting patterns of land use.
- To promote land use activities appropriate to the features and characteristics of the natural landscape.
- To support and promote consistency between the Land Use Plan and current land use pattern.
- To provide for adequate transitioning and buffering between residential uses and industrial and commercial uses.
- To promote growth in areas adjacent to existing urban development so that public services and facilities may be provided efficiently and economically.

In this particular project, the following main concept is put forward for land use zoning

- Classification of land into Agricultural area, Residential area, Commercial area, Industrial area, Forest area, Public service area and other uses.
- Identifying areas for potential residential, commercial, industrial and public utility keeping balanced environment.
- Classifying agricultural land into comparatively advantageous sub-areas on the basis of quality of land, land capability, and irrigation facilities to increase productivity.
- Proper conservation of natural resources including forest, shrub, rivers and rivulets and swampy land etc.

Based on these principles, objective and concept of land use planning, land use zoning is carried out giving special attention to the following broad criteria:

- Sufficient land should be zoned at appropriate locations throughout the area to accommodate the expected growth in population and other growth needs of the study area within the lifetime of the Plan.
- Zoning should be designed to promote particular uses in appropriate locations, to reduce conflict of uses and to protect resources both natural and human-made. Where appropriate, zonings should be used as a tool for shaping the area and not solely reflect existing land uses.
- Development should be encouraged in established centers and the redevelopment of underutilized land in these areas should be promoted with a view to consolidating and adding vitality to existing centers, and ensuring the efficient use of the lands thereby, according with the principles set out in the National Land Use Policy.

On the basis of the aforementioned broad criteria, the following specific criteria are used for zoning:

Existing (present) land use

Land capability and land system identified by the analysis of soil characteristics (PH value, Nitrogen, Phosphorous, Potash, Zinc, Boron, Organic Matter etc.), soils moisture, temperature, drainage, irrigation, slope, elevation, aspect, topography etc.

Suitability identified on the basis of the neighborhood and spatial analysis (distance from roads, markets, settlements, river and stream and other hazards)

For this project, the studies on land capability, land system and present land use classification were reviewed carefully. The base for this study is LRMP classification scheme. Further elaboration on LRMP classification is done on report on Land Capability mapping by the other study group. During land use zoning, the symbols and codes used on these earlier study reports were used. The detailed review is done on the other reports (For further details, please refer the reports on land capability, land system, and soil study). Similarly, the TOR provided by NLUP is taken as reference for categorizing the various land use zones.

2.2 Land Use Zones and their Descriptions

According to the National Land Use Policy 2072 BS, there must be following eleven land use zones:

1. Agricultural
2. Residential
3. Commercial
4. Industrial
5. Forest
6. Public uses
7. Other Zone
8. Mine and Minerals
9. Cultural and Archeological
10. Riverine and Lake Area
11. Excavation Area Construction Materials)

But on the basis of requirement, there can be other zones as well.

In this study also, we have followed the instruction of National Land Use Policy 2072 and categorized the study area on the following zones and sub zones as shown in the table 1.

Table 1: Land use zoning scheme of the study area

Zone No.	Zone Type	Sub type	Data Type	Description	Remarks
Zone 1	Agricultural Zone	Zone 1A	String	Cereal crop production area	
		Zone 1B	String	Cash crop area	
		Zone 1C	String	Horticultural area	
		Zone 1D	String	Animal husbandry area	
		Zone 1E	String	Fish farming area	
		Zone 1F	String	Agro forestry area	
Zone	Residential	Zone 2A	String	Existing residential zone	

2	Zone	Zone 2B	String	Potential area for residential zone	
Zone 3	Commercial Zone	Zone3A	String	Governmental institutions and service areas	
		Zone 3B	String	Business area	
Zone 4	Industrial Zone	Zone 4A	String	Areas under industrial use	
		Zone 4B	String	Potential Area for industrial use	
Zone 5	Forest Zone	Zone 5A	String	Existing forest	
		Zone 5B	String	Potential area for forest including barren lands, wet lands etc.	
Zone 6	Public Use Zone	Zone 6A	String	Areas under roads, railways, bus parks, air port and land fill site etc.	
		Zone 6C	String	Recreational area, picnic spots, playing grounds and stadiums etc.	
		Zone 6E	String	Public health/education/library, police station, fire station, telephone /electricity areas etc.	
		Zone 6F	String	Grazing land	
		Zone 6G	String	Government Institutional Area	
		Zone 6H	String	Open Space/area	
Zone 7	Other Zone	Zone 7A	String	Other Area	
Zone 8	Mine and Minerals	Zone 8A	String	Existing Mine and Minerals Area	
		Zone 8B	String	Potential Mine and Mineral excavation Area	
Zone 9	Cultural and Archeological	Zone 9A	String	Existing Cultural and Archeological Area	
		Zone 9B	String	Potential Cultural and Archeological Area	

Zone 10	Riverine and Lake Area	Zone 10A	String	Existing Riverine and Lake Area	
		Zone10B	String	Potential Riverine and Lake Area	
Zone 11	Excavation Area (Construction Materials)	Zone 11A	String	Existing Excavation Area (Construction Materials)	
		Zone 11B	String	Potential Excavation Area (Construction Materials)	

Chapter -3
METHODOLOGY

This chapter deals with the data used and method adopted for land use zoning and preparing land use zoning maps.

3.1 Data

There are many different sources of information on existing land use and land cover and on changes that are occurring. Local planning agencies make use of detailed information generated during ground surveys involving enumeration and observation. Interpretation of large-scale aerial photographs also has been used widely. In some cases, supplementary information is inferred on the basis of utility hookups, building permits, and similar information. Major problems are present in the application and interpretation of the existing data. These include changes in definitions of categories and data collection methods by source agencies, incomplete data coverage, varying data age, and employment of incompatible classification systems. In addition, it is nearly impossible to aggregate the available data because of the differing classification systems used (James R. Anderson et. al. 2001).

The primary data source used for the land use classification in this project is high resolution satellite image (2.0 m spatial resolution, MSS and 1 m for panchromatic). Various other vector, raster and imagery data sets were used as ancillary data, which enhanced interpretation and classification of land use classes.

Besides, the present land use, land capability and soil maps were prepared as part of the present study, which are also the major data sources for the preparation of VDC level Land Use zones.

Various data sources are used in this land use zoning. Some main data sources are

- Very high resolution satellite image GeoEye-1 of the study area
- DGPS observation data from field for enhancing geometric quality of the image
- GIS vector data (shape file) of mainly land capability, land system, present land use, Administrative boundary (VDC, Ward).
- Various maps (Land system, Capability) and data (Reports etc.) from LRMP
- Socio economic data and village profile

3.2 Methods

A rule based Multi Criteria Evaluation (MCE) methodology was developed for optimum use of land resources of the VDCs under the following broad land use zones: Agricultural area, Residential area, Commercial area, Industrial area, Forest area, Public service area and other category. The input for the application is a number of maps of each Village Development Committee (so-called 'criteria' or 'effects'), and a criteria tree that contains the way criteria are grouped, standardized and weighed. The output of MCA based on weight/rating consists of composite index maps that indicate the extent to which criteria for different classes of land capability or suitability for land use zoning for a location are met. For example, on the basis of maximum productivity and fertility, agricultural areas has been divided into sub areas of cereal/food crops areas; cash crops areas; vegetable production areas, fruit orchards, areas used for animal husbandry and grassland/grazing lands, fish farming area and Agro- forestry. The MCE Criteria was developed as per guidance by the environmental friendly perspective and as far as possible. Special care should be given to maintain and preserve maximum forest areas, protection of food crop.

Land use zoning is carried out on the basis of GIS based spatial analysis using multi-criteria analysis on several available data sets. GIS vector data (shape file) of mainly land capability, land system, present land use and socio economic data are used. These data files comprised the various parameters like soil characteristics, land form, land type, arability, slope, elevation, drainage system, topography, existing land use, crop patterns, population density and other necessary parameters used for land use zoning.

A rule base was developed by using multiple criteria on the basis of expert knowledge for land use zoning. These criteria were used to identify a suitable land use zone.
For example, to identify a potential area for future industrial use, the following criteria were used:

Those land units which are:

- Within a certain distance from road network
- Lower population density and less residential use
- Not of much importance from agricultural crop production point of view e.g. dry land
- Not within a certain distance from forest, wetland, water body

These kinds of analysis were carried out by using GIS attribute query and spatial analysis based on various data fields on the data files. ArcGIS 10.0 software was used for GIS analysis.

Apart from these kind of criteria formed on the basis of expert knowledge, some subjective analysis and logical inference was applied for land use zoning.
For example,

- The bed of a stream should not be used for agricultural but it can be used for forest plantation or grass land (though it can be very suitable for rice crop production).
- If a small unit of a land use zone (e.g. Zone 5) was found surrounded by some other land use zone (e.g. Zone 6), then the former zone was merged to the later.

3.3 General Approach and Methodology Framework

Land use zoning class and suitability ratings is evaluated based on aforementioned criteria and the land use unit is designated with appropriate land use zone class along with its suitability value. The approach for classification and designation of land use zones is presented on the following schematic diagram:

Figure 2: Methodology used for land use zoning

Chapter - 4
LAND USE ZONES OF THE STUDY AREA

4.1 Land Use Zones

Zoning of the area for regulation of land use practices does not necessarily mean to copy the present land use pattern one to one. Present land use practice can be a reference but it should not necessarily indicate the same pattern for land use zoning. It is because the land use to be imposed in future might give pressure on the agriculture land which may be highly suitable for diversified crops as well. On the other hand, spatial overlay analysis performed with the built up area based on the national topographic database and that rendered by the present study of land use mapping(residential) has revealed that enormous amount of agricultural land has sustained attack just for newly developed residential area. More importantly, the residential expansion has not taken care whether the area was cultivable or not. It has only seen the accessibility and proximity to the existing residential area.

Taking this fact into consideration and analyzing the rate of expansion of built up within the period of around 18 years, present residential area has been proposed in the area surrounding the existing residential area. While expanding such areas, due attention has been given to protect vegetative area of bamboo and orchard as well as pond area under the subcategory of agricultural land.

Based on the existing land use of the VDC described in the land use section of this report and considering the increasing trend of land use changes quite visible during the field visit, growing urbanization and industrialization trend along the industrial corridor and growing population and increasing demand of land for non-agriculture uses, land use zoning of the VDC has been prepared to address the need:

1. to meet the increasing demand for land to accommodate the growth of population due to rapid urbanization

2. to regulate and control land use changes in areas designated as agriculture zone

3. to protect and preserve areas which are environmentally sensitive

Thus taking into consideration the above issues, land use zoning of the VDC has been prepared and is presented in Table 2. This table has been prepared in accordance with TOR requirement to prepare Land use zoning according to NLUP defined land use zones. Accordingly the table has eleven zones with each zone with sub-zones as can be seen in the Table 2. Zone 1 in the table represents agriculture area which has been identified and demarcated on the basis of quality of land, land capability, and irrigation facilities which would contribute to increase agriculture productivity. The concept is that land use changes in non-agriculture use in this zone must be discouraged as well as controlled. Zone 2 covers existing residential area as well as potential area for future residential growth. Potential area for future residential expansion has been identified and demarcated on the basis of proximity to existing residential area, access road, access to infrastructural services and facilities and topography avoiding low land and flood prone areas. Zone 3 covers the commercial zone comprising of areas occupied by existing government institutions, community services and commercial activities. Zone 4 represents existing industrial areas as well as areas identified and demarcated as potential area for future expansion of industrial activities which would likely to take place in near future. Zone 5 represents forest area. Though at present there is no forest land in the VDC, but there are large chunks of barren land and wetlands which must be protected and developed as forest zone. These barren lands and wetlands have been identified and demarcated in the forest zone. Zone 6 in the table is self-explanatory and does not need further explanation. The most important aspect of this zone is identifying and demarcating public land containing man made features, governmental institutional areas, public utilities, public institutional area, offices, picnic spots and recreational areas etc. Zone 7 indicates the zoning of land that fall under other areas. Zone 8 represents existing mines and mineral areas as well as areas identified and demarcated as potential area for future mine and mineral utilization. Zone 9 represents the existing cultural and archeological areas as well as area identified and demarcated as potential area expansion or development of possible cultural and archeological sites. Zone 10 represents existing environmentally sensitive areas like water sources, rivers and streams, canals, ponds etc and need to be protected against encroachment as well as identified areas suitable for water diversion or collection for irrigation and other purpose. Zone 11 represents existing excavation area (construction material) as well as area identified as potential site for future excavation of construction material.

Figure 3 provides graphical presentation of percentage distribution of different zones in terms of VDC area and percentage distribution of sub-zones of each zone in terms of area of each zone.

The Land Use Zones identified in this VDC are summarized on the following table:

Table 2: Land use zones of the study area

Zone Type	**Zone Sub Type**	**Area (Sq.m.)**	**Area (Ha.)**	**Zone Type Area (Ha.)**
Agricultural Zone	1A-Cereal crop production area	10623939.81	1062.39	1149.46
	1B-Cash crop area	175104.14	17.51	
	1C-Horticultural area	165864.34	16.59	
	1E-Fish farming area	243873.78	24.39	
	1F-Agro forestry area	285811.17	28.58	
Residential Zone	2A-Existing residential zone	342559.16	34.26	36.62
	2B-Potential area for residential zone	23602.19	2.36	
Commercial Zone	3A-Service areas	1126.93	0.11	11.99
	3B-Business area	118788.05	11.88	
Industrial Zone	4A-Areas under industrial use	25564.34	2.56	2.56
Forest Zone	5A-Existing forest	1446.63	0.14	0.14
Public use Zone	6A-Areas under roads, railways etc	537529.34	53.75	54.14
	6E-Public health, education library, police station, fire station, telephone, electricity areas etc	3914.45	0.39	
Cultural and Archeological	9A-Existing Cultural and Archeological Area	2661.82	0.27	0.27
Riverine and lake area	10A-Existing Riverine and Lake Area	306284.61	30.63	30.63
	Grand Total	**12858070.75**	**1285.81**	**1285.81**

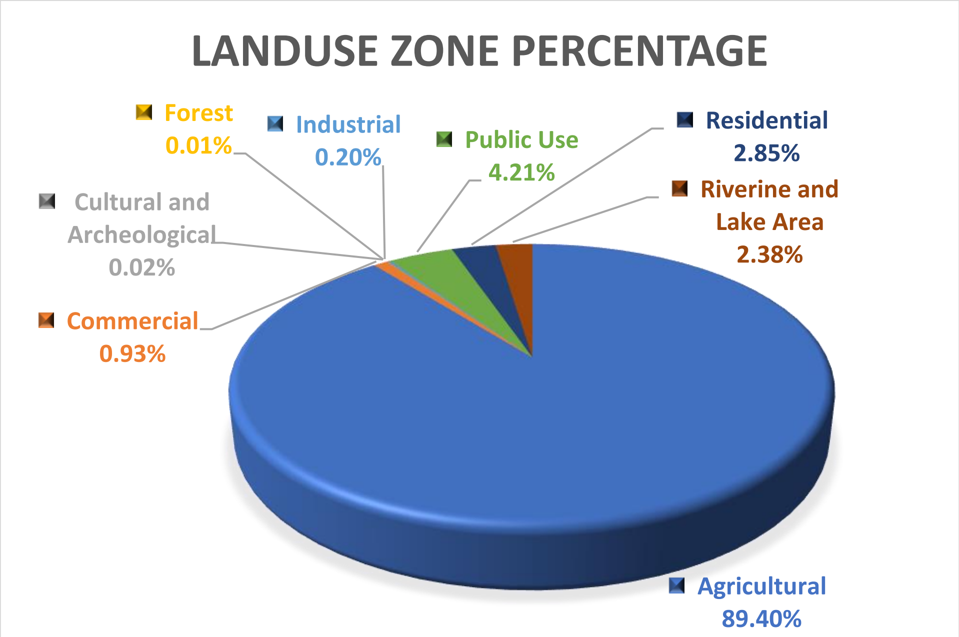

Figure 3: Details of Land Use Zoning of Gangobaliya VDC

Change in land use categories and transition from Present Land Use to Land Use Zone

Table 3: Change in land use categories

Landuse Category	Existing Coverage (Ha)	Proposed Coverage (Ha)	Change	
			Area (Ha)	Percentage
Agricultural	1162.52	1149.46	-13.07	-1.12%
Commercial	12.52	11.99	-0.53	-0.05%
Cultural and Archeological	0.28	0.27	-0.01	0.00%
Forest	0.14	0.14	0.00	0.00%
Industrial	14.83	2.56	-12.28	-1.06%
Public Use	19.91	54.14	34.23	2.94%
Residential	39.79	36.62	-3.18	-0.27%
Riverine and Lake Area	35.80	30.63	-5.17	-0.44%
Grand Total	1285.81	**1285.81**		

Table 4: Land use transitions

From	To								
	AGR	COM	CULARCH	FOR	HYD	IND	PUB	RES	Total (Existing)
Agricultural (AGR)	1137.58						22.59	2.36	1162.52
Commercial (COM)		11.99					0.53		12.52
Cultural and Archeological (CULARCH)			0.27				0.01		0.28
Forest (FOR)				0.14					0.14
Riverine and lake area (HYD)					30.63		5.17		35.80
Industrial (IND)	11.88					2.56	0.39		14.83
Public use (PUB)							19.91		19.91
Residential (RES)							5.54	34.26	39.79
Total (proposed)	1149.46	11.99	0.27	0.14	30.63	2.56	54.14	36.62	1285.81

4.2 Land Use Zoning GIS Database

The following database schema is used for preparation of GIS database

Table 5 : Database schema used for land use zoning

Field	Data Type	Description	Remarks
FID	Feature Id	Feature	
SHAPE	Geometry	Geometric Object type	
CLASS	Short Integer	Class code of the land use zone	
ZONE NO	String	Zone No	
ZONE TYPE	String	Zone type	
SUB ZONE TYPE	String	Subzone Type	
Description	String	Description of the zone (sub) type	
Shape_Length	float	length of the feature (auto generated field)	
Shape_Area	float	area of the feature (auto generated field)	

Chapter - 5
CONCLUSIONS

5.1 Conclusions

Land use zoning of the VDC under study was carried out based on the present land use data, land capability taking the witnesses of current remotely sensed image with the help of ground based information. As the VDC showed different degree of variability in land use pattern, maximum with agriculture and minimum on forest (although plantation), it rendered same degree of variation in the spatial distribution of land use zones.

Lack of clear guidelines on the classification system has posed a level of difficulty in assigning the classes of different hierarchy in land zoning, especially in assigning forest and public use category. The system does not say in which category the plantation should be kept as neither it belong to the category of Forest nor is it explicitly on agricultural use. This has posed a degree of ambiguity to assign the proper land zoning codes.

The study shows that the most of the part of the VDC, about 89.40% is suitable for agricultural activities and hence categorized as agricultural zone. The land under present residential use and potential residential use for future is about 2.85%. The land suitable for commercial activities is about 0.93% only. In this VDC, the forest cover is about 0.01%. Within the agricultural land, most of the land is found suitable for cereal crop, agro-forestry, production, fish farming and cash crop production. For public utility uses, about 4.12% of the land is identified. About 0.20% of land is separated for Industrial development and for existing riverine and lake area, about 2.38% land is identified.

The proposed land use zones are based on rigorous study of present land use scenario supplemented by the soil capability, socio-economic aspect and future prospect for expansion and development works at the same time keeping in view of risk information collected during the study. Residential, Public and Commercial area are major categories which have been proposed realizing the need based on the population growth trend and expansion compared to the topographic and demographic data of 1992-1995. Area such as Mine and Minerals, Cultural and Archeological and Excavation Area (Construction Materials) have not been proposed for now because of the lack of resources at the respective organizations related to them.

5.2 Recommendations

Comprehensive database model for land zoning provided by NLUP facilitated in establishing the physical model very much but if proper criteria of defining the land zoning in an objective sense is provided, then it would further enhance the consistency of the final product.

The land use zoning of an area highly depends upon the availability of some other primary as well as secondary data such as current land use pattern, land capability, land system, soil, temperature, topography, demography and socioeconomic status etc. of the area. For this purpose, latest satellite imagery of highest possible resolution would be very much useful. Similarly, the other data mentioned above should also be accurate and timely updated. Field verification in the final stage of map preparation could also enhance the accuracy of the mapping output. Above all, awareness training on land use and zoning for local bodies should be organized for better implementation of land use policies and programs.

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APPENDIX: Land Use Zoning Map of Gangobaliya VDC

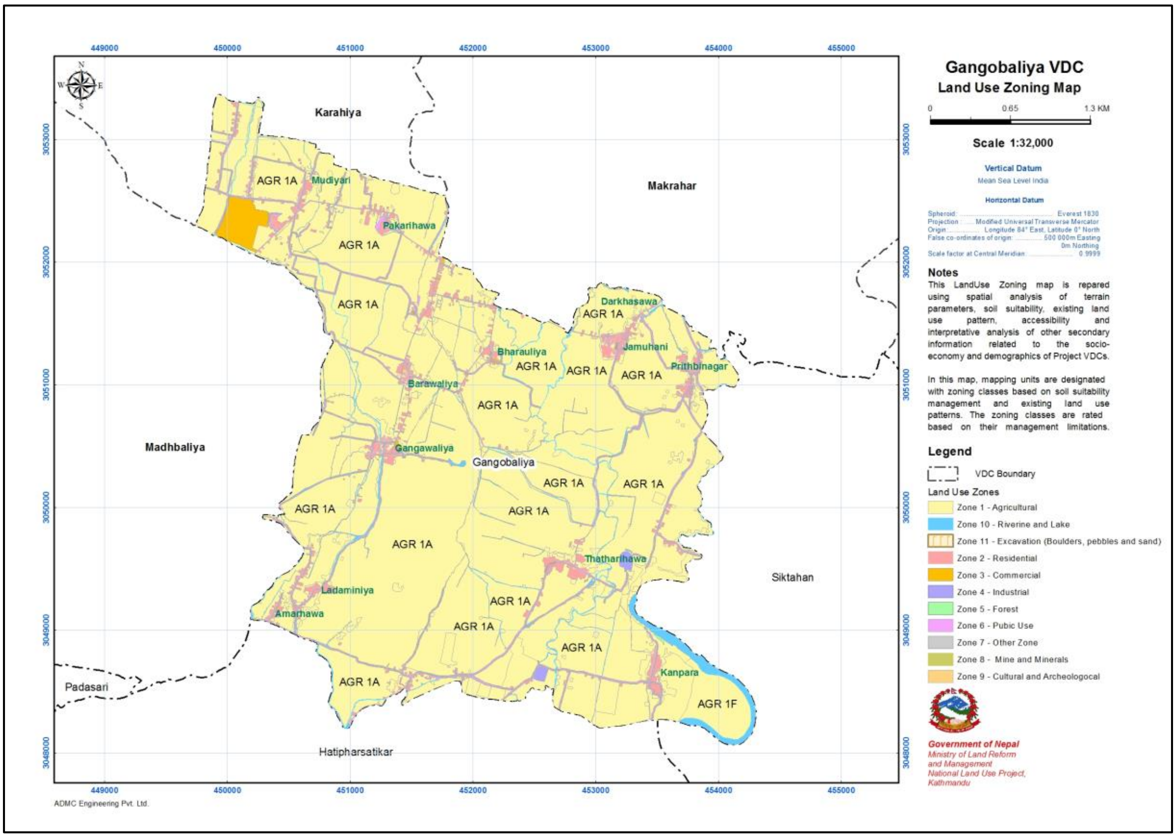

Figure 4: Land Use Zoning Map of Gangobaliya VDC

G. Cadastral Layer Superimpose with Land Use Zones

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Chapter - 1
INTRODUCTION

1.1. Background and Rationale

Government of Nepal has adopted the National Land Use Policy, 2072 with a vision to achieve sustainable social, economic and environmental development through optimum use of land and land resources. For this purpose it has assigned a goal to classify the whole land of the country in different classes (like agriculture, forest, residential, commercial, industrial, public use, mine and minerals, cultural and archaeological, riverine and lake area, excavation area and other designated) based upon the landscape characteristics, capacity, capability and needs; and to prepare and implement a hierarchical land use plan within 10 years; and complete the land use planning and its implementation in the municipalities, district, urbanizing VDCs and areas adjoining to major roads within 5 years. For this purpose a Land Use Management Department has been proposed, and the National Land Use Project will continue to carry out this function until such Department is established.

