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Preparation of VDC Level Land Resource Maps (Present Land Use Map, Soil Map, Land Capability Map, Risk Layer, Land Use Zoning Map, Superimpose of Cadastral Layer and VDC Profile), Database and Reports For F/Y 2072/073

Package No.: 11

FINAL REPORT

Karahiya VDC, Rupendehi District

- Present Land Use
- Soil
- Land Capability
- Risk Layer
- Land Use Zoning
- Cadastral Layer Superimpose
- VDC Profile

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Joint Venture With

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Present Land Use

FINAL REPORT

Preparation of Present Land Use

KarahiyaVDC of Rupandehi District

FOR

Consulting Services

for

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

Package No: 11

Anandaban, Devadaha, Karahiya, Kerwani, Madhawaliya, Makrahar, Shankar Nagar, Tikuligadh, of Rupandehi District (8 VDCs)

Preparation of Present Land Use KarahiyaVDC of Rupandehi District

This document is one of the outcomes of the project entitled **Preparation of VDC level Land Resource Maps** (Present Land Use Maps, Soil Maps, Land Capability Maps, Land Use Zoning Maps and Cadastral Layer Superimpose and VDC Profile), **Database and Reports** of Package 11 awarded to SHREEYA-KRS JV by the Government of Nepal, Ministry of Land Reform and Management, National Land Use Project (NLUP) in Fiscal Year 2072-073. The VDCs covered under this package include eight VDCs of Rupandehi district namely: **Anandaban, Devadaha, Madhawalia, Makrahar, Karahiya, Kerwani, Sankar Nagar and Tikuligadh**. Mr. KulBahadurChaudhari was involved and solely credited for the preparation of maps, database and reports on risk themes.

The VDC areas analyzed for different themes of the NLUP Project are computed from cadastral maps provided by DOLIA Office of Nepal. Therefore, the areas of the VDCs may not be the same as computed from Topographic Database provided by the Survey Department of Nepal.

The consultant is obliged to state that the Imageries, GIS database and other outputs produced for the project is owned by National Land Use Project (NLUP), Mid-Baneshwor, Kathmandu. Therefore, the authorization from the NLUP is required for the usage and/or publication of the data in part or the whole.

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1.1 Background and Rationale

1.1.1 Background

Land is the basic natural resource and it is limited to human beings. In the human history, most of the sustenance and much of his fuel, clothing and shelter obtained from the land. Itis the basis for habitat and living space for human.Land represents one of the major natural resources available in Nepal.Nepal is a land of diversity; climates range from subtropical (lowland) to arctic (high mountain) and vegetation ranges from subtropical forests to arctic like Tundra. The country has been divided into three physiographic regions; Lowland (Terai), Middle Hills and High Mountains. All the activities related to land and natural resources for economic development, social equity and of maintaining a sound environment are complementary but they frequently stand in competition with each other. Land is a fundamental factor for agriculture production which is directly linked to food security. And, it is also observed that improper management of land is mostly responsible for environmental degradation in Nepal.

Land is the precious natural resource that is at the center of the all economic activities. Nepal is an agrarian country, nearly 66percentof economically active population of the country is involved in agriculture; its contribution on GDP is 33 percent. The involvement of workforce in agricultural sector is huge; however, agricultural growth rate is not satisfactory (3.3percent) (ABPSD, 2012), and this could not fulfil the ever increasing demand of agricultural products in the country. Therefore, food security of the country is vulnerable due to impropermanagement of land, low fertility, soil erosion, population pressure, and land degradation.

An inventory of land, skillfully classified according to various economic uses, will always be an important database for governments, planners, policy makers and other stakeholders. At national level, databases regarding land resource are being produced using available resources and local needs. Exceptonly few landscapes on the Earth that is still in their natural state, significantly altered in some manner and man’s response on the Earth has had a profound effect upon the natural environment thus resulting into an observable pattern in the land use/land cover over time. Land resources are limited and finite, but population has been rising tremendously. With the increasing size of population, the demand of land for housing, food, fuel will double within next 25 to 50 years (FAO, 1993). Nepal is not an exception. Land is the fundamental and precious natural resource; the economic and social lifestyles of most of the Nepalese are intimately related to land resources. Proper land use planning is necessary for optimum utilization of this resource which is inevitable and essential for sustainable development and conservation.

Land is static, and nature and quality of land varies significantly across the space.Unlike capital, labor, management skills and technology,land cannot be moved, and different areas present different opportunities and different management problems. The issue of land management is being even critical in recent days as a result of climate change resulted inchanges in water availability, erosion and degradation of soil etc.Detail and up-to-date information about land resources is thus essential for proper land-use planning.

Due to the rapid human population growth, the proper and sustainable use of land resources is of global concern. There is a need of increasing production on the one hand and protection of environment on the other, which can be achieved through efficient management of land resources. Evaluation and the ensuing planning require basic data/information about the resources, the people and the institutional framework involved. Basic information on land resource is essential for policy-making, business and administrative purposes. It forms the basis for gauging developments and opting development programs. Information is required for planning infrastructure like road, drinking water, waste management, sanitation, health centre, schools, communication etc. The land resource data isalso required for the development and management of agriculture, forest and biodiversity and overall environmental management. Land resource data is the prerequisite for developing policy, implementation of the program and its overall management. It is of prime importance for local level planning and management of resources.

Land use planning is a systematic and iterative procedure carried out in order to create an enabling environment for sustainable development of land resources which meets people's needs and demands. It assesses the physical, socio-economic, institutional and legal potentials and constraintswith respect to the optimal and sustainable use of land resources, and empowers peopleto make decisions about how to allocate those resources. Land-use planning is ultimately about people and their relationship with land and other natural resources, and the skills that planners and land managers bring to these processes are those of recognizing and accommodating competing or multi-layered and co-existing interests (PIA, 2007). The concepts and the approaches it embodies are driven by the need to take a holistic approach to ensure that socio-cultural, technical, economic and environmental factors are taken into account in the development and resource management decision making. Integrated land-use or environmental planning are steeped in concepts of equity, benefit sharing, strategic visioning, participatory involvement and continuing processes of monitoring and review. As such they offer an ability to introduce an alternative dispute resolution system, that if designed well can reduce burdens on more formal adjudication systems and bring harmony to communities.

Land use policy and planning do not function according to international standards in Nepal for several reasons: landless and jobless people are encroaching on public and state land, such as forests, setting up squatter farms and settlements, ecosystems are deteriorating, and small-scale farmers are struggling to secure stable food supplies.The land use map is a useful resource to support the decisions of the city planners, economist, and ecologist and for every decision-maker involved in the sustainable development of the territory. In recent years, the technological development in RS and GIS has emerged as powerful tools in the management and analysis of large volume of spatial and thematic resource data to support land use/resource planning. The digital satellite images obtained from sensors are processed, prepared, classified and analyzed in different stages of remote sensing techniques to get information for various applications. The availability of remote sensing products with high spatial resolution made easy to derive spatial dataset for land use with good accuracy, more efficient and reliable way. Further, the computational power to extract meaningful quantitative results from remotely sensed data has also improved tremendously. These developments in both data access and data processing ability present exciting and cost-effective opportunities for remote sensing approaches to be used widely in land use planning and analysis of land utilization for land use planning.

1.1.2 Rationale

Although, the landuse planning for making the best use of the limited land resources is inevitable, yet, except sporadic attempts for the urban areas, Nepal has not practiced landuse planning for the country as a whole. However, several attempts were made for balanced use of country's existing natural resources in the past through different policies and national planning efforts.

Landuse 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, 1986). Realizing this fact, the Ministry of Land Reform and Management of Government of Nepal established the National Land UseProject (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 seat 1:50,000 scale for the whole Nepal. It had also preparedsame kinds of maps and database for Kirtipur, Lekhnath, MadhyapurThimi 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 2070/071 fiscal years,NLUP has completed preparation of land resource maps and database for most of the VDCs of Terai Districts. 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.

On the 4th *Baishakh* of 2069, the Government of Nepal has approved the National Land Use Policy, 2069.National Land Use policy, 2069 has modified by amendment in 2072 and introduced National Land Use Policy, 2072. It has intended to manage land use according to land use zoning policy of the government of Nepal and outlined eleven zones such as Agricultural area, Residential area, Commercial area, Industrial area, Mining and Mineral area, Cultural and Archaeological area, River, Lake and Water bodies area, Excavation area, Forest area, Public Use area and Others. The policy has defined the respective zones as per the land characteristics, capability andrequirement of the lands. Further, for the effective implementation of land use zones in the country, the National Land Use Policy, 2072 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.

In this regards, the National Land Use Project (NLUP) has commissioned JV of Shreya Engineering Consultancy (P) LTD- K.R.S.Engineering Consultancy (P) LTD in the Fiscal Year 2072-073 to conduct the project entitled Preparation of VDC level land resources maps (Present Land Use Map, Soil Map, Land Capability Map, Land Use Zoning Map, Superimpose of Cadastral Layers and VDC Profile), Data base and Reports for VDCs under Package 11 of Rupandehi District in the fiscal year 2072/073. The Package 11 covers 8 VDCs; Anandaban, Devadaha, Karahiya, Kerwani, Madhawaliya, Makrahar, Shankar Nagar and Tikuligadh.

The NLUP envisaged the following points as the basis for the preparation of present land use maps of the concerned VDCs:

- 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 Objectivesof the Study

The objective of the NLUP project is to prepare the VDC level land resource maps (Present Land Use Map, Soil Map, Land Capability Map, Land Use Zoning Map, VDC Profile for Land use Zoning and Superimpose of Cadastral Layer) at 1:10,000 scales, database and reports. The specific objective of the present study is to prepare Present Land Use Maps, GIS Database and Reports for the KarahiyaVDC in different hierarchical levels at 1:10,000 scales as per ToR, 2015 and National Level Specification for the Preparation of VDC Level Land Resource Maps, Database and Reports, 2015.

In order to achieve the objectives, the scope of work includes the following activities:

- Perform ortho-rectification of the satellite image,
- Prepare present land use maps in different hierarchical levels,
- Manage GIS database as per NLUP specification,
- Maintain quality of data in terms of accuracy, reliability and consistencies, and
- Prepare reports including methodology, existing land use pattern and model of GIS data base.

1.3 Study Area

Karahiya VDC lies in Rupendhei district, Lumbini Zone. The VDC has currently included in Tilottama Municipality. And it is known for ward no. 9, 10, 11 & 12 of the municipality. It is located between 83° 27' 50” to 83° 31' 20"E longitude and 27° 35' 20” to 27° 35' 58"N latitude. The VDC is bordered by Makrahar&Gangoliya VDCs to the east, Anandaban VDC to the west, Andandaban&Devadaha VDCs to the north and Madhawaliya&Gangoliya VDCs to the south.The VDC covers a total area of 2082.81 ha. The extension of the VDC is 4.7 km and 8.8 km in east-west and north-south respectively.

According to the population census 2011, the total population of the VDC was 18274 with 4267 households. Of the total population, the percentage of male is six percent lower than the female. The population of this VDC is composed of different caste/ethnic groups. Among them, Brahmin is in majority. The proportion of migrants is significant in the total population. Migrants were mainly from fromPalpa, Gulmi, Arghakhachi, Baglung, and Parbat. Ninety-five percent people follow Hinduism. People are involved in many occupations. More than half of the total populations are involved in agriculture. And it is the main source of income. Almost one-third of the total income comes from agriculture sector.

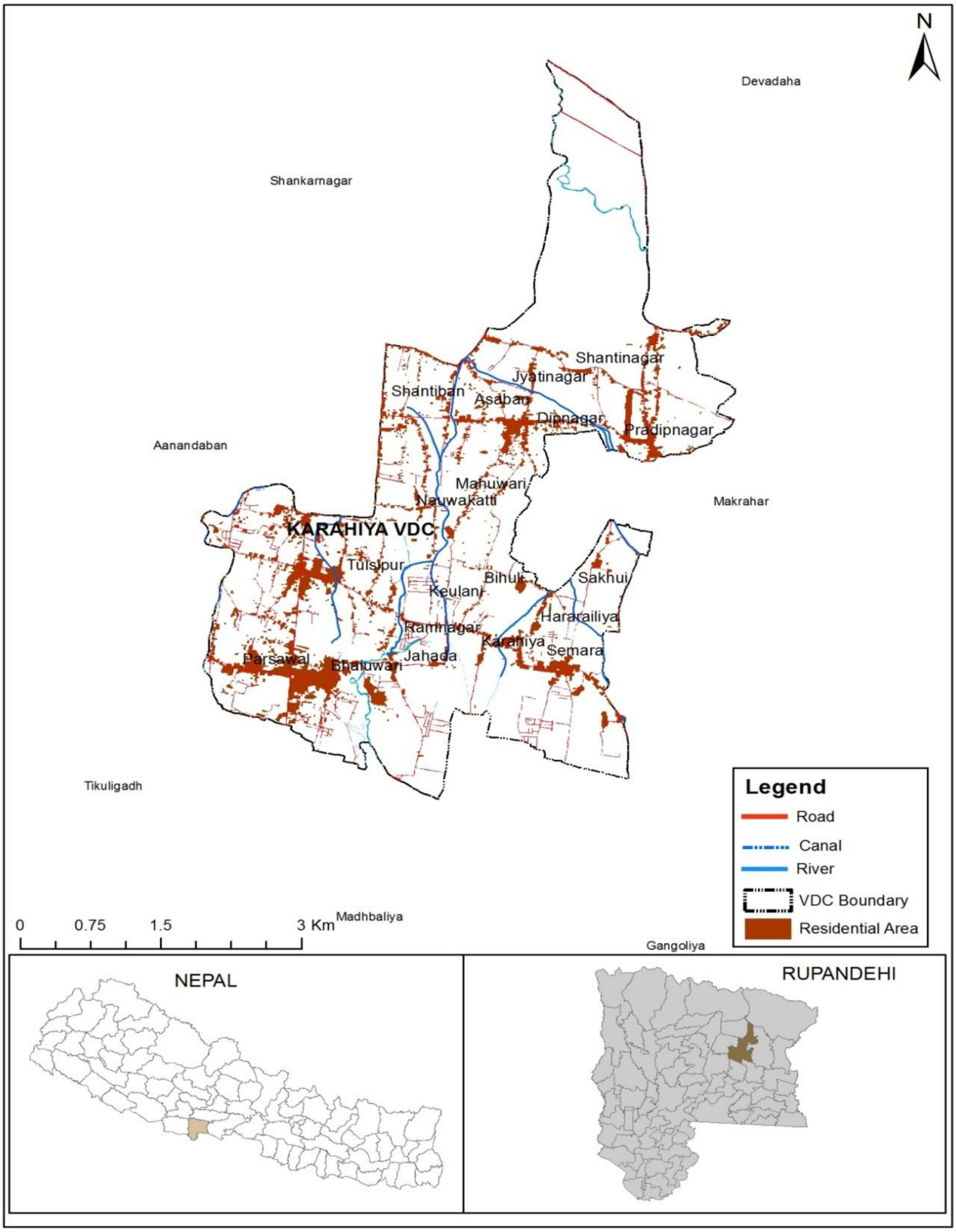

Figure 1.1 Location Map of KarahiyaVDC

CHAPTER 2: CONCEPTUAL BASIS OF LAND USE CLASSIFICATION

2.1 Classification System and Criteria

In most existing classification systems, the geographic variables such as “land use" and "land cover" are grouped together since these are closely related. However, the key differences between these create confusion when they are blended together in a single classification scheme and map. "Land cover" refers to the vegetative or non-vegetative characteristics of a portion of the Earth’s surface. "Land use" describes some human activity on the surface (Burley, 1961). The concept of land cover (LC) is best understood when applied to natural surfaces where no activity has occurred. The type of land cover present is determined directly by observation. This observation may use satellite imagery or aerial photography for certain levels of classification detail and positional accuracy. For very detailed levels of mapping, however, on-site inspection may be required. Land use (LU) types may also be determined through observation by deducing human activity or disturbance based on the appearance of the landscape. As in the case of land cover, land use classes may also be determined, in many cases from satellite imagery or aerial photographs. For detailed land use information (Levels 3, 4, and below in the hierarchy), on-site analysis is often required. In many cases, supplemental information gathered from business licenses or questionnaires is needed to reliably assign a land use class since the use is not always apparent through observation.

The performance of sustainable land resource management is essential for land use planning or zonation and its assessment based on performance of specific land use. The trend of land use are diverged in nature which has influenced by the physiographic, topographic, climatic, lithology, soil type, settlement pattern, cultural and traditional practices, and socio economic factors. Therefore, LULC should be classified with its actual/concrete situation in the particular field using well-defined diagnostic criteria of the classifiers. For this purpose, certain classification schema should be necessary. Classification of land use or land cover is performed with a set of target classes in mind; these set are called a classification scheme (or classification system). The purpose of such a scheme is to provide a framework for organizing and categorizing the information that can be extracted from the data (Jensen, 1996). Generally, classification system is the abstract tool which is described as the situation in the field using well defined process, rules and criteria’s. It also describes as the systematic framework with the name of classes and the criteria used to distinguish and related within defined framework among these classes. Classification system is defined as the ordering or arrangement of objects into groups or sets on the basis of their relationships (Sokal, 1974). Thus, classification system has necessarily involved in the definition of class boundaries, which should be clear, precise, possibly quantitative, and based upon objective criteria (Di Gregorio & Jansen, 1997). Classification system should be scale independent i.e. the classes should be applicable at any scale or level of detail and source of information should be independent i.e. it is independent of the collection mode, whether it is through satellite imagery, aerial photography, field survey or using a combination of sources). According to

Meinel and Hennersdorf (2002), a classification system should be the product of an on-going interaction between:

- A systematic approach whereby information is structured in accordance with logical principles (exhaustiveness, absence of overlaps, unequivocal definition of classes, rules for representing objects in the classification).
- A pragmatic approach taking accounts of user needs and existing information stocks, and
- A context-related approach that addresses specific constraints regarding to the geographical dimension of information of LULC.

Many classification systems have been developed for a certain purpose, at a certain scale and using a certain data type. So, classification system follow the general criteria for reference classification system to appropriate land cover classes for the specific purposes which are scale independent and source information independent. Furthermore, often the factors used in the classification system results in an undesirable mixture of potential and actual land cover. According to FAO land use land cover classification system, the reference classification system to be (FAO, 1995):

- comprehensive, scientifically sound and practically oriented;
- meet the needs of a variety of users (neither single-project oriented nor taking a sectorial approach);
- users can use just a sub-set of the classification and develop from there according to their own specific needs;
- potentially applicable as a common reference system, and facilitate comparisons between classes derived from different classifications;
- be a flexible system, which can be used at different scales and at different levels of detail allowing cross-reference of local and regional with continental and global maps without loss of information;
- able to describe the complete range of land cover features (e.g., forest and cultivated areas as well as ice and bare land, etc.), with clear class boundary definition that are unambiguous and unique;
- adapted to fully describe the whole variety of land cover types with the minimal set of classifiers necessary (the less classifiers used in the definition, the less the error expected and the less time and resources necessary for field validation); and
- based on a clear and systematic description of the class, where the diagnostic criteria used to define a class must be clearly defined, with pure land cover criteria distinct from environmental criteria (e.g., climate, floristic and altitude), as the latter influence land cover but are not inherent features.

Priori classification system assumes that all possible classes can be derived, independent of scale and classifiers tools are used in the system and produce most effective standardization of classification results among user communities. Priori classification system is considering the following substantial requirements (Meinel and Hennersdorf, 2002).

- Spatial Consistency
- Temporal Consistency
- Independence from data collection and processing tools
- Consistency of scale
- Identification rules
- Completeness
- Absence of overlap
- Compatibility
- Multi-user systems, etc.

Hierarchical systemize multi-tiered abstract representation in the particular field using well-defined diagnostic criteria of the classifiers. In hierarchically structured form of classification system 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 (Anderson et al., 1976).Once the hierarchical land-cover structure is defined, knowledge rules for each land-cover type have to be generated. Three types of information are considered in constructing the knowledge rules for each land-cover type in the hierarchy:

- Domain spectral knowledge: Spectral knowledge can be used to construct the hierarchical structure of LULC classes.
- Spectral classification rules obtained from training data: Qualitative spectral knowledge involved in high resolution satellite images has to be transformed to more specific quantitative classification rules. Training data help to generate thresholds to be used later as rules for discriminating and classifying LULC categories more accurately.
- Spatial knowledge: Spectral knowledge alone is insufficient for classification of all LULC types; spatial rules have to be used to increase the resultant accuracy.

In the study, prior defined hierarchical system has used for land use classification schema.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 (Di Gregorio & Jansen, 2000). At present, the requirement or demand of high quality land use data is increased in planning process of land resources including land use planning, land development, land management and land administration. So, improved land use data sets are essential to fulfill the increasing need, which describe and classify precisely land use in order to develop sustainable land use systems. There is also a growing need for standardization and compatibility between data sets and for the possibility to map, evaluate and monitor wide areas in a consistent manner (Di Gregorio, 1991; Reichert and Di Gregorio, 1995; Thompson, 1996; FAO, 1995). For the standardization of land use data, it needs pre-arrangement of the name of classes with different diagnostic criteria.

Similarly,the minimum mapping unit (MMU) is the fundamental factor for the classification system, which is determined by the minimum mapping area to show on the map. The size of the minimum area which can be depicted as being in any particular land use category depends partially on the scale and resolution of the original remote sensor data or other data source from which the land use is identified and interpreted. It also depends on the scale of data compilation as well as the final scale of the presentation of the land use information. For implementation of land use planning and management purposes, the accuracy of classified land use data are needed. So, 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 (Anderson, 1971).When land use classification has done using orbital and high-altitude remotely sensed data, the certain specific criteria are effectively employed (Anderson et. al 1976). The criteria used are listed as:

- The minimum level of interpretation accuracy in the identification of land use and land cover categories from remote sensor data should be at least 85 percent.
- The accuracy of interpretation for the several categories should be about equal.
- Repeatable or repetitive results should be obtainable from one interpreter to another and from one time of sensing to another.
- The classification system should be applicable over extensive areas.
- The categorization should permit vegetation and other types of land cover to be used as surrogates for activity.
- The classification system should be suitable for use with remote sensor data obtained at different times of the year.
- Effective use of subcategories that can be obtained from ground surveys or from the use of larger scale or enhanced remote sensor data should be possible.
- Aggregation of categories must be possible.
- Comparison with future land use data should be possible.
- Multiple uses of land should be recognized when possible.