Land-use planning is the systematic assessment of land and water potential, alternatives for land use and economic and social conditions in order to select and adopt the best land–use options (FAO, 1993). Except sporadic attempts for the urban areas (GoN, 2002), Nepal has not practiced land-use planning for the country as a whole, although attempts were made for balanced use of Country's existing natural resources in the past through different policies and national planning efforts. The National Land Use Policy 2072 envisages land-use planning to be applied at three broad levels: national, district and local municipality/ VDC. Local level planning is about a detailed outline of getting things done on particular areas of land – what shall be done, where and when, and who will be responsible. It requires detail basic information about the land, the people and services at local level. The available data base on land use, land system and land capability produced by Land Resource Mapping Project (LRMP, 1986) could be useful as reference material for national and regional or district level planning. However, we need very detailed information for local level planning at the Municipality/ VDC level. Use of present day geo-information technology like satellite remote sensing (RS) and the Geographic Information System (GIS) can be helpful in acquiring spatial/temporal data, and preparing different thematic digital data base like current land use at this level. These spatial databases together with data on different land characteristics collected from the field survey and secondary sources are used to prepare land use zoning maps at local VDC level.

Sustainable land resource management requires a systematic approach towards a comprehensive study of land use patterns, land forms, soil, vegetation, climate and other socio-economic aspects of the study area. The land use practice has a direct impact on environment, ecology and other socio-economic factors of the study area. Realizing this need, Government of Nepal, Ministry of Land Reform and Management, National Land Use Project has undertaken an initiative to study and map the present land use pattern and soil characteristics as well as land capability and land use zoning based on soil and physiographic characteristics at VDC level. The proposed land use plan given in the land use zoning maps need to be implemented on the ground. In the local level while implementing the land use zoning, the current land tenure pattern like ownership, use and size and shape of the individual parcels need to be dually considered. The overall objectives of a land use planning implementation process are to improve the production and productivity of land; and individual property and their usage is involved. Therefore, a comprehensive picture of the current land use, proposed land use given in the zoning maps and the individual property information given in the cadastral maps and records need to be dually looked into.

The superimposition of cadastral layer on land use zoning serves this purpose. This activity is carried out for individual VDCs in the project area (Package 27) and maps and detailed report for each VDC has been prepared.

The rationale for the preparation of VDC level superimposition of cadastral maps on land use and land use zoning maps by NLUP are to identify individual parcels according to present land use and propose land use. For all land related decision making land ownership and land tenure information provide essential in gradient. The implementation of land use plan cannot be successes without the active and positive support of the individual land owners. Therefore the main rationale of superimposition of cadastral maps on land use and land use zoning maps is to support in the formulation and implementation of land use plans and land use zoning policy within the VDCs.

More specifically this information will be necessary for the following:

i. Delineation of land parcels according to land use zoning viz. agricultural area, Residential area, Commercial area, Industrial area, Forest area, Public use area, and other designated areas.
ii. Classification of land parcels for the purpose of non-agricultural land uses.
iii. Delineation of the areas for conservation of forest, shrubs/herbs, river, wetlands for achieving environmental balance.
iv. Sub-classification of agricultural land parcels into optimum production sub-areas based on soil characteristics, land capability, irrigated and potential irrigable areas to increase the productivity of the land.
v. Preparation of VDC level data base and maps using GIS for the implementation of VDC land use plan.
vi. Management of land resources on the basis of land characteristics as well as the conceived policy of the government.

1.2. Objective and Scope of the Study

The broad objective of National Land Use Project (NLUP) Package 27 (2073/074 fiscal year) is to prepare Village Development Committee (VDC) level land use maps, soil maps, land capability maps, land use zoning maps, Land hazard maps, cadastral layer superimposition and preparation of profile for In this regards, the National Land Use Project (NLUP) has awarded to conduct the project entitled Package 27: Preparation of VDC level land resources maps (Present Land Use Map, Soil Map, Land Capability Map, Land Use Zoning Map and VDC Profile for Land Use Zoning Map, Land Hazard Maps, and Superimpose of

Cadastral Layers), Data Base and Reports of Rupandehi District to our consultancy for fiscal year 2073/074. The Package 27 covers 17 VDCs; Bagaha ,Basantapur, Bodabar, Chhipagadh Chhotki Ramnagar, Chilhiya, Dhakadhai, Gangobaliya, Harnaiya, Hatipharsatikar, Hatti Banagai, Mainahiya, Padasari, Pajarkatti, Patkhauli, Pokharbhindi and Siktahan.

As for other themes, separate maps and report for each VDC for the superimposition of cadastral layer has been prepared. This report is prepared to describe the VDC wise superimposition of cadastral layer of Package 27.

The main objective of the study is to prepare 1:10,000 scale map of Cadastral Layer superimposition on Land Use Zones, prepare data base and report of Chilhiya VDC of Rupandehi district.

Scope of this study included the following activities for the VDC under study:

i. Collect and prepare seamless cadastral maps at 1:10000 scale
ii. Collect land use zoning maps and present land use maps at 1:10000 scale
iii. Prepare cadastral layer superimposition map on present land use and land use zoning at 1:10000 scale.
iv. Classify the cadastral parcels according to present land use and land use zoning.
v. Design GIS database on cadastral parcels with zoning characteristics and current land use
vi. Report on the accuracy, reliability and consistencies of data, and
vii. Report describing methodology, distribution of cadastral layers as per land use zones and present land use, and model of GIS database.

1.3. Study Area

The study area has been already described in the present land use section this report.

Chapter - 2

CONCEPTUAL BASIS OF SUPERIMPOSE OF CADASTRAL LAYER

This chapter describes the conceptual basis behind the superimposing of cadastral layer on land use zoning map.

2.1 Concepts

The superimposing of the land use zoning in cadastral layer is useful for implementation the national land use policy at the local level like VDC or municipality of the country. This will provide information regarding the proposed land use directly in relation with the land owner, its tenant, current land use and the shape and size of the individual parcel it will subsequently relate the concerned land owner with the country wide property information. Therefore, the local governments can develop a comprehensive plan and administer the land use regulations that as per the standards for planning set by national government. A local comprehensive plan of cadastral layer guides a community's land use, conservation of natural resources, economic development, and related public services. For this, it needs several databases: with a cadastral layer as base information together with the existing land use and a land use zoning layer.

Cadastral map is defined as "the outlines of the property and the parcel identifier normally are shown on large scale maps which, together with registers, may show for each separate property the nature, size, value and legal rights associated with the parcel" (Dooley). The cadastral map should be defined as the outline of parcels or pieces of land which constitute the units of the land recorded whatever the purpose of the land may be. Generally, cadastral maps are prepared based on the ground survey either with plane table or total station, and/or interpretation of ortho-photo prepared from stereo pairs of aerial photograph or high resolution satellite imageries. The cadastral map at all times should show the real situation, shape and size of each and every individual land parcel within the area with complete accuracy and adequacy. Cadastral maps are dynamic; they must reflect the changes in the cadastral framework arising from land development and land fragmentation. In Nepal, a systematic cadastral survey was carried since B.S. 2021 using the plane tabling techniques at the scales of 1:2400 and 1:4800 in the beginning, but later shifted to 1:2500, 1:1250 and 1:500 depending upon the size and density of the parcels. The district survey offices maintain the mutations of each parcel upon fragmentation due to transactions. Though the accuracy of plane tabling survey cannot be considered too high, it is more than enough here since the superimposition is carried out at the 1:10000 scales. The digital data provided by NLUP is from the digitization of the existing up to date maps from the DOLIA at the date of digitization. Though with the passage of time some of the parcels may have been outdated at the time of implementation, the parcel history available at the Survey Office may be linked to update such information when needed.

Land use maps are maps which provide information about current or proposed land use of any area. There are a number of different applications for such maps, and in many nations, land use maps are prepared by several government agencies, for a variety of reasons. Individual groups and organizations can also generate maps with land use information.

Often, such maps are publicly available, so that people who are interested in land use trends can access them.

One form of land use map is a **zoning map**. Zoning maps are used to mark out areas designated for specific types of land use, so that people developing land know which kinds of uses are allowed by land use regulations in a particular area. The creation of zoning maps is part of the overall process of community planning, in which communities decide how they want to develop their land and vicinity in the future. Zoning decisions can include things like setting aside green space, isolating industrial land, and so forth. Another type of land use map is a map which shows utilization. Utilization maps are often used in zoning decisions to determine whether or not zoning changes need to be made. If, for example, only 60% of the land designated for residential use is in active use or development, it would suggest that making more residential zoning available is not necessary. Utilization land use maps show how land is being used, and may also indicate historic utilization information, and provide information about how long land has been developed.

Utilization maps can be very detailed and tremendously useful. They can highlight a variety of activities, including farming, mining, residential use, light industrial, heavy industrial, waste storage, and so forth so that people get a clear visual impression of how land in the area covered by the map is being used. Utilization land use maps can also be important from a development perspective because they provide data about historical use; land used for a tannery, for example, might not be a great place for a residential development.

Land use maps, records, and archives are maintained by competent authorities as a coherent record. Researchers who want to study land use or the history of a region can access these archives, as can developers who want to know more about their land use options, and government officials who monitor land use. These maps can become important in zoning and property disputes, as people may be able to use them to prove or argue their case.

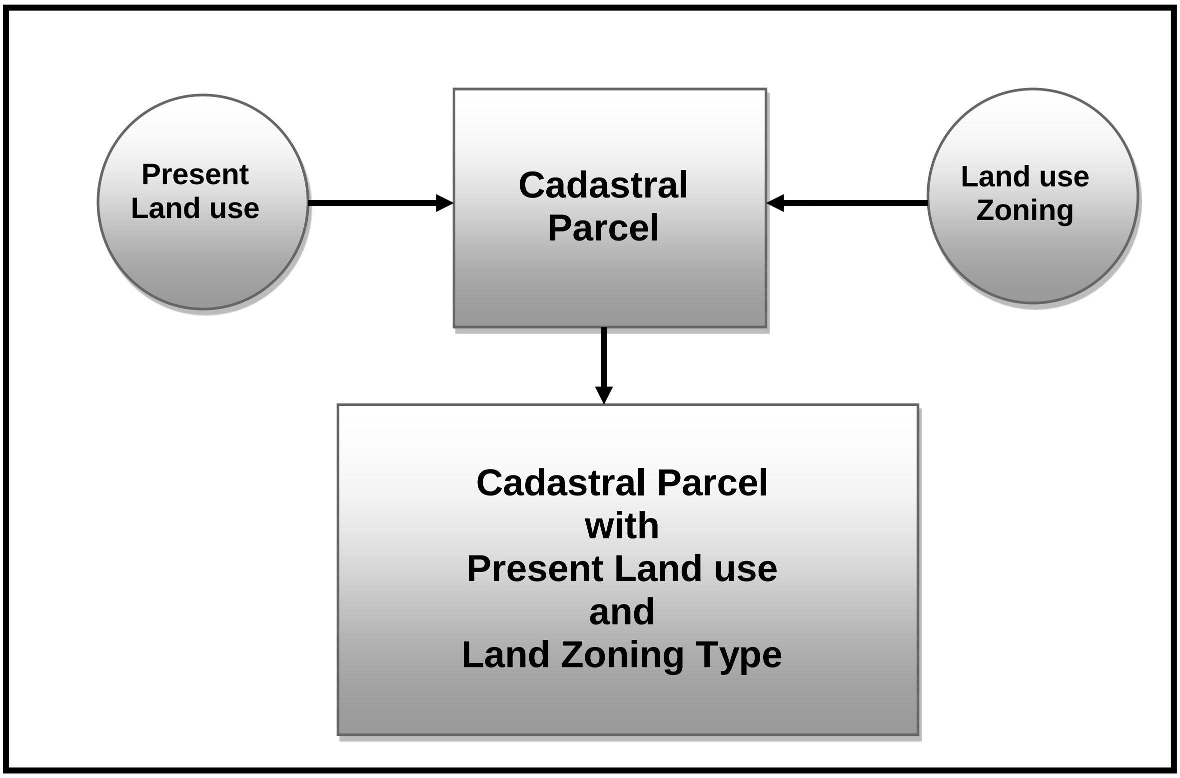


Figure 2.1: Spatial Function Related to Spatial Databases

2.2 Spatial Function related to Spatial Database

The overlay process of two spatial data layers (cadastral and zoning map) having same reference system facilitates to prepare a composite map and data bases (Figure 2.1). It leads to generate a new set of polygons that explain the relations between the two inputs of spatial data (land use zone class and parcel id). The overlay of seamless cadastral map layer and present land use map provides information on which parcel belongs to which present land use, similarly the overlay of cadastral layer over proposed zoning map will provide information on proposed use of the particular parcel. The overlay function will as well provide information on the proposed change of use parcel wise, and will as well provide a summary on the overall change in land use anticipated upon the implementation of the land use zoning.

2.3 Attribute Data Management

The connections between graphical and alphanumerical database is based on the use of a GIS internal table as a linkage with other tables in external databases. This data are usually managed by a relational database management system (RDBMS). The procedures are based in the connection of each graphical element to a line of column of the alphanumerical table containing its attributes. The attribute table used for superimposing land use zoning map on cadastral layers are prepared and managed in GIS environment.

Chapter - 3
METHODOLOGY

Superimposing cadastral parcels on to the land use and land use zoning will enable land use classification and zoning at parcel level required for micro planning of land based resources in the smallest unit of administrative division i.e. VDC level. For the preparation of the cadastral layer to be superimposed on land use and land use zoning maps of the project areas, the following methodological approach was adopted.

3.1 Data Sources/ Acquisition of Cadastral Maps and Data

The original source of cadastral data for the VDCs of district was respective Survey Office who maintains the original cadastral maps and records, and those cadastral maps were digitalized by DOLIA and stored as sheet wise geodatabase in .gdb format. This was made available to the project/ NLUP for this exercise. NLUP has provided digital copies of island cadastral maps in vector format together with the attribute database. The data thus obtained were not synchronized with national reference frame. The data were based on the digitization of related cadastral maps available with the Survey Office and current to the date of digitization by DOLIA.

List of free sheet maps in Rupandehi district as per VDC, of which were in the Package 27 project area and their corresponding cadastral geodatabase tiles files are listed the Appendix.

The present land use and land use zoning maps for the study area were prepared by this Company under the separate components of the project as per the TOR. The land use zoning map of the VDCs is based on the categories of National Land Use Policy, 2068 of Government of Nepal.

3.2 Scanning

In case of unavailability of digital cadastral maps, scanning of paper maps was performed and database was generated by following the standard adopted by Department of Land Information and Archive. Scanning of each sheet was carried out at the DPI of 200 following the standard operation procedure set by DOLIA.

3.3 Georeferencing of Cadastral Data

A sheet-wise free-sheet digital cadastral database was available for the project. Therefore geo-referencing was necessary. This was carried out with the help of ortho-rectified satellite image of the area. The steps adapted to geo-referencing and superimpose cadastral parcel on land use zoning map within the prescribed area is shown in Figure 3.1.

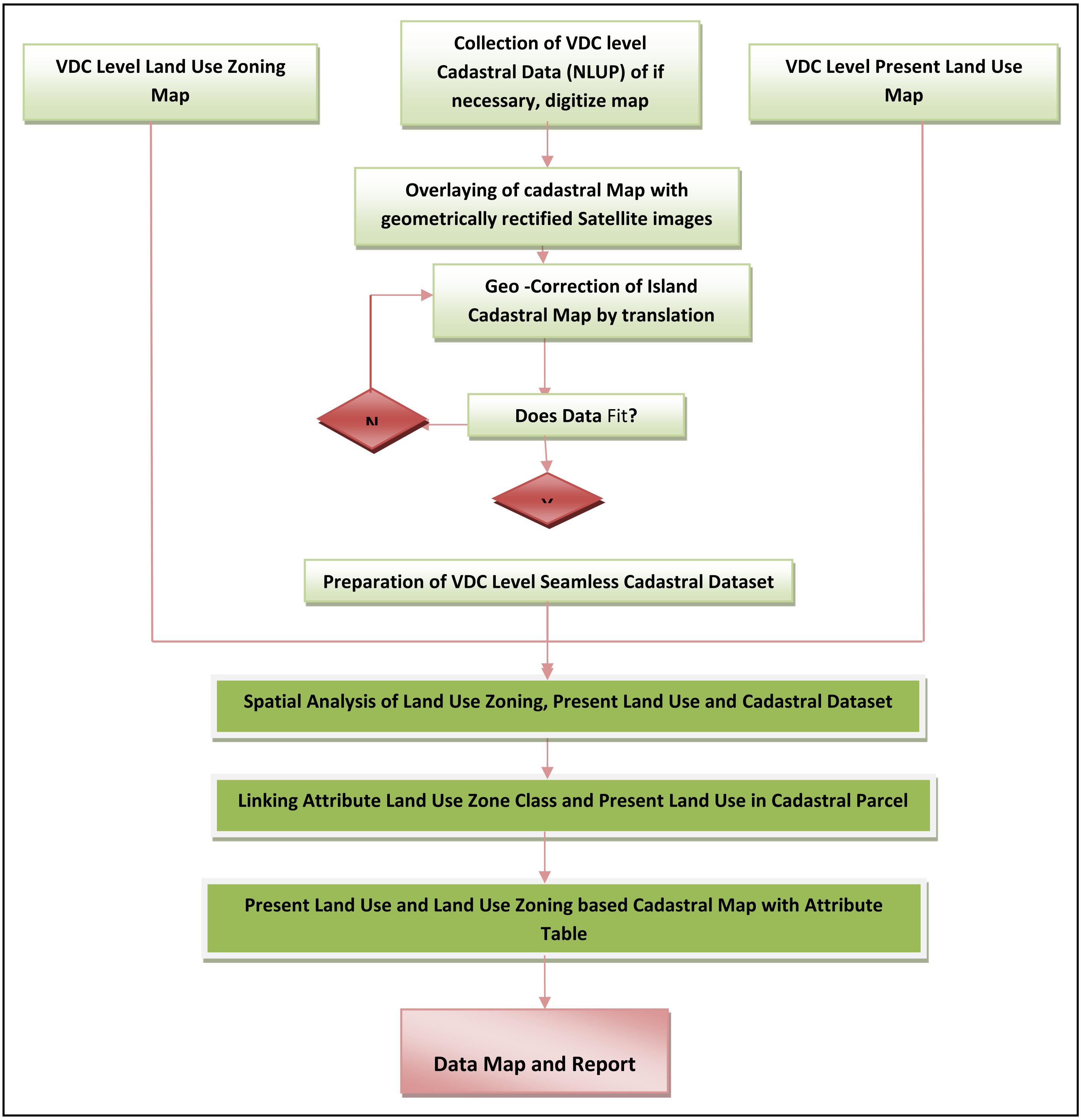


Figure 3.1: Schematic Diagram of Methods Adopted

Geo-referencing is the process of aligning cadastral parcel maps on to the geometrically oriented and corrected to ground scale and in terms of national reference frame. As the cadastral vector data obtained from NLUP were not geo-referenced in national reference frame, the following method was applied. The details of ortho-rectification are given in Land Use Report:

- A team of surveyors visited project areas for carrying out survey of GCPs as necessary using DGPS technology.

- Using these control points orthorectification of 0.5m resolution WORLDVIEW-2 PAN Imagery was made.
- The geo-referencing was carried out matching the sharply identifiable common points GCPs in the cadastral map and the orthorectified image map. Geo-correction of vector layer of cadastral data need GCPs at least on the four corners of the map sheet, however to maintain the accuracy, and ensure even distribution of errors the consultant used 10 GCPs in one cadastral map sheet for geo-referencing. A 2nd degree polynomial transformation was applied for rectification of the vector layer of cadastral dataset after assigning the required GCPs. Due to larger errors in source data, mainly due to the plane tabling methodology using limited local control, some of the cadastral maps still were not free of overlapping and gap errors even after affine rectification. However, this has limited consequence due to the scale of end product (1:10000). Moreover the gaps and overlaps occurred in the margin of separate cadastral map sheets which were generally road, stream, and jungle/unsurveyed public land in some other cases. Accuracy of individual cadastral map sheet transformation has been assessed and an error report has been generated.

Details of national reference system coordinate used are presented in table 3.1.

Table 3.1: Projection Parameters Adopted

Projection	Modified Universal Transverse Mercator
Spheroid	Everest 1830 (Adjustment 1937)
Semi-Major axis	a=6377276.345m
Semi-Minor axis	b=6356075.413
1/f	300.8017
Central Meridian	84^{o} E, 0^{o} N
False Coordinate	500,000 m E, 0 m N
Scale Factor at Central Meridian	0.9999

Some of the constraints the consultant faced during the rectification process are listed below:-

- Very difficult to find easily identifiable ground control points corresponding to the distinct features
- Adjacent sheets are difficult to match and create problem to get seamless mosaics even after polynomial, similarity transformation or triangulation.

3.4 Digitization and Preparation of Digital data

Georeferencing and matching with the ortho-rectifiied image maps provides a common geodetic framework for all related maps, and will therefore provide a common basis for overlay and other GIS operation functions.

3.5 Preparation of VDC level Seamless Cadastral Dataset

A ward level and subsequently VDC level seamless cadastral datasets of vector cadastral layer was prepared by spatial analysis process of merging of different geo-reference cadastral map sheets in GIS environment. An error of overlapping and gap between individual cadastral map sheets was noticed during the spatial merging process; however those errors were eliminated with building topology within the permissible limit of threshold already assigned. In extreme cases as already explained such gaps or overlaps were assigned at the margin of free sheets falling in river or other unsurveyed areas.

3.6 Superimpose of VDC Level Seamless Cadastral Dataset on Land Use Zoning Map

Spatial Analysis of land use zoning map and cadastral dataset was carried out by overlaying VDC level land use zoning map on cadastral datasets of the same area and level using spatial analysis function in GIS environment. This was possible since all datasets were on the same geo-reference frame. During overlay process, caution was taken to maintain different topology functions viz.

- Topology function must not overlap
- Topology function must not intersect
- Topology function must not contained

3.7 Linking Attribute of Land Use Zoning and Present Land Use with Cadastral Parcel

Land use zoning map is linked with seamless cadastral datasets by the process of querying in the attribute table of VDC level cadastral datasets and land use zoning class datasets. Geographic objects in a vector map were linked to one or more tables. A link defines driver database to be used. Each parcel category number in a geometry file corresponds to a row in the attribute table. The practical use of this system is that it allows placement of thematically distinct but topologically related objects on a single map. Further, the table can be linked to subsequent layers.

Chapter - 4
CHARACTERISTICS OF THE SUPERIMPOSE OF CADASTRAL PARCEL

Some analysis of the superimposition of cadastral maps over the present land use and the land use zoning map is provided here. Some details on the suitable conversion upon comparison of zoning map with the present land use with respected to surveyed cadastral plans are as well provided.

The Cadastral Survey in Rupandehi district was carried out during 2021 B.S. Due to lack of a land use zoning regulations the parcel size and use have undergone random conversions over the years. Similarly due to the lack of strict regularizations on maintenance of public and government land some changes have undergone in their uses as well. Accuracy of the original plane table survey should as well be considered while assessing on the figures on the database, however this will have limited implications on the scale of the map 1:10,000.

At the time of digitization, the VDC had 9657 land parcels and area covered in the survey was 1279.69 ha.

4.1 Cadastral Parcel Superimpose on Present Land Use

Table 4.1 shows the present characteristics of cadastral parcels that falls in the VDC under study.

Table 4.1: Parcel Characteristics of Present Land Use

Present Land Use Class	Area(sq.m.)	Area(ha.)	Parcel Count	Area (%)
Agricultural	9078298.94	907.83	6792	70.94
Commercial	103752.75	10.38	43	0.81
Cultural and Archeological	7632.53	0.76	15	0.06
Forest	79413.55	7.94	25	0.62
Industrial	107327.67	10.73	30	0.84
Public Use	215194.17	21.52	180	1.68
Residential	1442671.91	144.27	1503	11.27
Riverine and lake area	1762599.01	176.26	1069	13.77
Grand Total	**12796890.53**	**1279.69**	**9657**	**100**

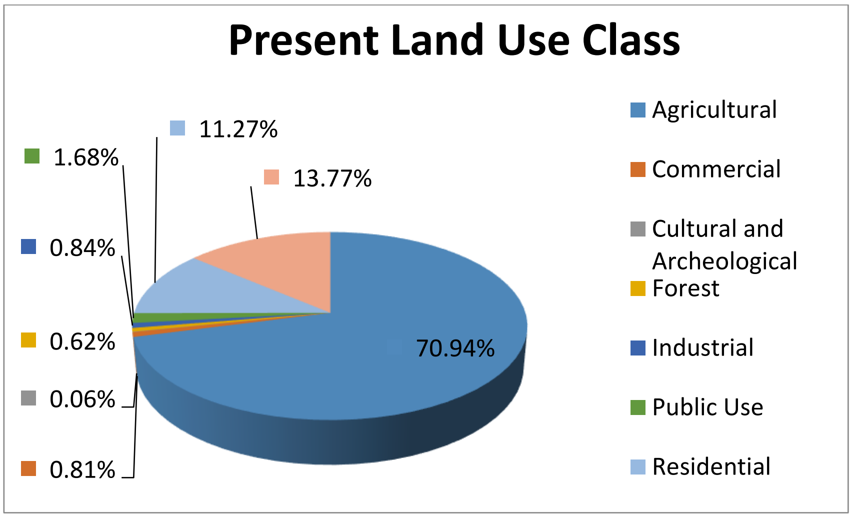


Figure 4.1 Distribution of Parcels over Present Land Use (%)

4.2 Cadastral Parcel Superimpose on Land Use Zoning

Table 4.2 shows the characteristics of cadastral parcels superimposition on Land Use Zoning for the VDC under study of Rupandehi district of Nepal. In the cadastral area of the VDC, out of the designated 11 classes, zoning for all eight classes except other specially designated classes were planned. The distribution of parcels over proposed landuse zone is shown on table and chart below.

Table 4.2: Parcel Characteristics of Land Use Zoning

Proposed Land Use Class	Area(sq.m.)	Area(ha.)	Parcel Count	Area (%)
Agricultural	7753192.91	775.32	5933	60.59
Commercial	101793.52	10.18	41	0.80
Cultural and Archeological	7632.53	0.76	15	0.06
Forest	79413.55	7.94	25	0.62
Industrial	63985.66	6.40	18	0.50
Public Use	2105158.90	210.52	1418	16.45
Residential	1169277.08	116.93	1285	9.14
Riverine and lake area	1516436.38	151.64	922	11.85
Grand Total	**12796890.53**	**1279.69**	**9657**	**100**

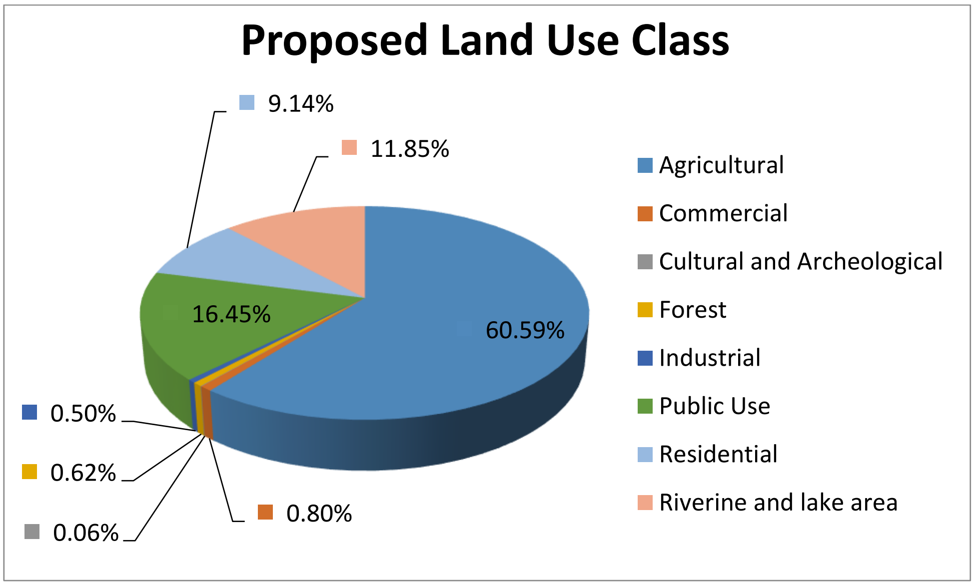


Figure 4.2 Distribution of Parcels over Land Use Zoning (%)

Parcel characteristics: This could be assessed from the superimposition of present land use and proposed land use given in the land use zoning maps. The parcel characteristics could be analyzed with this superimposition. Table 4.3 gives the details.

Table 4.3: Parcel Characteristics of Present Land Use Land Use Zoning Superimposition

Present Land Use / Proposed Land Use	Area(sq.m.)	Area(ha.)	Parcel Count	Area (%)
Agricultural / Agricultural	7712122.69	771.21	5922	60.27
Agricultural / Public Use	1364104.95	136.41	861	10.66
Agricultural / Residential	2071.30	0.21	9	0.02
Commercial / Commercial	101793.52	10.18	41	0.80
Commercial / Public Use	1959.23	0.20	2	0.02
Cultural and Archeological / Cultural and Archeological	7632.53	0.76	15	0.06
Forest / Forest	79413.55	7.94	25	0.62
Industrial / Agricultural	41070.22	4.11	11	0.32
Industrial / Industrial	63985.66	6.40	18	0.50
Industrial / Public Use	2271.79	0.23	1	0.02
Public Use / Public Use	215194.17	21.52	180	1.68
Residential / Public Use	275466.13	27.55	227	2.15
Residential / Residential	1167205.78	116.72	1276	9.12
Riverine and lake area / Public Use	246162.63	24.62	147	1.92
Riverine and lake area / Riverine and lake area	1516436.38	151.64	922	11.85
Grand Total	**12796890.53**	**1279.69**	**9657**	**100**

Note: Conversion from Forest to Agriculture or Public use or Residential is due to unavoidable geometrical inconsistencies and therefore requested to be read as negligible and ignored.

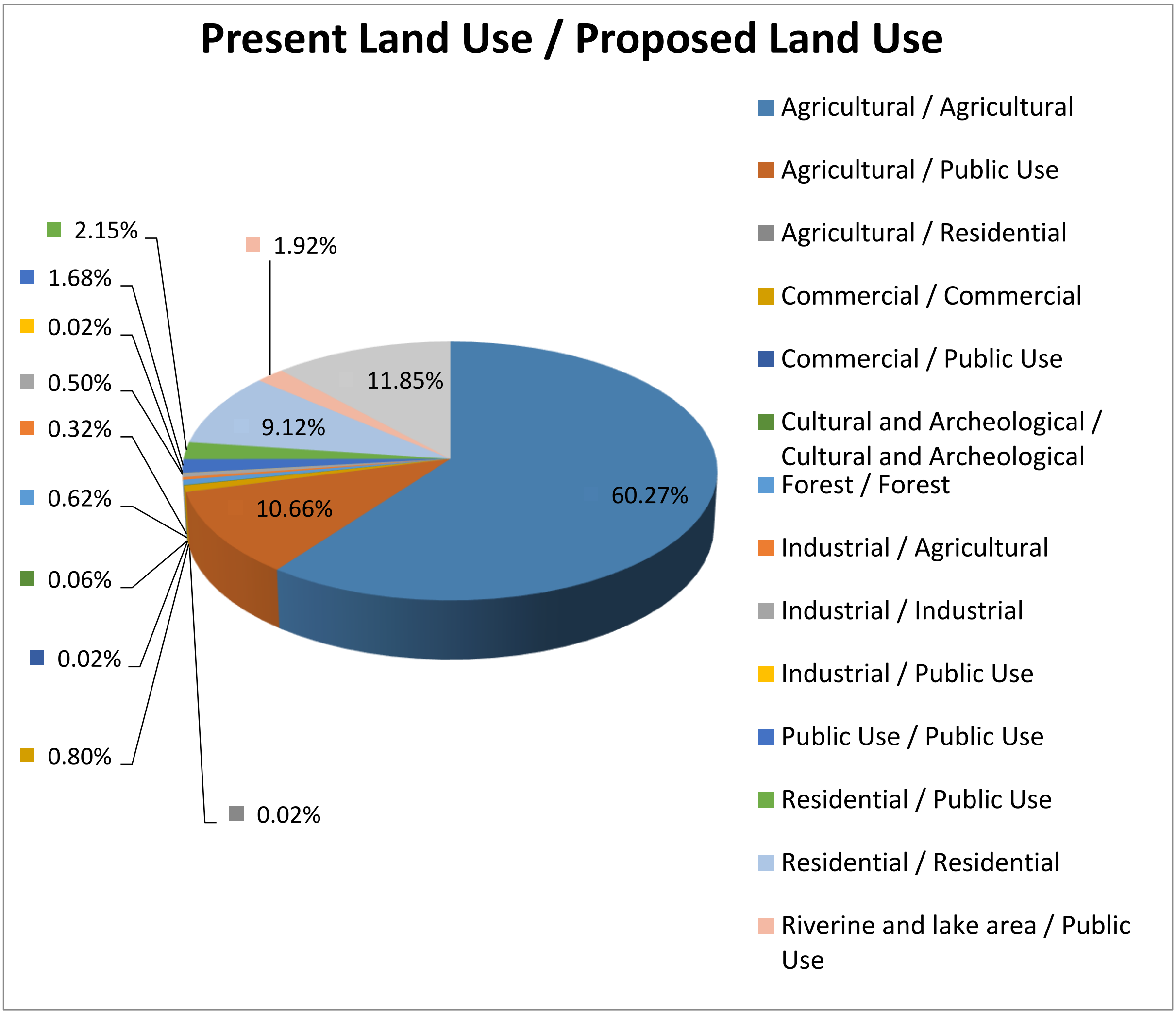


Figure 4.3 Parcel of Present Land Use versus Proposed Land Use (%)

Chapter - 5

CONCLUSIONS

5.1 Conclusions

Land use planning and management is a distinctive cross-sectorial issue, as many stakeholders are involved. Therefore, single measures have very little impact in reducing demand for land. To reach a sustainable level of land use, a wide variety of instruments, including fiscal, economic, regulatory and planning tools, must be used in combination. Furthermore, the activities, strategies and instruments must involve the relevant stakeholders, such as representatives from the administration (national, regional and local level) and the different disciplines (regional versus urban planning, nature conservation and environment protection, economy and traffic) in order to efficiently achieve a sustainable level of land use. Even more important would be the involvement of the local bodies, the local people and the local user groups, which has been very much emphasized in the National Land Use Policy 2072, and its implementation directives, 2072.

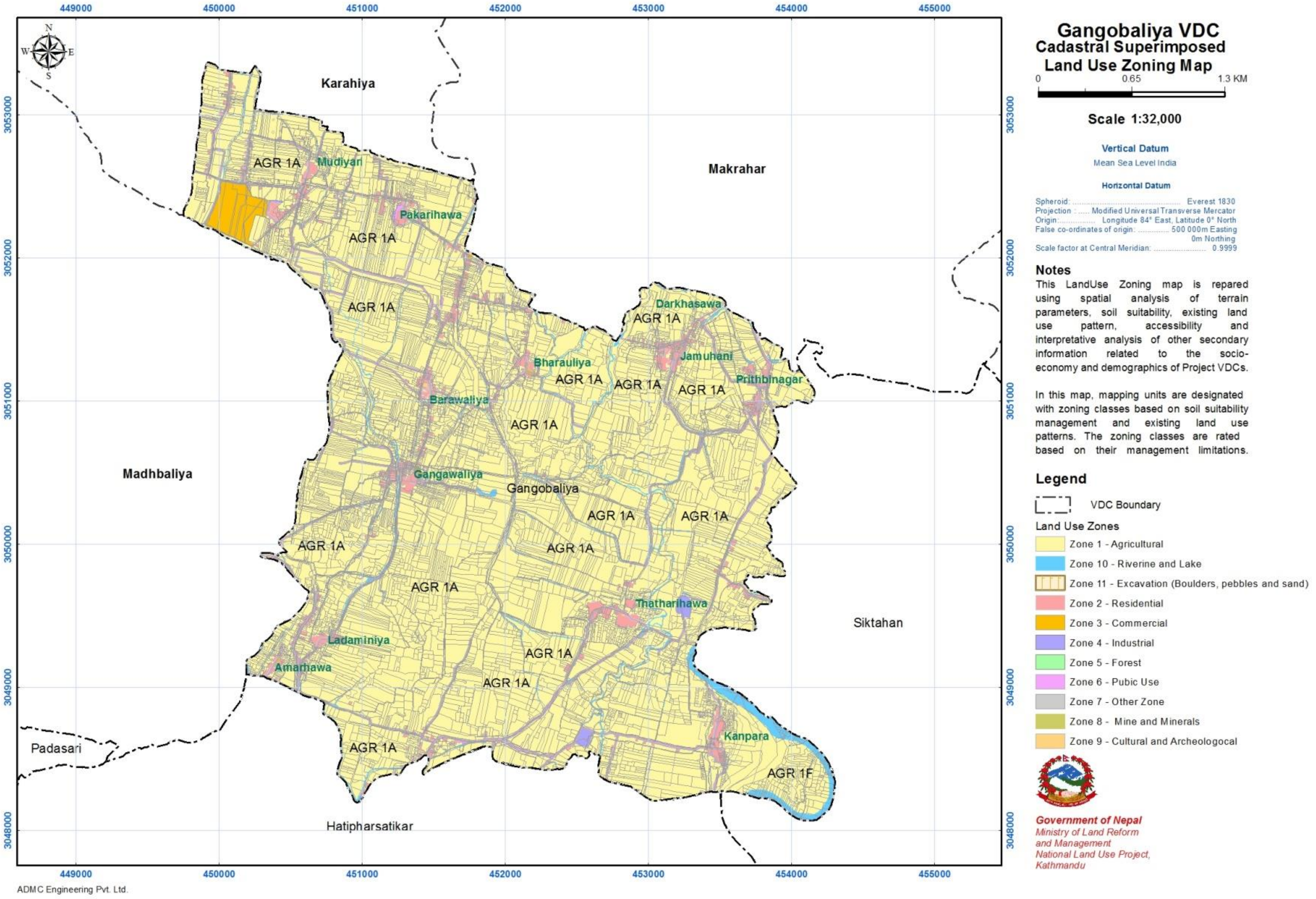
The present exercise is fruitful and it produced required maps, data base and reports on the theme, which will be fundamental technical reference for implementing land use plan at the local level. Such a database will certainly help the concerned authorities to think of the ongoing practices on the lands, the finite resources of the country. It will further help to develop plan for the local areas and implement accordingly. In this sense, the exercise can be regarded as milestone for the planners and authorities working within the area.

5.2 Recommendations

The study team has observed that the digital cadastral databases provided by through NLUP are not adequately accurate as seen from the differences in consistency rendered by the variation of map scales. During field work, ortho-rectification and geo-referencing few under and overlapping and mismatch with the ground reality could be seen. Therefore it is recommended that the parcel wise data could be used for reference only and boundary adjudication of proposed land use zoning should be implemented cautiously.

It is highly recommended that the land use zoning implementation on the ground has to be confirmed through local consultation, for which these technical maps and data should be used as important reference.

Appendix 1: Cadastral Superimpose Map of Gangobaliya VDC



H. Profile of the VDC

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CHAPTER -1

GANGOBALIYA VDC - AN OVERVIEW

1.1 Context/Naming and Origin

The word *"Gangobaliya"* is derived from the source of water located at ward no 4. The spring water was very fresh like the water of the Ganga and everybody started saying Ganga water and the VDC got it named after it.

1.2 Location

Gangobaliya VDC is located at the central western part of the district. The Gangoliya VDC is covered by Sikatahan in the East, Madhbaliya in the West, Makrahar in the North and HatiPharsatikar in the South. The rectangular extent of the VDC is 83°29'27" E to 83°32'8"E and 27°33'1"N to 27°35'51"N. Total area 12.86 sq.km. The total population of this VDC is 6966, of which male population accounts for 49.14 percent and female population is 50.86 percent (VDC profile, 2011). However, all the wards vary in area and population size. Total number of household in the VDC is 1172.

1.3 Settlements and Administrative Units

All the VDCs in Nepal are divided into nine wards. It is the provision of local government in Nepal. Ward is considered as the smallest administrative unit in the local level. More than one small villages and settlements are included under one ward in the context of mountain and hill. But there may be more than one ward in one settlement particularly in the case of Terai.

Table 1.1: Settlements and Administrative Units

Number of households and population by Settlements and Wards							
Ward	Settlements/Toles	No. of HHs	%	Male	Female	Total	%
1	Mudiyari, Darkhasahawa	180	15.4	520	562	1082	15.5
2	Piparhiya, Aarihawa, Nayatol	144	12.3	411	420	831	11.9
3	Barauliya, Dando, Pandihawa	209	17.8	464	557	1021	14.7
4	Gangobaliya	95	8.1	249	242	491	7.0
5	Jamuhanitol, Darwarhawa	161	13.7	540	501	1041	14.9
6	Maraulia, Maraulia danda	126	10.8	336	346	682	9.8
7	Kanpara	65	5.5	230	209	439	6.3
8	Kanpara thaiya	88	7.5	294	342	636	9.1
9	Thatiya	104	8.9	379	364	743	10.7
	Total	**1172**	**100.0**	**3423**	**3543**	**6966**	**100.0**

There are sixteen small and large settlements in Gangobaliya VDC. Those settlements have encompassed nine wards of the VDC. Ward no three has three settlements with 209 households but in terms of population and household ward number one is the biggest as there are 180 households and 1082 population followed by ward no five with 161 households and 1041 population.

Likewise, in terms of the number of households and population, ward number 7 is the smallest one. In this ward there is one major settlement with 65 households and 439 populations.

The house type indicates the economic status of the local people. House type are represented by roof types, type of water wall and foundation of house. It is good that about 70 percent house are with RCC roof followed by 14 percent tile roof and thatch with 5 percent. In terms of outer wall, about 62 houses have cement bounded brick followed by 19 percent with mud bounded brick. About 8 percent houses have bamboo wall. Rapid changes in house types have taken place mainly due to income from labor migration as they give first priority to construct house.

Table 1.2: House Types

House by roof types and outer wall						
SN	Roof Types	Household	%	Wall Types	Household	%
1	Thatch/Straw	63	5.4	Mud Bonded Bricks/Stone	225	19.2
2	Galvanized Iron	105	9.0	Cement Bonded Brick/Stone	731	62.4
3	Tile/Slate	159	13.6	Wood/Plank	2	0.2
4	RCC	822	70.1	Bamboo	93	7.9
5	Wood/Planks	1	0.1	Unbaked Brick	12	1.0
6	Wood/Planks	0	0.0	Other	99	8.4
7	Others	12	1.0	Not Stated	10	0.9
8	Not stated	10	0.9			
Total		**1172**	**100.0**	**Total**	**1172**	**100.0**

Improvement has also appeared on house foundation as about 37 percent houses are with cement bounded brick foundation. About 32 percent houses have mud bonded foundation. Thirteen percent houses have RCC with pillar followed by wooden pillar by 10 percent house.

House by Type of Foundation			
SN	Types	Household	Percent
1	Mud Bonded Bricks/Stone	373	31.8
2	Cement Bonded Brick/Stone	431	36.8
3	RCC With Pillar	152	13.0
4	Wooden Pillar	117	10.0
5	Other	89	7.6
6	Not Stated	10	0.9
	Total	**1172**	**100.0**

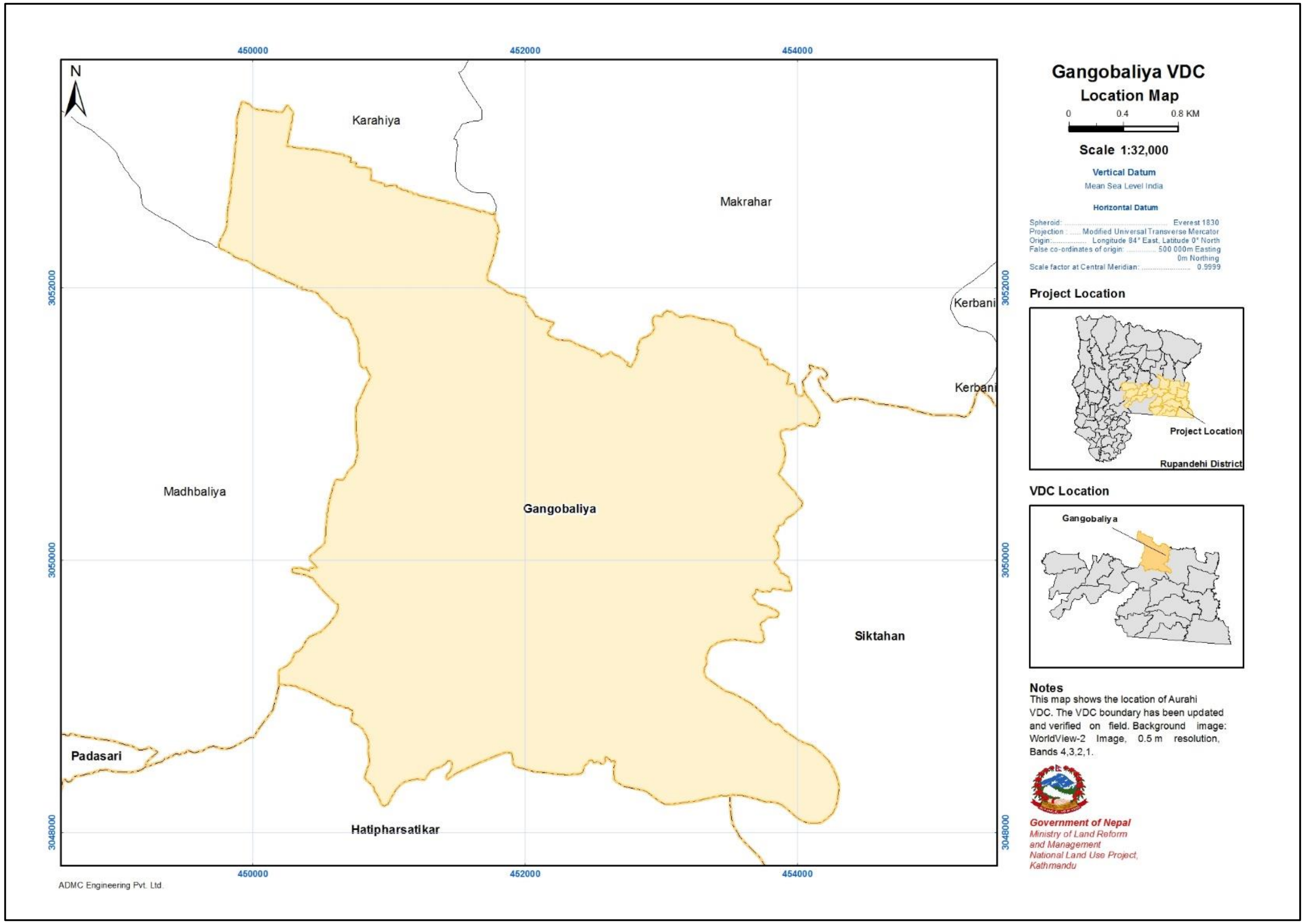


Figure 1.1: Location of Gangobaliya VDC

CHAPTER 2

PHYSICAL SETTING

2.1 Physiographic region

The study area falls within the Terai physiographic region which spans over Western part of Nepal.