2.2 Land Use Hierarchy and Description

Priori classification system having hierarchical level classification schemas are recommended in Terms of Reference (ToR) and Specification (2012) provided by the National Land Use Project (NLUP). The National Land Use Policy, 2069 provides the nomenclature of the Land Use classes. The specification provided by NLUP has categorized the land use classes up to 7th level. The level one categories of the land use are such as Agricultural area, Residential area, Commercial area, Industrial area, Mining and Mineral area, Cultural and Archaeological area, River, Lake and Water bodies area, Excavation area, Forest area, Public Use area and Others as provided in ToR and specification 2015.

2.2.1 Agricultural Area

Agricultural land is defined broadly as land used primarily for production of food and fiber crops. 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 largely due to physical (e.g. climatic condition, moisture, topography, soil) and social/cultural settings 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 cultivation. Hill cultivation is further sub-divided into level terraces and sloping terraces. The Mountain cultivation is further divided into Level terraces, Upland cultivation and Sloppy upland. Similarly, Valley cultivation is divided into four groups: 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 of the Taraiis further sub-divided into Low khet land cultivation and Upper khet land cultivation-torikhet. Different cropping patter is presented in level five, whereas cropping intensity is also resented in level six category. Based on above information, NLUP has provided hierarchy of agricultural land (Table 2.1).

Table 2.1 Hierarchy of Agricultural Area

Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5 Cropping Pattern** **Monsoon- Winter-Dry season**	**Level 6 Cropping Intensity**
Agricultural Land Use	**Terai Cultivation**	• **Wet Land Cultivation**	• **Low Khet Land Cultivation** (Poorly drained with High bond) ------------------- • **Upper Khet Land Cultivation- TariKhet** (Intermediate land between wet and dry land with well drain soil bonds are lower)	Rice-Wheat Rice-Rice Rice-Maize Rice-Pulses Rice-Wheat-Pulses Rice-Maize-Veg. Rice-Potato-Veg. Rice-Veg.-Veg. Rice-Pulses Maize-Oilseeds Maize-Pulses Pulses-Fallow Fruit-fruit Sugarcane-Sugarcane Rice-Pulses Maize-Oilseeds Maize-vegetables Rice-Veg. Pulses-fallow	Intense (75%-100% cultivated) medium(50%-75% cultivated) Light (25%-50% cultivated) Not Applicable
		• **Dry Land Cultivation** (Upland Pakho/ Bhith land Cultivation,	Unclassified		

Level 1	Level 2	Level 3	Level 4	Level 5 Cropping Pattern Monsoon- Winter-Dry season	Level 6 Cropping Intensity
Agricultural Land Use		Drained, smallest bond height)			Light-1 Medium-2 Intense-3
		• **Mixed Land Cultivation** (Commonly found near River where River have change the course)	Unclassified		
	Hill Cultivation	**Level Terraces**	• **Level Terraces Khet Land Cultivation** (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		
Agricultural Land Use	**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.	Light-1 Medium-2 Intense-3

Level 1	Level 2	Level 3	Level 4	Level 5 Cropping Pattern	Level 6 Cropping Intensity
				Monsoon- Winter-Dry season	
	Valley Cultivation	• **Valley slope upland/Pakho cultivation** (Cultivated on natural slopes) ---------------------- • **Valley Riverbeds(Lower footslope) Alluvial Fans Cultivation** (alluvial riverbed fans)	Unclassified		Not Applicable -4

2.2.2 Residential Area

Residential areas are the built-up areas used for housing purposes. This includes annex buildings like cow sheds, garage and farm house etc. are also include in this category. 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 is also falls in this category.

Based on density of houses, the residential area is further divided into three categories; as dense (>70 percent), moderate (40-70 percent) and sparse (<40 percent). 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).

Table 2.2 Hierarchy of Residential Area

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

2.2.3 Commercial Area

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. Detail hierarchical structure of the commercial land use is shown in (Table 2.3.)

Table 2.3 Hierarchy of Commercial Area

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 includes the following:

Market Subcategory (M)	Recreation Subcategory (R)	Utility Subcategory (U)
Shop - s1	Cyber cafe - y1	Water Reservoir - w1
Boutique - b2	Cinema Hall - c2	Hydropower Area - h4
Departmental Store - d1	Concert Hall - h2	Cable Car - c5
Retail Business - r2	Theatre - t2	Gas Plant - g3
Supermarket - m1	Dance Hall - d2	Oil Storage - o4
Hotel Subcategory (H)	Night Club - n1	Other storage - x3
Hotel - h1	Gaming Hall - g2	
Guest House -g1	Gambling Hall - l1	Government Service Area Subcategory(G)
Fast-food -f1	Exhibition Centre - e1	Agriculture Office - ag
Restaurant - r1	Gym House - m2	CBS - b5
Bar - b1	Other Entertaining area - x2	Civil Aviation - ca
Travel Agency - t1		Communication - cm
Other hotel - o1	Services Subcategory (S)	Court - co
	Bank/Money Exchange - b3	Cultural Office - cu
Hotel Subcategory (H)	Private Post office - p1	District Administration office - a1
Hotel - h1	Private Communication Area - c3	Doildar - do
Guest House -g1	Broadcast Studio - d3	Education - en

Fast-food -f1	Private School Area - e2	Electricity office - eo
Restaurant - r1	Private Health Service Area - h3	Forestry office - f2
Bar - b1	Petrol Pump - m3	Health office - h5
Travel Agency - t1	Radio Station - r3	Irrigation office - i1
Other hotel - o1	Service centre - s2	Land Transaction Office -lt
	TV Station - t3	Local Development office - l2
Storage Subcategory (T)	Other Service - o3	Mining and Geology - mg
Storage house/ area - s3		Other - o5
Consultancy service area - c4		Petroleum - pm
Business house - b4		Post Office - po
		Road Office - r4
		Soil Conservation - sc

2.2.4 Industrial Area

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 also 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.)

Table 2.4 Hierarchy of IndustrialArea

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

2.2.5 Forest Area

Area covered by vegetation, completely or partially which does not fall under above mentioned categories 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 is sub-divided into level 2 sub-types as per the climatic vegetation zone such as tropical (<1000 m), sub-tropical (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 sub-divided into level 3 categories by cover type as hardwood, coniferous and mixed forest. On the basis of crown density, forest is classified as dense, sparse and degraded types. Likewise, according to the forest ownership category or use right, it is classified as private, protected, government managed, community, and leasehold, collaborative and religious forest. The hierarchy of forest land use is shown in (Table 2.5**.)**

Table 2.5 Hierarchy of Forest Area

Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
Forest	***Climatic Vegetation Zone:*** **Tropical Forest** (<1000m) **Sub-tropical** (1000-2000/2100m) **Temperate** (2000/2100-3000/3100m) **Sub-alpine** (3000/3100-4000/4100m) **Alpine** (4000/4100-4500m)	***Cover Type*** **Hardwood** **Coniferous** **Mixed**	***Species Type*** As described as below	***Crown Density:*** **Dense** (>70% Crown Density) **Sparse** (40-70% Crown Density) **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)	***Maturity Class*** ***Mature*** To over mature-trees have reached at least estimated rotation age of saw timber size **Immature**or small timber size materials **Reproduction** New generation to pole size	***Forest Ownership Category or Use Rights:*** Private Protected Government Managed Community Leasehold Collaborative Religious Others
		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.

Species type forest is shown as below:

Sal forest (Sl)	Cedrusdeodara Forest(Cd)
Pinusroxburghii Forest(pb)	Cupressustorulosa Forest(Ct)
Quercusincana-Q. lanuginose Forest(Qq)	Larix Forest(La)
Quercusdilata Forest(Qd)	Tropical Evergreen Forest(Te)
Quercussemecarpifolia Forest(Qs)	Alnus Woods(Aw)
Castanopsistribuloides-C.hystrix Forest(Cc)	Populus ciliate Woods(Pc)
Quercus lamellose Forest(Ql)	Hippophae Scrub(Hp)
Lithocarpuspachyphylla Forest(Lp)	Moist Alpine Scrub(Ma)
Aesculus-juglans-Acer Forest(Aa)	Dry Alpine Scrub(Ds)
Lower Temperate Mixed Broadleaved Forest(Lm)	Juniper wallichiana Forest(Jw)
Upper Temperate Mixed Broadleaved Forest(Um)	Wetland area(Wl)
Tropical Deciduous Riverain Forest(Tr)	Rock outcrops/ barren lands(Ro)
Rhododendron Forest(Rh)	Sub-tropical Evergreen Forest(Se)
Betulautilis Forest(Bu)	Terminalia Forest(Tn)
Abiesspectabilis Forest(As)	Dalbergiasissoo-Acacia catechu Forest(Da)
Tsugadumosa Forest(Td)	Sub-tropical Deciduous Hill Forest(Sd)

Pinusexcelsa Forest(Pe)	Schima-Castonopsis Forest(Sc)
Piceasmithiana Forest(Ps)	Sub-tropical Semi-evergreen Hill Forest(Ss)
Abiespindrow Forest(Ap)	Other Forest Species(Of)

2.2.6 Public Use (Open Area)Area

Public services are those services which cannot exclude someone to use it under certain terms of condition. Public lands used by School, College, Hostel, Well, 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 Services, and Institution. School, Colleges and Universities are placed in Educational class. Police station, Military area and Fire station are categorized in Security services. Transportation Infrastructure includes Road, Trail, Airport, Bus Park, Railway, Ropeway, etc. Likewise, Hospital, Health Post, Polyclinics etc. are included under Health services. Institutional service includes Government and Public institutions. The hierarchy of public services is given below (Table 2.6)

Table 2.6 Hierarchy of Public Use Area

Level 1	Level 2	Level 3
Public Services	Educational	Designated Name
	Security Services	
	Transportation Infrastructure	
	Recreational	
	Health Service	
	Institution	

Subcategories of Public service at Level 4 are shown as below:

Subcategory of Transportation

Sub-Category Transportation- T	Sub-Category Institutional- I
Highway - h2	Private Institution - r3
Feeder Road - f2	Public Intuition - p6
District Road - d3	NGO - n2
Local Road - i1	INGO - i4
Other Road - o5	Other intuitional- o8
Bus park - b1	Sub-Category Recreational- F
Airport - a2	Public Theatre- c8
Railway - r2	Drama House - d4
Car Park - c4	Stadium - s3
Port - p3	Play ground - g4
Pavement - v1	Open space - o9
Cart Track - t3	Other - x2
Other Transportation - x1	Zoo - z1

Bridge - g3	Rest-point-Chautari- r4
	Museum - m1
Sub-Category Education- E	Sub-Category Security Service- S
Primary - p5	Police Station - p8
Secondary - s2	Military Area - m2 Military Area - m2
Campus - c5	Armed Force - a3
University - u2	Other Security- o10
Other educational area- o6	
Sub-Category Health - H	
Hospital - h3	
Nursing Home - n1	
Health Centre - c7	
Pharmacy - f3	
Polyclinic - i2	
Other - o7	

2.2.7 Mine and Minerals Area

Mines and mineralsare the mineral excavation, production and processing, or a certain geographic area that the mines and minerals sector in the area of land set by the government. The mine and mineral land use category also consists of discovered mines areas, mining operation areas, mineral excavation and production, processing and purification region etc. Level 2 categories of mine and minerals land use consists ofmetallic minerals, non-metallic minerals, construction materials, decorative and dimension materials (basalt, colored sandstone, granite, and marbles), fuelling materials (coal, hot springs, methane, petroleum and natural gases), gemstones, and aquamarine (beryl, garnets, gem, kyanites, quartz crystal, ruby, sapphire, tourmaline, etc). It also metallic (iron, copper, zinc, lead, cobalt, nickel, gold, silver, tin, tungstone, molybdenum, uranium, lithium, mica, tantalum, bismuth, arsenic, cadmium, chromium, mercury, titanium, etc), and non-metallic (clay, dolomite, magnetite, phosphorate, silica, talc, phyllite, etc) minerals.The hierarchy of mine and mineral land use is given in (Table 2.7.)

Table 2.7 Hierarchy of Mine and MineralsArea

Level 1	Level 2	Level 3	Level 4	Level 5
Mine and minerals	Metallic Minerals	Iron Copper Zinc Lead Cobalt Nickel Gold Silver Tin Tungsten Molybdenum Uranium Lithium	• Licensed • Not-Licensed • Reserved • Banned	• Not Operated So Far • Currently under Operation • Closed • Other Operation status

		Lepidolite(Mica) Tantalum Bismuth Arsenic Cadmium Chromium Mercury Titanium Other Metallic Minerals		
	Non-metallic Minerals	Clay Dolomite Limestone Magnetite Mica Phosphorate Quartz Silica sand Talc Phyllite Other Non-metallic minerals		
	Construction Minerals (Materials)	Sand Cobbles Flaggy Quartzite Limestone Pebbles Quartzite River Boulders Schist Slates Other Construction Minerals		
	Fuel Minerals	Coal Hot Springs Methane Petroleum Natural Gases Other Fuel Minerals		
	Decorative and Dimension Stones	Basalt Colored sandstone Granites Quartzes Other Decorative and Dimension Stones		
	Gemstones	Aquamarine Beryl Garnets Gem Kyanites Quartz Crystels Ruby Sapphire Tourmaline Other Nemstone Minerals		
	Other Minerals			

2.2.8 Cultural and Archaeological Area

Cultural and Archeological class covers the cultural site along with archeological place, historical places and religious places. Cultural services include Chowk, Patis, Bihar etc. Religious places include Temple, Stupa, Monastery, Mosque, Church, etc. Historical Services includes Durbar Square, Gadh, Archeological Site, Heritage etc. The hierarchy of cultural and archeological land use is given below (Table 2.8.)

Table 2.8 Hierarchy of Cultural and ArcheologicalArea

Level1	Level2
Historical and Archeological	Heritage Site Durbar Square Gadh Archeological Site Cultural Site Fort Temple Stupa / Monastery Mosque Church Bahal Patis Bihar Other

2.2.9 River line and Lake Area

River line and lake land use categories have the hydrographical feature which includes River, Lakes, Ponds, Canal, Glacier, Snow covered area, wetland, sand, well, spring etc. The hierarchy of river line and lake land use is given in (Table 2.9.)

Table 2.9 Hierarchy of River line and LakeArea

Level1	Level2
River line and Lake Area	Pond Lake Canal Glacier Snow Area Wetland River Spout Well Kulo Sand Other

2.2.10 Excavation Area

Excavation area has mainly construction material area which directly excavated in the industrial purpose. It has included the construction material as cobbles, flaggy quartzite, limestone, pebbles, phylitte, quartzite, river boulders, sands, schist, slates etc.The hierarchy of excavation land use is given below (Table 2.10.)

Table 2.10 Hierarchy of ExcavationArea

Level 1	Level 2	Level 3
Excavation (Construction Materials) Area	Cobbles Flaggy Quartzite Limestone Pebbles Phylitte Quartzite River Boulders Sands Schist Slates Other Excavation Materials	• Licensed • Not-Licensed • Reserved • Banned

2.2.11 Other Land Use

Other land use includes the types of land that does not belong to the categories mentioned above. Such types of lands are: grass land, orchard, bamboo plantation etc. 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), which are shown in (Table 2.11.)

Table 2.11 Hierarchy of Other Land Use

Level 1	Level 2	Level 3	Level 4
Others	Grass land	**ClimaticVegetation Zone** Tropical (<1000 m), Sub-tropical (1000-2000/2100 m), Temperate (2000/2100-3000/3100 m) Sub-alpine (3000/3100-4000/4100 m) Alpine (4000/4100-4500 m).	
	Bamboo		
	Orchard		Specific species

CHAPTER 3: METHODOLOGY

3.1 Data Sources

There are varieties of sources of information on existing land use and land cover and on changes that are occurring. Land use (LU) and land cover (LC) has determined with primary source of data such as ground survey method, aerial photographs, satellite images as well as secondary sources of data from topographical maps, cadastral maps and other relevant land use land cover maps. Withthe development of recent technology-Remote sensing, mostly LULC map has been prepared from high resolution satellite images. Today, large numbers of high resolution satellite images such as IKONOS, Quickbird,Worldview, Geo eye etc.are in use. 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 and Anderson et el., 2001).

For the present land use analysis, both primary and secondary types of data were used. Maps and related information regarding Land utilization, Land Capability, Land System, and Topographical Map were used as secondary information. Maps and reports mentioned above were gathered and analyzed before interpretation of satellite imagery and field visit. Information/data regarding land use types, cropping pattern, and forest types/management etc. were collected during the field work applying intensive field data collection technique and tools like formatted questionnaires. All data and information obtained from secondary sources related to this theme were verified during field work.

In this study, satellite images such as 0.5m panchromatic images and 2m multispectral imagery from WorldView-2 satellite constellation (which was provided by NLUP)were used as primary sources of data acquisition of land use along with field verification.The various ancillary vector data (topographical map/data, land utilization map etc.) includingGoogle images were also used as secondary sources for enhancing data accuracy and interpretation. LU classification was done with visual interpretation and manual designation of land uses along with extensive field knowledge and field verification in pre-defined hierarchical classification system. Various other vector, raster and imagery data sets were used as ancillary data, which enhanced interpretation and classification of land use classes. This chapter briefly describesthe sources and characteristics of datasets used in the study.

3.1.1 WorldView-2 Satellite Images

WorldView-2 satellite system is one of the best ground resolution commercial satellitesimaging at the present time having both PAN and MSS spectral resolution images. The satellite has extraordinary detail, high accuracy and enhanced stereo imagery for DEM generation. WorldView-2 satellite simultaneously collects panchromatic imagery at 0.46m and multispectral imagery at 2.05m ground sample distance (GSD) at nadir view. The WorldView-2 image has the stereo capability with cut off angle 30^0 for/or aft and 0^0 off nadir view for the topographical data extraction using Radmin Phone Book (RPB) file extension which has used to read the rational polynomial coefficient (RPC) metadatadomain and provided by vendor along with the satellite image(Worldview, 2009). Due to U.S. Government licensing, it make available at 0.50m images other than the U.S. Governmental offices.The sensor characteristic of WorldView-2 is described in Table 3.1 and scene details used in this study are shown in (Table 3.2.)

Table 3.1 Specification of World View-2Image

Product	***Data Detail***		
Processing Level	*Standard Radiometric Corrected*		
Sensor	*WorldView-2*		
Product Line	*LV2A*		
Product Type	*Standard*		
Image Type	*PAN/MSS*		
Imaging Mode	*Mono*		
Image Format	*GeoTIFF*		
Interpolation Method	*Cubic Convolution*		
Band/Resolution	*Panchromatic*	*450-800nm*	*0.46m*
	Blue	*450-510nm*	*1.85m*
	Green	*510-580nm*	*1.85m*
	Red	*630-690nm*	*1.85m*
	NIR	*770-885nm*	*1.85m*
Satellite Altitude	*770 km*		
Scan Direction	*Reverse*		
Dynamic Range	*11 bits Per Pixel*		
Swath Width	*16.4 Km*		
Revisit Time	*1.1 days (depends upon latitude)*		
Map Projection	*Universal Transverse Mercator*		
Datum	*WGS84*		
Zone	*45N*		

Table 3.2 Scene description of Worldview- 2Image

Scene	Acquisition Data	Time (GMT)	Sun Azimuth	Sun Elevation	Collection Azimuth	Collection Elevation	Cloud Cover
054823654030_01_001	17-Nov-15	05:10 GMT	160.9^0	41.3^0	146.8^0	74.5^0	0%
054823654030_01_002	17-Nov-15	05:17 GMT	162.6^0	43.9^0	231.1^0	81.3^0	0.008%
054823654030_01_003	8-May-15	05:07 GMT	117.0^0	69.7^0	122.3^0	65.8^0	0%

The Worldview- 2images used in the study area are shown in Figure 3.1.

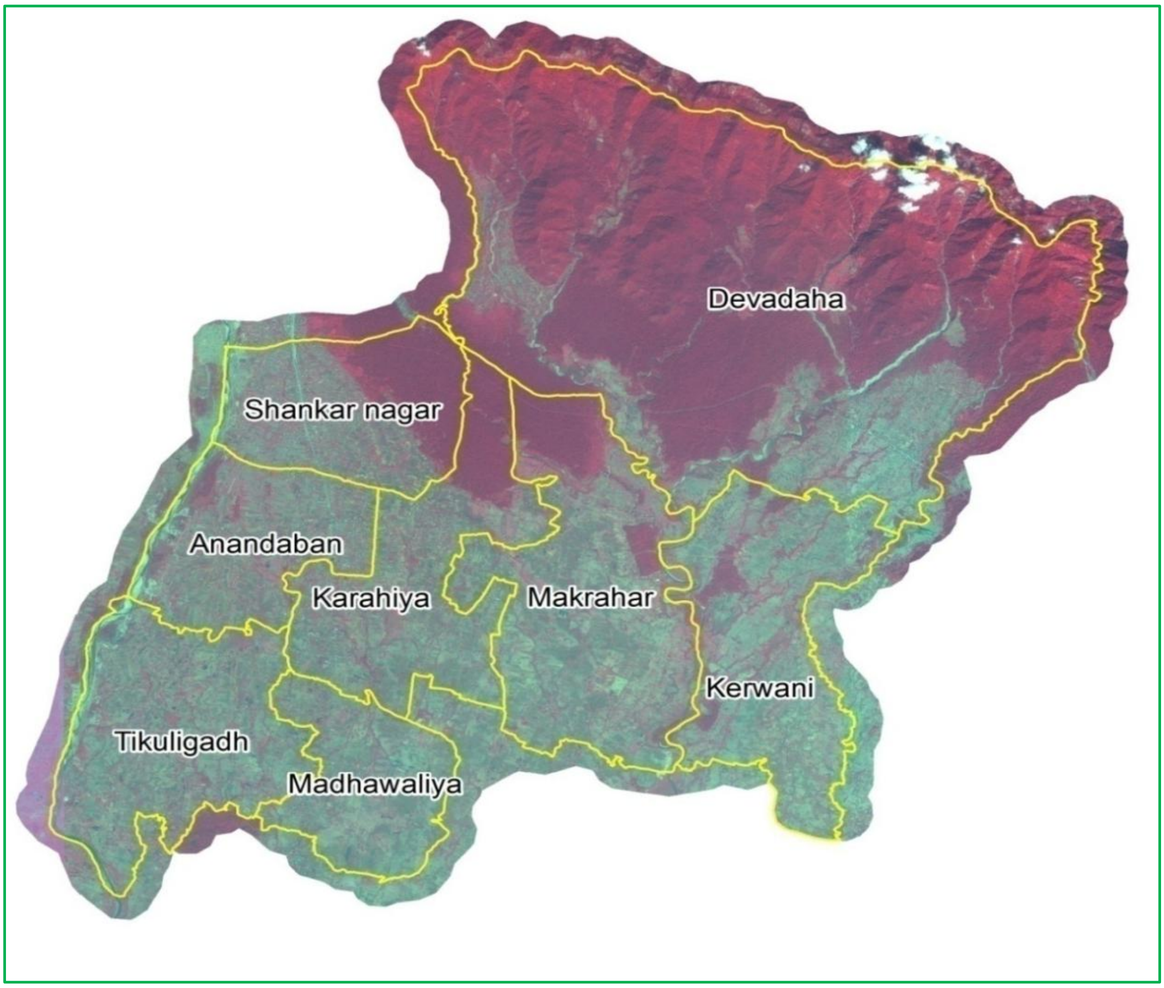

Figure 3.1 WorldView-2Images of the Study Area

3.1.2 Topographical Maps

The Topographical Mapsof the Package 11 of Rupandehi districtareas includes Sheet No. 2783-06B, 2783-06D, 2783-07A, 2783-07B and2783-07C in 1: 25,000 scales with 20m contour interval. These maps were published in 1996, which were compiled from 1:50,000 scale aerial photography of 1992. Field verification of the map was done in1994.Both hard and soft copiescovering the 8project VDCs and its surrounding area were obtained from Survey Department, Government 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. DEM was generated from digital topographical map of 20m contour interval using ANUDEM algorithm with *topoto raster tool* in ArcGIS (ArcGIS Desktop Help 10). These DEM was used for ortho-rectification of WorldView-2satellite images and created DEM derivatives such as slope, aspect, relief, and hill shade using terrain analysis techniques. The DEM generated from topographical map overlayingcontours with VDC boundary of Karahiya is shown in Figure 3.2.