2.2 Geomorphology

Most of study area falls in the Terai Plain (fluvio – alluvial sediments deposited by the inflowing streams into the plain and is consisting of the Quaternary sediments deposited by them). The land is mostly flat with slopes 0^0 to 14.554^0 and covering the portion of VDC by less than 15^0 Slope. Most of the land are cultivated with diverse crops and fruit trees.

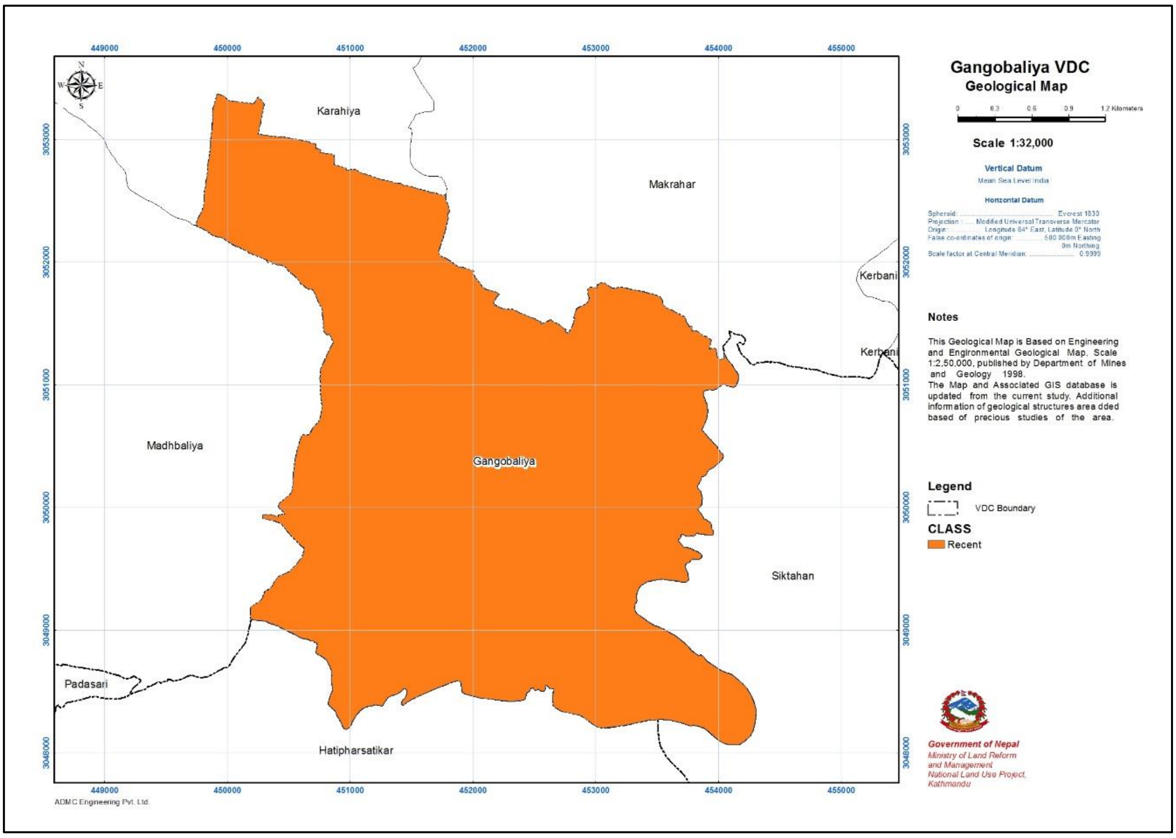


Figure 2.1: Geological Map of Project Area with VDC Boundary

2.3 Geology of Gangobaliya VDC

Mainly **Quaternary alluvial sedimentary deposits** (a section of the northern part of Indo - Gangetic alluvial deposits) represent the materials. Bedrock geology cannot be found here. Only the gravels of sandstone, mudstone with silty clay, sand, silt and gravels from Siwaliks found along the stream beds. Alluvium in Terai is predominantly loamy textured, slightly acidic and stone free.

Quaternary Deposits represent the Sub – Recent to Recent sediments deposited by the fluvial action. They are divisible into two types in an ascending order**: Alluvium Deposits** and **Flood Plain Deposits**.

Alluvium Deposits: This is distributed on both sides of the rivers and streams with low gradient and open valley. They are characterized by river terrace deposits and are of unsorted, rounded to sub rounded pebbly and gravely materials mixed together with fine sand, silt as well as clay giving rise to the development of the fertile top fine soil usable for the cultivation. Active Alluvial Fan is locally deposited debris as fan derived from landslides and brought down by tributaries to the main streams.

Flood Plain Deposits (River Bed Deposit): It occurs along the riversides and on the flood plain (present river channel) itself which also contain the water during the winter season and cover the area as high as the water level rises during the heavy rainy season. In other words this is the area that is covered by the flooding river and left barren during the dry season after depositing the various materials carried at flood time. It has alluvial loose sediments consisting of boulders, cobbles, pebbles, coarse sand and gravels mainly of sandstone, siltstone and claystone with silt. When mixed with clay it gives rise to the fertile top fine soil usable for the cultivation. The aggregates thus derived and deposited by the river often provide an excellent source of building and construction materials (Figures 1, 2,3 and 4 below).
During monsoon (rainy season), the water in the rivers, streams, kholas and nalas increases and runs above the river bed flooding the surrounding areas. The river bank scouring, side cutting and erosion is common feature often seen in these river systems. Side cutting causes the gully erosion developing badland topography. In addition, inundation and flooding of relatively low – lying areas are commonly found in nearby areas of main rivers.
Blocking of water by the roads creates marshy land. Water when gets collected in marshy lands for a longer period of time increases the moisture content of the soil and thereby lowers its bearing capacity and thereby develops in to permanent water logged lands creating havoc to the nearby urban settlements.

Flood Prone Areas: These are the low lands adjacent to the rivers and streams flowing in the area and are likely to be affected by floods. Hence, these lands are not suitable for human settlements but can be utilized for agriculture purposes. A risk of flash flood can always be a threat in these areas in the downstream in the future.

Earthquake (Seismicity) and Liquefaction: Nepal has experienced several quakes of intensity 7 or more (in Richter scale) since 1833. Most of the time epicenters are found to confine or concentrate mainly in the Middle Mountains, that is, between north of Main Boundary Thrust (MBT) and further to its north the Main Central Thrust (MCT). Normally earthquake commonly triggers landslides in the mountain region while in the flat land area liquefaction; subsidence as well as cracking effects are possible.

Liquefaction: Liquefaction is the tendency to lose shear strength of saturated soil layers under the stress of earthquake motion. Liquefaction mostly occurs in the saturated soil layers composed of coarse silt to fine sand particles. The liquefaction potential of the soil strata decreases as the particle size of constituting materials and the depth increases. Also in the soil layers that are composed of fine materials like fine silt and clay size particles the liquefaction effect will be less likely to occur.

Bearing Capacity: The bearing capacity of soil layers depends on the degree of its compaction or relative density. Higher the value of relative density greater will be its bearing capacity. Generally, the loose and soft top soil layers have low bearing capacity. The allowable bearing pressure of the structure built on such strata will be very low. In such areas deep foundation or the ground improvement works should be carried out to build heavy structures. In the flat ground (areas) the bearing capacity might be different and higher than in the slopes.

Natural Resources: Surface as well as ground water, non – metallic minerals like river aggregates (sand, gravel, and pebbles) as well as natural forests are the prominent natural resources one can count in the area. The seasonal stream beds have enormous deposits of pebbles, gravels and sand as a good source of construction materials in the area. Proper management of these resources for optimum utilization for the livelihood of people is necessary.

Nepal Government has been carrying out petroleum exploration works in the south of Siwaliks (Terai) since last more than thirty years and is awaiting to do the drilling works under Petroleum Exploration Promotion Project (PEPP) at Department of Mines and Geology (DMG).

2.4 Drainage/Hydrology

The VDC is endowed with rivers among which major river is Tinau Khola. The small streams are present in the VDC which remains dry during dry season and generally originate after the onset of monsoon.

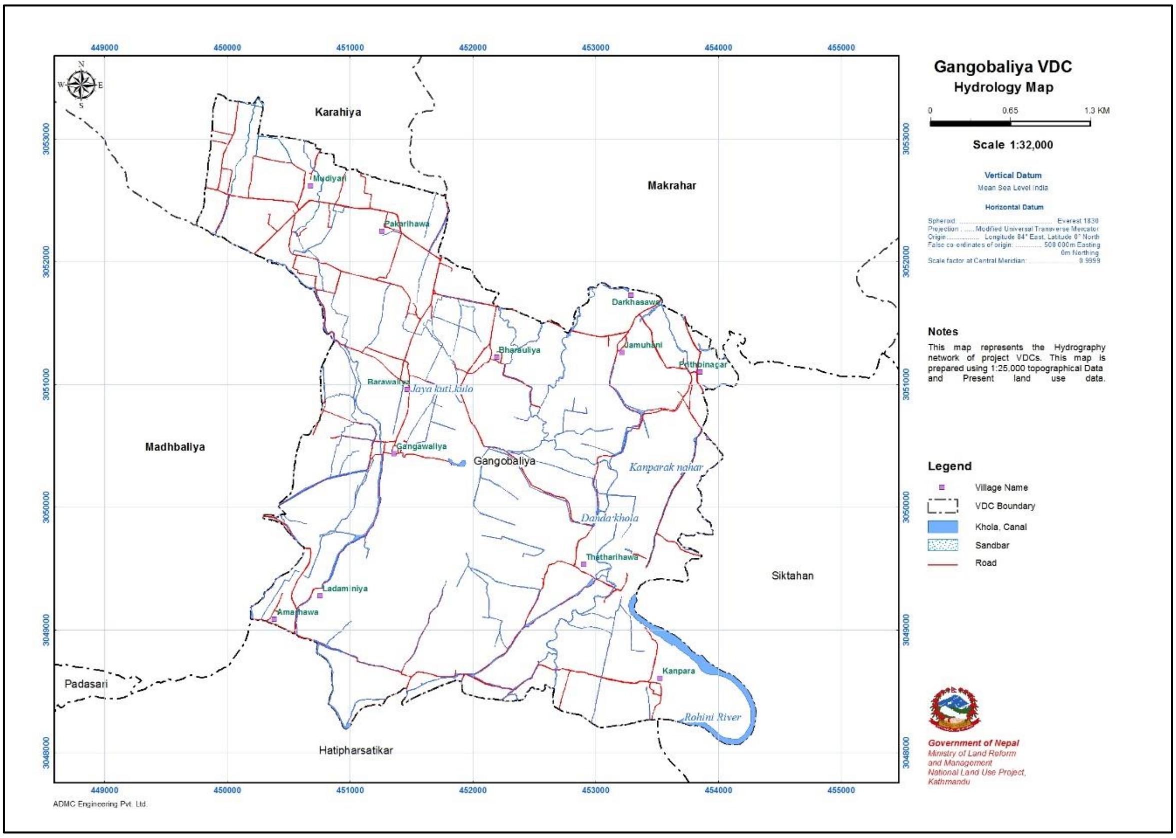


Figure 2.2: Hydrology Map of Gangobaliya VDC

2.5 Terrain

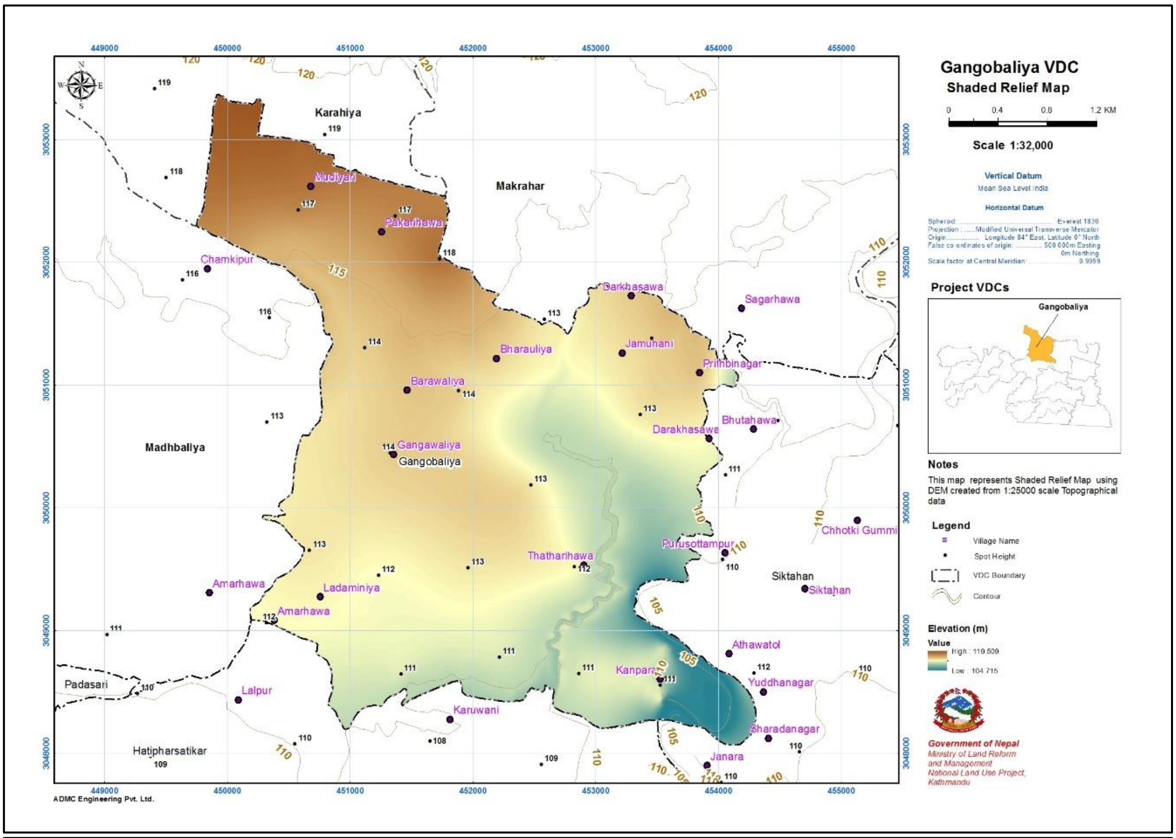
Terrain is the vertical and horizontal dimensions of land surface. It determines the drainage pattern, depth and profiles of soil, land use pattern and susceptibility of land surface to denudation and natural hazards. The Slope of this Gangobaliya VDC ranges from 0^0 to 14.554^0 and covering the portion of VDC by less than 15^0 Slope.

2.5.1 Elevation

The elevation is an important topographic element affecting the soil formation. Elevation influences the soil formation by affecting the type of vegetation and soil type along with the climatic factors. The Elevation of the Gangobaliya VDC ranges from 104.715 m. to 119.509 m.

2.5.2 Slope

Slope is influences the soil formation controlling soil erosion and water movement in the soil along with the other soil forming factors and affecting the soil characteristics. The Slope of this Gangobaliya VDC ranges from 0^0 to 14.554^0 and covering the portion of VDC by less than 15^0 Slope.



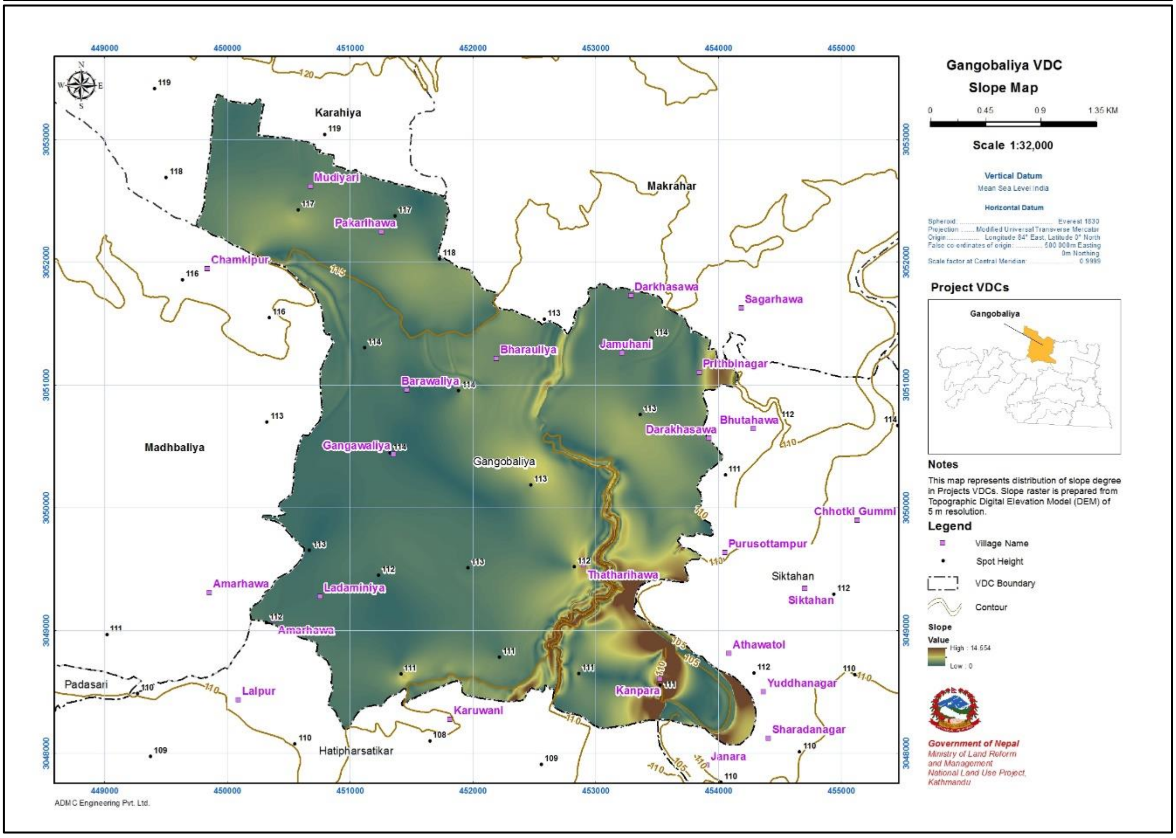


Figure 2.3: Elevation and Slope Distribution Map of Gangobaliya VDC

2.6 Climate

The climatic condition of this VDC is as usual as of other Terai Districts, i.e. subtropical monsoon type. The VDC is represented by meteorological station at Bhairahawa Airport. According to Bhairahawa Airport station, the mean yearly minimum temperature is lowest (8.55^{0}C) in the month of January and it slowly rises from the month of February and attains highest (26.17 ^{0}C) in the month of July. Similarly, the mean yearly maximum temperature is lowest (20.52 °C) in the month of January and maximum recorded temperature is 37.05 °C in Bhairahawa Airport. Table 2.1 shows the Yearly Mean Minimum Temperature and Yearly Mean Maximum Temperature in ^{0}C at Bhairahawa Station (1995-2015).

Table 2.2 shows the Yearly Mean Rainfall at Bhairahawa Airport, Rupandehi station. It is seen that the rainfall is intensified within four months i.e. June to September, of the year. Highest rainfall (584.84 mm) is obtained in the month July and lowest rainfall is in November.

Table 2.1: Yearly Mean Minimum Temperature in ^{0}C at Bhairahawa Station (1995-2015)

Temperature of Bhairahawa Airport, Rupandehi (1995-2015)												
Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Average	14.54	18.09	22.78	27.84	30.25	30.72	29.88	29.82	29.16	26.64	22.16	17.11
Max (avg.)	20.52	25.55	31.40	36.34	37.05	35.79	33.60	33.61	33.43	32.59	29.36	23.87
Min (avg.)	8.55	10.63	14.16	19.34	23.45	25.66	26.17	26.03	24.89	20.70	14.96	10.35

Source: Department of Hydrology and Meteorology

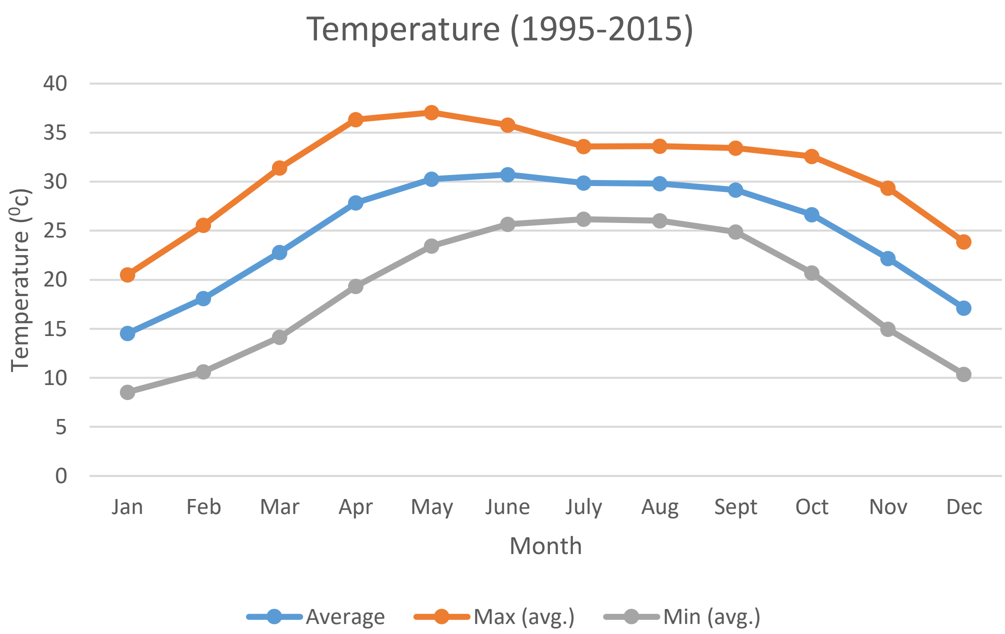


Figure 2.4: Yearly Mean Temperature at Bhairahawa Airport Station (1995-2015)

Table 2.2: Yearly Mean Rainfall (in mm) at, Bhairahawa Airport, Rupandehi (1995-2015)

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Rainfall (mm.)	18.9	25.3	17.17	26.74	98.5	285.85	584.4	441.7	221.5	73	6.605	9.679

Source: Department of Hydrology and Meteorology

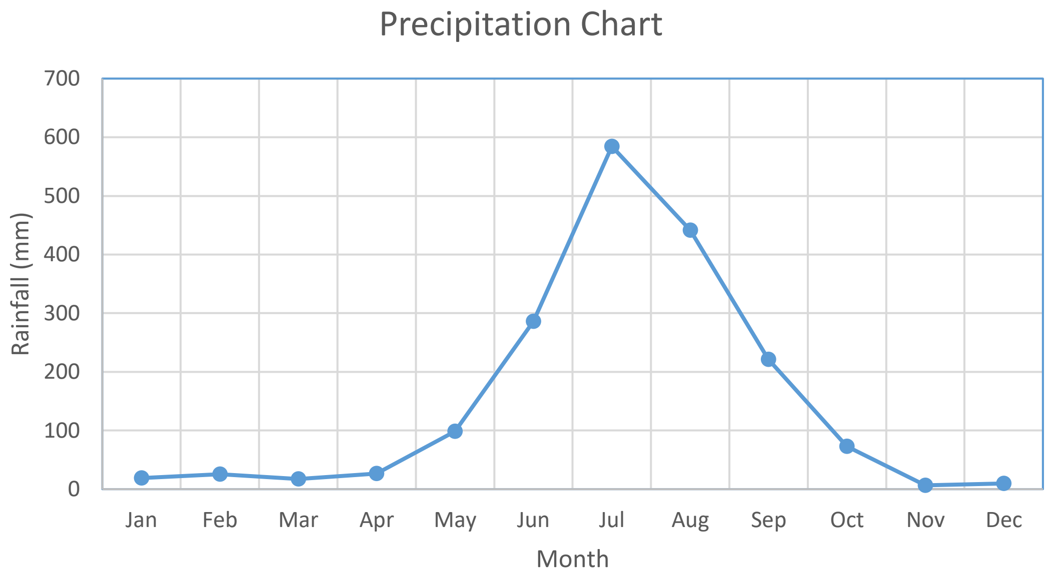


Figure 2.5: Yearly Mean Rainfall at Bhairahawa Airport Station (1995-2015)

Between the months June and September of every year, the highest total rainfall is recorded i.e. 1533.45 mm and the lowest total rainfall of 53.879 mm is recorded between the months of December and February. (Table: 2.3) shows Yearly Mean Seasonal Rainfall (in mm) at, Bhairahawa Airport, Rupandehi (1995-2015)

Table 2.3: Yearly Mean Seasonal Rainfall (in mm) at, Bhairahawa Airport, Rupandehi (1995-2015)

Season	**Duration**	**Total Rainfall**
Winter	Dec-Feb	53.879
Pre-Monsoon	Mar-May	142.41
Monsoon	June-Sept	1533.45
Post-Monsoon	Oct-Nov	79.605

2.7 Forest and Biodiversity

The study area no mixed forest in small area. Bushes and hardwood is found as the dominant species in the region. Orchard mainly Mango trees are in planted in this area.