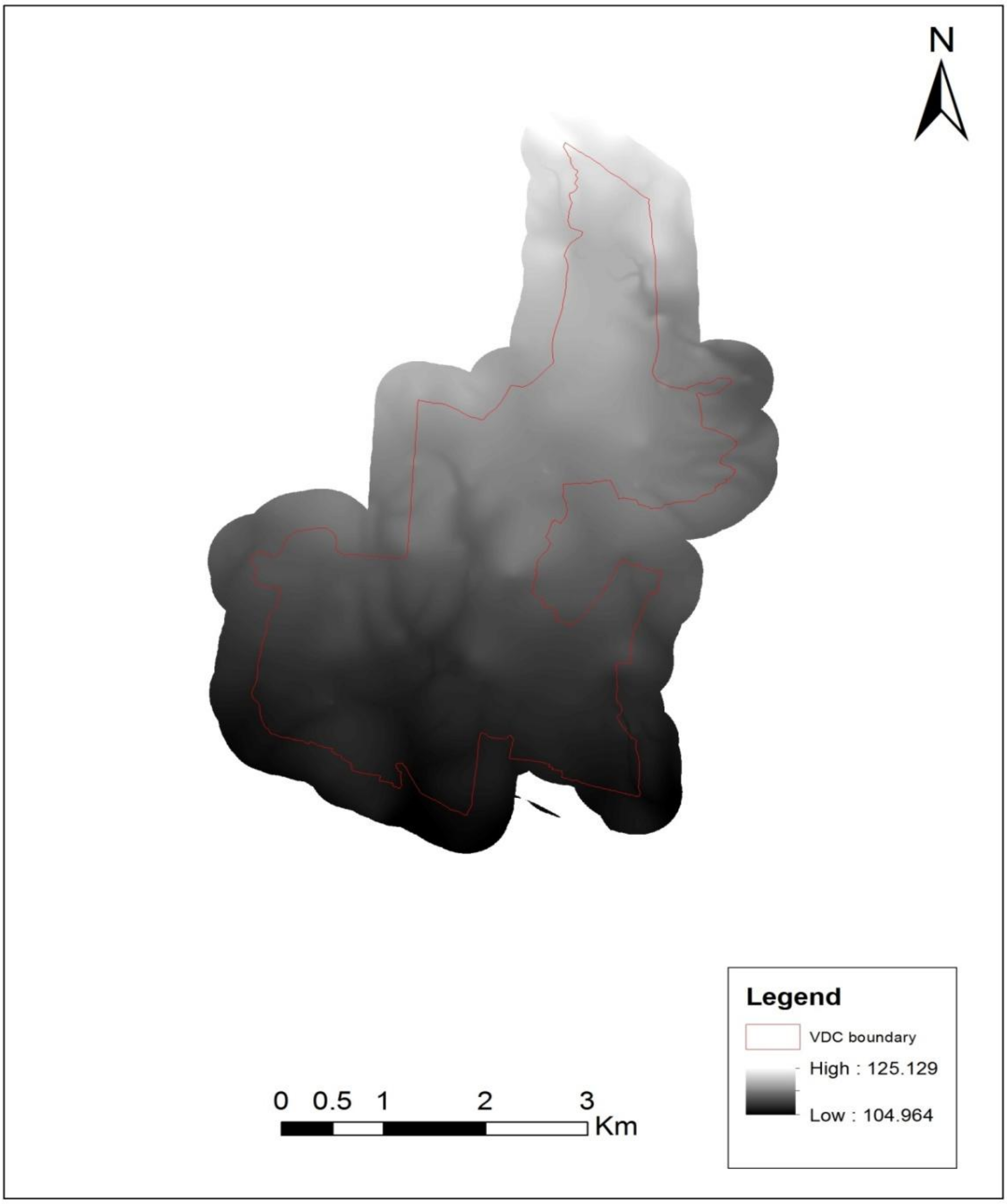

Figure 3.2 KarahiyaVDC Boundary Overlaid on DEM

3.1.3 LRMP Maps/Reports

Land Utilization, Land System and Land Capability maps and reports of LRMP (1986)were used as references for planning land use classification. These were obtained from Department of Survey. These maps and reports were used to get an in depth existing LULC classification and land use hierarchical system of Nepal. District level Land Utilization, Land System and Land Capability maps and reports prepared by NLUPwere also used for planning the land use classification.

3.1.4 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 11 VDCs was carried during 05th to 11thMagh, 2072. DGPS survey was done using Pentax G3 100R Receiver with TIAPENG 3100 R1 Antenna of 4 sets instruments connecting with reference points which is linked with national geodetic network and established by Survey Department.Pentax G3 100R DGPSReceiver has worked on single frequency with 1575.42 MHZ (L1 Band) in C/A mode and 1227.60 MHZ (L2 Band) of p code signal acquisition. The collected data throughPentax G3 100R DGPSReceiverwere proceed in Bernese GNSS version 5.2 processing software in AUSPOS online processing service and provided (x,y,z) in terms of easting, northing and ellipsoidal height.The DGPS stations were established on the locations identifiable in the WorldView-2image as well as on the ground covering entire study area and range of elevation. Thirty-two GCPs were measured in which 15GCPs as control point and 17GCPsascheck points were used for DGPS observation. At each GPS station, readings were made for 2 hours. DGPS readings were later processed using post processing software 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 this study is shown in Appendix-1. The distribution of GCPs point location overlay on WorldView-2 imagery is shown in Figure 3.3.

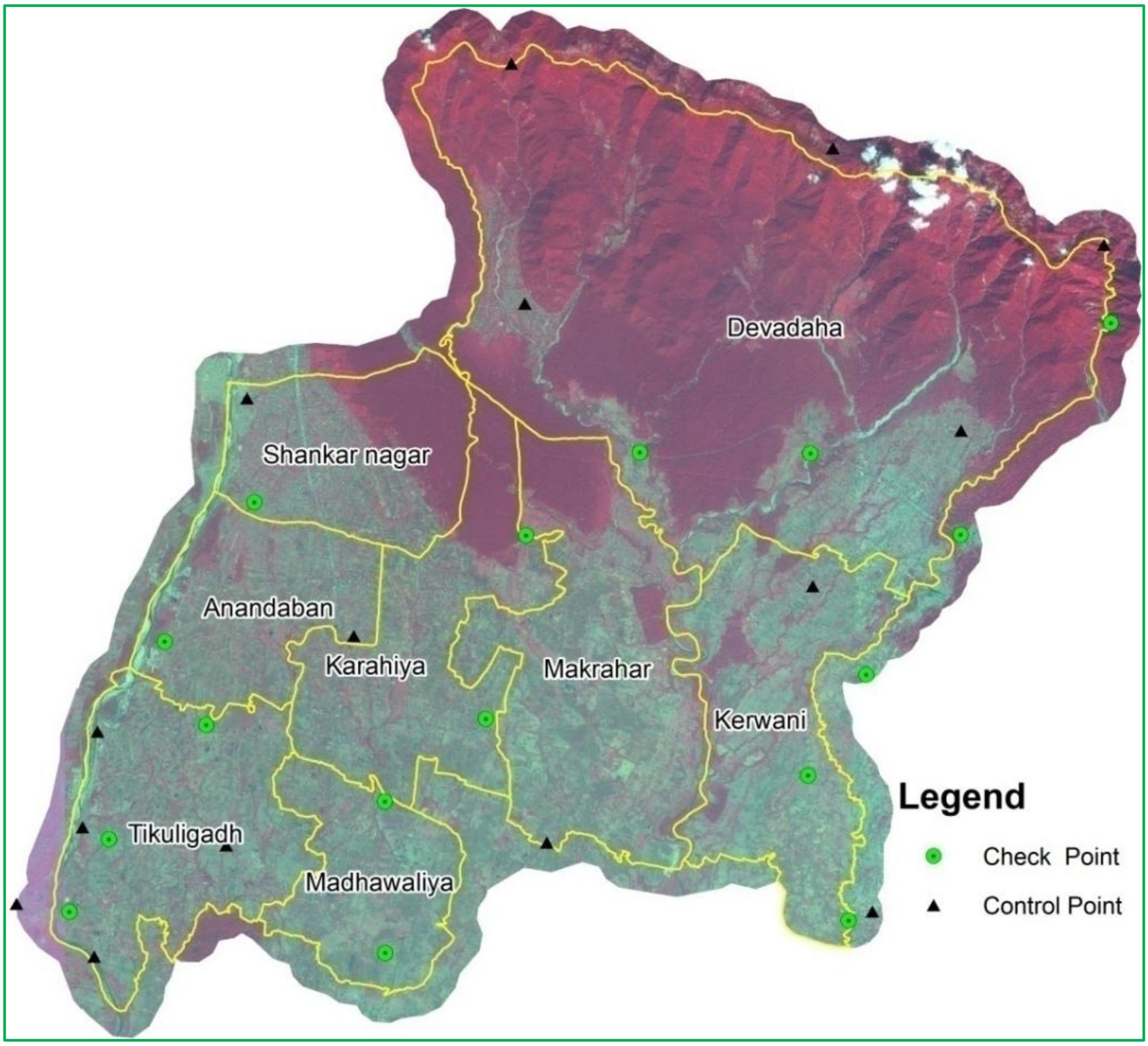

Figure 3.3 DGPS Point Overlaid on WorldView-2 Image

3.2 Method Adopted

The specific approaches and methods adopted to generate the VDC level land use map in the project area is explained briefly with the overall work flow diagram (Figure 3.4). The stepwise procedure adopted to generate the land use map of the area is following:

- Geometric Correction and Ortho-rectification
- Classification
- Visual Image Interpretation
- Accuracy Assessment

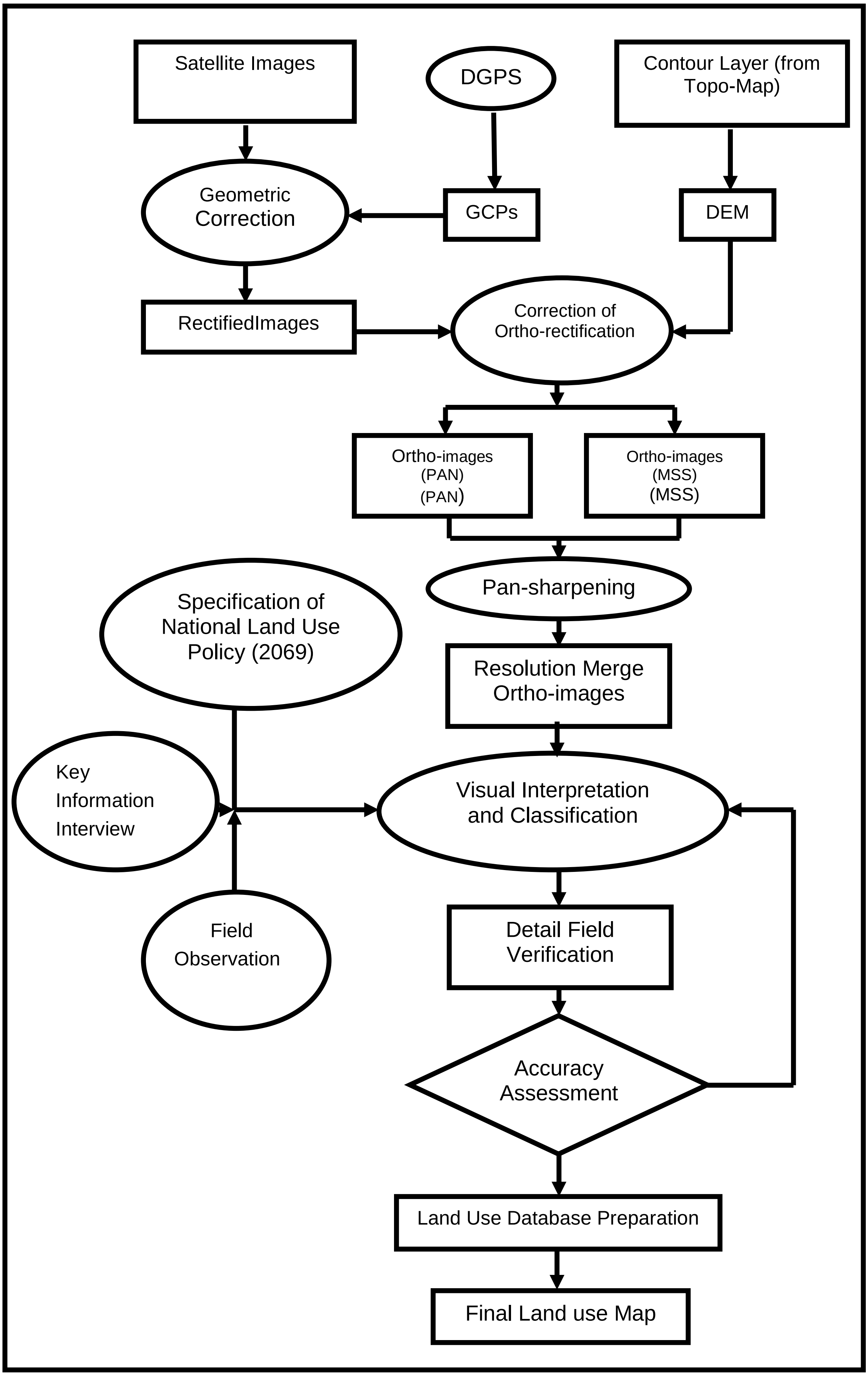

Figure 3.4 Work Flow Diagram

3.2.1 Geometric Correction and Ortho-Rectification

Without precise geo-referencing of satellite images the included very high resolution object information has only limited use. The image taken from very high resolution satellite (VHRS) with push broom sensor has its own perspective projection model for each image line is taken at a different instance of time, i.e. each scan line. On satellite board, there is GPS receiver along with gyros and star trackers or sensor for positioning and determining satellite ephemeris, i.e. camera position with respect to time. GPS receiver has used to determine the acquisition or exposure condition of satellite location. 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 corrections for geometric distortions due to sensor-earth geometry variations, and conversion of the data to real world. So, geometric correction has established the relationship between image co-ordinates of the object with respect to ground co-ordinates of such object in the image. 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 that 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 establishes relationship between the point on the image and the corresponding point on the ground (Kaveh and Mazlan, 2011).The mathematical RSM models built a correlation between the pixels (2D image space) and their ground locations (3D object space using any other sensor model. This model is termed as rational polynomial functions (RPFs). This correlation is based on ratios of polynomials. For the ground-to-image transformation, the defined ratios of polynomials have the forward form:

$$x = \frac{p_{1(X,Y,Z)}}{p_{2(X,Y,Z)}}$$

$$y = \frac{p_{3(X,Y,Z)}}{p_{4(X,Y,Z)}} \qquad (3.1)$$

where x and y are the row and column in the image respectively. X, Y, and Z are the coordinates of points in objectspace, and, Pi (i = 1, 2, 3, and 4) are polynomial functions with the following general form:

$$pi = a_{1_i} + a_{2_i}X + a_{3_i}Y + a_{4_i}Z + a_{5_i}XY + a_{6_i}XZ + a_{7_i}YZ + a_{8_i}X^2 + a_{9_i}Y^2 + a_{10_i}ZY^2 + a_{11_i}XYZ + a_{12_i}X^3 + a_{13_i}XY^2 + a_{14_i}XZ^2 + a_{15_i}X^2Y + a_{16_i}Y^3 + a_{17_i}YZ^2 + a_{18_i}X^2Z + a_{719_i}Y^2Z + a_{820_i}Z^3 \quad (3.2)$$

Usually, rational functions having third order polynomials i.e. the rational function model (RFM) is used to general rational functions with some variations, as is the case with terrain-dependent rational functions. The rational functions are expressed by third order polynomials as shown in Equation 3.2, though the number of coefficients in the polynomials can be reduced gradually. 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 (Reinartzet al., 2010). Exterior and interior orientation can be implicitly encoded in the form of RPFs using third order polynomials for numerator and denominator 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 second mathematical model is the rational polynomial co-efficient (RPCs), which is non–parametric or generic and advanced form of RPF model. In the RPCs model co-ordinate transformation can be solved using an object grid with its nodes coordinates determined using the physical sensor model (Tao and Hu, 2001) and also termedas physical sensor model or universal sensor models which provide a standardized and easy to use mathematical model to transform map object coordinates to image column and row values of the original image. The RPC model 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.This method can be applied without GCPs (because of that it is called terrain-independent), although the accuracy obtained is not very good and generally not applied in the actual geometric correction of the satellite images.A very interesting possibility of this method is that users can update or improve the accuracy of the rational function model, refining the image vendor coefficients by a few GCPs. In very high-resolution satellite imagery, the RPCs may be refined directly or indirectly(Hu et al., 2004). Direct refining methods update theoriginal RPCs themselves (HuandTao, 2002), while theindirect refining introduces complementary transformation (usually polynomial) in image or object space, and they do not change the original RPCs.

In order to improve the geometric accuracy of the original RPCs, these has to be corrected using GCPscollected 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:

$$row = a_0 + a_1 \, . \, rpc_r + a_2 \, . \, rpc_c$$

$$col. = b_0 + b_1 \, .rpc_r + b_2 \, .rpc_c \qquad (3.3)$$

Where rpc_randrpc_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 VHRS 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 plain metric features or objects as a map (Toutin, 2004). So, it is a map like geometric properties i.e.

orthogonal projection with earth reference terrestrial 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, 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 are 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 quality of ortho-image has based on the quality of GCPs, check points and the quality of DEM used in the process of ortho-rectification.

The present projectusedgeometric 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 geometric corrected images and DEM generated from topographical contours. The ranges of positional residual entered in ortho-rectification processes are minimum ±0.014m to maximum ±0.772m in X and minimum ±0.033m to maximum ±0.980m in Y having the overall root mean square error (RMSE) is ±0.578m.The error assessment report is shown in Appendix-2.

Visualization of different Color Composite

Enhancing of the spatial resolution was carried out by fusioning of 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.

3.2.2 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. In this study, pan-sharpening was done with Brovey transform technique. The pan-sharpening using Brovey transform was applied 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

3.2.3 Classification

Initially, the radiometrially and geogmetricall rectified satellite Image 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. Expert Knowledge 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.

3.2.4 *Visual Image Interpretation*

Most intuitive way to extract feature from high resolution satellite images is in depth class hierarchy level with visual image interpretation. Image analysis was done to evaluate objects and or analyze phenomenon on images. The objects or feature of land use land cover has been identified with the help of interpretation keys by the experienced image interpreter from prior knowledge and the study of the images. The identified features were verified with extensive field verification and finally, the features of land use classes were extracted from the image. Different ancillary layers such as simple ratio, NDVI, NDWI, DEM and DEM derivatives along with field data were used while performing this task.

Two extremely important issues must be addressed before undertaking task of image interpretation for determining and delineating land use classes. The first step is to define the criteria to distinguish the various categories of features occurring in the images. For this, the interpreter must fix firmly in mind that what specific characteristics may determine and separate the proper land use classes as described in classification hierarchy which is described in section 2.2 guided by Land Use Policy,2072. The second important issue for determining and delineating 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 (MMU) for delineating of land use category was onefourthof a hectare. However, important and essential features smaller than the MMU were also mapped. However, in overall for this particular study, the MMU was taken as 0.25 ha as specified in land use specification for mapping in scale 1:10000.

Interpretation of elements based on tone, size, shape, texture, shadow, 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. The object or feature such as forest, agriculture, road, residential area or commercial area in one category, industrial area, river etc which was easily identified was classified with interpretation element incorporate with expert knowledge. These features wereincluded in the classification hierarchy. Further, these classified features were verified with intensive field verification using raw classified map.
After visual interpretation and desk study based classified feature were verified in the field. If any modification at the first level classification was found; these correction was immediately modified in classified map. For lower level classification, object or features within the hierarchy of first level was done based on actual ground information. In this way, classified feature such as public use, commercial and industrial feature was categories by remote sensing expert. Similarly, agriculture land was categorized based on the cropping pattern and its intensity up to six level classification hierarchy schemas by group of experts such as horticulture, agriculture expert and agro forester. Forest land was also categorized based on species cover, type, crown density, maturity status and ownership right of forest by forester up to seven level classification hierarchy schema. This intensive detail field verification increase the quality of land use classes. Thus, the

land use classes yield better accuracy because the classes are designated manually based on ground knowledge rather than automatic classification.

3.2.5 Accuracy Assessment

Validation of 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 methodsfor evaluating accuracy. In general, one method compares the classified image to a reference image and a random set of pointsare 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 using a GPS and again a random set of pointsare 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 were used for sample schema and evaluation process was 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 samples with visual interpretation of original images and classification result classes at Level-1. A total of 272 samples points in package 11were taken for confusion matrix generation. 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 (Cong Alton, 1991).

$$K = \frac{N\sum_{i=1}^{r} X_{ii} - \sum_{i=1}^{r}(X_{i+} * X_{+i})}{N^2 - \sum_{i=1}^{r}(X_{i+} * X_{+i})} \qquad (3.4)$$

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.

Based on the cross validation of land use, the summary of error matrices of classified images is shown in Appendix-3. The summary of accuracy assessment 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 95.59 percent and 0.93respectively for the classified objects of the Pakage-11.

CHAPTER 4: PRESENT LAND USE PATTERN IN THE STUDY AREA

This chapter describes the detail hierarchical level of the present land use pattern based on prior classified schema of the preparation of present land use map at 1:10,000 scalesas per the land use specification 2015, provided by NLUP. There is analysisof broad hierarchy level present land use pattern of the KarahiyaVDC at first. Later, it describes the details of the different hierarchical level of each broad categories of land use.

4.1 Land UsePattern

The general land use pattern of KarahiyaVDC at the broad hierarchical classification Level 1 has been provided in the (Table 4.1.)

Table 4.1 Land use Pattern at Classification Level 1

Description	Area (ha)	Percentage
Agriculture	1440.33	69.15
Forest	339.46	16.30
Residential	186.28	8.94
Public Services	72.48	3.48
Riverine & Lake	14.22	0.68
Commercial	11.41	0.55
Industrial	8.88	0.43
Cultural & Archeological	0.29	0.01
Excavation	0.28	0.01
Others	9.17	0.44
Total	**2082.81**	**100.00**

Karahiya VDC covers a total of 2083 hectares (approximately 20.83sq. km) of land. Table 4.1 shows that the Agricultural land is the dominant land use category which covers1440 haof land with 69.15 percent of the total areal extent. Similarly, Forestland is 339 ha (16.30percent of the total extent). Likewise, the coverage of Residential, Public Service area, River line and lake area,Commercial,Industrial,Cultural and Archeological landExcavation land use covers 8.94 percent, 3.48 percent, 0.68 percent, 0.43 percent, 0.01 percent and 0.01 percent respectively. The other category covers 0.44 percent of the total area.

4.1.2 Agriculture Land Use Pattern

All the agricultural land of the KarahiyaVDC is categorized as TeraiCultivation based on the physiographic region at the hierarchical classification Level 2. At the hierarchical classification Level 3, all the agricultural land in the VDC was categorized as Wet land cultivation andDry landcultivation based on the land form and land system. The agriculture land use pattern at the hierarchical Level 3 has shown in the Table 4.2.

Table 4.2 Agriculture Land use Pattern at Classification Level 3

Description	Area (ha)	Percentage
Wet Land Cultivation	1095.88	76.09
Dry Land Cultivation	344.45	23.91
Total	**1440.33**	**100.00**

The total agriculture land of the VDC was about 1440ha in which Wet land and Dry land cultivationcombination covers1096haand 344harespectively. The distribution pattern of agriculture land is shown in Figure 4.1.

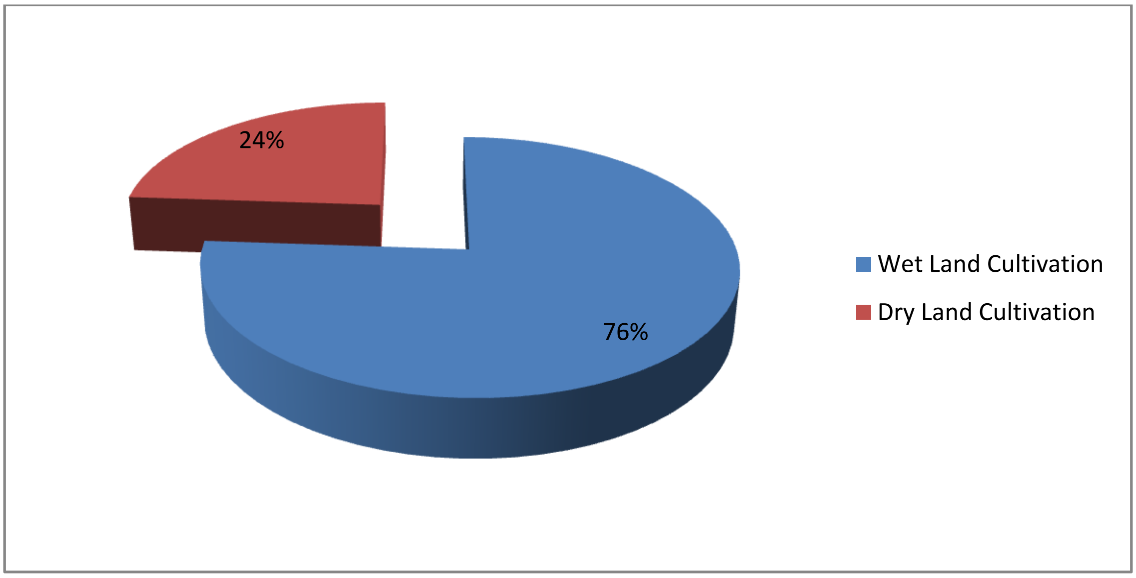

Figure 4.1 Agriculture Land by Types of Cultivation

Similarly, at Level 5, based on the cropping pattern the agricultural land use pattern in the VDC has been found under Rice-Pulse, Rice-Wheat-Pulses,Rice-Wheat, Rice-Oilseed, Rice-Fallow, Rice-Rice, Pulses-Others, barren Cultivable Land, Bamboo, Fruits, Pond for Fish Farming, Pulses-Fallow and Livestock/Cattle/buffalo Farm. The agriculture land use pattern at the hierarchical Level 5 has shown in the Table 4.3.

Table 4.3 Agriculture Land use Pattern at Classification Level 5

Description	Area (ha)	Percentage
Rice-Pulses	401.46	27.87
Rice-Wheat-Pulses	365.38	25.37
Rice-Oilseed	319.96	22.21
Rice-Wheat	151.26	10.50
Rice-Fallow	80.65	5.60
Barren Cultivated Land	43.34	3.01

Rice-Rice	30.81	2.14
Pulses-Others	22.31	1.55
Maize-Pulses	8.40	0.58
Bamboo	6.66	0.46
Fruits	6.06	0.42
Pond for Fish Farming	2.31	0.16
Pulses-Fallow	1.58	0.11
Livestock, Cattle, Buffalo Farm	0.12	0.01
Total	**1440.33**	**100.00**

The total agriculture land of the VDC was 1440ha in which Rice-Pulses combination was dominating with 401ha followed byRice-wheat-pulsescropping pattern. The area under other crop combination was less dominating cropping pattern in the VDC (Table 4.3).Cropping pattern is mostly intense in types.

4.1.3 Forest Area

Forest land has been observed as the least dominated land use categories among the groups under Level-1 with 339.46ha(16.30 percent) of the total areal extent of Karahiya VDC. As the Karahiya VDC lies within Terairegion, the forest is of tropical climatic vegetation in hierarchical level 2 characterized by Hardwood in hierarchical level 3. Similarly, the Forest in the VDC is characterized on species type such as Sal, Sisso, Khair and Other species at Level 4 hierarchy. Within Level 5, all forest covers were found in degradedcrown density. All types of forest covers were found immature based on Maturity class at Level 6. The forest covers were kept in Community and Other category because of the ownership right for its use.

4.1.4 Residential Area

The residential area in Karahiya VDC was categorized as Dense, Sparseand Moderate in the hierarchical Level 2, based on the concentration and dispersion of houses. The concentration of houses in residential area is shown in the (Table 4.4.)

Table 4.4 Concentration of House in Residential Area

Description	Area (ha)	Percentage
Dense	175.62	94.28
Moderate	3.18	1.70
Sparse	7.48	4.02
Total	**186.28**	**100.00**

The area underdense populationfunddominated within the VDC with the extent of 175.62ha (94 percent of the residential area) followed by sparse population having 7.48 ha (4 percentof the residential area) and 3.18 ha(2 percentof the residential area) with moderate population density. The distribution of concentration and dispersion of houses in residential area at hierarchical Level 3 is shown in Figure 4.2.

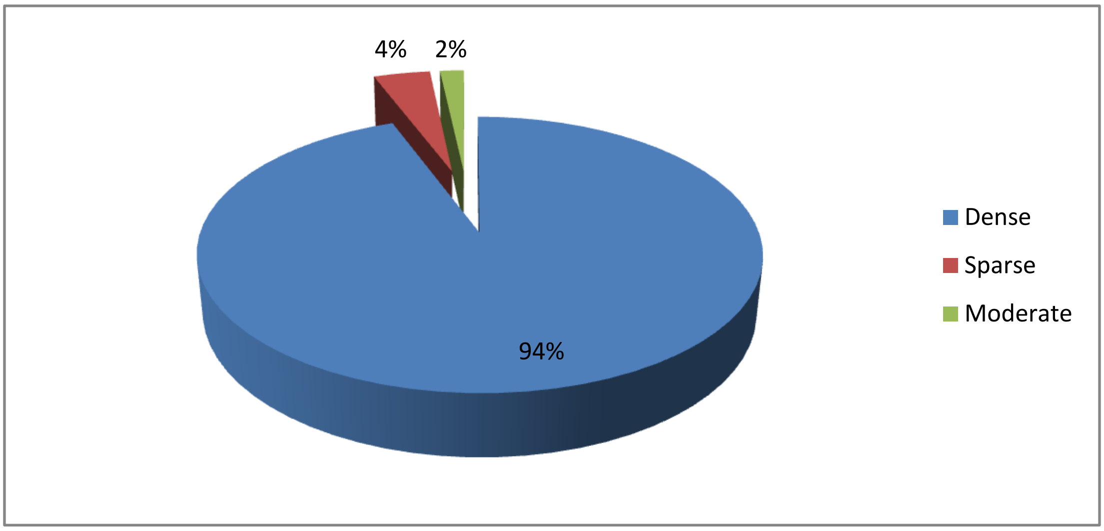

Figure 4.2 Concentration of Houses in Residential Area

The residential area has categorized as Old area andnewly developed area based on residential concentration at classification Level 3. The area under old area has dominated within the VDC with the extent of 179 ha followed by newly developed area having 9ha and 7 ha with planned area as parcels plotting.Similarly,the entire residential site has residential cluster classification Level 4.

4.1.5 Commercial Area

Commercial areaoccupies only 0.55 percent area (11.41 ha) of the total land area of the Karahiya VDC. Businessarea and service area occupy1.69 ha and 9.72 ha respectively.

4.1.6 Industrial Area

A total of 8.88 ha (0.43 percent of the total) land inKarahiyaVDC occupiesby the industrial area. Of the total 8.58 ha industrial area, large scale industriesoccupies 3.10 ha. The area covered by medium scale and small scale industries is0.25 ha and 0.05 ha respectively.

4.1.7 Public Services Area

According to the hierarchical Level 2, the public services area in the KarahiyaVDC is categorized into Transportation Infrastructure area, Open area, Educational area, Health service area and Recreational facility area. The area covered by each type of the public service is shown in the Table 4.5. The table clearly reveals that the area occupied by the transportation Infrastructure is the largest, (more than 90 percent), which is followed by educational (4.05 percent). The open area ranks third in terms of area occupied by the 5.79 percent. The land area occupied by other categories is minimal.

Table 4.5 Categories of Public Services Area

Description	Area (ha)	Percentage
Transportation Infrastructure	65.36	90.18
Educational	2.94	4.05
Open area	2.37	3.27
Utility	0.81	1.11
Security	0.69	0.95
Institutional	0.14	0.20
Health	0.11	0.15
Recreational	0.03	0.04
Other	0.03	0.04
Total	**72.48**	**100.00**

4.1.8 River line and Lake Area

According to the hierarchical Level 2, the river line and lake area in the Karahiya VDCis categorized into Sand, River, Kulo, Wetland and Others. The area covered by each type of the river line and lake group is shown in the Table 4.6. The area occupied by the river is the largest, about half of the area covered by river line and lake area in the VDC. The other hydrographic features occupied very limited land areas of the VDC.

Table 4.6 Categories of River line and Lake Area

Description	Area (ha)	Percentage
River	7.55	53.10
Kulo	6.09	42.84
Sand	0.52	3.68
Other	0.05	0.37
Total	**14.22**	**100.00**

4.1.9 Excavation Area

KarahiyaVDC has cobbles as the excavation feature at the hierarchical Level 2. The coverage of the cobbles in this VDC is only 0.28 hectares.

4.1.10 Cultural and Archaeological Area

Temple and mosqueis the only one cultural and archeological feature at the hierarchical Level 2 in Karahiya VDC. The total area covered by the temple and mosque was0.29 hectares.

4.1.11 Others

Grazing err landsare considered as other category at the hierarchical Level 2. The area occupied by grazing land was9.17 ha.

4.1.12 Land Use Geo-database Creation and Mapping

The classified land use data was stored in vector "feature data class" format in geo-database which is provided by NLUP. The vector data contains the attribute data of hierarchical classification of land use classes. So, these vector data of land use classes in hierarchical level can be used for various purposes to represent land use at different scale with generalized or detailed form as per the requirement of user. The attribute of land use classes in the feature data class is shown in (Table 4.7.)

Table 4.7 Attribute of land use classes

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 7	String	Land Use Class	LEVEL 7
AREA	Double	Area in m2	AREA
AREA_HA	Double	Area in Hectare	AREA_HA

With this geo-database, the land use map at the scale of 1:10000 was generated having up to land use classification Level 1 in A4 paper map and different classification level in A1 paper map as mention in Specification, 2015. The present land use map is shown in Appendix-4.

CHAPTER 5: CONCLUSIONS

5.1 Conclusion

The present land use mapping was carried out from very high resolution satellite images of WorldView-2 constellation along with visual interpretation and extensive field verification. The prior defined hierarchical classification schema is used for classification in standardization complex land use pattern of KarahiyaVDC. During the visual image interpretation, the knowledge of experience image interpreter along with ancillary data such as LRMP maps/data, DEM, DEM derivative, different ratio and indices, Google earth image and field visit data were used. Land use map at the scale 1:10000 has been generated up to the available level classes with a combination with road networks.

The accuracy of the results was assessed and overall accuracy was obtained as95.59 percent with KIA coefficient 0.93. The VDC showed less variability in land use pattern in which much of the land is used for cultivation of agricultural crops. The land use classes have yielded a better accuracy because of the visual interpretation and extensivefield verification rather than automatic classification.

These land use data and map can be used to formulate land use zoning system for controlling land fragmentation, unplanned urban slump, and encroachment of public and government land. It can be achieved through interactions and negotiations between planners, stakeholders and decision-makers at national, regional and local levels. Therefore, these databases could be used in land zoning and for planning, analyzing and decision making process on the sustainable, equitable and economic use of the land and sustainable land development of the VDC.

5.2 Recommendation

Based on the present experience of the project,the following recommendation can be made for future undertaking of similar projects.

Present land use policy excludes municipal areas and concentrates only on VDCs. Since many municipalities currently declared do not have such maps and database on the one hand and some of the VDCs selected for this study are already included in the municipalities. In such a situation, the overall objectives of land use project could not be fulfilled, thus this is the matter of consideration.

The present land use map and data might be useful forland use as well as environment planners. It can be used for devising sustainable environmental planning strategies for therural development.

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APPENDICES

Appendix-1: Co-ordinate List of Control Points

S.N.	Easting	Northing	Ortho-metric Height	Remarks
1	443578.241	3051670.151	114.992	Check Point
2	446550.705	3058571.415	139.657	Check Point
3	449228.230	3049342.139	112.334	Check Point
4	451290.046	3054135.448	121.594	Check Point
5	458710.619	3050003.057	112.113	Check Point
6	454078.567	3055180.978	120.003	Check Point
7	444716.397	3055712.132	125.065	Check Point
8	445568.115	3054012.782	118.649	Check Point
9	454438.304	3059591.042	125.354	Check Point
10	457977.993	3056853.662	127.960	Control Point
11	452086.358	3062639.303	149.768	Control Point
12	442770.483	3050184.696	108.833	Check Point
13	452113.702	3057888.786	130.716	Check Point
14	448588.485	3055833.781	126.620	Control Point
15	457933.773	3059568.418	132.283	Check Point
16	443342.248	3053873.127	119.887	Control Point
17	443273.545	3049268.641	109.861	Control Point
18	459200.624	3050191.026	110.380	Control Point
19	441688.070	3050345.298	120.143	Control Point
20	461006.484	3057902.536	142.331	Check Point
21	458393.124	3065822.543	709.271	Control Point
22	463932.839	3063842.807	389.495	Control Point
23	459071.665	3055036.275	126.486	Check Point
24	457881.601	3052979.374	120.876	Check Point
25	452539.365	3051601.048	113.363	Control Point
26	464078.589	3062241.551	270.200	Check Point
27	461013.828	3060032.293	160.178	Control Point
28	446402.248	3060702.061	144.657	Control Point
29	451814.139	3067550.570	920.776	Control Point
30	445981.211	3051546.763	113.455	Control Point
31	443037.977	3051913.593	114.772	Control Point
32	449224.616	3052442.496	115.864	Check Point

Appendix-2: Ortho-rectification Error Report

S.N.	Image_X	Image_Y	Reference	Reference1	Residual_x	Residual_Y	Residual	Remarks
1	443394.652	3051523.648	443578.241	3051670.151	-0.126	-0.401	0.420	Check Point
2	446700.493	3058722.726	446550.705	3058571.415	0.315	-0.124	0.338	Check Point
3	449043.343	3049197.045	449228.230	3049342.139	0.366	-0.663	0.758	Check Point
4	451439.834	3054286.758	451290.046	3054135.448	0.146	0.247	0.287	Check Point
5	458521.115	3049858.370	458710.619	3050003.057	-0.772	0.456	0.897	Check Point
6	453889.178	3055033.547	454078.567	3055180.978	0.192	-0.117	0.224	Check Point
7	444529.116	3055552.076	444716.397	3055712.132	0.050	0.710	0.712	Check Point
8	445717.903	3054164.092	445568.115	3054012.782	0.095	-0.347	0.360	Check Point
9	454248.710	3059420.948	454438.304	3059591.042	-0.237	0.458	0.515	Check Point
10	457751.640	3056719.762	457977.993	3056853.662	-0.447	-0.033	0.448	Control Point
11	451883.155	3062495.021	452086.358	3062639.303	0.557	-0.137	0.574	Control Point
12	442620.695	3050033.386	442770.483	3050184.696	-0.559	0.375	0.674	Check Point
13	451929.072	3057729.876	452113.702	3057888.786	-0.482	0.013	0.482	Check Point
14	448408.574	3055674.381	448588.485	3055833.781	0.687	-0.369	0.780	Control Point
15	457714.208	3059426.945	457933.773	3059568.418	0.755	0.583	0.954	Check Point
16	443197.786	3053735.015	443342.248	3053873.127	0.980	-0.015	0.980	Control Point
17	443121.144	3049116.240	443273.545	3049268.641	0.304	-0.302	0.428	Control Point
18	458885.606	3049755.552	459200.624	3050191.026	0.100	0.210	0.233	Control Point
19	441532.511	3050195.740	441688.070	3050345.298	0.516	-0.481	0.706	Control Point
20	460782.177	3057749.970	461006.484	3057902.536	-0.442	-0.264	0.515	Check Point
21	458355.159	3065568.527	458393.124	3065822.543	-0.087	-0.182	0.202	Control Point
22	463736.265	3063734.911	463932.839	3063842.807	-0.116	-0.243	0.269	Control Point
23	458849.296	3054888.686	459071.665	3055036.275	0.052	0.109	0.121	Check Point
24	457664.542	3052831.785	457881.601	3052979.374	0.050	0.201	0.207	Check Point
25	452349.120	3051444.096	452539.365	3051601.048	0.138	0.642	0.656	Control Point
26	463879.712	3062127.220	464078.589	3062241.551	0.107	0.225	0.249	Check Point
27	460800.419	3059897.063	461013.828	3060032.293	0.433	0.207	0.479	Control Point
28	446212.098	3060555.148	446402.248	3060702.061	-0.543	-0.552	0.774	Control Point
29	451632.363	3067339.434	451814.139	3067550.570	-0.668	0.572	0.880	Control Point
30	445806.118	3051382.472	445981.211	3051546.763	-0.206	0.524	0.564	Control Point
31	442891.787	3051764.020	443037.977	3051913.593	-0.476	0.690	0.838	Control Point
32	449374.404	3052593.806	449224.616	3052442.496	-0.014	0.127	0.128	Check Point
						RMSE	0.578	