2.8 Natural Hazards and Environment

In this VDC, flooding and river cutting is seen as a major Natural Hazard. During Monsoon, the level of water rises and the cutting of riverside is seen every year. Apart from that, the area is very safe and majority of the area is used for cultivation and orchard farming.

CHAPTER- 3

SOILS AND LAND CHARACTERISTICS

3.1 Land System and Soil Characteristics

Soil is considered as the integral part of the landscape and their characteristics are largely governed by the landforms in which they are developed. Physiography influences soil formation affecting the climate, vegetation of an area as if it is considered as passive factor of soil formation. Moreover, there is a close relationship between physiography and soil development which ultimately affects the availability of nutrients (Verma et al., 2005). The physiography has influential role in soil formation through slope and exposure. The flat topography has more depth of soil as compared to the steep slopes because the steep slopes are more prone to the erosion (Sehgal, 2002).

Soil properties like profile development, texture, structure, color, acidity, cation exchange capacity, base saturation etc are related to land form. There is a close relationship between physiography and soils. The formation of the diverse group of soils can be attributed to the variation in topography causing erosion, leaching, sedimentation and other pedogenic processes modified by water table (Mini *et al.,* 2006). Thus, physiographic influence of soil properties has been recognized which ultimately leads to evolution of the soil-landscape relationship. Topographic maps, aerial photographs stereo-capability and remote sensing data provide useful tool for geomorphic analysis of the region and help in soil survey and mapping.

The present investigation is based on the physiographic-soil relationship approach assuming the physiographic controlled landform as the basic spatial and structural entities of forming soil mapping units (Table 3.1). Physiography in study area is further divided into land system according to recurrent pattern of landforms, geology and slope and arable agriculture limits and then land units based on map able land surface significantly from some user oriented point of view for delineation (LRMP 1986). Within the land units, land types were delineated based on position, slope, direction, drainage of landscape features which is especially important for local level project design (Carson 1985). The soil properties within the land types further subdivided based on the cropping pattern were determined by detailed field soil survey. These observations were further studied on *Soil Association* for classification. Digital Terrain Model (DTM) is employed for delineation of landform, land units and land types for detailed soil survey at local level planning.

3.1.1 Land System

The project area lies in the Valley physiographic region. It encompasses land system units of 1, 2 and 3 basically differentiated based on geology and geomorphology. Physiography is further subdivided into landforms basically defined by the position of land surface in landscape and it is characterized by slope and its direction, elevation, rock exposure and soil type.

<u>Land form/Type</u>

The user further subdivides landform into land units defined by the mapable size of land surface for demarcation in landscape. In addition, landscape features characterize it. The land units in the project area are shown as below:

- Intermediate position level
- Depressions

- Khola, sandbar and flood plain

Among the land units defined by LRMP Land System, land types are demarcated considering the local situation of land units representing micro-relief differences based on the local slope and elevation and its orientation.

Landform affects soil formation and its profile development in association with the steepness of land and slope direction. The slope classes are required for land type classification.
The soil classes based on their texture are sand, clay and loams with intermediary class such as sandy loam. The texture is the relative proportion of sand, silt and clay particles in the soil. Soil texture of top layer is used for land system classification, soil suitability and classification of soil at family level. The soil textures found in project area are given with symbol in Table 3.1.

Table 3.1: Soil texture and symbol

Texture Classes	Symbol
Clay	Cl1
Clay Loam	Cl2
Loam	Lo1
Loamy Sand	Lo2
Sand	Sa1
Sandy Clay Loam	Sa2
Sandy Loam	Sa3
Silt	Si1
Silty Clay Loam	Si2
Silty Loam	Si3

Description of Individual Land Type Units (Gangobaliya VDC)

The land units defined by LRMP are further subdivided based on local field variation associated with the different land use practices. Altogether four land units identified in the project are associated with the local micro-relief variations. The spatial extent covered by the VDC area is presented in Table 3.2 and distribution of the land units are shown in figure 3.1 and 3.2.

Table 3.2: Land System/ Land type

Region	Land system	Landform	Description	Land Unit	Dominant Slope	Area (ha.)	Total (%)
Terai	1	Active Alluvial Plain (depositional)	1a. present river channel	1a	-	35.87	2.79
	2	Recent Alluvial Plain lower piedmont(depositional and erosional)	2a. depressional	2a	<1/2	388.14	30.19
			2b. intermediate position level	2b	<1/2	769.66	59.86
	3	Alluvial Fan complex, upper piedmont (erosional)	3c.undulating	3c	1 to 3	92.14	7.17

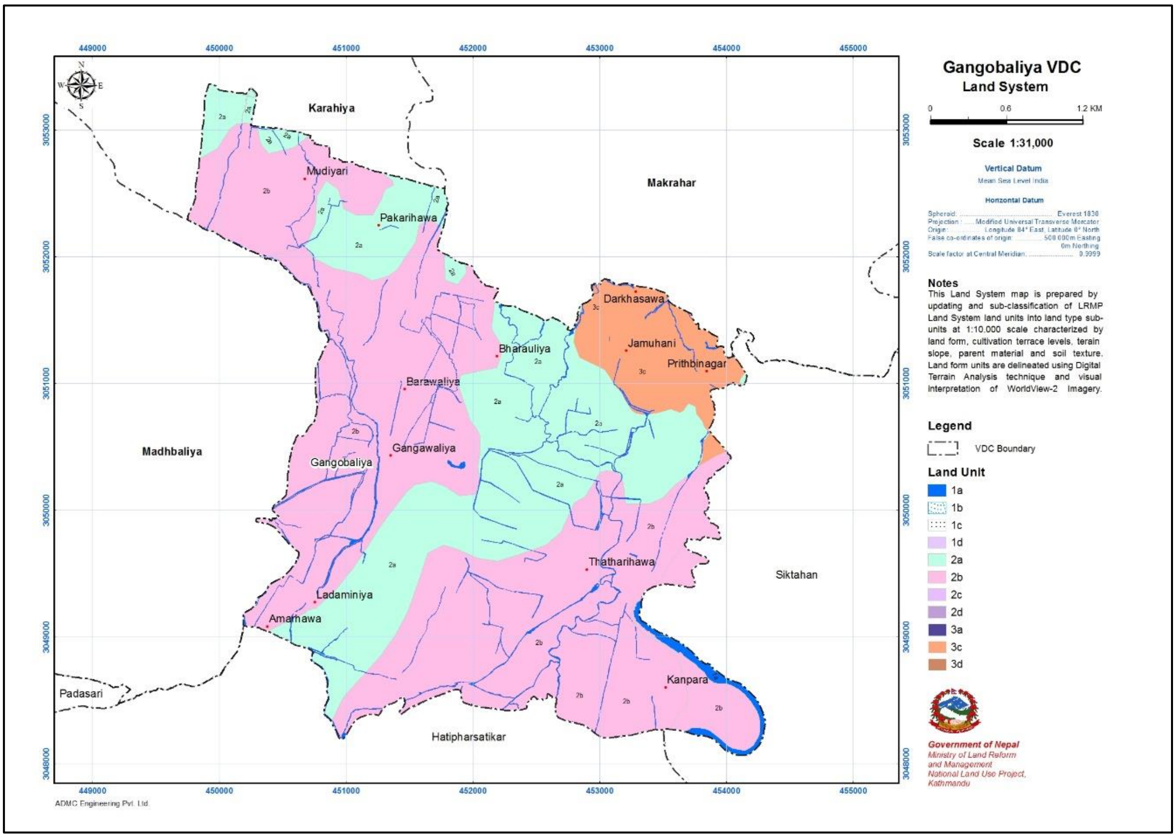


Figure 3.1: Spatial Distribution of Land Units Gangobaliya VDC.

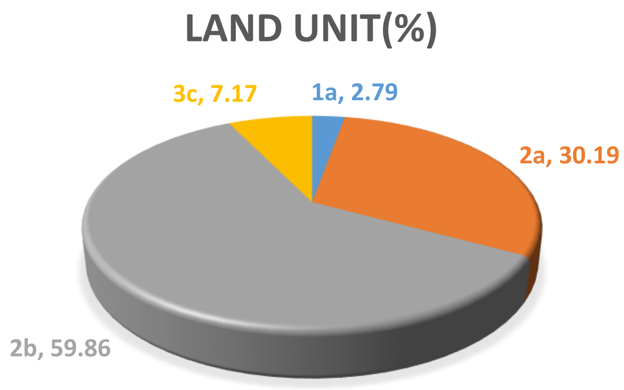


Figure 3.2: Distribution of Land Units

The soils of VDC of Rupandehi District are classified based on the morphological, chemical and physical properties of soil acquired from the soil profile study by digging the soil pit and soil mapping unit level. USDA soil taxonomy system of soil classification was adopted for the classification of soil in which soils are classified into order, sub-order, great group, sub-group, family and series levels. The soil taxonomy classification of Gangobaliya VDC is presented in the Table 3.3 and figure 3.3.

The Gangobaliya VDC has four soil orders, four sub-orders, five great groups and five sub-groups were found from the survey of the soils. The detail descriptions of soil category are explained as below.

Table 3.3: Soil Taxonomy Classification of Gangobaliya VDC

VDC	Order	Sub order	Great group	Sub group	Area (ha.)	Percentage (%)
River					1285.807	5.263
Gangobaliya	Entisol	Fluvents	Ustifluvents	Typic Ustifluvents	1285.807	5.263
	Inceptisol	Ustepts	Dystrustepts	Fluventic Dystrustepts	5143.228	21.053
	Mollisol	Ustolls	Argiustolls	Vertic Argiustolls	1285.807	5.263
	Vertisols	Usterts	Dystrusterts	Typic Dystrusterts	5143.228	21.053
			Haplusterts	Typic Haplusterts	10286.457	42.105
Total					**24430.334**	**100.000**

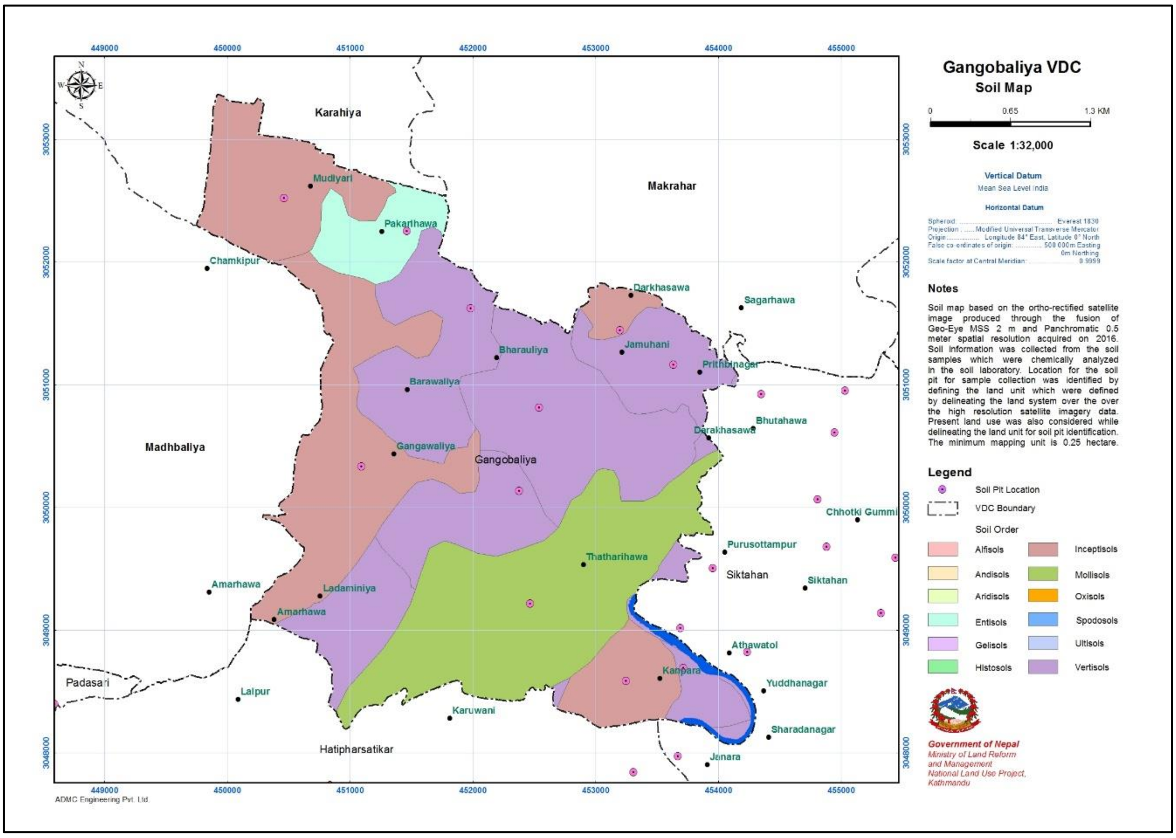


Figure 3.3: Soil Types of Gangobaliya VDC

3.2 Land Capability of Gangobaliya VDC

Land capability classification of the land type units was conducted on the basis of various criteria of soil and other parameters. This chapter presents the result of land capability class coverage in Gangobaliya VDC. The chapter also presents the summary of each type of management limitations as represented by the capability sub-class and units.

Land Capability of Gangobaliya VDC was conducted on the basis of the soil properties, terrain slope, erosion and drainage characteristics. The land capability class distribution in the VDC is presented in the Table 3.4 and Figure 3.5 and spatial distribution of land capability class of the VDC is shown in the map figure 3.6. Majority of land (83.08%)

consists of land capability Class I AU/1R, 15.14% land has I Au /1 class and 1.78% of land is II Ah/5sd Class. These classes are suitable for diversified crops and potential for arable agriculture with minor limitations and requiring low management inputs.

Table 3.4: Land Capability Classes of Gangobaliya VDC

Capability Class	Area (Sq.m)	Area(Ha.)	percent	Description
Class IAU/1	1746806.462	174.6806462	15.14%	Lands with very few or no physical limitations to use of agriculture purpose, sub-humid, arable agriculture, diversified crops
Class IAU/1R	9584732.209	958.4732209	83.08%	Lands with very few or no physical limitations to use of agriculture purpose, sub-humid, wetland rice arable agriculture
Class II Ah/5sd	204827.5155	20.48275155	1.78%	Land with few physical limitations to use for agricultural purpose, humid moisture regime with soil deficiency

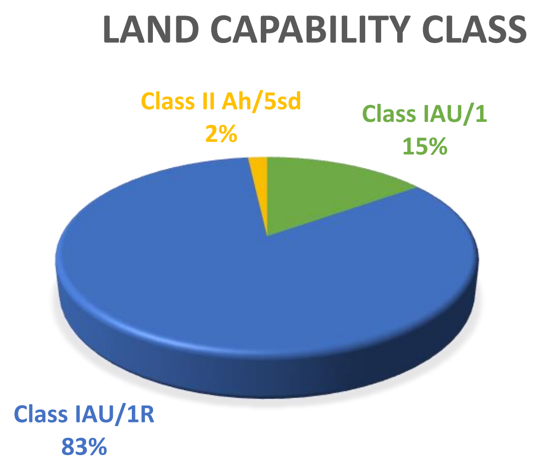


Figure 3.4: Distribution of Land Capability Classes

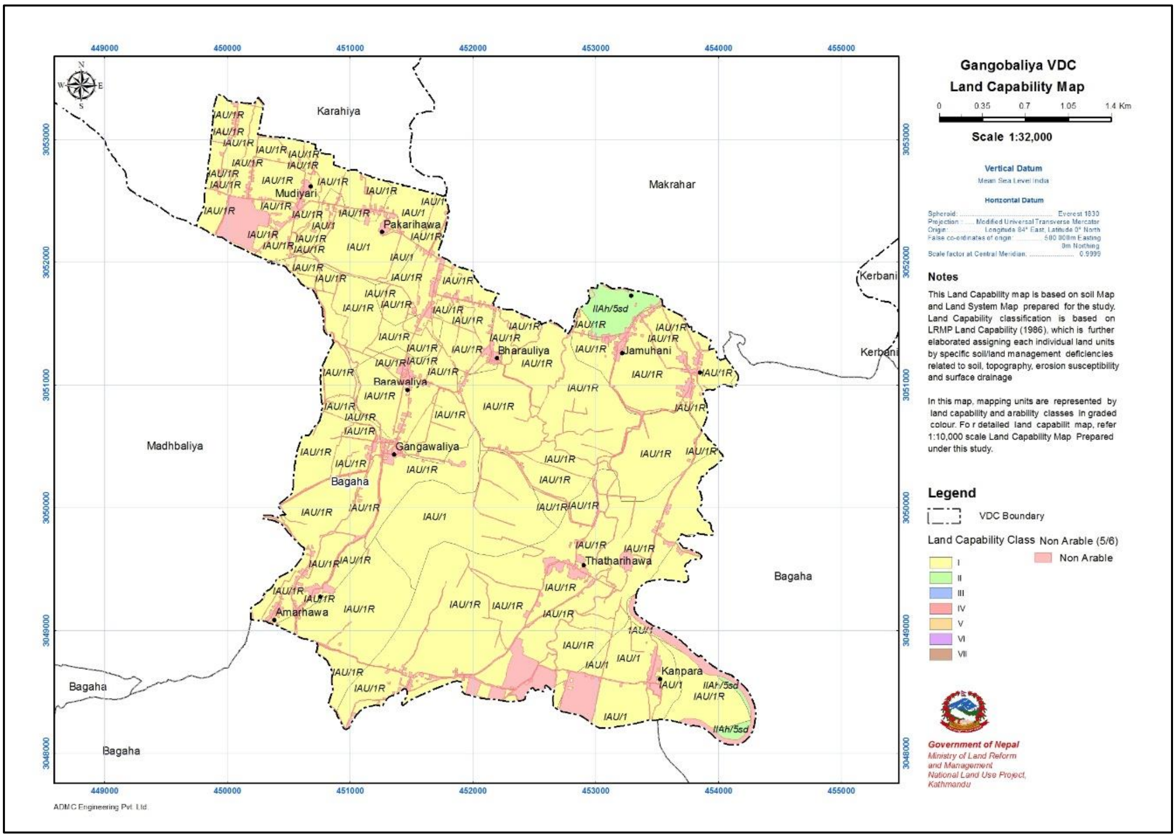


Figure 3.5: Spatial Distribution of Land Capability Classes of Gangobaliya VDC

3.3 Present Land Use

The majority the land (89.71%) is used for the agriculture purpose. The remaining area of land is used for commercial, forest, public use, residential, industrial, cultural and archeological, riverine and lake area. The small patches of private forest are seen in the area.

Table 3.5: Present Land Use in Gangobaliya VDC

S. No.	Landuse Class	Area(sqm)	Area(ha)	Percentage
1	AGRICULTURAL	11534919.57	1153.49	89.71
2	RESIDENTIAL	397946.50	39.79	3.09
3	RIVERINE AND LAKE AREA	357979.69	35.80	2.78
4	INDUSTRIAL	238648.60	23.86	1.86
5	PUBLIC USE	199140.86	19.91	1.55
6	COMMERCIAL	125187.33	12.52	0.97
7	CULTURAL AND ARCHEOLOGICAL	2801.58	0.28	0.02
8	FOREST	1446.63	0.14	0.01
	Grand Total	**12858070.75**	**1285.81**	**100.00**

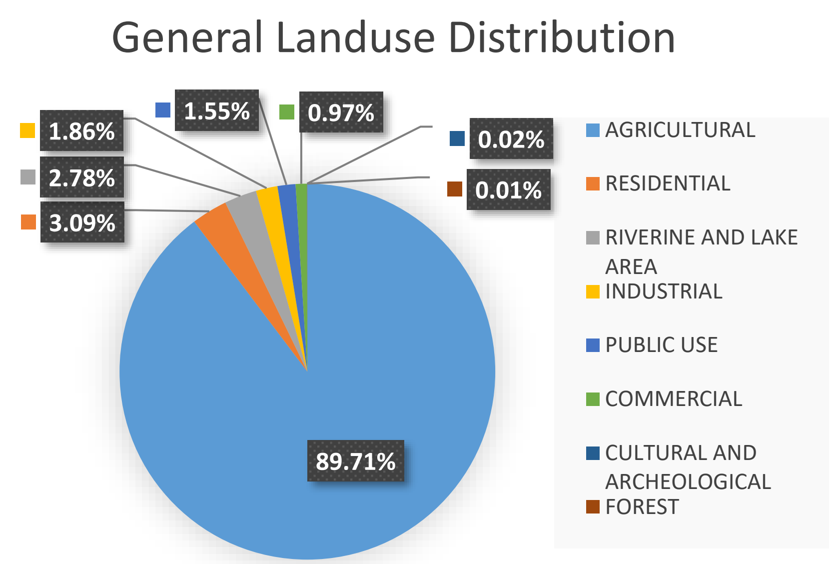


Figure 3.6: Land Use Distribution in Gangobaliya VDC

3.4 Agricultural Pattern

Agricultural Land Use: Almost all agricultural land of the Gangobaliya VDC is classified as Terai cultivation based on the physiographic region.

Agriculture level 3 is further divided into wet land cultivation, mixed land cultivation and Dry Land Cultivation. About 95.19% of level 3 of agriculture are on Mixed land cultivation category.

Table 3.6: Agriculture land use level 3

S. No.	Agricultural Landuse (level 3)	Area(sqm)	Area(ha)	Percentage
1	Mixed Land Cultivation-X	10980446.92	1098.04	95.19
2	Dry Land Cultivation-D	442000.96	44.20	3.83
3	Wet Land Cultivation-W	112471.69	11.25	0.98
	Grand Total	**11534919.57**	**1153.49**	**100.00**

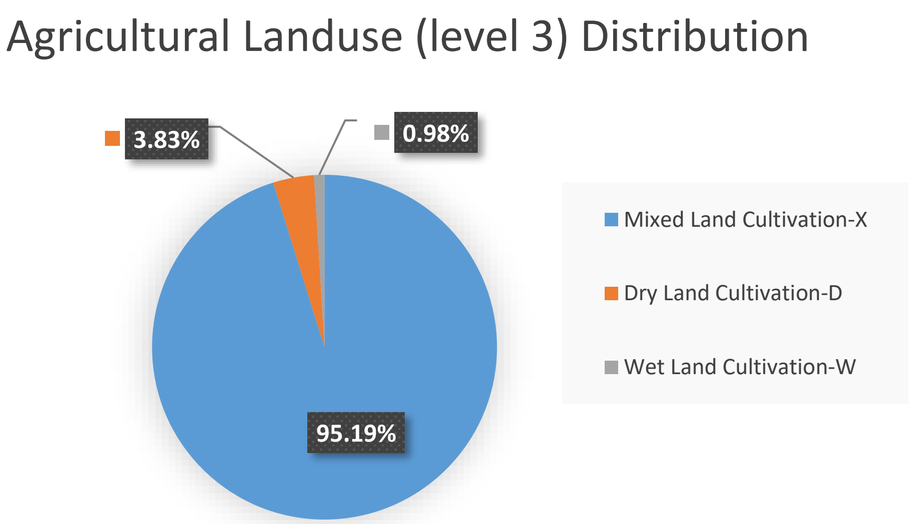


Figure 3.7: Agriculture land use level 3

Table 3.7: Agriculture land use level 4

S.No.	Agricultural Landuse (level 4)	Area(sqm)	Area(ha)	Percentage
1	Unclassified-000	11422447.88	1142.24	99.02
2	Upper Khet Land Cultivation-TariKhet-Uk	112471.69	11.25	0.98
	Grand Total	**11534919.57**	**1153.49**	**100.00**

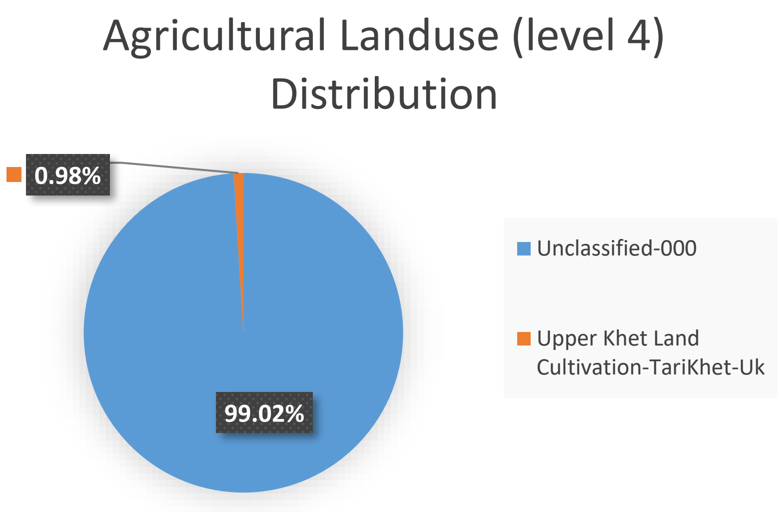


Figure 3.8: Agriculture land use level 4

The cropping pattern of the VDC varies according to agricultural land types, irrigation and precipitation. The wetland cultivation comprises of crops such as rice, wheat, maize, fruits, oilseeds, pulses, pond for fish farming and vegetables. Rice is the dominant summer crop. The table below presents the cropping pattern of the Gangobaliya VDC.

Table 3.8: Cropping pattern

S. No.	Cropping Pattern	Area(sqm)	Area(ha)	Percentage
1	Rice-Wheat-r2	10000906.01	1000.09	86.70
2	Rice-Others-r13	548131.30	54.81	4.75
3	Rice-Rice- Vegetable-r6	406367.76	40.64	3.52
4	Fruit-Others-f3	358904.42	35.89	3.11
5	Pond for Fish farming-p3	127101.98	12.71	1.10
6	Barren Cultivable land-b5	67951.47	6.80	0.59
7	Fruit-Fruit-f1	16602.64	1.66	0.14
8	Fruits-f4	8711.34	0.87	0.08
9	Vegetables-Vegetable-v3	242.65	0.02	0.002
	Grand Total	**11534919.57**	**1153.49**	**100.00**

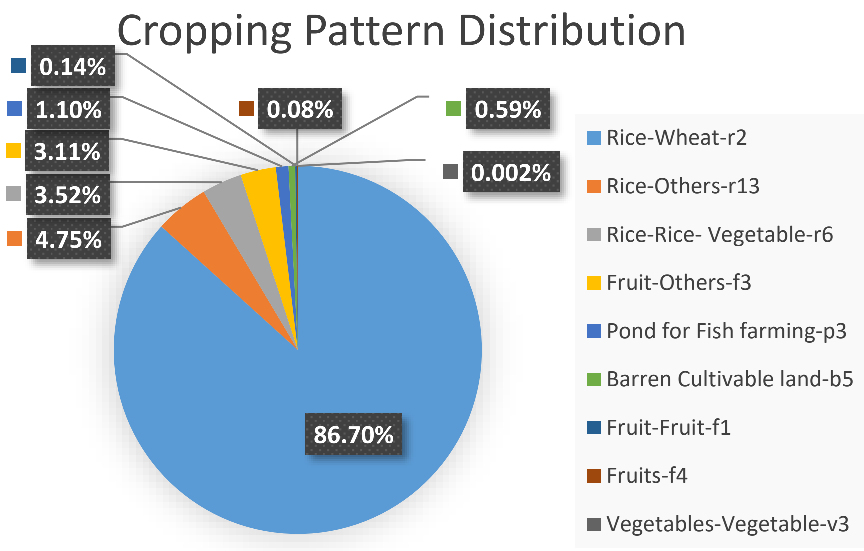


Figure 3.9: Cropping Pattern in Agricultural land

The VDC witness 52.92% of agricultural land having high cropping intensity, 38.52% of arable land of medium cropping intensity and 8.56% of land as of light intensity. Although, pond for fish farming areas do not directly relate themselves with cropping intensity, these have been included in the table as they also bear some degree of agriculture area related production. The following figure shows the distribution of cropping intensity including pond for fish farming.

Table 3.9: Cropping intensity

S. No.	Cropping Intensity	Area(sqm)	Area(ha)	Percentage
1	Intense-3	6104074.91	610.41	52.92
2	Medium-2	4443533.58	444.35	38.52
3	Light-1	987311.09	98.73	8.56
	Grand Total	**11534919.57**	**1153.49**	**100.00**

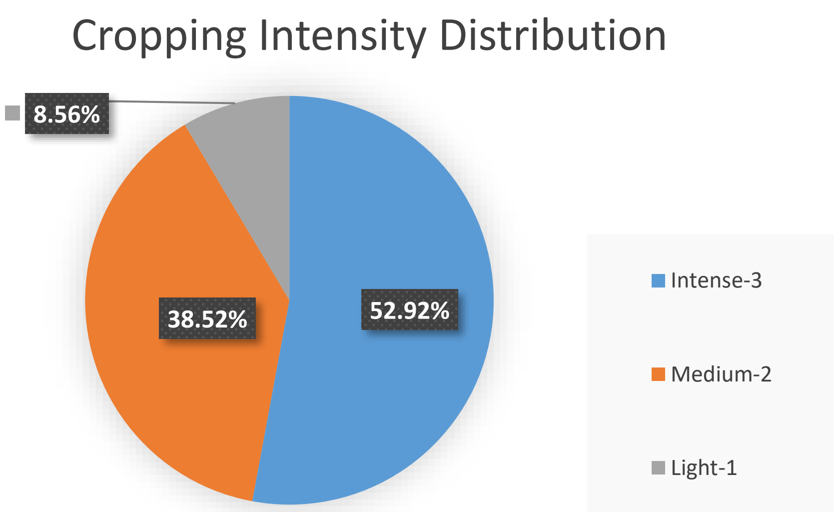


Figure 3.10: Cropping Intensity

3.5 Land Use Zones

Proposed Land Use Zones are presented for this VDC is shown on map.

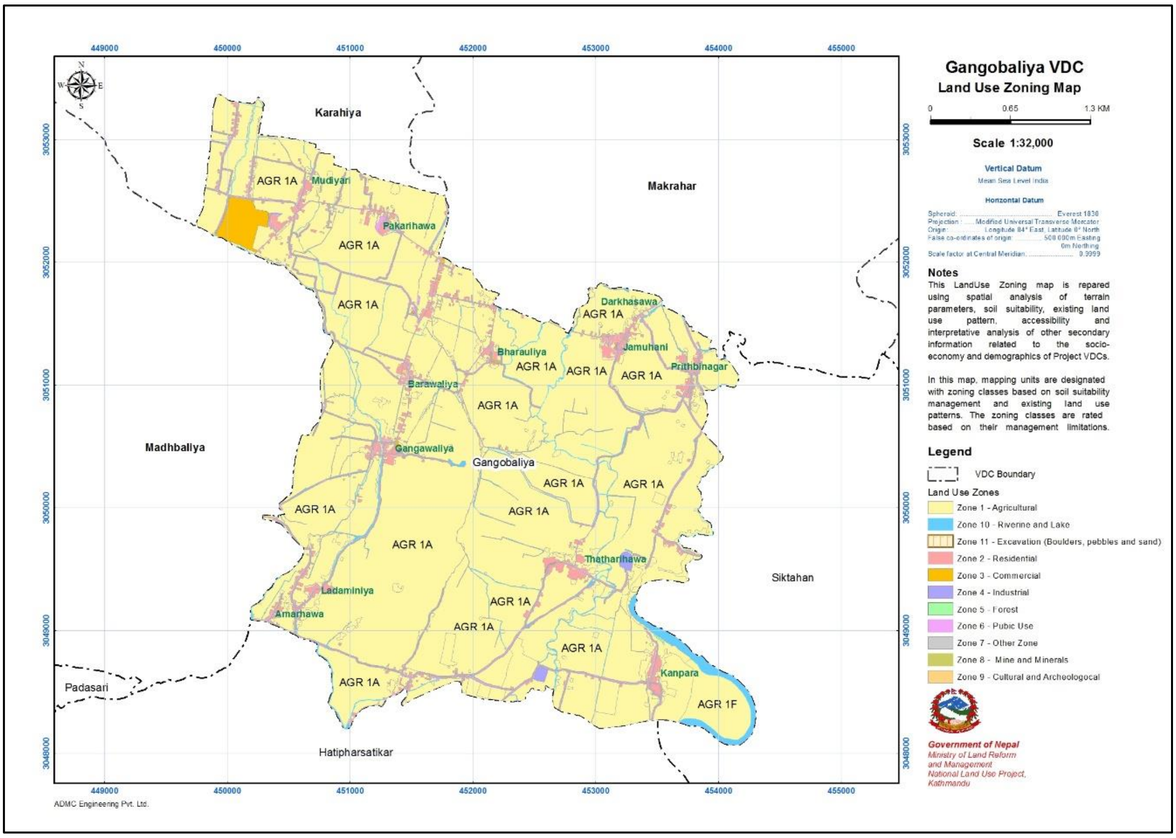


Figure 3.11: Land Use Zoning Map

3.6 Cadastral Data

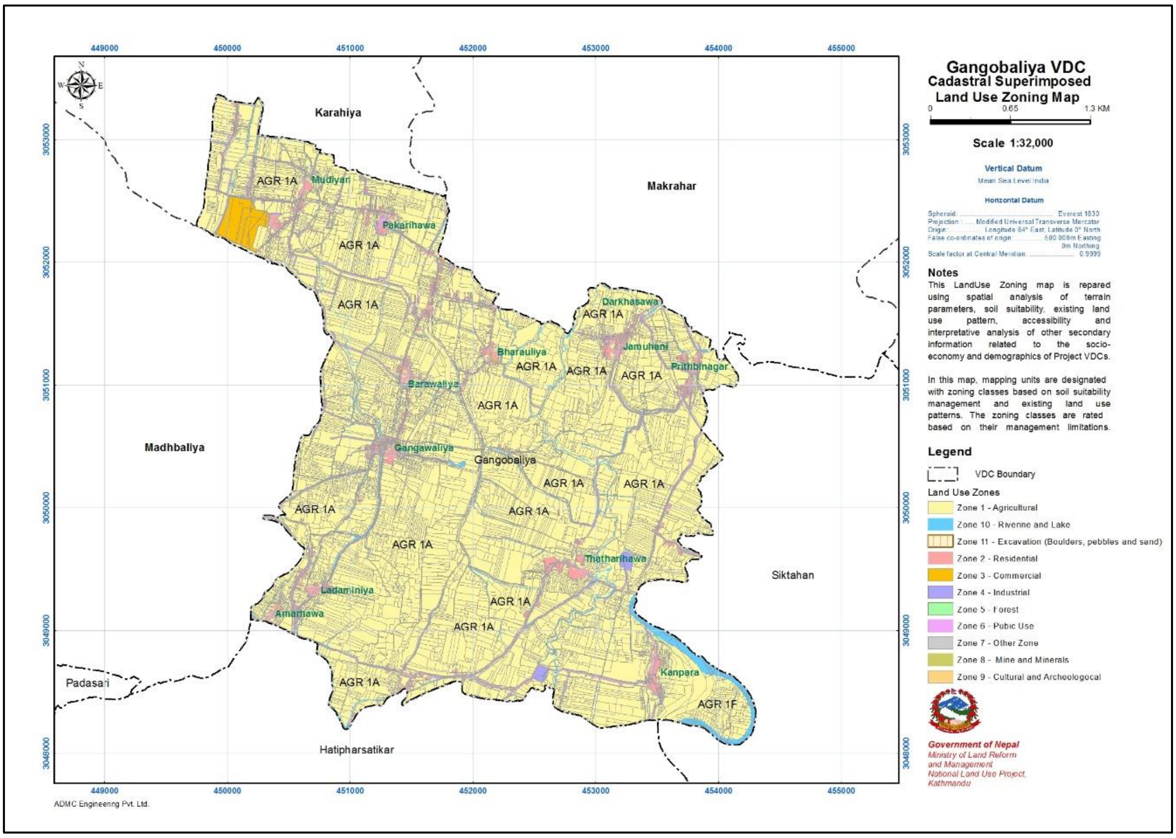


Figure 3.12: Cadastral Map

3.6.1 Cadastral land Parcel based on land-use

The Cadastral Survey in Rupandehi district was carried out during 2021 B.S. Due to lack of a land use zoning regulations the parcel size and use have undergone random conversions over the years. Similarly, due to the lack of strict regularizations on maintenance of public and government land some changes have undergone in their uses as well. Accuracy of the original plane table survey should as well be considered while assessing on the figures on the database, however this will have limited implications on the scale of the map 1: 10,000.

At the time of digitization, the VDC had 9657 land parcels and area covered in the survey was 1279.69 ha.

Following table shows the characteristics of parcel over present land use.

Table 3.10: Parcel Characteristics of Present Land Use

Present Land Use Class	Area(sq.m.)	Area(ha.)	Parcel Count	Area (%)
Agricultural	9078298.94	907.83	6792	70.94%
Commercial	103752.75	10.38	43	0.81%
Cultural and Archeological	7632.53	0.76	15	0.06%
Forest	79413.55	7.94	25	0.62%
Industrial	107327.67	10.73	30	0.84%
Public Use	215194.17	21.52	180	1.68%
Residential	1442671.91	144.27	1503	11.27%
Riverine and lake area	1762599.01	176.26	1069	13.77%
Grand Total	**12796890.53**	**1279.69**	**9657**	**100.00%**

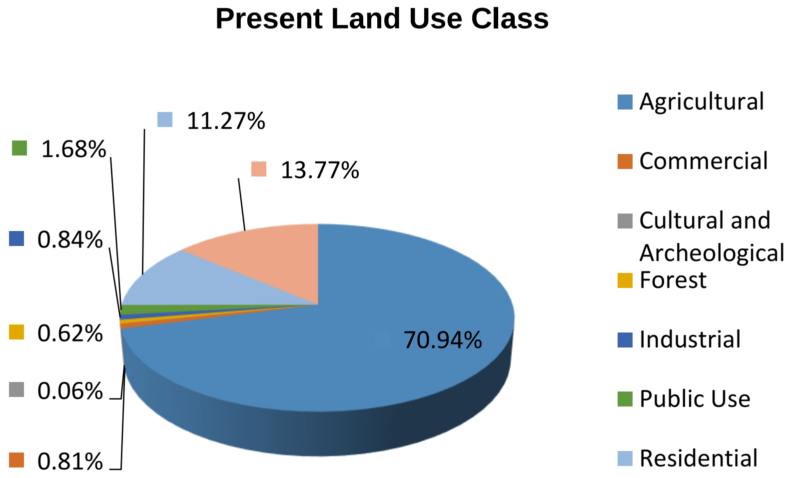


Figure 3.13: Distribution of Parcels over Present Land Use (%)

3.6.2 Cadastral Land Parcel based on Land Use Zoning

Table 3.11 shows the characteristics of cadastral parcels superimposition on Land Use Zoning for the VDC under study of Rupandehi District of Nepal. In the cadastral area of the VDC, out of the designated 11 classes, zoning for all seven classes except other specially designated classes were planned. The distribution of parcels over proposed landuse zone is shown on table and chart below.

Table 3.11: Parcel Characteristics of Land Use Zoning

Proposed Land Use Class	Area(sq.m.)	Area(ha.)	Parcel Count	Area (%)
Agricultural	7753192.91	775.32	5933	60.59%
Commercial	101793.52	10.18	41	0.80%
Cultural and Archeological	7632.53	0.76	15	0.06%
Forest	79413.55	7.94	25	0.62%
Industrial	63985.66	6.40	18	0.50%
Public Use	2105158.90	210.52	1418	16.45%
Residential	1169277.08	116.93	1285	9.14%
Riverine and lake area	1516436.38	151.64	922	11.85%
Grand Total	**12796890.53**	**1279.69**	**9657**	**100.00%**

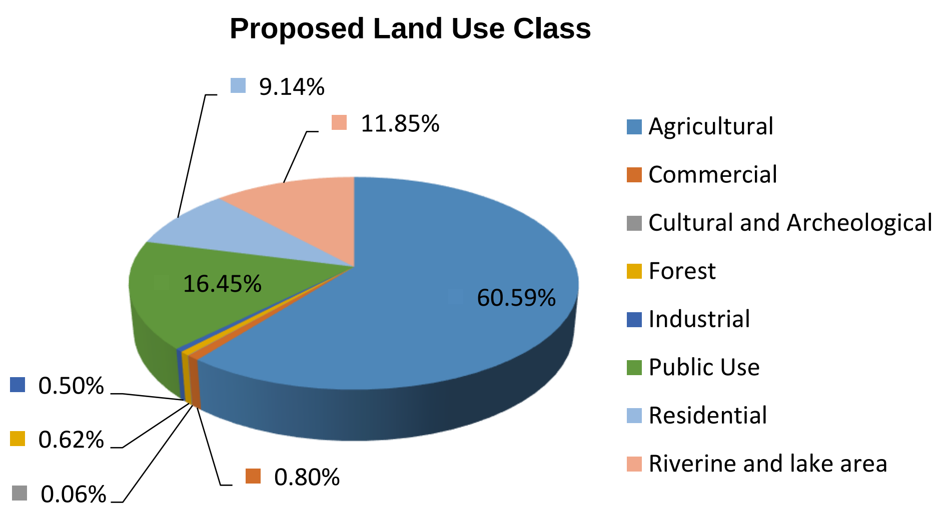


Figure 3.14: Distribution of Parcels over Land Use Zoning (%)

Parcel characteristics: This could be assessed from the superimposition of present land use and proposed land use given in the land use zoning maps. The parcel characteristics could be analyzed with this superimposition. Table 3.12 gives the details.

Table 3.12: Parcel Characteristics of Present Land Use Land Use Zoning Superimposition

Present Land Use / Proposed Land Use	Area(sq.m.)	Area(ha.)	Parcel Count	Area (%)
Agricultural / Agricultural	7712122.69	771.21	5922	60.27%
Agricultural / Public Use	1364104.95	136.41	861	10.66%
Agricultural / Residential	2071.30	0.21	9	0.02%
Commercial / Commercial	101793.52	10.18	41	0.80%
Commercial / Public Use	1959.23	0.20	2	0.02%
Cultural and Archeological / Cultural and Archeological	7632.53	0.76	15	0.06%
Forest / Forest	79413.55	7.94	25	0.62%
Industrial / Agricultural	41070.22	4.11	11	0.32%
Industrial / Industrial	63985.66	6.40	18	0.50%
Industrial / Public Use	2271.79	0.23	1	0.02%
Public Use / Public Use	215194.17	21.52	180	1.68%
Residential / Public Use	275466.13	27.55	227	2.15%
Residential / Residential	1167205.78	116.72	1276	9.12%
Riverine and lake area / Public Use	246162.63	24.62	147	1.92%
Riverine and lake area / Riverine and lake area	1516436.38	151.64	922	11.85%
Grand Total	**12796890.53**	**1279.69**	**9657**	**100.00%**

Note: Conversion from Forest to Agriculture or Public use or Residential is due to unavoidable geometrical inconsistencies and therefore requested to be read as negligible and ignored.

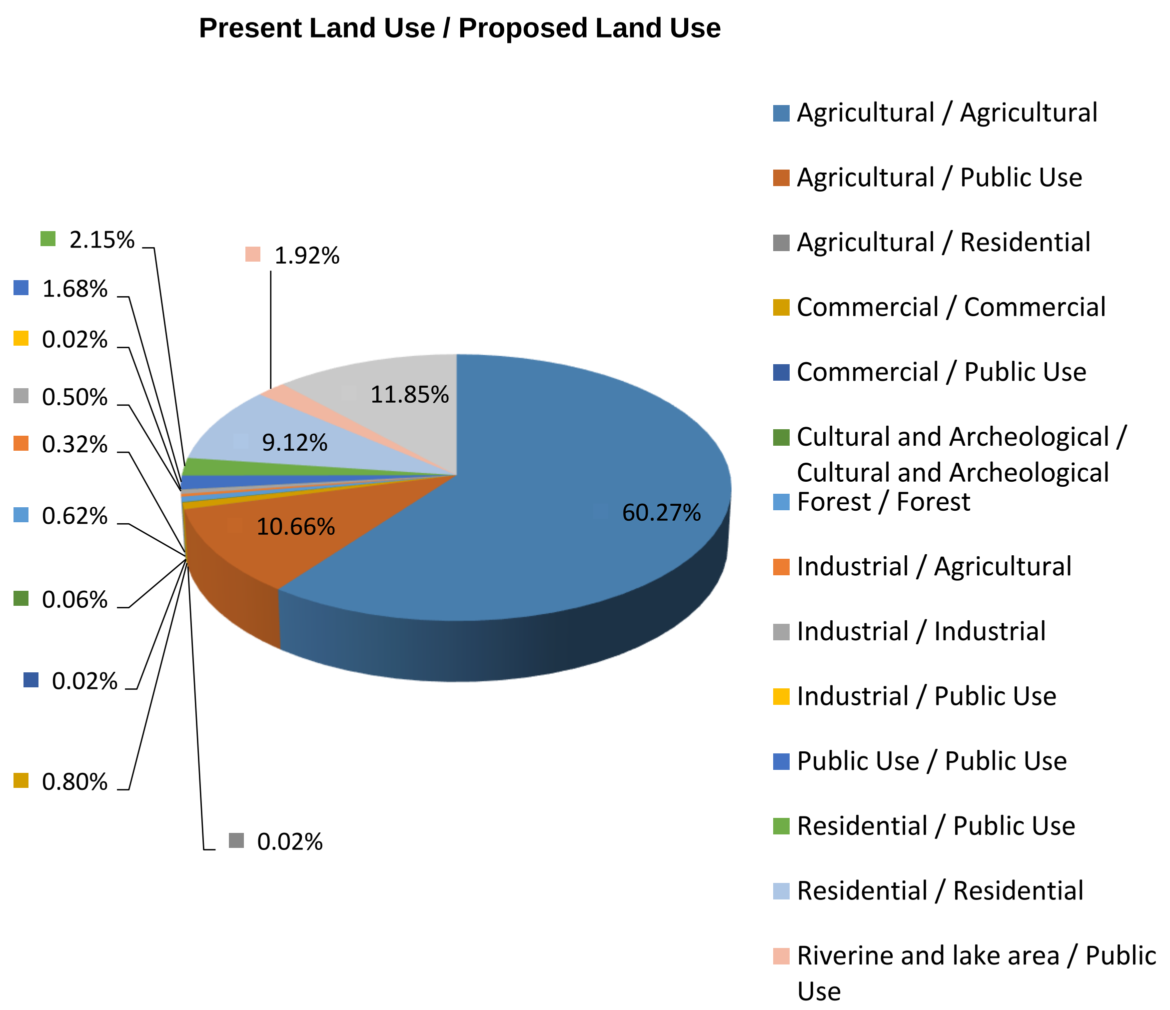


Figure 3.15: Parcel of Present Land Use versus Proposed Land Use (%)

CHAPTER- 4

SOCIO-ECONOMIC SETTINGS

4.1 Social Settings

Social settings consist of ward-wise population distribution, migration, caste/ethnic composition, age composition, linguistic composition, religious composition and so on of this VDC.