Appendix-3: Error Matrix for Accuracy Assessment

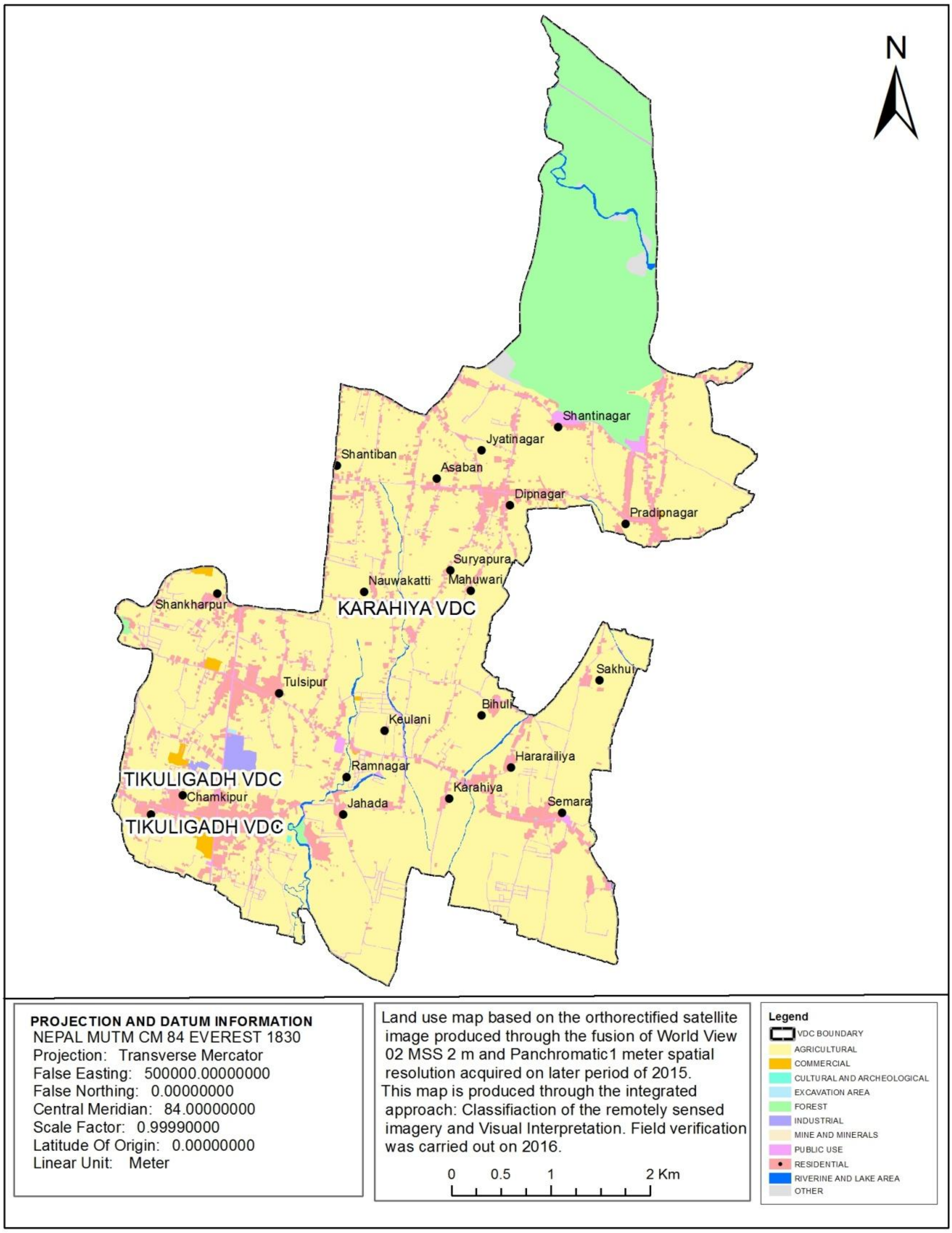
Use Categories	Agriculture	Forest	Residential	Commercial	Industrial	Public Services	Cultural and Archeological	River line and Lake Area	Other	Total
Agriculture	162	0	1	0	0	1	1	0	0	165
Forest	0	28	0	0	1	0	0	1	0	30
Residential	0	0	12	1	0	0	0	0	0	13
Commercial	0	0	1	11	0	0	0	0	0	12
Industrial	0	0	0	1	8	0	0	0	0	9
Public Services	0	0	0	0	0	13	1	0	0	14
Cultural and Archeological	0	0	1	0	0	0	9	0	0	10
Riverine and Lake Area	0	0	0	0	0	1	0	9	0	10
Other	1	0	0	0	0	0	0	0	8	9
Total	**163**	**28**	**15**	**13**	**9**	**15**	**11**	**10**	**8**	**272**

Overall Accuracy = 95.59

Overall KIA = 0.93

Land Use Category	Producer Accuracy	User Accuracy	Omission Error	Commission Error	KIA
Agriculture	99.39	98.18	0.61	1.82	0.96
Forest	100.00	93.33	0.00	6.67	0.93
Residential	80.00	92.31	20.00	7.69	0.92
Commercial	84.62	91.67	15.38	8.33	0.91
Industrial	88.89	88.89	11.11	11.11	0.89
Public Services	86.67	92.86	13.33	7.14	0.92
Cultural and Archeological	81.82	90.00	18.18	10.00	0.87
River line and Lake Area	90.00	90.00	10.00	10.00	0.90
Other	100.00	88.89	0.00	11.11	0.89

Appendix-4: Present Land Use Map of KarahiyaVDC



Soil

FINAL REPORT

Preparation of Soil

Karahiya VDC of Rupandehi District

FOR

Consulting Services

for

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

Package No: 11

Anandaban, Devadaha, Karahiya, Kerwani, Madhawaliya, Makrahar, Shankar Nagar, Tikuligadh, of Rupandehi District (8 VDCs)

Preparation of Soil

Karahiya VDC of Rupandehi District

This document is one of the outcomes of the project entitled **Preparation of VDC level Land Resource Maps** (Present Land Use Maps, Soil Maps, Land Capability Maps, Land Use Zoning Maps and Cadastral Layer Superimpose and VDC Profile), **Database and Reports** of Package 11 awarded to SHREEYA-KRS JV by the Government of Nepal, Ministry of Land Reform and Management, National Land Use Project (NLUP) in Fiscal Year 2072-073. The VDCs covered under this package include eight VDCs of Rupandehi district namely: **Anandaban, Devadaha, Madhawalia, Makrahar, Karahiya, Kerwani, Sankar Nagar and Tikuligadh**.

Mr. Kul Bahadur Chaudhari was involved and solely credited for the preparation of maps, database and reports on risk themes.

The VDC areas analyzed for different themes of the NLUP Project are computed from cadastral maps provided by DOLIA Office of Nepal. Therefore, the areas of the VDCs may not be the same as computed from Topographic Database provided by the Survey Department of Nepal.

The consultant is obliged to state that the Imageries, GIS database and other outputs produced for the project is owned by National Land Use Project (NLUP), Mid-Baneshwor, Kathmandu. Therefore, the authorization from the NLUP is required for the usage and/or publication of the data in part or the whole.

ACKNOWLEDGEMENT

The SHREEYA-KRS JV is highly obliged to National Land Use Project (NLUP), for awarding the project **Preparation of VDC level land resource maps** (Present Land Use Maps, Soil Maps, Land Capability Maps, Land Use Zoning Maps and Cadastral Layer Superimpose and VDC Profile)**, database and reports, Package 11 of Rupandehi district**. The consultant would like to extend special thanks to Mr. Nagendra Jha, the Project Chief of NLUP, for his constructive supports during the project period. Similarly, the consultant would also like to highly acknowledge the overall supports of Mr. Nabaraj Subedi, Chief Survey Officer. Likewise, the consultants would like to extend thanks to Mr. Sumir Koirala, Survey Officer, Mr. Ekraj Giri, Account Officer, Mrs. Manju Devi, Store Keeper and the other staffs of the NLUP Office for their supports during the project period.

The consultant would also like to thank the local people, members of the different political parties and staffs of the VDCs and local institutions of **Karahiya VDC** of Rupandehi District for providing their valuable time to the study team in discussing different aspects of the project. Without their support this work would not have been completed.

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CHAPTER 1: INTRODUCTION

1.1 Background and Rationale

A doubling of global population and food demand projected for the next 50 years poses huge challenges for the sustainability of food production as well as for terrestrial and aquatic ecosystems and the services they provide to society. New incentives and policies for ensuring the sustainability of agriculture and ecosystem services will be crucial if we are to meet the demands of improving yields without compromising environmental integrity or public health (Tilman et al., 2002). There seems no viable alternative other than to intensify food production in an environmental-friendly and sustainable manner. Proper land use planning is therefore, a necessary condition to address the deteriorating conditions of food production and natural environment that we are facing today. Information at different spatial scale is needed to improve land use decisions and to understand effects of various soil management practices on food production and environment. The work begins with the systematic collection of soils data and developing information to provide a sound basis for policy direction required for sustainable land use in the future. Such a comprehensive collection and interpretation of soils data could be implemented through soil survey. The soil survey is a strong scientific tool to describe soils in a given area, classify them, locate boundaries on the map, and help make predictions about the responses of individual soils to specific management practices.

In the context of Nepal, land degradation is one of the greatest challenges (Karkee, 2004; Singh 1994) accelerated by a host of factors including mismanagement of land, overgrazing, deforestation, soil erosion, loss of soil nutrients and water, pollution, landslides in the slopes and flooding in the downstream. Interactions of these biophysical factors with socio-economic factors make land degradation a complex phenomenon (Sah, 2007) that is unique in Nepal. Food safety is threatened therefore; an improvement is urgently needed in management practices so that soil quality is maintained for sustaining diverse cropping systems and productivities. This is where lies the values of soil survey in documenting detail soil information based on ground realities and thus help identifying its limitations and suitability for various productive purposes.

Therefore, the land use planning for making the best use of the limited land resources is inevitable. However, except sporadic attempts for the urban areas, Nepal has not practiced land use planning for the country as a whole. However, several attempts were made for balanced use of country's existing natural resources in the past through different policies and national planning efforts. Proper land use planning was also emphasized by Gill (1996) and many others for future food security of Nepal.

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, 1986). 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.

On the 4th *Baishakh* of 2069, the Government of Nepal has approved the National Land Use Policy, 2069. It has 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.

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 NLUP has been preparing VDC level land resource maps and database for the VDCs of Terai Districts. 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 database.

In the context stated above, the **SHREYA –KRS JV** has been commissioned to pursue the project (Preparation of VDC level land resource maps, databases and reports) for eight VDCs of Rupandehi district under package 11 in Fiscal Year 072/073. They are Anandaban, Devadaha, Karahiya, Kerwani, Madhabaliya, Makrahar, Shankar Nagar, and Tikuligadh VDCs. The NLUP envisaged the following points as the basis for the preparation of soil maps of the concerned VDCs:

- Preparation of soil maps of the VDCs for formulating land use plan according to the quality of soil in order to identify areas of Agricultural area, Residential area, Commercial area, Industrial area, Forest area, Public use area and other uses.
- Identification of the residential and other non-agricultural areas within the inferior soil quality areas.
- Promotion of agricultural productivity as per soil quality in comparatively advantageous sub-areas.
- Conservation of non-agricultural areas including forest, shrub, rivers and rivulets and wetlands for sustainable development.

1.2 Objectives of the Study

The purpose of this study is to support National Land Use Project (NLUP) initiative of Ministry of Land Reform and Management (MLRM), Government of Nepal (GoN) to develop soil information database for preparing VDC level land use zoning maps that could be put to their best uses. The specific objective of this study is to prepare Soil Maps (at 1:10,000 scales), GIS database and Reports of Karahiya VDC.

The above objectives are achieved by focusing on the following specific 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) Analyse the physio-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.

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

Karahiya VDC lies in Rupendhei district, Lumbini Zone. The VDC has currently included in Tilottama Municipality. And it is known for ward no. 9, 10, 11 & 12 of the municipality. It is located between 83° 27' 50” to 83° 31' 20"E longitude and 27° 35' 20” to 27° 35' 58" N latitude. The VDC is bordered by Makrahar & Gangoliya VDCs to the east, Anandaban VDC to the west, Andandaban & Devadaha VDCs to the north and Madhawaliya & Gangoliya VDCs to the south. The VDC covers a total area of 2082.81 ha. The extension of the VDC is 4.7 km and 8.8 km in east-west and north-south respectively.

According to the population census 2011, the total population of the VDC was 18274 with 4267 households. Of the total population, the percentage of male is six percent lower than the female. The population of this VDC is composed of different caste/ethnic groups. Among them, Brahmin is in majority. The proportion of migrants is significant in the total population. Migrants were mainly from Palpa, Gulmi, Arghakhachi, Baglung, and Parbat. Ninety-five percent people follow Hinduism. People are involved in many occupations. More than half of the total populations are involved in agriculture. And it is the main source of income. Almost one-third of the total income comes from agriculture sector.

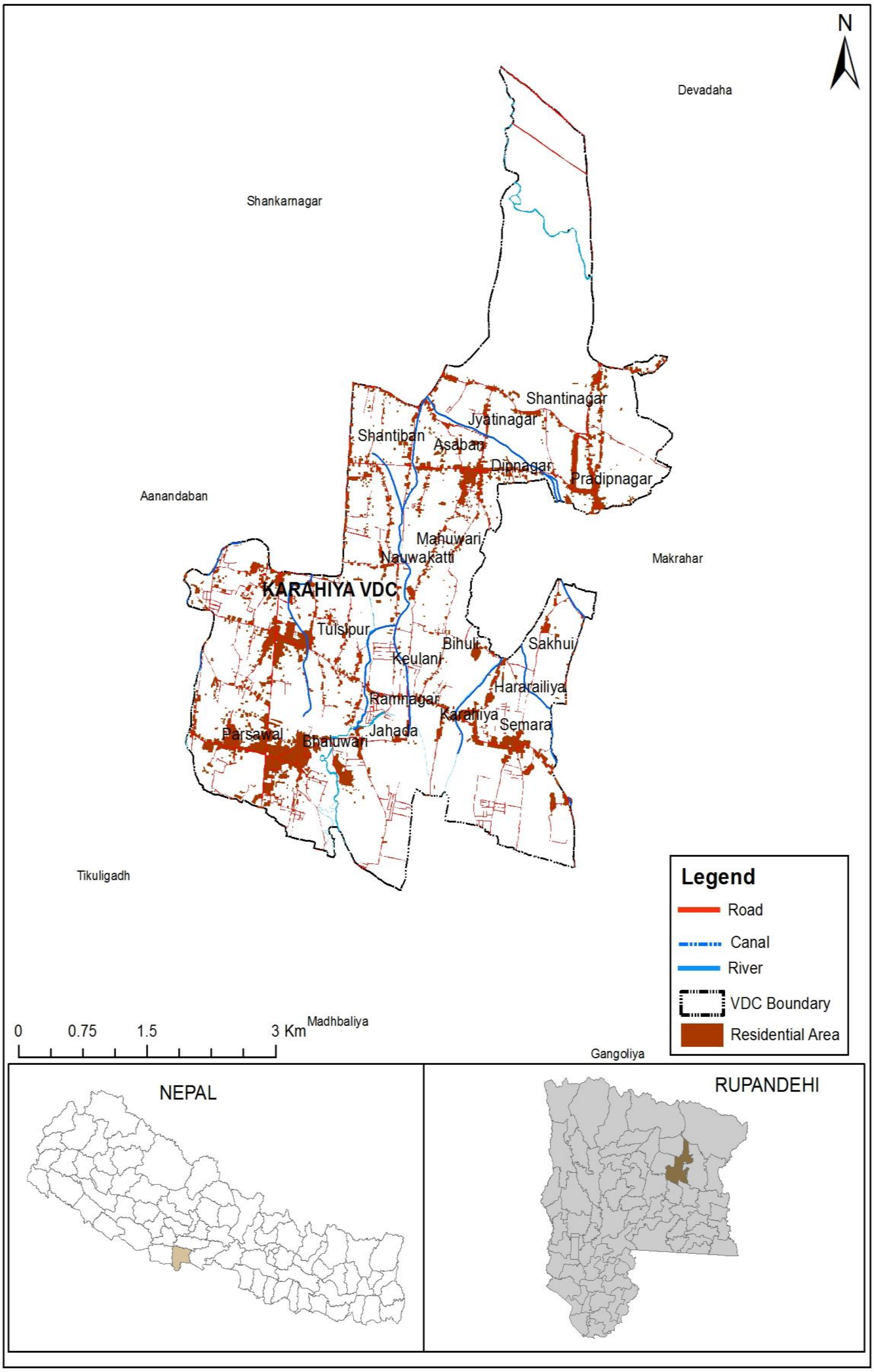


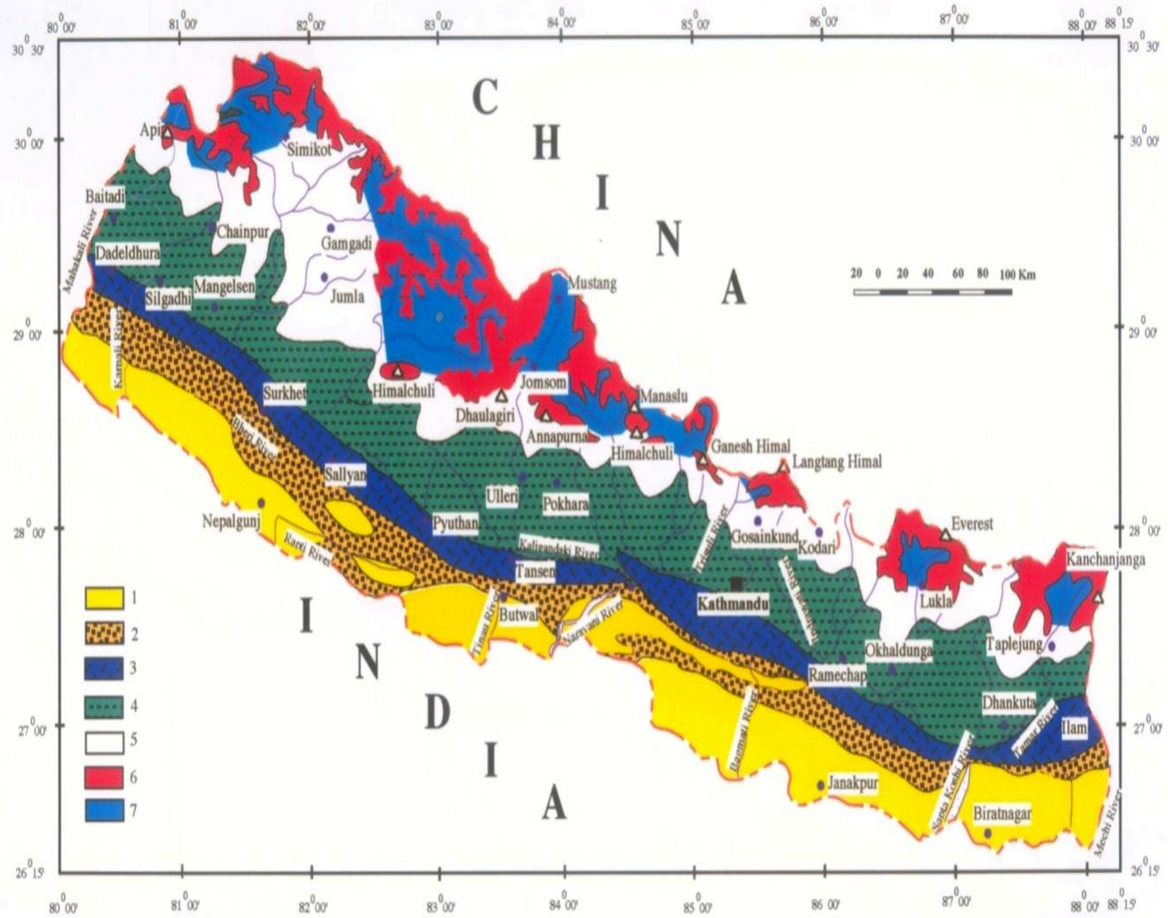
Figure 1.1: Location of Karahiya VDC

CHAPTER 2: BIO-PHYSICAL CONDITIONS OF THE STUDY AREA

Natural environment determines, to a greater extent, the distribution of soil landscape, physiography, terrain, geology, water bodies, climatic conditions and biological diversity- all interact with one another for the development of specific soil in a geographical setting. Therefore, soil is said to be an important component of terrestrial ecosystems and the factors that determine soil formation and development also control the terrestrial ecosystems (Vitousek, 1994). In this section, the important components of bio-physical conditions affecting soil development in the area are discussed.

2.1 Physiography

Land resource mapping project of Nepal (LRMP, 1986b) published a report and classified the country into five broad physiographic regions (Figure 2.1). Based on this report, the VDC under study occurs in Terai physiographic region.



Physiographic subdivisions of Nepal (Upreti, 1999). 1: Terai (Northern Gangetic Plain) and Dune Valleys (100-200 m) 2: Churia Range (Siwaliks) (200-700 m) 3: Mahabharat Range (1000-2500 m) 4: Lesser Himalaya (Midlands) (300-2000 m) 5: Fore Himalaya (2000-4500 m) 6: Higher Himalaya (>4000 m) 7: Inner Valleys (2500-4000 m)

Figure 2.1: Physiographic regions of Nepal

The Terai region is nearly flat and lower in elevation relative to other physiographic regions of Nepal. Not just the VDC but most of Terai districts share a common physiography from Churia hill in the north extending to Nepal-India border in the south with nearly homogenous physiographic features. The width of Terai varies between 10 and 50 km and forms a continuous belt from the east to the west. The Terai plain is distributed south of the Main Frontal Thrust (MFT) separating the loose sediments of the Indo-Gangetic Plain in the south from the sedimentary rocks of the Siwalik range in the north. The fertile soil properties of the study area should have been dominated mostly by the characteristics of this physiographic condition. This is because the process of alluvial deposition at different time scales carrying younger soil materials and nutrient rich floods from the northern Churia hills and mountains farther north, have contributed to the restoration of soil fertility of this plain area in the south.

2.2 Elevation

Soil development is greatly influenced by elevation on which soils occur, the plant and animal life which they support and the amount of time which they have been exposed to these conditions. Shallow soils on the sloping lands and deeper soils on flat areas downstream are typical examples of how elevation controls formation and distribution of soil types on the landscape. Based on elevations, recorded using GPS receiver at 14 soil pit locations in this VDC, average elevation of these pits was found to be 108.5 m above msl (± 4.3m). This means that land systems within this VDC occur at very low elevation and differences across the locations is not big. According to digital elevation model (DEM), the VDC elevation varies from 104 to 125m amsl (Figure 2.2). The northern region of the VDC map with gray tone indicates the region of higher elevation whereas the southern region with darker tone signifies the lower elevation.

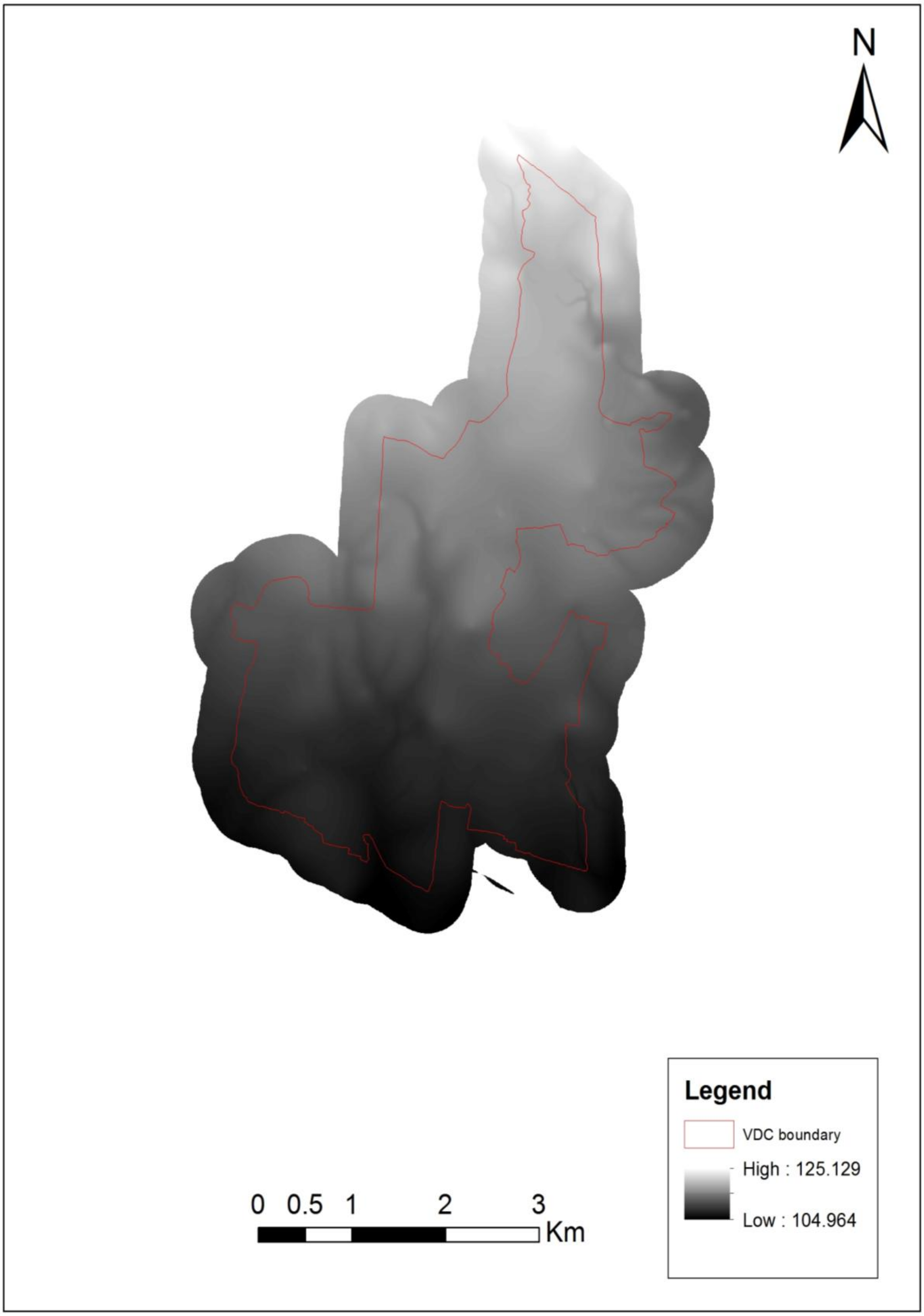


Figure 2.2: Digital elevation model of Karahiya VDC

2.3 Slope

Slope is an important topographic factor affecting landform and soil development process. That is why soils appearing at different slope positions (i.e., summit and back slope or toe slope or flat areas) along a slope transaction exhibit great variability in soil fertility and productivity. Slope generally is expressed as a percentage that is calculated by dividing the difference in elevation between two points by the horizontal distance and multiplying by 100. In Karahiya VDC, nearly 99 percent areas occur on simple slopes 0-3 degree slopes meaning to be nearly level (Figure 2.3). This is a clear indication that unlike in neighboring hills, these plain areas do not have land degradation problem due to erosion. Here the rate of deposition of natural sediments should be greater than the rate of sediment removal.

Slope also forms an important criteria for soil classification. The slope of the project area is mostly found to be less than 3 degree and 3-5 degrees slope are found in very small quantity. The classified slopes are presented in Table 2.1.

Table 2.1: Soils distribution in the VDC area based on slope classes

Slope description	Slope (in degree)	Symbol
Nearly level	<1	S1
Gentle slope	1-3	S2
Gentle slope	3-5	S3

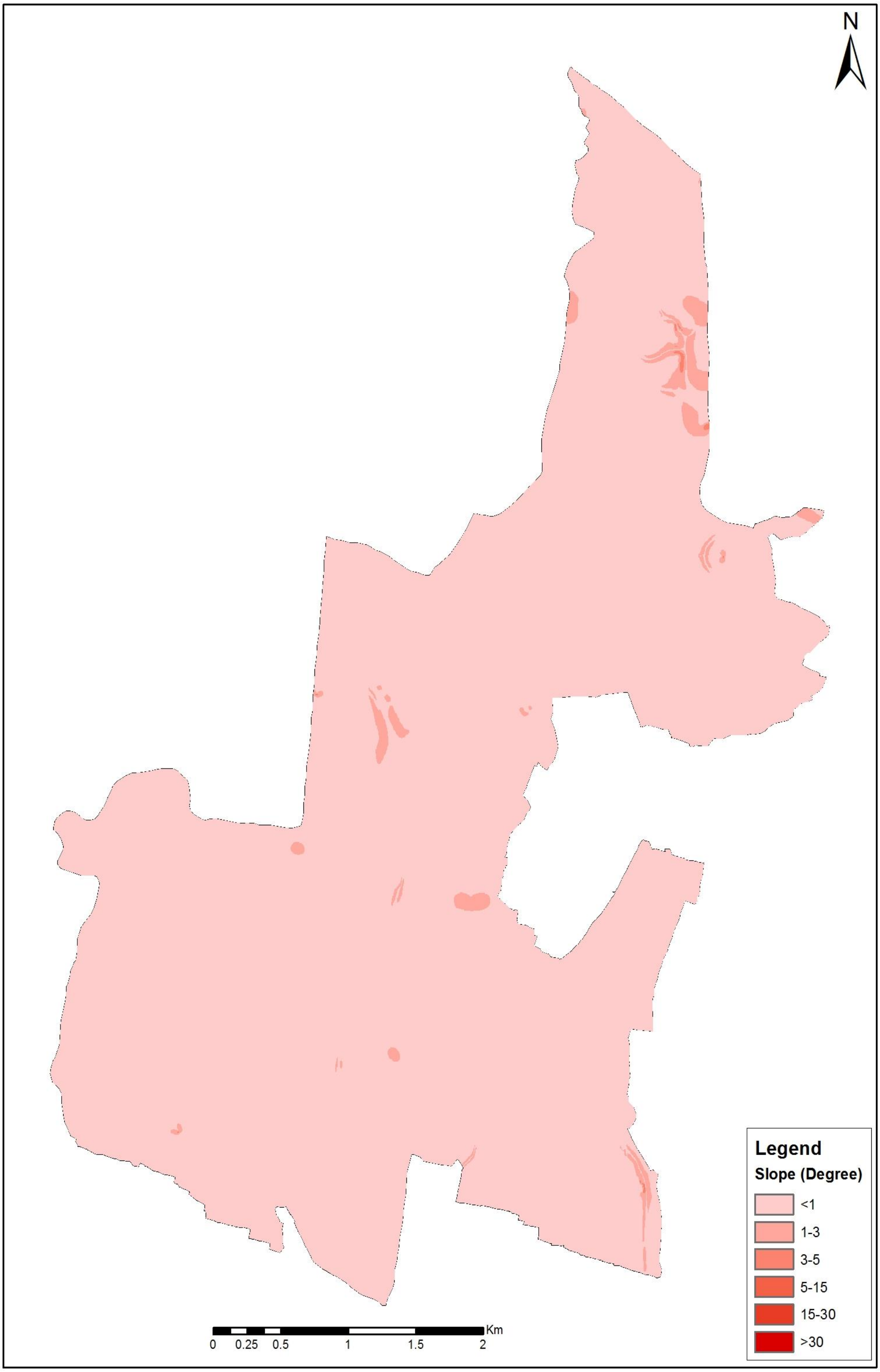


Figure 2.3: Slope map of Karahiya VDC

2.4 Geology

The Nepal Himalaya is sub-divided into five major tectonic zones from south to north, viz., Indo-Gangetic Plain (Terai), Himalayan Frontal Thrust (HFT), Sub-Himalaya (Siwalik or Churia Group), Main Boundary Thrust (MBT) and Lesser Himalaya (Fig. 2.4). From geological perspectives, the vast Nepal-Terai region forms part of Indo-Gangetic plain where these flat areas at the foothill of the mountain receive floods and sediments at different time scales and restore the broader ecosystem functions and services required to maintain the local biodiversity and fulfil the needs of humankind.

Geologically, the Karahiya VDC belongs to the Indo-Gangetic Plain (Middle Terai Plain). The sediments in the VDC are represented by the presence of alluvial deposits (mainly silty sand and clays) by active ancient rivers like Narayani River and Kaligandaki River in the past. These sediments mainly consist of unconsolidated sands and clays, some sub-rounded to rounded, well sorted cobble and pebble inter-bedded with sands and silty clay layers derived from Siwalik and Lesser Himalaya rocks.

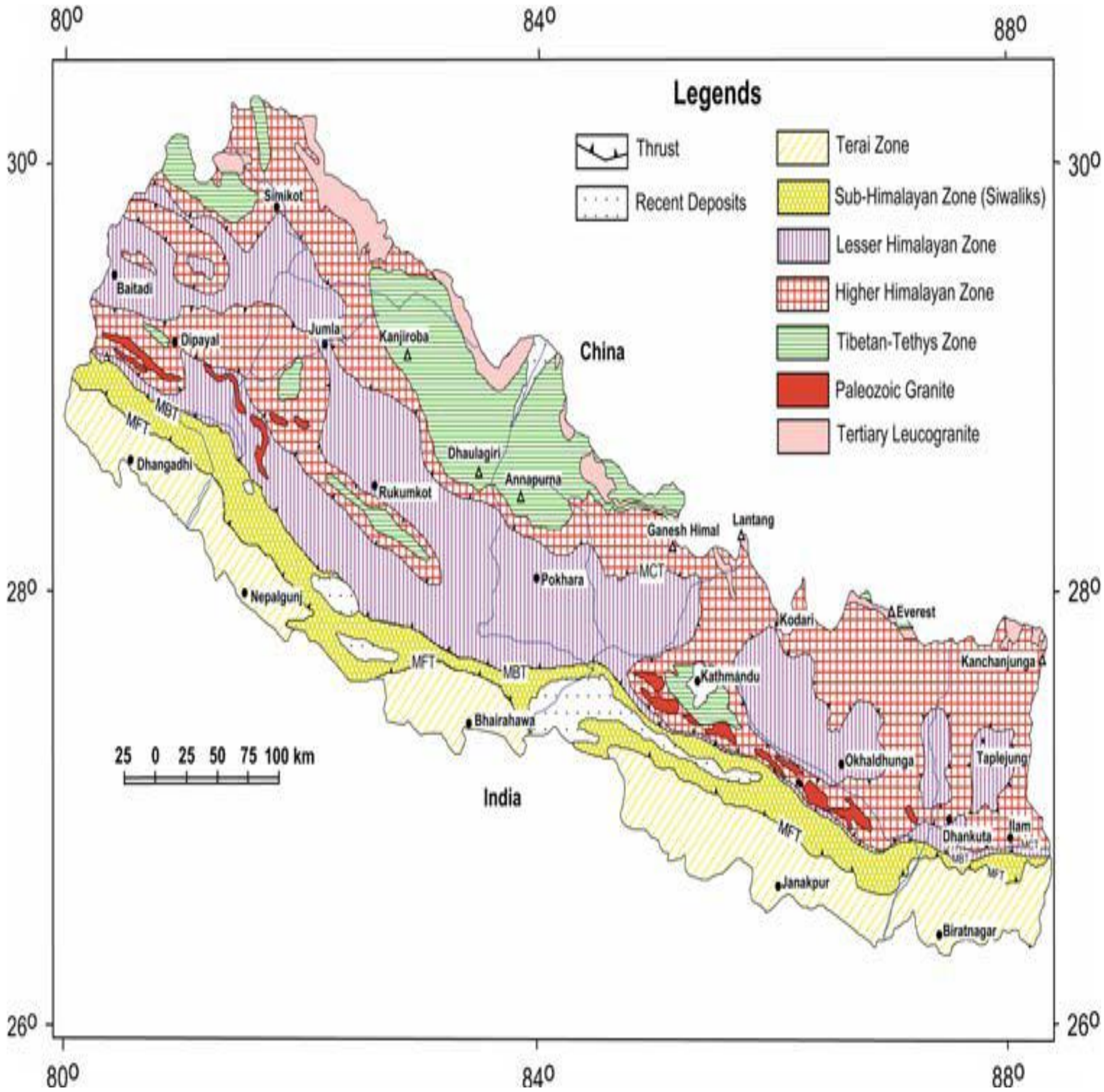


Figure 2.4: Geology of the Nepal Himalaya

The gravel mainly consists of quartzite, sandstone, and slate. The beds are roughly horizontal and show fining upward succession with cobble pebble at base and silty clay at the top. The top layers are covered by thick residual soils contents of silty sands and clayey sands. Thickness of residual soil is more than 3m. Topography formed by the distribution of the sediments are more or less flat. Thicknesses of the sediments are considered as more than 500m. The fineness of the sediments increases towards south of the VDC area. The age of the sediments deposition of the Indo-Gangetic Plain is Pleistocene. Geomorphic units of Nepal are shown in Table 2.2. The sediments have developed alluvial terraces and recent alluvial deposits. They are still in formative process and could potentially be inundated during the high floods. The yearly monsoon flooding and the frequent migration of the riverbed contribute to the continual change in the mosaic like landscape in VDC along the active riverbed. The relative height of this area does not exceed 5m relative to the present level of riverbed which decreases downstream. The geological map of the study area is shown in Figure 2.5.

Table 2.2: Geomorphic units of Nepal

SN	***Geomorphic Unit***	**Width (km)**	***Altitude (m)***	**Main Rock Types**	***Age***
1.	Terai Bhabhar zone Middle Terai zone Southern Terai zone	20-50 5-7 km 10-15 km 10-25 km	100-200 300 100-200 100	Alluvium (gravels in the north near the foot of the mountain, and gradually becomes finer southward Boulder, cobble, pebble and sands Sands and pebbly sands, silts Clay and silt	Pleistocene-Recent
2.	Churia Hills (Siwaliks)	10-50	200-1,300	Sandstone, mudstone and conglomerate.	Mid-Miocene to Pleistocene

In this VDC, total landscape could be mapped and represented by units such as 1a and 1b (Fig. 2.5). Soils in both mapping units are common in terms of geological materials such that they are derived from unconsolidated sediments and occur mainly in Terai and inter-mountain valley. The followings are the differences between these units:

1a = Alluvium, deposited and reworked by water, wind, or ice and includes river terraces.

1b = Alluvial fans, talus, and colluvium.

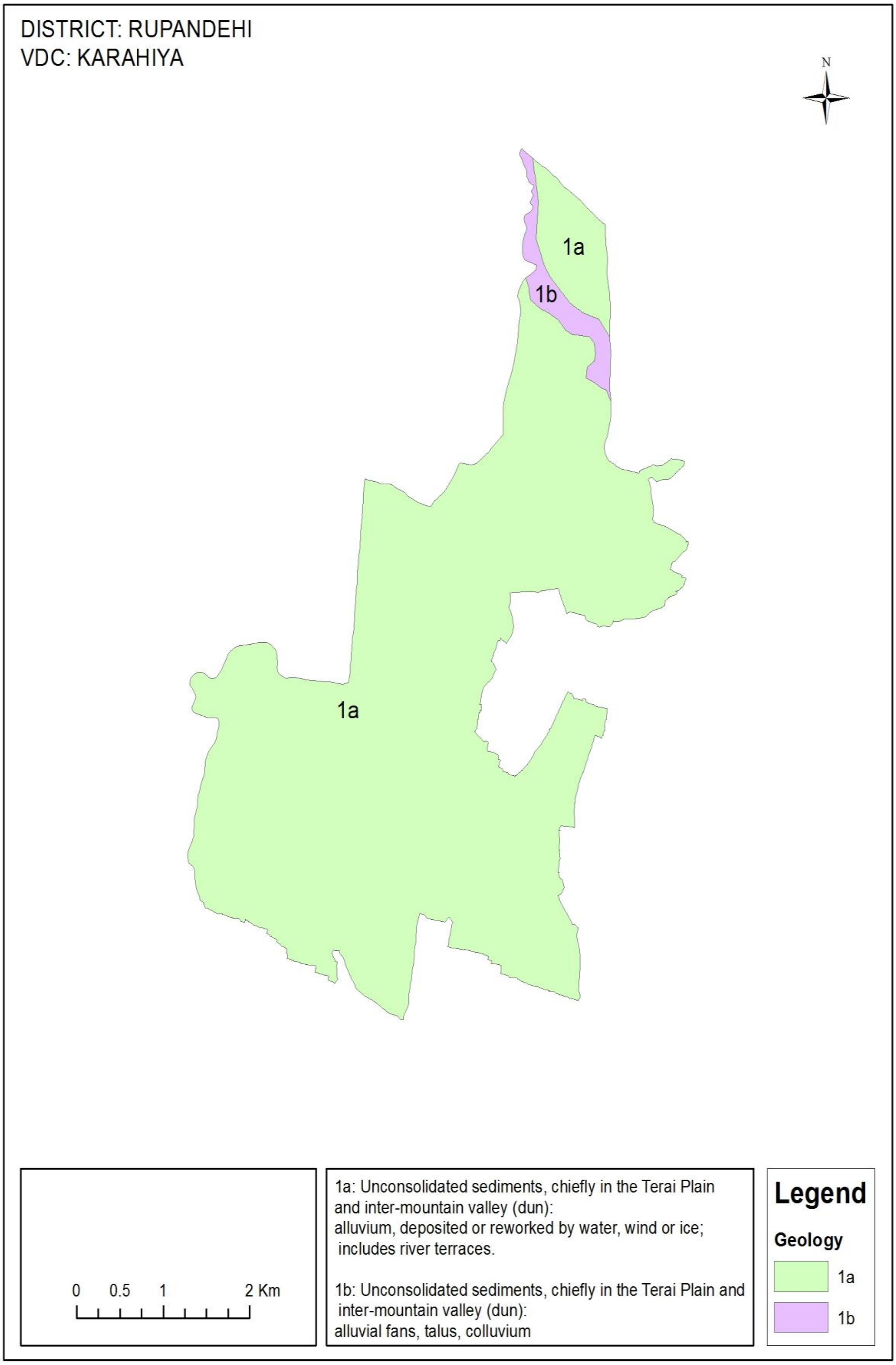


Figure 2.5: Geology of Karahiya VDC

2.5 Streams and Canals

The VDC area is endowed with historic farmers managed irrigation system called Sorah Chhattis (Fig. 2.6). Water is therefore not a scarce commodity, although irrigation management is not very efficient. Rivers network seem to be found on the south part in very small area but branches of Sorah Chhattis irrigation system as shown in the Figure covers large spatial area of the VDC. The branching of this irrigation system indicates that water flows in N-S fashion of the VDC. No other irrigation canals of prominence are seen to supply water in this VDC. Farmers reported that it is not hard to find groundwater aquifers (commonly 20 – 30 ft) down from the land surface. A large number of farmers also depend partly on private shallow tube-wells or dug-wells for supplying water for growing cereal crops, and culinary or household purposes.

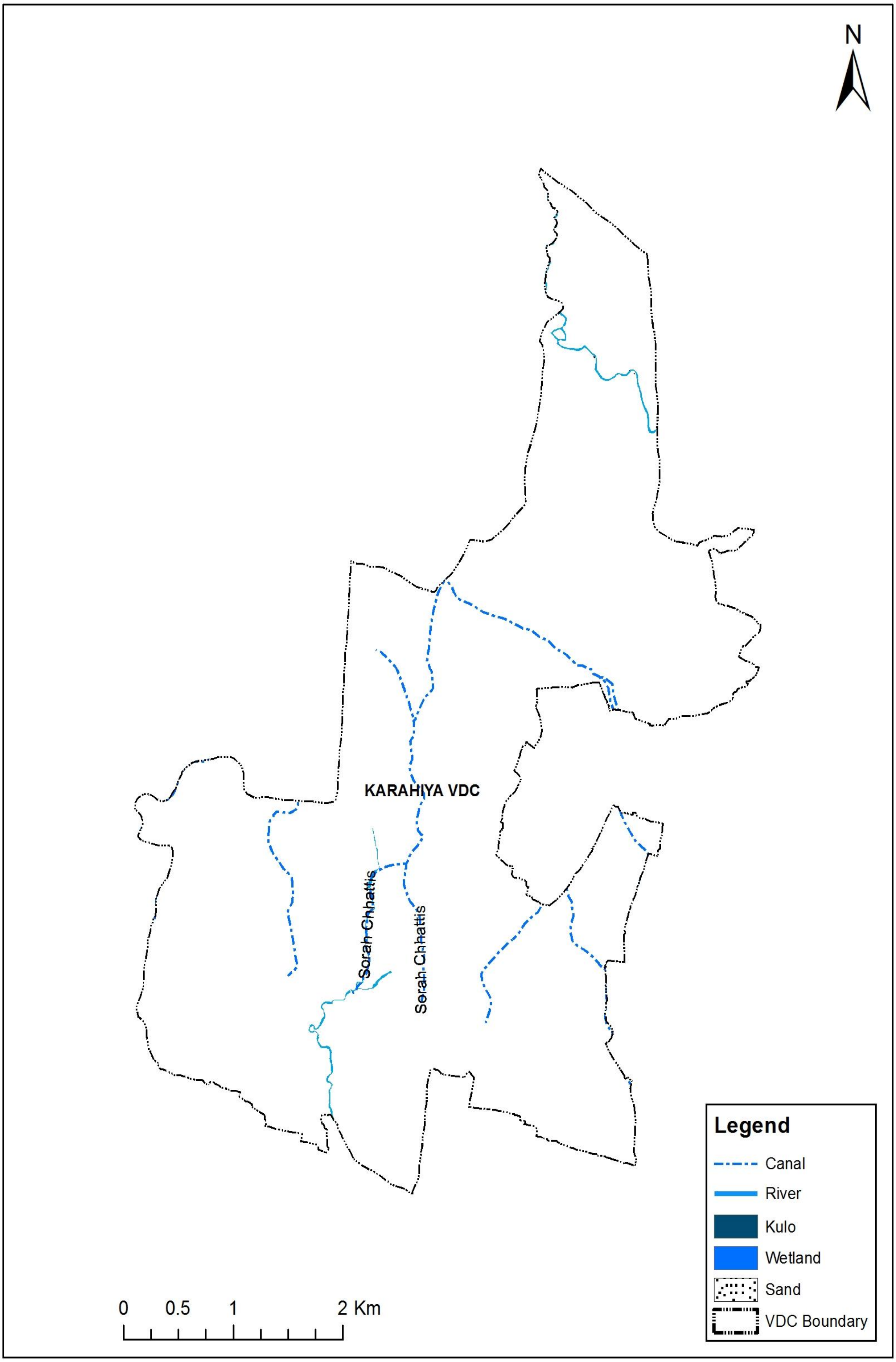


Figure 2.6: River system network and canals in Karahiya VDC

2.6 Climatic Condition

The monthly average maximum and minimum temperature for the period of 10 years (2005 and 2014) measured at the nearest weather station at Butawal is shown in Figure 2.7. Differences in maximum and minimum temperatures through the months from January to December as seen on the figure in these years remained fairly homogenous. Maximum monthly average temperature ranged between 21-37^{o}C with April being the hottest month, whereas minimum monthly average temperature ranged between 11-24 ^{o}C with December being the coldest month of the year. The range within which these temperatures are distributed across months is the range suitable for biochemical processes in the pedosphere and also for favorable growth of most of crop plants.