4.1.1 Population Distribution and Density

According to CBS (2068), the total population of this VDC is 6966 with 1172 households. Out of total population, 49.1 percent are male and 50.9 percent are female. The average family size of the VDC is 5.9.

Table 4.1: Population Distribution within the VDC

Population Distribution						
Ward	Household	Total Population	Male	Female	Average Family size	Disable population
1	180	1082	520	562	6.0	4
2	144	831	411	420	5.8	5
3	209	1021	464	557	4.9	
4	95	491	249	242	5.2	
5	161	1041	540	501	6.5	
6	126	682	336	346	5.4	
7	65	439	230	209	6.8	2
8	88	636	294	342	7.2	
9	104	743	379	364	7.1	2
Total	**1172**	**6966**	**3423**	**3543**	**5.9**	**13**

Among the nine wards, ward number one has the highest population (1082) followed by ward no five (1041) and ward no three (1021) in this Gangobaliya VDC. Similarly, ward no seven has the lowest population (439) followed by ward no 4 (491) and ward no 8 (636). The average family size is of the VDC is 5.9. It is ranges from 4.9 to 7.2. The total area of this VDC is 12.86 sq. km and the population density is 542 persons per square km.

There are 13 disable people in the VDC. They are mostly physical disability. The highest number of them is in ward no 2 followed by ward no 1.

Table 4.2: Population Distribution by Mother Tongue

Population by Mother Tongue			
S.N	**Mother Tongue**	**Population**	**%**
1	Nepali	1199	17.2
2	Maithili	472	6.8
3	Bhojpuri	2658	38.2
4	Tharu	2391	34.3
5	Dotali	19	0.3
6	Newari	28	0.4
7	Magar	175	2.5
8	Others	24	0.3
	Total	**6,966**	**100.0**

There are seven major mother tongues in the VDC. Bhojpuri is the major mother tongue spoken by about 38 percent of the people in this VDC. Similarly, Tharu is the second major mother tongue spoken by about 34 percent people. Nepli is the third largest mother tongue that share about 17percent. It is followed by Maithili (6.8%) and Magar (2.5%).

In terms of population distribution by broad age group, it can be categorized into three wide-ranging age group i.e. 0-14, 15-59 and 60 over. This age group indicates to the economically active and non-active group of population of a place.

Table 4.3: Population Distribution by age group

Number of population by broad age group						
Sex	**0 - 4**	**5-9**	**10-14**	**15 - 59**	**60 and above**	**Total**
Male	288	418	479	1953	285	**3423**
Female	256	354	487	2211	235	**3543**
Total	544	772	966	4164	520	**6966**
Percentage	**7.8**	**11.1**	**13.9**	**59.8**	**7.5**	**100.0**

Out of the total, about 60 percent of the population includes under the 15-59 years age group. Likewise, the second largest group is 10-14 which has about 14 percent and which is followed by the age group of 5 - 9 years which is about 11 percent. Age group of 60 and above shares 7.5 percent of the total population in this VDC.

4.1.2 Population by Caste/ethnicity

Out of the 125 caste and ethnic groups of the country reported in 2011 census, there are 28 caste and ethnic groups in this VDC. In addition, there are Terai other and 'other' groups as well. The caste and ethnic groups of VDC belongs to Chhetree/Brahman, Janajati, Madhesi caste, Dalit, Musalman and other not stated. The three groups namely Tharu, Braham Hill and Yadav are the major groups that together share about two thirs of the population of the VDC. Tharu is the first largest group and it shares about 45 percent population flowed by Brahman Hill (12.9%), (16%), Yadav (9.3%), Mallaha (4.0%), Magar (3.6%), Gaderi (3.3%), Chamar (2.9%), Haluwai (2.5%), and Musalman (1.9 %)

population of the VDC. The other caste ethnic groups of the VDC are Kahar, Lodh, Magar, Cheetri, Teli and Kami.

Table 4.4: Population Distribution by Caste Group

Population Distribution by Caste Group			
S.No.	Caste/ethnic group	Population	Percentage
1	Chhetri	99	1.4
2	Brahman Hill	901	12.9
3	Magar	249	3.6
4	Tharu	3105	44.6
5	Newar	32	0.5
6	Musalman	132	1.9
7	Kami	35	0.5
8	Yadav	649	9.3
9	Damai/Dholi	42	0.6
10	Thakuri	31	0.4
11	Teli	34	0.5
12	Chamar	204	2.9
13	Koiri	67	1.0
14	Kurmi	45	0.6
15	Musahar	54	0.8
16	Dusad/Paswan	37	0.5
17	Kathbaniyan	88	1.3
18	Mallaha	278	4.0
19	Hajam	37	0.5
20	Lohar	25	0.4
21	Dhobi	20	0.3
22	Majhi	15	0.2
23	Haluwai	174	2.5
24	Marwadi	63	0.9
25	Baraee	12	0.2
26	Kahar	75	1.1
27	Lodh	85	1.2
28	Gaderi	232	3.3
29	Others	44	0.6
30	Terai Others	102	1.5
	Total	**6966**	**100.0**

In terms of religion, there are four religious groups in the VDC. Hinduism is the major one that covers about 90 percent of the total population. Likewise, Islam is the second largest religious group that shares 6.6 percent population. Christianity is the third religion as it is followed by 1.1 percent and Buddhism by 1.0 percent population.

Table 4.5: Population Distribution by Religion

Population distribution by Religion		
Religion Type	**No. of Population**	**Percentage**
Hinduism	6286	90.2
Islam	459	6.6
Buddhist	71	1.0
Christian	74	1.1
Other	76	1.1
Total	**6966**	**100.0**

The dependency ratio is not so high in the VDC. The total dependency ration is 67.3. Child dependency ratio is 54.8 and aged dependency ratio is 12.5.

Table 4.6: Dependent Population Statistics

Dependency Ratio	
Children	54.8
Old aged	12.5
Total	**67.3**

Migration is a common phenomenon. Rural to urban migration is widespread in Nepal. Another form of migration is from hill to Terai region. Migration has not noticed as a common phenomenon here. Within last two years, 5 households have migrated to this VDC. The migrants' households are from the western Hill districts particularly from Palpa, and Syangja and other VDCs within the district. The Number of out migrants' household is less compared to in-migrants households and only 2 households out-migrated from the VDC. All the out-migrated households, destination is within the district.

Table 4.7: In Migration Households Statistics

Number of Households by In-migration and outmigration (within last 2 years)				
Ward No	In migrants Origin Districts	Number of in migrated households	Out-migrants households	Destination Place
1	Syangja	1		
2	Palpa	1		
4	Within the district	2		
5			1	Within the district
7	Within the district	1		
8			1	Within the district
	Total	**5**	**2**	

4.2 Economic Setting

4.2.1 Agriculture

Agriculture is the main occupation of this VDC. Total agricultural land is about 1000 hectares in the VDC. The major crops include paddy, wheat, maize, pulses, and oilseeds.

The agriculture system is subsistence and traditional. Commercialization in agriculture is essential. Attraction towards agriculture has been decreasing day by day. But vegetable farming and fish farming has been gradually increasing.

Agriculture is the major source of livelihood in this VDC. The total agriculture land of the VDC is about 470 hectares where farmers' crops both in summer and winter seasons. The major crops producing in this VDC are rice, wheat, pulse and oilseed. Rice ranks first position which occupies more than 90 percent agricultural land of the VDC. The pulses like; Dal, Chana, Musuri and Rahar are also grown in the VDC but its cultivated area and production are decreasing. Fish, poultry and vegetable farming are gradually taking place in many settlements in the VDC. Fish farming has becoming an important source of income of this VDC. A few new ponds are constructed in the VDC.

Production of major crops (quintal)		
Name of Crops	Production	Remarks
Cereal crops	25,600	
Pulses	15250	
Oilseed	1700	
Vegetables	2080	
Fruit	300	
Total	**44930**	

4.2.1.1 Food production

Cereals are the major agricultural production of the VDC. Rice rank first in terms of cultivation area and production. It is cultivated in all wards and covers about 950 ha. Wheat is cultivated in about 500 ha followed by pulses (150 ha) and oilseeds (150 ha). Different vegetables and Mango cultivation I are also done. Mango is cultivated in about 10 ha in the different villages of the VDC.

The recent agricultural production data is not available. The VDC officials and villagers claim that production has not much changes within last 5-10 years. VDC profile of 2067 shows that cereal crops primarily rice and wheat are the most important crops. The total annual production is about 26000 quintals is the VDC. Similarly, about 15000 quintal pulses, 1700 oilseeds are produced.

Table 4.8: Landless Household Information

Landless Household status			
Ward No	Total HHs	No. of Landless HHs	%
1	180	8	21.6
2	144	3	8.1
3	209	4	10.8
4	95	2	5.4
5	161	6	16.2
6	126	9	24.3
7	65	2	5.4
8	88	1	2.7
9	104	2	5.4
Total	**1,172**	**37**	**100.0**

Problem of landlessness and near landlessness are serious problem in all over Nepal. In Gangobaliya VDC, the number of landlessness and near landlessness are growing rapidly, according to the local people. In this VDC, there are almost 3 percent households are landless and near landless but in the past it was very less which was less than one percent before ten years. According to the field survey, there are 37 landless households in the VDC. The highest number of such households are in ward no 6 followed by ward no 1 and 5. There are 9 households of landless people in ward no 6, 8 households in ward no 1 and 6 households in ward no 5.

The political and social landscape of the VDC has changed a lot since 1990, and a burgeoning problem is the rise in rural poverty and unorganized squatter settlements. Comprehensive data and analysis on slums, slum dwellers and squatters are unavailable, but the local people say that the approximate number of squatters could be around 15 households in this VDC. The Lodh, Chamar, and a few migrants are the major squatter groups.

Irrigation is the most considered as determining factor for agriculture. There is no big irrigation project in this VDC. Most of the farmers are depended upon rain water in the summer season. Irrigation facility is relatively better in the VDC. There is irrigation water from Bhairahawa Lumbini underground irrigation project. There are also irrigation canals in the VDC. The Behuli canal irrigate in piprahiya, Amarhawa, Nayatol of ward no 2 and Gangobaliya, Jamuhadotol of ward no 4. It irrigates about 500 bigha in these two wards. Rohini river water is used for irrigation extracting using pump set in ward no 7, 8 and 9. In addition, there are 57 shallow boring in the different wards of the VDC.

Table 4.9: Boring Distribution

Number of Boring in the VDC	
Ward no	Number of Boring
1	2
2	7
3	5
4	5
5	5
6	2
7	8
8	8
9	15
Total	**57**

In Gangobaliya VDC, about 60 percent household are food sufficient that they produce to meet their annual food demand for the whole year. Within this 60 percent, 35 percent just produce enough for their own consumption while remaining 25 percent produce above their food requirement for the household and sell the surplus produces. About 20 percent household produce for 6-9 months, 6.5 percent for 3-6 months and about 13 percent just produce for up to 3 months.

Time period	Up to 3 months	3-6 months	6-9 months	9-12 months	Food above sufficiency	Total
Number of households	155	76	233	410	298	**1172**
Percent	13.2	6.5	19.9	35.0	25.4	**100.0**

4.2.1.2 Production of High Value Crops

There are limited high value crops. Off-season vegetable farming has become an attractive source of cash income. People grow potato, cauliflower, peas and sag as the main vegetable in this VDC for commercial purpose. Vegetable farming has become an attractive sector for farmers in these days. Vegetable farming is done in about 10 bigha land in the VDC. People do vegetable farming in winter season and sell to market. Vegetable cultivation is mainly done in a few villages. It is done for commercial purpose in ward no 5, 7, 8 and 9 where people. It is primarily grown in Muhanitol and Darkhahawa of ward no 5 and Kanpara of ward no 7, Kanpara and Dhatiya of ward no 8 and Dhatiya of ward no 9.

In addition to vegetables, a few households also grow a few mango trees for commercial purpose and banana for their own consumption in this VDC.

4.2.1.3 Livestock Farming

Livestock farming is an inseparable part of agriculture. Without livestock, agriculture is not possible. Cattle, buffalo and goat are the major animals that farmer raise. It is raised for milk, manure and draught power. The total number of cattle in the VDC is 1987 in Gangobaliya VDC.

Table 4.10: Livestock Farming Information

Livestock Farming by Ward wise					
Ward No.	Cow	Buffalo	Goat	Chicken	Total
1	182	180	234	236	832
2	2210	153	469	369	3201
3	102	194	300	503	1099
4	118	55	244	248	665
5	222	102	280	524	1128
6	155	82	108	297	642
7	204	111	191	331	837
8	198	108	98	334	738
9	209	121	282	456	1068
Total	**3600**	**1106**	**2206**	**3298**	**10210**

Looking at available data, there are about 7000 livestock primarily buffalo, cow and goat. Among the nine wards of the VDC, ward number 3 has the highest number of livestock followed by ward no 5, 3, and 9. People prefer buffalo for milk and manure. The number of buffalo is highest in ward no 3, 1 and 9. Similarly, the highest number of cows are in ward no 2 followed by ward no 5 and 9. The highest number of goat is in ward no 2, 3 9 and 5. Chicken is commonly rared in all wards of the VDC.

4.2.1.4 Poultry and Fish Farming

Poultry and fish farming are emerging sources of livelihood but these both sources are quite behind in this VDC. Poultry plays important social and cultural roles in the lives of rural people, not least in building social relations with other villagers. Village poultry have many advantages in mixed farming systems as they are small, reproduce easily, do not need large investments and can scavenge for food. Chickens are the most common species, but mixed flocks including species such as ducks, geese also often exist.

Although, there is no poultry farming in an organized way but most of the Janajati households have kept it. They usually keep local verity of poultry and sell while they are in need. Though they keep a few number of poultry they get good price for a single cock/hen. They usually consume it and different feast and festival. There are 7 poultry firm in the VDC. The maximum i.e. 6 firms are in ward no 4. The average income from each poultry firm is 150,000 to 200,000 annually. Similarly, there are 11 fish ponds in the VDC. There are 6 fish ponds in ward no 8 and 2 in ward no four. The income from fish farm is good. Farmers earn at least 50,000 per farm annually.

Table 4.11: Poultry and Fish Farming Information

Poultry and Fish Farming				
Ward No.	**Number of poultry firm**	**Average annual income (NRS)**	**Number of Fish Pond**	**Average annual income (NRS)**
1	1	200,000		
2				
3			1	50,000
4	6	1000,000	2	150,000
5				
6			1	50,000
7				
8			6	400,000
9			1	100,000
Total	**7**		**11**	

Ostrich Nepal Pvt Ltd has started ostrich farming in Gangobaliya VDC ward no one. The farm has covered eight bigha land. It is one of the most innovative work in the VDC. There are 4200 ostriches in the farm. The farm produces about 2500 ostrich chicks. They start selling the chicks after three months. The price of chick is very expensive as one ostrich chick is sold in 60,000 rupees.

Ostrich meat and skin is very expensive. Ostrich meat is 1650 per kilogram at farm gate and 2000 per kilogram in the market. One ostrich can be of 60 kilograms to 120 kilograms. Ostrich has long life. One ostrich gives 30-120. In the whole life time one ostrich can give about 5000 eggs. Its egg is bigger. It is about 1.5 kilogram. Ostrich egg is also very expansive. From the farm gate, they charge 2000 rupees for one egg. There is no problem of market of both mean and egg.

Ostrich are kept in open field fenced by iron wire. Its food is grass. They produce grass in the farm. The ostrich farm is a place of attraction for local people and the people from different parts of the country. It has provided employment to 30 people.

Ostrich farm at Ganglia

4.3 Employment/Occupation

Various types of occupation are adopted by the people of Gangobaliya VDC. On the other, people are associated with more than one occupation. Multiple occupations determine the multiple sources of income and makes less vulnerable to the livelihood of the people.

Table 4.12: Employment/Occupation Information

Occupational structure by household			
SN	Occupation	Total population	Percentage
1	Agriculture	2092	65.8
2	Service	599	18.8
3	Professional	76	2.4
4	Foreign labor	411	12.9
Total		**3178**	**100.0**

Despite the various occupations, the major occupation of this VDC is agriculture and livestock farming. Those both go side by side in the nature of the existing farming system. About two thrid people are involved in this occupation. The second most important occupation is the service in which about 19 percent people are involved. Foreigh labor migration is the third largest occupation that about 13 percent people are involved in it.

The professional work is another occupation in which about two percent people are involved in the VDC.

4.4 Industries

There are a few of different types of industries in this VDC such as gas, agro processing and animal feed. Most of the industries are in ward no 9, 1 and 2. There are gas and juice industry in ward no 2. There is one brick factory in ward no 9. Rice mill is established in almost all wards. Cardboard factory is in ward no 1.

Table 4.13: Industries List

Distribution of Factory/Industry in the VDC		
Name of Industry	Ward No, Settlement	Remarks
Manakamana cardboard	1, Mudiyai	
Rice mill	1,3,4,5, 8,9	
Brick factory	9	
Ostrich farm	1, Mudiyai	
Gas Industry	2	
Juice factory	2	

In addition, there three NCELL tower - two in ward no 1 and one in ward no 9 - in the VDC.

4.5 Remittances

Unemployment is a great burning problem in Nepal. Due to the lack of employment opportunities in the country, many people especially young are moving to foreign country to earn their livelihood. Foreign labor migration has become major source of income in the country. So, it has become an important component of Nepalese economy.

Table 4.14: Temporary Foreign Migration Information

Number of Population by Foreign Migration (Temporary migration)			
SN	Destination countries	Total	Percentage
1	Malaysia	155	37.7
2	Qatar	90	21.9
3	Saudi Arab	52	12.7
4	UAE	67	16.3
5	India	20	4.9
6	Japan	4	1.0
7	S. Korea	23	5.6
Total		**411**	**100.0**

Altogether 411 people are involved in foreign labor migration at present. Malaysia, and Gulf countries are major destinations for foreign employment. Out of total labor migrants, about 38 percent are in Malaysia. Among the Gulf countries, Qatar shares about 22 percent of total labor migrants followed by UAE (16.3%) and Saudia Arab (12.7%) India is another destination of Nepalese labor migrants which share about 5 percent. A new shift has gradually taking place as people have started going to S Korea and Japan too.

4.6 Sources of Income

Diversification of the sources of income indicates that the people are engaged in different sectors for their livelihood. Almost about 90 percent people are involved in agriculture. A few households are in business and wage labor as their major occupation.

Agriculture is another important source of income of the local people which contributes a major part of income. The most important source of cash income is remittance. Poultry, fish farm and wage labor are other sources of income in the VDC.

4.7 Potential Income Opportunities

The major opportunity is in agricultural sector. Agriculture is better. Cereal and vegetables farming have better opportunity. Poultry, fish farm are also emerging sector. Small scale tourism industry cab be flourished here as the number of visitors to Ostrich farm has been gradually increasing. Thus agro based tourism can be developed.

The VDC is situated in the rural area and established a number of industries. So service and wage labor is another potentiality. The number of foreign labor from the VDC is high so income from remittance can be invested for different sector that can generate income and employment.

CHAPTER -5

INFRASTRUCTURE AND SERVICES

5.1 Road

Road is one of the most important infrastructures. It is also the backbone of development. It helps local people to travel from place to place and importantly facilitate people to market their agricultural products. There are different types of road such as black topped, graveled and earthen in the VDC.

The VDC is 13 km from the district headquarter and it is connected with all-weather road. There are three major roads in this VDC. These are Madhbatiya-Rataha road, Korihawa-Kanpara road, Keruwani-Gangobaliya road. The blacktopped road is in ward no 1, 2,3,4,5, and 6 and its total length is 15 km. Gravel road's length is 30 km. There is earthen road in all wards of the VDC.

5.2 Health

Health is wealth. It is known as fundamental thing for human life. But education and awareness are prerequisite for this purpose. It requires more government investment for health infrastructure. There is one health post in ward no 3 and two health clinics one each in ward no 3 and 6 of the VDC. People from all wards can visit health post with half an hour. People first visit health post for health problem. People also visit traditional healer and health volunteers.

Table 5.1: Health Facility Information

Type of Health Facility Use by Household			
SN	Types of Facility	Household	%
1	Health Post	1007	85.9
2	Local Clinic	100	8.5
3	Local healer	65	5.5
Total		**1172**	**100.0**

Out of the total household, about 86 percent households have got health post facility at their first attempt. Similarly, about 9 percent households get local clinic facility for this purpose. Only about 5.5 percent household visit to traditional local healer until todays. Dhami, Jhankri are recognized as traditional healer. As the VDC has good access, people visit health facilities outside of the VDC.

The provision of toilet at house is an important aspect of health. The VDC has declared as open defecation free (ODF) VDC. All houses have modern toilet. Local people share that though they have toilet at home, some family member still follow traditional practice of open defection as it rooted in their everyday practice for a long time.

5.3 Drinking Water

There are different sources of drinking water in Gangobaliya VDC. About 86 percent households of the VDC use tube well/hand pump for drinking water. About 9 percent household use tap water for drinking and other purposes at home. Only 6 other various sources such as river, open well water for managing drinking water.

Table 5.2: Source of Drinking Water Statistics

Drinking Water Services			
S.No	Type	No. of HHs	Percentage
1	Tap water	110	9.4
2	Tube-well/Hand pump	980	83.6
3	Closed Well	1	0.1
4	Open well	1	0.1
5	Others	68	5.8
6	NA	12	1.0
	Total	**1172**	**100.0**

Tube well water is not safe for drinking as it contains arsenic element. Even though, the people of this place are compelled to use such water and water from river and other unsafe sources.

5.4 Electricity

There are various sources of lighting in the VDC. Among them two sources are the most important. These are electricity and kerosene. Electricity service is in all wards of the VDC. Abbot 83 percent households use electricity for lighting. Kerosene is the second most important source of lighting that is used by about 16 percent households of the VDC. A few households use biogas, solar for lighting purpose too.

Table 5.3: Sources of Fuel for Lighting Statistics

Sources of Light			
S.No.	Types	Total household	Percentage
1	Electricity	968	82.6
2	Kerosene	186	15.9
3	Bio Gas	3	0.3
4	Solar	1	0.1
5	Other	2	0.2
6	Not Stated	12	1.0
	Total	**1172**	**100.0**

People use different types of energy for cooking. Firewood, cow dung cake and LP gas are the major sources of cooking energy in the VDC. Among them, firewood is the major source that cover 44 percent households. The second important source of cooking energy is the cow dung cake that is used by 29 percent households of the VDC. The third most important source of cooking fuel LP gas. About 16 percent household use it for cooking purpose. Only a few households use other sources of energy for cooking such as biogas (7%) and kerosene.

Table 5.4: Sources of Fuel for Cooking Statistics

Sources of Cooking Fuel			
S.No	Fuel	Household	%
1	LP Gas	189	16.1
2	Kerosene	4	0.3
3	Firewood	511	43.6
4	Biogas	87	7.4
5	Dung cake	344	29.4
6	Electricity	1	0.1
7	Not stated	12	1.0
8	Other	24	2.0
	Total	**1172**	**100.0**

While observing at the villages and discussing with local people it has known that women are primarily responsible for making cow dung in winter for securing the cooking energy need primarily for rainy season and throughout the year. The use of cow dung is not much as compared to other VDC of the district but farmer are deprived from manure as they use most of the dung for making dung cake. It has affected in agricultural production in the VDC.

5.5 Educational Institutions

The literacy situation of the VDC is not poor as 72 percent people are literate. It means about 28 percent people are still illiterate in the VDC. Importantly, there is a sharp difference between male and female literacy rate. Out of total male above 5 years and above ages, about 83 percent are literate while the percentage for female is about 62 only.

Table 5.5: Literacy Statistics

Literacy situation (5 years and above)				
Description	Male	Female	**Total**	**Percent**
Can read and write	2611	2046	**4657**	**72.5**
Can read only	75	67	**142**	**2.2**
Cant not read and write	448	1170	**1618**	**25.2**
Literacy not stated	1	4	**5**	**0.1**
Total	**3135**	**3287**	**6422**	**100.0**
Literacy %	**83.3**	**62.2**		**2.3**

The level of education obtained by male and female is also different. Data shows that the number of male is far higher than female in all levels of education attainment. Majority of the literate people have passed primary level. Out of total literate, 37 percent have passed primary level which is class 1-5 and about 24 percent have passed class 6-8. It shows that these two groups share about 61 percent of the total. Furthermore, 9 percent have passed SLC. Intermediate is passed by 4 percent. Only one percent has passed bachelor and above degree in the VDC.

Literacy Status by level of education (5 years and above population)				
Description	Male	Female	**Total**	**Percent**
Beginners	186	108	**294**	**6.2**
1-5 class	933	814	**1747**	**37.0**
6-8 class	637	487	**1124**	**23.8**
9-10 class	402	281	**683**	**14.5**
SLC	266	179	**445**	**9.4**
Intermediate	127	69	**196**	**4.2**
Graduate	29	12	**41**	**0.9**
Post-graduate	9	1	**10**	**0.2**
Informal education	38	98	**136**	**2.9**
Level not stated	20	21	**41**	**0.9**
Total	**2647**	**2070**	**4717**	**100.0**

According to the VDC record that there are only six schools within this VDC. They are located in different villages.

Table 5.6: School and its Location

School and Its Location		
S.No.	School Name	Ward
1	Shree Barawahiya Seconday School	3
2	Shree wali Kalyan Pre- Primary School	1
3	Shree Wali bikas lower seconday School	2
4	Shree Rohini bal bikas kendra	8
5	Shree Janatawali bikas kendra	6
6	.. boarding school	2

The total number of school from primary to higher secondary is six including balbikas Kendra and boarding school in Gangobaliya VDC. Among them, there are one secondary, one lowe seconday and other are bal bikas and boarding school. Attraction towards private school of publics has been increased day by day in this VDC like other place.

5.6 Financial Institutions

Gangobaliya VDC has many institutions of different kinds. There are five financial institutions. Those cooperatives and other type of financial institutions have played great role for the saving and credit. It has helped local people in need. The cooperative is primarily for agriculture and livestock based. The women’s cooperative help women in organizing themselves for various activities of income and employment generation and support in livelihood improvement.

Table 5.7: Financial Institutions Statistics

Types of Institution/Organization			
S.No.	Institutions/Organizations	Numbers	Remarks
1	Cooperatives	5	Small farmers cooperative, Utkata saving &credit, Dairy prod. , Aakashganga women cooperative, Rohini Swabalamba
2	School	4	Except bal bikas kendra
3	Health Post	1	
4	Post Office	1	
5	Police Post	1	APF

There are various governmental and non- governmental institutions and organizations in this VDC. There is one police post and one post office. Police has helped for maintaining peace and security of the VDC. Many local people are associated with those institutions and organizations existed here.

CHAPTER-6

HERITAGE, CULTURE AND TOURISM

6.1 Heritage

Heritage is the important property of our society. Any events, process, structure that are particular importance to society is known as heritage. There are different types of heritage handed over to new generation from ancestors. Cultural heritage is the artifacts and intangible attributes that are inherited from past generations, maintained by the present generation and are kept for the benefit of future generations. Cultural heritage includes buildings, monuments, landscapes, books, works of art, and artifacts folklore, traditions, language, and knowledge and important landscape and bio-diversity too. So, it is our common property. There are some common heritages in this VDC which include temple (mandir) located in different wards of the VDC.

In Chilhiya VDC there are mandirs in all wards. The mahadev mandir of ward o 5 and Shiva mandie of ward no 9 are considered as important mandir. There is one Masjid in ward no 8.

6.2 Culture

Multi ethnic and multi culture is the main characteristics of this area. This village is rich in indigenous culture and custom. Both hill origin and Terai caste groups and Dalit are in the VDC so that they celebrate many feast and festivals such as Dashain, Tihar, Lhosar, Chhat, Maghi and Holi. Holi are also celebrated in this VDC. Those festivals are celebrated with enthusiasm in this place.

6.3 Tourism

New prospect of tourism has emerged after the establishment of Ostrich farm in the VDC. Ostrich farming is an innovative work in Nepal and a new thing as well. It is because of this, many people from other districts of Nepal visit this farm. Local people from different VDCs within the district also visit here. Organized agro-tourism visit, visit of school and college students also increasing to the farm.

The farm office at the farm gate provided the data of number of visitors. About 30-40 people visit the farm everyday throughout the year. Importantly, the number of visitors increased in holidays and usually 150-200 people visit in holidays such as Saturdays and other holidays. Furthermore, during Dashain festival of the last year, about 2500 people visited the farm in a day.

Ostrich Farm at Gangobaliya VDC.

Chapter-7

RISK IN THE STUDY AREA AND SAFE AERAS FOR SETTLEMENT

7.1 Flood Risk

The result acquired through the analysis reveals the fact the study area needs immediate action to take against flood such as river training or embankment or levee construction to protect the given area by flood. Rohini river cutting is in ward no 7, 8, and 9. About 20 bigha is under cutting. During rainy season, the area along the river of these wards get inundated.Settlement like Kanpara, Darakhasawa and surrounding area are more prone to flood as revealed by the study. The people in such area are at risk of flood hazard so these people needs to be shifted from these areas to the area free of flood and other risk.

The present land use information in the study area renders the following statistics.

Table 7:1 Industry list with probable Pollution Type

Land Use Type	Area (Sq. m.)	Area (Hectares)	%
AGR	545432.16	54.54	81.65
FOR	1446.63	0.14	0.22
HYD	115093.69	11.51	17.23
PUB	1419.66	0.14	0.21
RES	4630.97	0.46	0.69
Total	**668023.12**	**66.80**	**100.00**

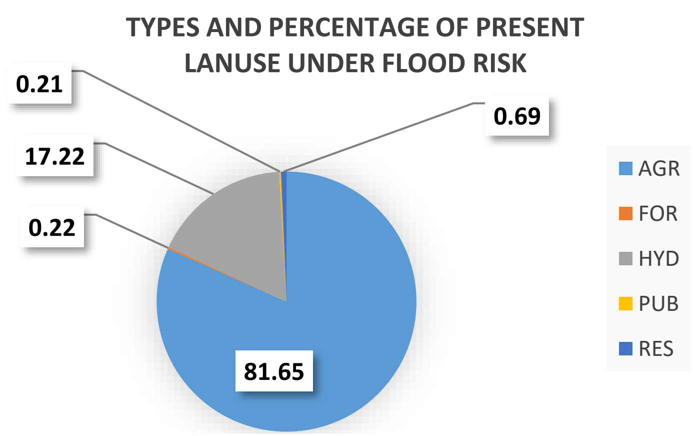


Figure 7.1: Classified land use under flood Risk

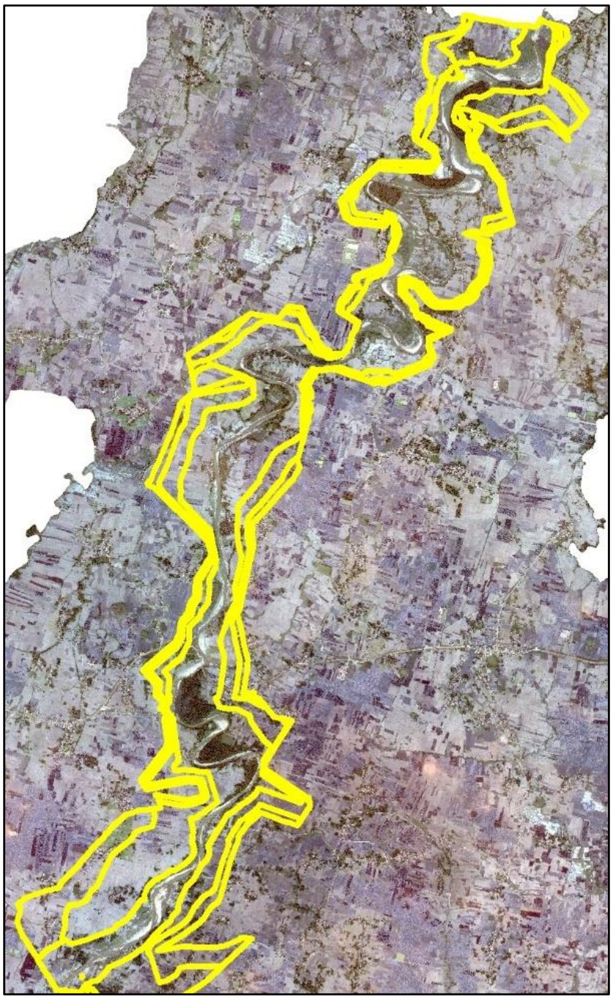


Figure 7.2: Flood Risk overlaid over satellite Image

7.2 Fire Risk

There is no significant forest cover in this package. Scattered Bamboo plantations were seen in this package which is fire sensitive too since it produces large amount of leaf litters. Bamboo plantation nearby the settlements, in general are more fire sensitive than the other areas due to possibility of extending fire from the settlements. Similarly, On the other hand, the distant plantation is in low risk of fire incidents. Sometimes, because of transmission line, lightening, firing may happens. Planted area encroachment nearby settlement and trail will increase the risk of forest fire, but in community forest these things are managed by community so the risk of firing is also low.

Most of the houses in the study area were constructed from locally available raw material. Houses with straw roofing are very susceptible to fire hazards as the material easily catches fire. In addition, houses for residential purpose are developed in cluster basis which are more susceptible of catching fire and spreading over there immediately due to close connectivity especially in the dry season. In the study area Improper management of straw; use of mechanical threshers; burning straw for heat; feeding cooking stoves with rich husks and packed long cow dung; preparing animal feed on outdoor stove throughout the day and other causes are the main reason for firing. Since the majority of houses were built from stone and wood, there is high risk of firing at any time during cooking and heating. This risk could be reducing if we can give proper attention after cooking and house heating. During site visit, besides few cases we don't find any devastating firing records that have damaged whole settlement area. One good aspect of settlement pattern of the study area is that, scattered settlement area, which will reduce the firing risk in whole settlement areas. But, the settlement area must be built in clumped pattern with good spacing, which will reduce the firing risk. Along with this, artificial pond must be built to control fire if it occurs suddenly at house or at whole settlement area.

Concrete building of sub urban areas as well as rural areas they area also risk to firing because of fault electric wiring and equipment, and LPG gas, but the risk is low. Regular maintenance of those equipment will reduce the risk. Similarly, due to electric short, factories and industries are also in risk of firing. Firing on industries is very hard to control, so the loss on environment and on natural resources will be very high. So, some distant should be kept between two industries and with settlement area too which will reduce spreading of firing from one industries to another industry and on settlement area. Petro-chemical sources station is always at high risk. The impact of firing on petro-chemical station is huge which will destroy live and property and cause huge environmental and economic losses. So, this should be kept at least 1km far from the settlement area.

Finally, fire preparedness activities most be carried out, which includes spreading messages through television, radio, street drama, video, folk songs, drills, posters, pamphlets, and hoarding boards to reduce the risk of firing.

7.3 Landslide Risk

No significant landslide risk was seen in the study area.

7.4 Seismic Risk

Bagaha, Basantapur, Bodabar, Chhipagadh, Chhotki Ramnagar, Gangobaliya, Dhakadhai, Gangobaliya, Harnaiya, Hatipharsatikar, Hatti Banagai, Mainahiya, Padasari, Pajarkatti, Patkhauli, Pokharbhindi, Siktahan of Rupandehi district areas fall in the seismic zone of 4, high seismic hazard area.

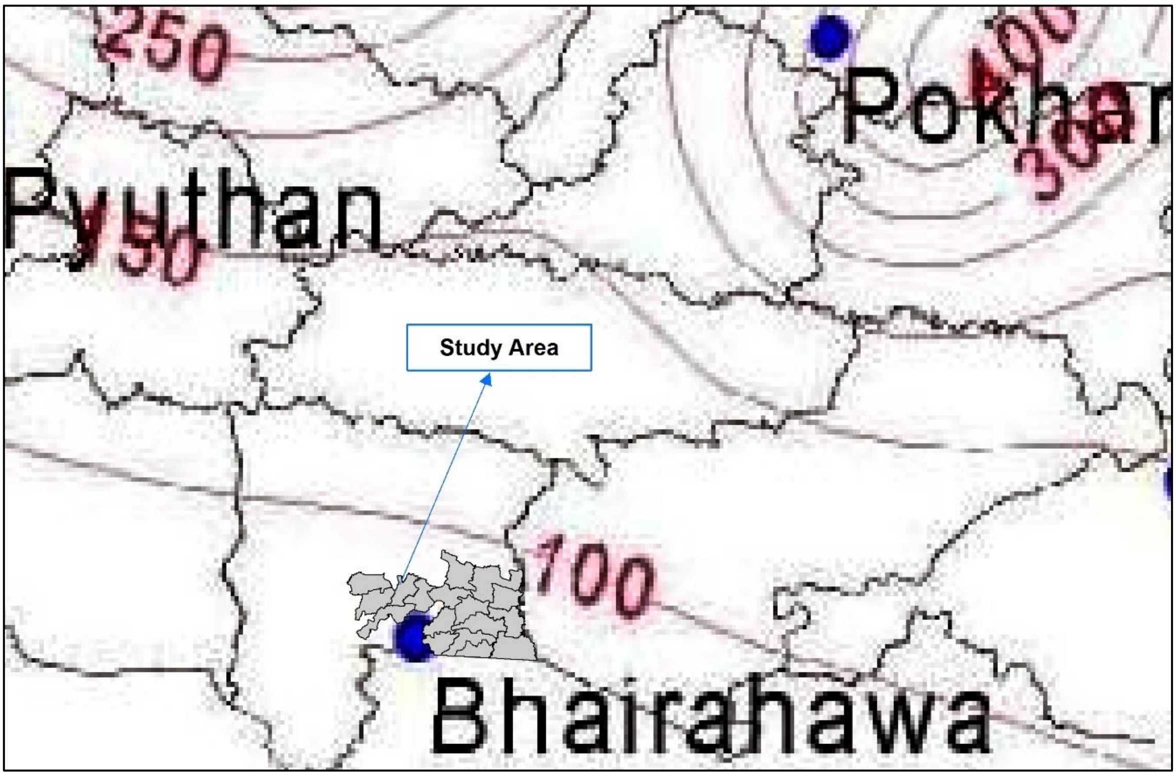


Figure 7.3: Seismic Hazard Map

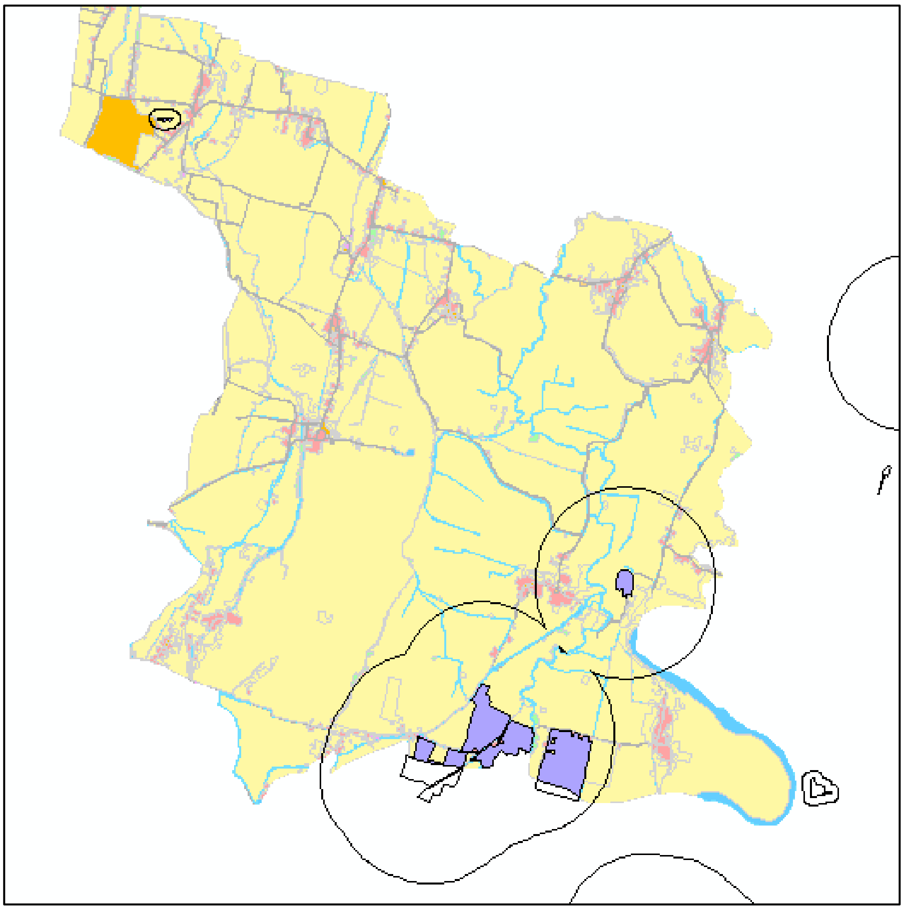
The seismic coefficient in bedrock of the VDC area is considered as 0.051. But the area is composed of fluvial soil so amplification in soil is higher than 20% so the seismic coefficient is considered as 0.061.

7.5 Industrial Risk

In this package, mainly on Gangobaliya VDC, few brick industries and Gaddha udyog could be noticed. The list of industriy present in this VDC is given on below table:

Table 7:2: Industry list with probable Pollution Type

VDC	Industries	Probable Pollution Type	Probable Risk area of some common industries (from center)
Gangobaliya	Industrial	Air pollution	100
	Bindabasini itta udhyog	Air pollution	500
	Gaddha udyog	Sound pollution	50
	Purna itta udhyog	Air pollution	500
	RNC itta udhyog	Air pollution	500



Major industries in the area are brick industries and Gaddha udyog which mainly affects the air quality,sound quality and water quality in the surrounding area. The industrial risk will be higher at the nearer site and vice versa. The risk due to air pollution will be increase or decrease depending on the flow of air and also depends on meteorological parameters such as wind velocity, temperature, humidity, rainfall, cloud coverage and solar radiation determine the dispersion, diffusion and transportation of particulate matter and emissions into the atmosphere. The volume of industries present on this VDC is low, although pollution controls measures should be properly installed in order to minimize environmental impact. Furthermore, separate corridor must be made for industrial growth in sustainable and environmental friendly way.

Since this package is nearer to boarder, in future industries could grow in rapid way which could lead further degradation of environment. The proper control measures should be adopted to minimize the risk of industrial pollution in the surrounding area which area as follows.

a. Flora and fauna

- Support community based forest activities to conserve a habitat for flora and fauna.
- Allocated certain money to invest in conservation of biodiversity.

b. Water:

- Maintain and promote water bodies/wetlands and ponds.
- Prohibit polluted water discharge into rivers and any water bodies.
- Develop an irrigation facility in order to increase agricultural productivity of nearer farmers.
- Conduct a community-based watershed/lake management programme.

c. Air Quality:

- Maintain air quality controls in the surrounding areas as per the national standard.
- Prohibit polluted air emission directly into ambient environment.
- Adopt short-term and long-term strategies and equipment to control air pollution by the existing industries in the region.
- Adopt Polluter Pays Principle (PPP) to control the air pollution in the region.
- Monitor the air polluting industries and sources by the concerned authority.

d. Waste pollution and noise pollution:

- Make a green belt on both sides in industrial areas.
- Promote renewable energy for domestic use.
- Encourage 6R of solid waste.
- Adopt noise pollution control measures by the existing industries in the Region

e. Soil Pollution:

- Prohibit the discharge of metal, hazardous material, dye, chemical and other into soil.
- Plantation of plants that absorbs pollutant of soil.

f. Legal Framework:

- Ensure that the projects are accompanied by an evaluation of their impact on the environment. Include an alternative projects to minimize the adverse effects (EIA/IEE).

7.6 Other Risk

No other risks in relation to land use zone are seen in the study area.

7.7 Safe areas for re-settlement

The Study area holds major threat of Flood and inundation alongside the rivers. Major river flowing though the study area is Tinahu Nadi and Rohini nadi Rupandehi District. Mainly, agricultural area is under high threat from the flood and inundation. Other existing threats include the industrial hazards and Fire Hazards. Some industries in the study area include the brick factories which mainly affect the air quality and soil fertility around the region. No Natural Fire risk is seen in the Study area though there is potential risk of fire due to the thatch roofed houses which easily catches fires and the petrol pumps which need to be operated under the safety regulations. In case of Seismic risk, no fault line passes through the study areas. Some rare occurring of earthquakes as epicentre falling in the area has been seen. No landslide risk is seen in the study area considering the flat landscape although river bank cutting can be a serious concern.

The Study area has been under many potential threat. The bank cutting in the study area has created probability of entering flood into the nearby agriculture land and settlements. Many agricultural lands have been converted to river deposits and Bagar. Therefore, check dam or embankment or spur need to be constructed for the conservation of land resources. Fire preparedness activities most be carried out, which includes spreading messages through television, radio, street drama, video, folk songs, drills, posters, pamphlets, and hoarding boards to reduce the risk of firing. The risk zoning is a very broad and dynamic topic which demands data to be very accurate and must represent the current scenario of the area. The data currently available and used are not sufficient to fully depict the actual picture in regard to risk in the area though it gives possible scenario of existing risk. The present exercise produced preliminary results on the risk areas of the selected hazards. These outputs could be worked for the purpose of the present exercises for delineating the land use zoning of the VDCs. The present risk map and data may be useful for land use planners and environmentalist who uses geospatial tools. It could also be useful for preliminary devising sustainable environmental planning strategies for the rural development of the area. This data can aid in proper zoning of the study area keeping in mind the risk aspect and help to make proper planning for sustainable development.