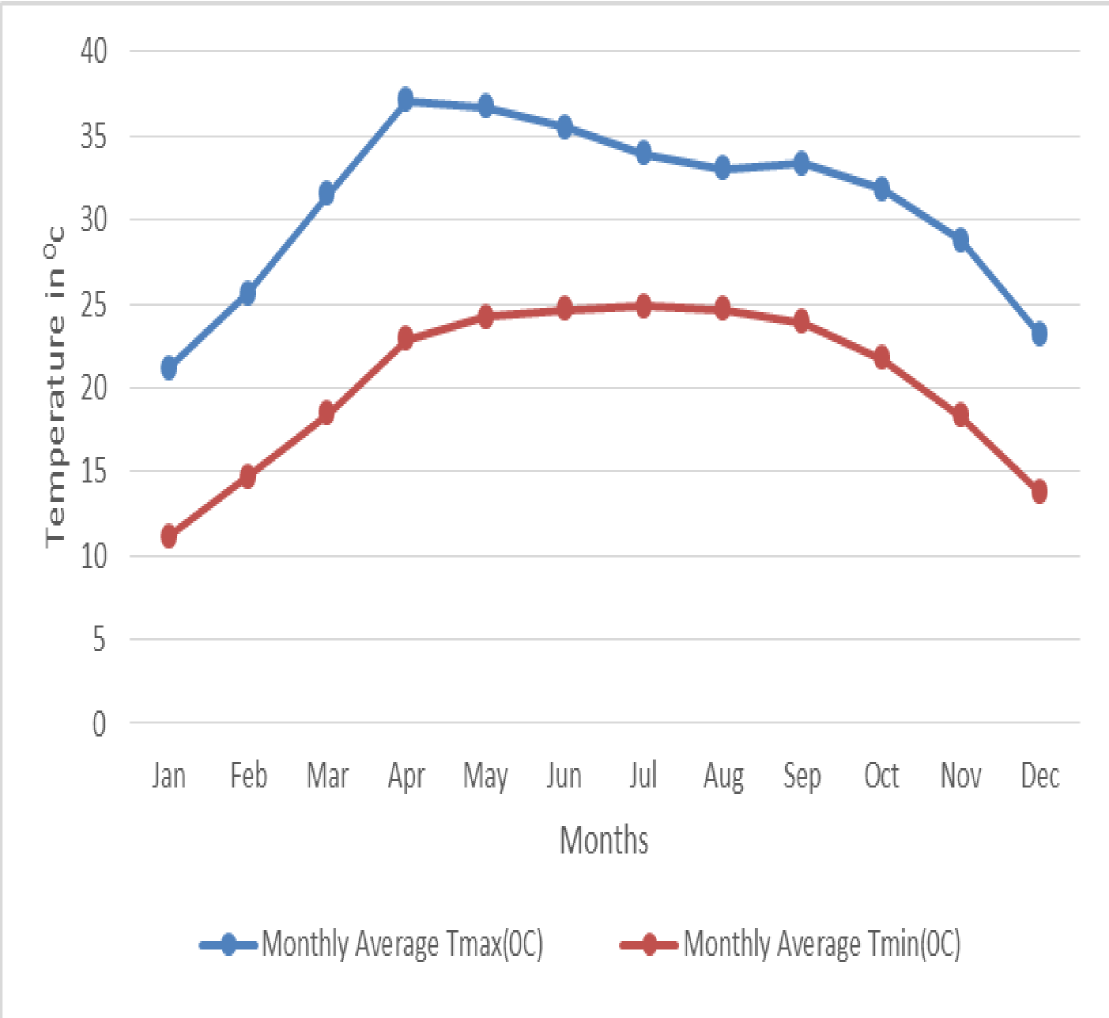


Figure 2.7: Monthly average maximum and minimum temperatures recorded at the Butwal weather station of Rupandehi district for the years from 2005 to 2014.

Annual total rainfall (2005 - 2014) of the VDC is shown in Table 2.3. Minimum (1224 mm) was recorded in 2012 and maximum (2907 mm) in 2010. This clearly shows a tendency of great year to year variation in annual rainfall pattern which in a way poses risk in crop production facing scarcity of water in some years and flooding in other years. Looking at more details, Figure 2.8 shows a greater variation in monthly average rainfall in these years. Monthly average rainfall increased sharply from April, peaked in the month of July (619 mm), dropped sharply after August and remained below 80 mm towards October. Such a seasonal distribution of rainfall shows that rainfall alone would not be enough to recharge soil profile for profitable crop production. Hence, irrigation development is necessary to improve soil fertility for food production in this area.

Table 2.3: Annual rainfall (mm) at the Butwal weather station for the year from 2005 to 2014

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total	1496	2769	2532	2173	1614	2907	2061	1224	2035	2726

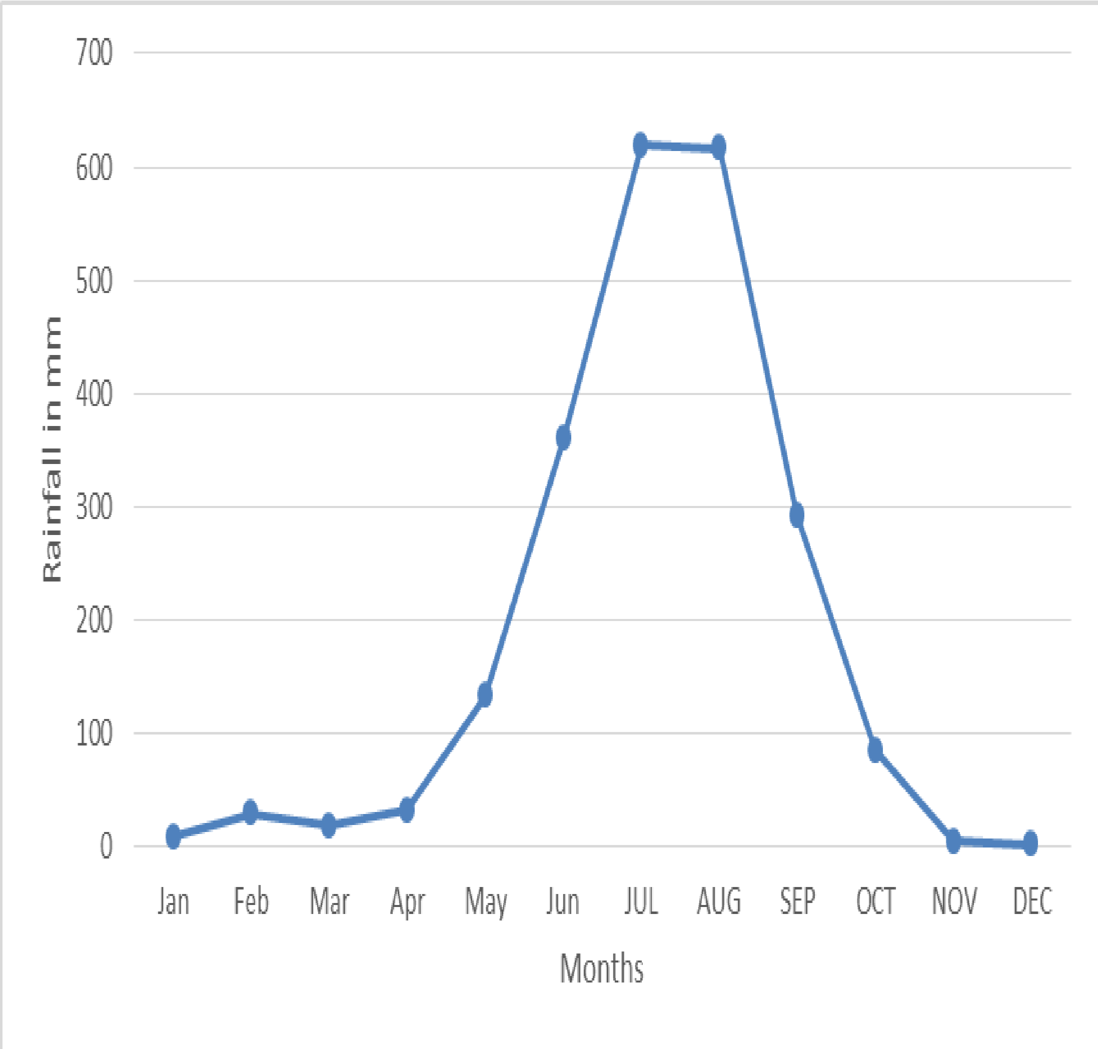


Figure 2.8: Monthly average rainfall at Butwal weather station for the years from 2005 to 2014.

2.7 Vegetation and Land Use/Land Cover

Land use map (Fig. 2.9) shows that over 70 percent of the VDC area is used for crop production indicating that farming provides the only major source of employment and income in this VDC. Other land uses that occupy fairly good amount of spatial area are residential (9 percent), forestry (16 percent), public (3.5 percent) and others (0.5 percent).

As discussed earlier, agriculture is the only basis of livelihood and income for most of the people in this VDC. Rice-wheat is the dominant cropping system; however, more of crop areas during winter which was traditionally occupied by wheat is being put to varieties of vegetable, pulse and oilseed crops exhibiting winter crop diversity. Winter crops such as lentil and mustard relay is used after harvest of the main rice. Some areas grow peas and coriander while others are left as winter fallow. Cropping intensity does not exceed 200 percent due to lack of irrigation facility in large part of the VDC. Although some rice is also grown on uplands, most of it is grown to the lowland type areas where water could be collected during rainy season expecting higher productivities.

Soils are fairly deep and fertile in nature, but productivity seems constrained by poor soil and crop management factors. Rivers and perennial streams do not exist except Tinau River. Farm level agriculture production in some areas operate on rain water naturally collected in depressions (low-lands) which are naturally wet or moist in most part of the year. Therefore, to improve soil fertility and crop productivity in this VDC, farmers increasing access to irrigation development and better soil management practices appear to be the viable alternatives.

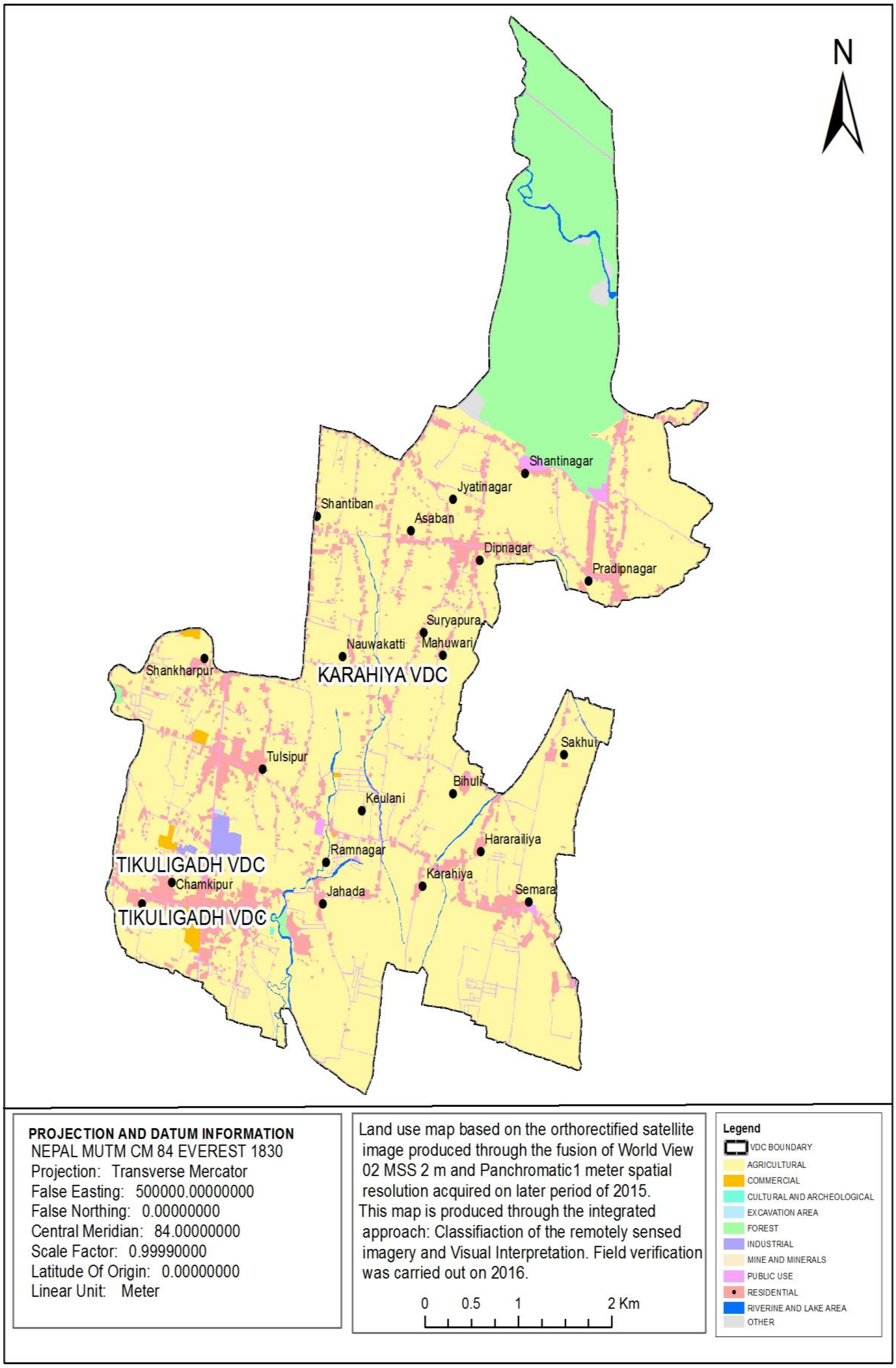


Figure 2.9: Land use in Karahiya VDC

Chapter 3: Methodology of soil survey and Mapping

3.1 Review of Soil Survey Methods

Soil survey describes the characteristics of the soils in a given area, classifies the soils according to a standard system of classification, plots the boundaries of the soils on a map, and makes predictions about the behavior of soils (USDA Handbook No. 18, 1993). Systematic soil survey has been carried out for over one hundred years. Research advances have made soil survey more reliable, efficient, cheaper and useful for making recommendations to put soils to best uses. Increasing concern with the study of soils is that soil survey must confirm to the needs of a continuously evolving society. Formerly, as an effort to survey the soils, soil scientists started with the blank paper as a base map and counted steps to measure distances on the land. Until recent past, panchromatic vertical aerial photographs were used as base map for demarcating physiographic units using aerial photo interpretation technique. More recently, high resolution remotely sensed data added further advantages of getting synoptic views of a large area under consideration. In other words, traditional soil survey methods are being taken over by digital soil mapping. This study uses high resolution (2m) satellite imagery, the WorldView-2 available for detailed soil survey.

Generally, there are two approaches of soil mapping using the satellite data. Satellite data are delivered in 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.

Depending on the purpose and scale of soil survey, general traversing, grid and free survey methods are practiced widely. These are briefly described below:

General Traversing

The surveyor interpreting the physiographic-soil relationship on aerial photo sheets or imagery walks briskly along the field by boring a hole at interval depending upon the intensity of mapping and studying soil morphological properties and locates these observations on the map.

Grid Survey

The grid survey method is adopted in the pre-selected sample strips to establish correlation between soil and aerial photo/imagery units in the small area. Smaller the girds, more accurate would be the work. In this method, traverse lines are located along the grid pattern of geo-referenced image and four-five observations are recommended per hectare of area.

Free Survey

The free survey method is adopted for checking and confirming the established soil-physiographic relationship mapping units and inferred soil boundaries demarcated are to be matched with the actual soil properties depending upon indicators and associated features.

The methodology adopted for the present soil survey was based on integrated use of visual interpretation and computer aided technology (integrated use of GIS and RS techniques). The entire methodology comprises three-tier approach furnished below. The characteristic of present soil survey is shown in Table 3.1. National Land Use Project/GoN recommends detailed type of soil survey for the preparation of VDC level soil survey and mapping with the purpose of solving management problems, because it contains 1: 10,000 scales and having the frequency of pit defined by the need exhibited by the topography, land unit, geology, land use and land system.

Table 3.1: Characteristics of soil survey

Kinds of soil survey	Kinds of map unit	Kinds of components	Approx. scale	Minimum size delineation
1st order	Mainly consociations and some complexes	Phases of soil series	1:10,000	1 ha

3.2 Desk Study

Different kinds of LRMP maps including land system maps, land capability maps and land utilization maps (1:50,000), geological maps (1:125,000), VDC map and topographic maps (1:25,000) as well as WorldView Satellite image (MSS 2m) and Pan (sharpened 0.5m spatial resolution) and associated reports were first reviewed as part of preparatory work for this soil survey. All these layers and satellite images were made compatible for GIS overlay by geo-referencing them on same projection system as prescribed by NLUP. Standard False Colour Composites (FCC) of the VDC areas was produced at the scale of 1:10,000. These imagery sheets were visually interpreted for lithological (parent material) units which were initially delineated based on available geological maps. It then followed the delineation of broad physiographic units based on relief information available on topographical maps. Topographic information, such as relief and slope could also be deduced by interpreting drainage features, and drainage density exhibited on imageries. The DEM, relief and hill shade map were produced for the visualization of virtual 3D terrain surface to help for delineating the land system units. The soil mapping units were interpreted and delineated on the imagery with the aid of physiographic-soil relationship such as topography, geology, drainage and wetland features.

Soil mapping units derived from land units were overlaid on Standard FCC of the project area at 1:10,000 scales. An adequate number of sample pits (fourteen) were located in order to represent the soil characteristics of the VDC. The first pit of Karahiya VDC coded in GIS database was KR-01. Other pits in the VDC followed the same code in the GIS database but with increasing numerical values. The spatial distribution of studied soil pits in this VDC is shown in Figure 3.1.

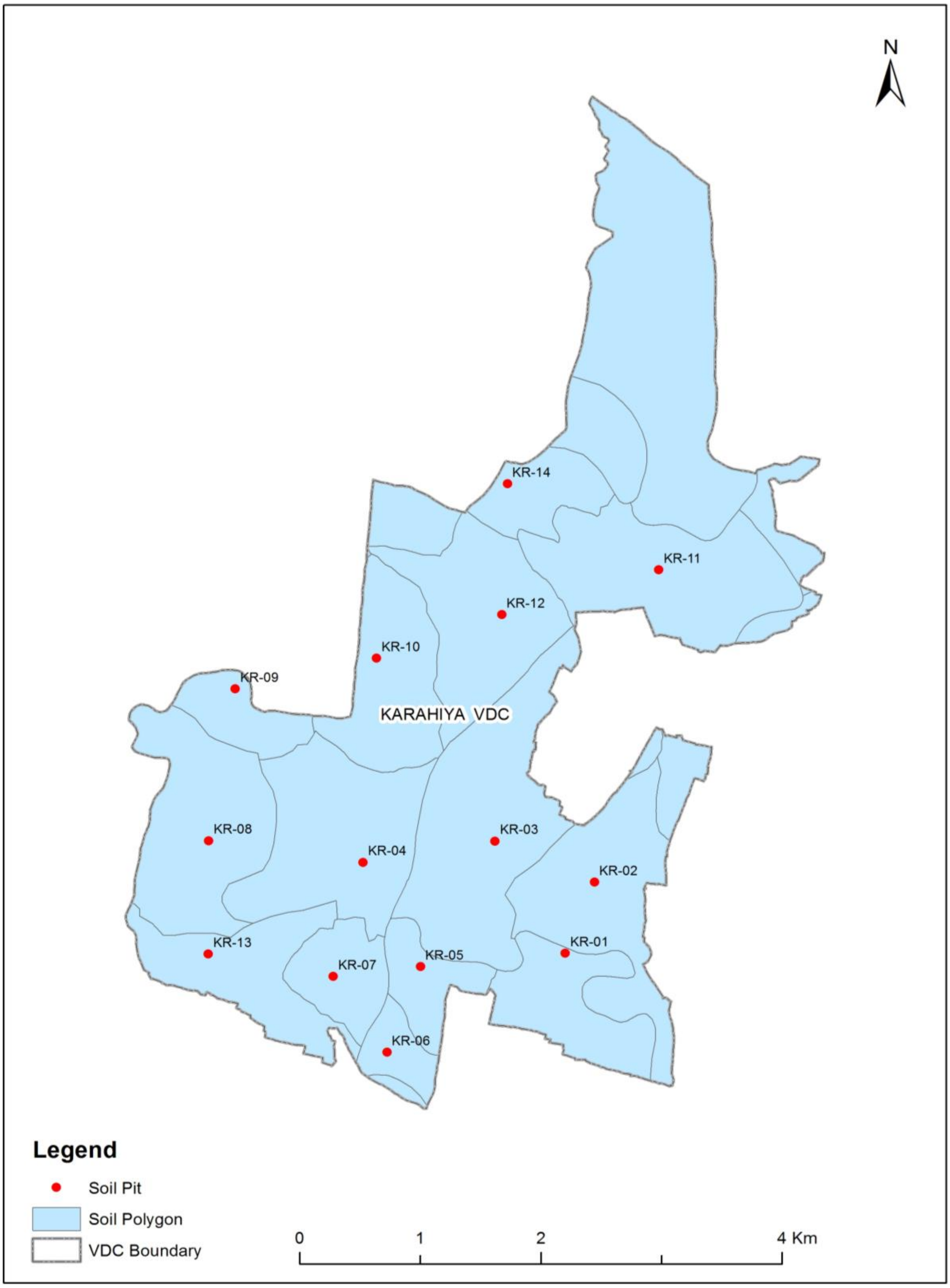


Figure 3.1: Soil pit locations in Karahiya VDC.

3.3 Field Survey

A preliminary reconnaissance survey was carried out during the pre-field activities to get the insight of ground situation of project area regarding landform association and soil variation. It helped in identifying soil mapping units and designing the soil sample collection work. Field work was carried out to study the physiography, landform and their associated soils based on the soil pit. Soil sample pits covering all the units were dug based on the interpreted soil map, topographical map, and satellite imagery for determination of soil profile characteristics.

Each of the sample points identified on the base map were visited, pits dug, described and samples collected following standard soil profile description sheets provided by the NLUP. Various field test, analysis and interpretation for each of soil pits were done to study the physical and morphological characteristics of soils at different horizons.

The soil profile description sheet provided by the NLUP includes the following information:

a. On-site record

- Sampled pit number, date of observation/sampling, author of sampling, GPS coordinates of sample site location, elevation, landform, vegetation, and tentative soil classification

b. General information of soil

- Parent material, drainage, moisture condition, ground water table, surface stones of rock outcrops

c. Detail description of individual soil horizon

- Soil horizon, solum depth, colour, mottling, texture, structure, consistency, cutans (clay skins), cementation, pores, pans, biological contents, roots, pH, soil boundary

Soil samples collected from field were transferred to the laboratory for analysis and the results used to classify soils according to the USDA Keys to Soil Taxonomy (2014).

After completion of field work, soil pits information was compiled and modifications made in the soil mapping units associated with physiographic units as needed. Soil mapping units with the land type were subsequently translated into soilscape units by incorporating soil information. Soilscape units were subsequently transferred onto base map of the same scale generated from topographical maps. Back in the GIS-lab, making of soil maps involved two major steps as below:

Spatial data analysis: After completing the field study, different thematic layers such as contour, spot height, drainage, land system and land use were made compatible by transforming into the same projection system (MUTM) adopted by Survey Department. The soil pit locations were transferred onto base map and vector to raster conversion of line segment made for preparation of DEM and Hill shade.

Attribute data analysis: This involved developing GIS database by inputting and analyzing physical and morphological soil attributes obtained from standard soil description sheets for each soil pit and horizon; in other words, conversion into digital tabular format by a unique spatial-join function to link attribute data with their respective coordinates of soil pits in the VDC. These spatial locations were then transformed into the geo-referenced base map of the same scale and projected using MUTM parameters.

3.4 Laboratory Soil Analysis

The soil samples collected from the field were sent to Soil Testing Laboratory to examine the chemical properties of soil including soil texture. Surface soil or epi-pedon properties were examined in the laboratory for fertility evaluation, whereas sub-surface or endo-pedons were examined for the classification purpose. In the laboratory, following methods were used to analyze the physical and chemical properties of soil samples (Table 3.2).

Table 3.2: Methods adopted for soil test in the laboratory

Soil Sample Tests	Analytical method employed
Texture	Hydrometer method
pH	1:2 water suspension after calibration of pH meter with Buffer 7 and 4.10
Organic matter content	Modified Walkley and Black
Available Phosphorous (P_2O5)	Modified Olson Biocarbonate
Available Potassium (K_2O)	Flame photo metric method, extraction with neutral Normal Ammonium Acetate
Total Nitrogen (N)	Microjeldahl apparatus
Zn(ppm)	Extraction, Carmine, FAO Bulletion No. 19
Boron (ppm)	DPTA Extraction & AAS, FAO Bulletin, No 19

Chapter 4: Land System, Land Form and Land type

4.1 Land System

Land systems are areas or regions with recurring patterns of component parts, in geographical, geological, and ecological terms. They are generally seen in terms of landform, underlying geology, vegetation and can also have other components that may be recurrent across regional landscapes. They are used extensively in surveys of land use planning and land management (Speck, 1960). The land system of the VDCs presented in this report was seen as fairly homogeneous and in accordance with LRMP (1986), it falls under land systems 2 characterized by recent alluvial plain, depositional and erosional lower piedmont.

4.2 Landform

Within the physiographic regions, land systems are characterized as landform types based on recurrent pattern and processes of landform, geologic materials, terrain slopes, and limit of arable lands. The landforms affect soil formation and profile development. They could be named variously depending on the location they are formed. They might be mountain landform, continental landform, river landform, fluvial landform, glacial landform, aeolian landform, slope landform and so on. Strong interactions are seen between landform, topography and vegetation to influence the process of soil formation and development.

The VDC reported herein, falls under the Terai Physiographic Region, is an alluvial plain - a largely flat landform mostly created by the deposition of sediment over a long period of time by one or more rivers coming from highland regions in the north and a big Tinau River in the West, from which this alluvial soil is formed. Other terms like ‘floodplain’ may also appear in this manuscript which may mean that this plain is formed a part of the land forming process, denotes the smaller area over which the rivers flood at a particular period of time, whereas the ‘alluvial plain’ is the larger area representing the region over which the floodplains have shifted over geological time. The landform of this VDC is defined as recent alluvial plain, depositional and erosional lower piedmont.

4.3 Description of Individual Land Type Units

This study underlines the importance of soil-landform relationship and uses this concept as a scientific approach to form soil mapping units. LRMP (1986) divided physiographic regions of Nepal into distinct land systems following the recurrent pattern of landforms, geology, slope, and limits to arable agriculture. In LRMP report, Carson (1985) assigned land units to different land systems, and defined the boundaries based on position, slope, direction, and drainage pattern of landscape features and considered these features particularly important for local level project designing. The soils within the land types were classified based on detailed field survey. This study report also used these observations and experiences as a guide for soil association level classification. DEM technique proved to be helpful to delineate boundaries for landforms, land units and land types for detailed soil survey.

In developing map units, landform is further subdivided into land units basically defined by the mapable size of land surface aided by topographical variation. The description of soil mapping unit and the symbol was formed with the integration of land system, landform, land type with geological map and land use/land cover. The whole VDC area under study comes under 2b land unit which is predominantly a recent alluvial plain with position level and dominant slopes < 2 degrees.

Based on shape, size, tonal, color variation and relative elevation of the location, the landform and land types were identified on satellite imagery and DEM. The color variation ranging from light to dark represented the soil differences associated with degrees of soil wetness. Soil association as the universally accepted parameter for soil mapping was adopted in orders to correlate the soil pit with soil mapping units because these two spatial entities are geometrically different. Thus classifications were made based on soil association. Definitions of land system units of Karahiya VDC and associated map are shown in Table 4.1 and Figure 4.1, respectively.

Table 4.1 Definitions of land system, landform and land units of Karahiya VDC

Region	Land system	Landform	Land unit	Dominant slopes$^{(0)}$
A. Tarai	1	Active Alluvial Plain (depositional)	1a. present river channel	
			1b. sand & gravel bars	<1
			1d. higher terrace	<1
	2	Recent Alluvial Plain lower piedmont(depositional and erosional)	2b. intermediate position level	<1/2
			2c. intermediate position undulating	<1
	3	Alluvial Fan complex, upper piedmont (erosional)	3b. gentle slopes	1-3

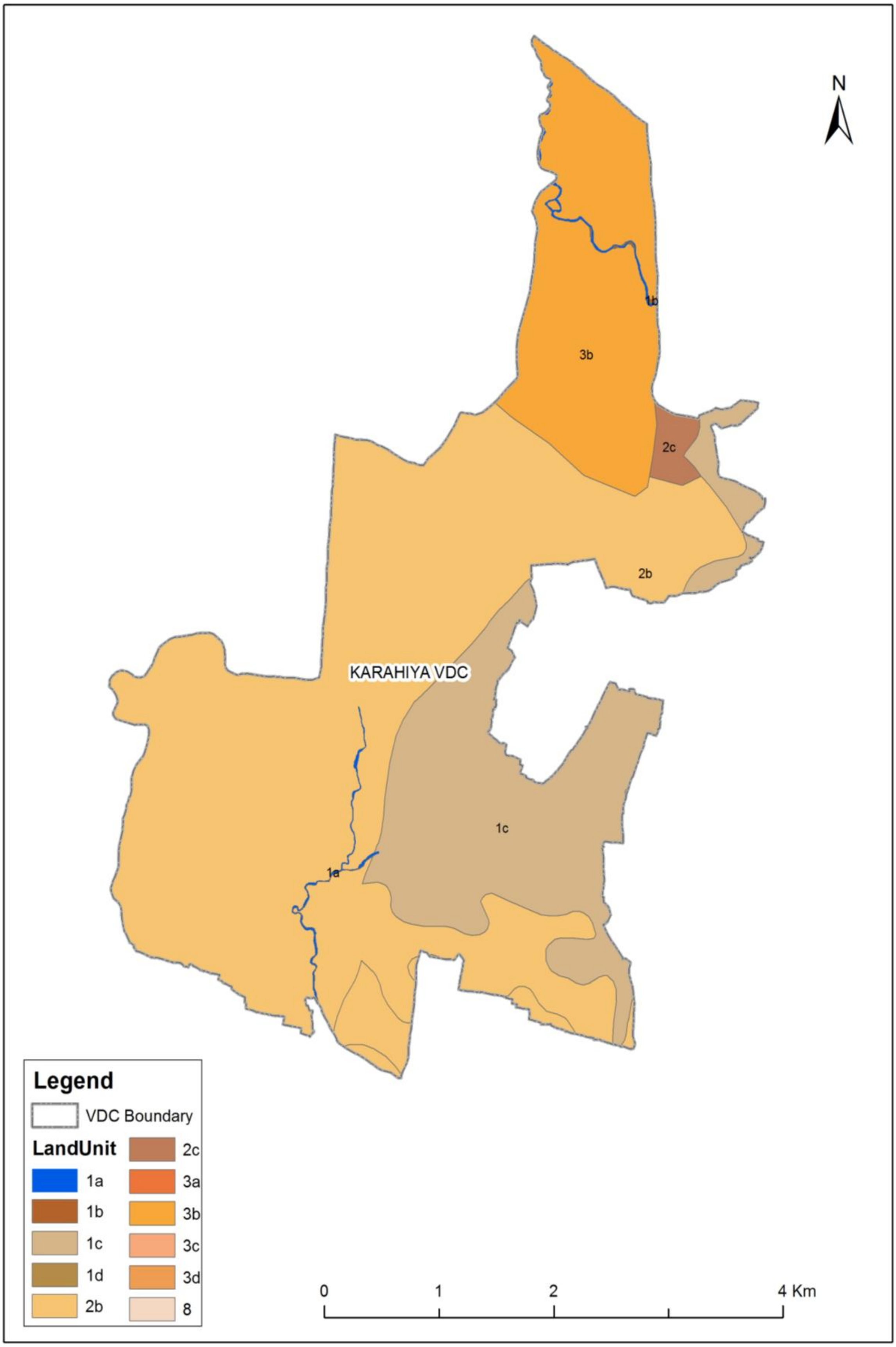


Figure 4.1: Distribution of Land units in Karahiya VDC

Chapter 5: Soil classification scheme

5.1 Soil Diagnostic Horizons

Soil description is essential in any soil survey and classification program where diagnostic horizons are used as a key to foster global communication among soil scientists, land managers and policy makers alike. Soils are described based on extent of soil horizon development (also called as horizonization). Description is done in term of: a) master horizons, b) transitional horizons and c) subordinate distinctions within master horizons. They are briefly discussed below:

Master horizons

Master horizons (major horizons) are designated by capital letters, such as O, A, E, B, C, and R. The description of master soil horizons is given in Table 5.1.

Table 5.1: Master soil horizons

Symbol	Definition
Oi/ Oe/ Oa	Oi = Surface of mineral soil where thin layer of organic matter occurs at initial stage of decomposition, Oa = Intermediate stage of decomposition, Oe = Material at extensively decomposed stage
A	A dark colour soil horizon of mixed mineral and organic matter, generally ploughed.
E	A light colored horizon of max. eluviation (material removal/leached horizon)
EB	Transitional to C but more like E than B
BE	Transitional to B but more like B than E
B	Max. accumulation of silicate clays or of R_2O_3 and organic matter (zone of illuviation)
BC	Transitional but more like B than C
CB	Transitional but more like C than B
C	Weathered parent material (single grained particles)
R	Rock beneath the soil, Unaltered materials

Transitional horizons

Transitional horizons are layers of the soil between two master horizons. There are two types of transitional horizons as the first letter indicating the dominant master horizon and the second letter indicating subordinate characteristics.

Separate components of two master horizons are recognizable in the horizon and at least one of the component materials is surrounded by the others. The designation is by two capital letters with a slash in between. The first letter designates the material of greatest volume in the transitional horizon such as A/B, B/A, E/B or B/E. For example, an AB horizon indicates a transitional horizon between the A and B horizon, but one that is more like the A horizon than the B horizon. An AB or BA designation can be used as a surface horizon if the master A horizon is believed to have been removed by erosion.

Subordinate distinctions within master horizons

Lower case letters are used to designate specific features within master horizons. For example, highly decomposed organic material, as 'e' is used only with the O master horizon in which rubbed fiber contents should be <17 percent of the volume.

The following information is collected for assembling standard profile descriptions:

Horizon boundary characteristics, color, texture, rock fragments, structure, consistence, roots, pH, effervescence, and special features such as coatings, nodules, and concretions

Diagnostic soil horizons are found in the surface or the subsurface (Table 5.2). Those found in the surface are called epi-pedons (from the Greek words epi meaning over and peon meaning soil). The epi-pedons includes the upper part of the soil darkened by organic matter, the upper alluvial horizons, or both. It may include part of B horizon if the latter is significantly darkened by organic matter.

Table 5.2: Major Features of diagnostic horizons of Soil Taxonomy

Surface Horizon (Epipedons)	
Mollic	Thick, dark colored, high base saturation, strong structure
Umbric	Same as Mollic except low base saturation
Ochric	Light colored, low organic content, may be hard and massive when dry
Histic	Very high in organic content, wet during some part of year
Anthropic	Man-modified Mollic-like horizon, high in available P
Plaggen	Man-mad sod-like horizon created by year of manuring
Melanic	Thick black horizon rich in organic matter usually associated with aluminium-humus complex
Folistic	A more or less freely drained horizon formed in organic materials
Subsurface horizons (Endopedon)	
Argillic	Silicate clay accumulation
Natric	Argillic, high in sodium, columnar or prismatic structure
Spodic	Organic matter, Fe and Al oxides accumulation
Cambic	Changed or altered by physical movement or by chemical reactions
Agric	Organic and clay accumulation just below plow layer resulting from cultivation
Oxic'	Highly weathered, primarily mixture of Fe, Al oxides and non-sticky-type silicate
Duripan	Hard pan, strongly cemented by silica
Fragipan	Brittle pan, usually loamy textured, weakly cemented
Albic	Light colored, clay and Fe and Al oxides mostly removed
Calcic	Accumulation of $CaCO_3$ or $MgCO_3$
Gypsic	Accumulation of gypsum
Salic	Accumulation of salts
Kandic	Accumulation of low activity clays
Petrocalcic	Cemented calcis horizon
Petrogypsic	Cemented gypsichorizon
Placic	Thin pan cemented with iron alone or with managanese or organic matter

Sombric	Organic matter accumulation
Sulphuric	Highly acid with Jarosite mottles

Source: USDA/NRCS (2014)

5.2 Local Classification System

Farmers are widely recognized as best engineers because of the fact that they know many things about soils behaviors intuitively. They possess local knowledge derived from their ancestors and age old historical practices. Knowledge of local classification helps the farmers to use most appropriate practices for the crops to be grown successfully and thereby take advantage of agricultural profession. Indigenous knowledge of local people regarding soils nomenclature and management is also dealt separately in Ethno-pedology which is another branch of soil science. Table 5.3 shows local farmers terms used to name a soil in this region.

Table 5.3: Local soil names used by farmers to denote soil textural variations

Sand	Baluwa
Loam	Domat
Silt	Pango
Clay	Chimato
Sandy soil	Balute mato
Loamy soil	Chimatailo mato
Silty clay loam	Pango chemto domat

5.3 USDA Soil Taxonomy Systems

Soil classification is grouping of soils into categories based on soil's morphology (appearance and form). While classifying soils, pedogenetic and morphological approaches are considered; the former includes the study of the soil evolution and their distribution in nature, whereas the later includes the observable features within various soil horizons and the description of the kind and arrangement of the horizons (Buol et. al., 2011). In classifying soils of Nepal, LRMP (1986) adopted the USDA system. However, their equivalents (not exact, however) could also be given in FAO system of soil classification.

USDA system of soil classification is variously called as the comprehensive soil classification system or Soil Taxonomy (Soil Survey Staff, 1975) which maintains the natural body concept of soil and has two other major features that make it most useful. First, the system is based on soil properties that are easily verified by others. This lessens the likelihood of controversy over the classification of a given soil, which can occur when scientists deal with systems based on soil genesis or presumed genesis. The second significant feature of Soil Taxonomy is the unique nomenclature employed, which gives a definite connotation of the major characteristics of the soils in question. Consideration is given to the nomenclature used after brief reference is made to the major criteria for the system soil properties.

The chemical, physical, and biological properties are used as criteria for Soil Taxonomy. A few examples of physical properties include the soil wetness, temperature, color, texture, and structure of the soil. Similarly, chemical and mineral properties include organic matter, clay, iron and aluminum oxides, silicate clays, salt, the pH, the % base saturation, and soil depth. Differences between horizons generally reflect the type and intensity of processes that cause differences in soil properties. Ideally, efforts should be made in profile descriptions to maintain a link between process and morphology. In many soils, these differences are expressed by horizonization reflecting vertical partitioning in the type and intensity of the various processes that influence soil development.

In classifying soils, Soil Taxonomy uses concept of six categories. At the most general level is Order; likewise, soils under each Order become more specific in generalization. They are sub-order, great group, sub-group, family, and the lowest category called soil series. These categories are briefly explained below:

Order: The order category is based largely on soil-forming processes as indicated by the presence or absence of major diagnostic horizons. A given order includes soil whose properties suggest that they are not too dissimilar in their genesis. As an example, many soils that developed under grassland vegetation have the same general sequence of horizons and are characterized by a thick, dark epipedon (surface horizon) high in metallic cations. Soils with these properties are thought to have been formed by the same general genetic process and are included in the same order, Mollisols. There are twelve soil orders in Soil Taxonomy (Table 5.4).

Table 5.4: Soil orders and their major characteristics

Name	Formative element		Major characteristics
	Derivation	Pronunciation	
Entisols	Nonsense symbol	Recent	Little profile development, ochric epipedon common
Inceptisols	L. inceptum, beginning	Inception	Embryonic soils with few diagnostic features, ochric or umbric epipedon; cambic horizon
Mollisols	L. mollis, soft	Mollify	Mollic epipedon, high base saturation, dark soils, some with argillic or natri horizons
Alfisols	Nonsense symbol	Pedalfer	Argllic or natric horizon; med. to high saturation
Ultisols	L. ultimus, last	Ultimate	Argillic horizon, low base saturation
Oxisols	Fr. Oxide, oxide	Oxide	Oxic, no argillic horizon, highly weathered
Vertisols	L. verto, turn	Invert	High in swelling clays; deep cracks when soil dry
Aridisols	L. aridus, dry	Arid	Dry soil, orchric epipedon, sometimes argillic or natric horizon
Spodosols	Gk. Spodos, wood ash	Podzol; odd	Spodic horizon commonly with Fe, Al, and humus accumulation
Histosols	Gk, Histos, tissue	Histology	Peat or bog;>30% organic matter

Andisols	Modified from Ando	Andesite	From volcanic ejecta, dominated by allophane or Al-humic complexes
Gelisols	Gk. Gelid, meaning cold	Crysols	Permafrost within 100 cm

Sub-order*:* The suborders are subdivisions of order that emphasize properties suggesting genetic homogeneity. Thus, wetness, climate environment, and vegetation, which help determine the nature of the genetic process, help determine the suborder in which a given soil is found.

Great group: Diagnostic horizons are the primary bases for differentiating the great groups in given suborder. Soils in a given great group have the same kind and arrangement of these horizons.

Subgroup: The subgroups are subdivisions of the great groups. The central concept of a great group makes up one subgroup. The subgroup with typical features of its higher categories is called Typic. Other subgroups may have characteristics that are integrates between those of the central concept and soils of other orders, suborders, or great groups.

Family*:* In the family category are found soils with a subgroup having similar physical and chemical properties affecting their response to management and especially to the penetration of plant roots (e.g., soil-water-air relationships). Differences in texture, mineralogy, temperature, and soil depth are primary bases for family differentiation.

Series: The series category is the most specific unit in the classification system. Its differentiating characteristics are based primarily on the kind and arrangement of horizons. Conceptually, it includes only one polypedon; however, in the field, aggregates of polypedons and associated inclusions are also included in the soil series mapping units. Soil names at series level follow the name of widely known place, city, river or mountain and so on in the area where a particular type of soil was described first in the country; for example, a particular type of soil in Jhapa also bears the name as Rupandehi series if the soil properties at series level in Jhapa were found similar to soils in Rupandehi. This tries to avoid duplicity and redundancy in naming soils.

An example of how a soil type is named in this classification system is given below:

Order: Entisols
    Suborder: Fluvents
        Great Group: Torrifluvents
            Subgroup: Typic Torrifluvents
                Family: Fine-loamy, mixed, calcareous, Typic Torrifluvents
                    Series: Nepalganj.

5.3.1 Soil Classification at Family Level

This is more restrictive category in soil taxonomy (Soil Survey Staff, 1975). The major intention of using family class is to make the classification system useful for productive purpose (for growing plants)-use the soil variables that directly affect soil management practices. Three types of differentia, viz., sub-soil textural property (particle size distribution class), and mineralogical composition, CEC to % clay ratio and soil temperature variations are used. Sub-soil in this context indicates the soil volume between 25 and 100cm depth or root limiting layer if shallower. However, redundancies are removed if any of these parameters are already used in higher categories, they are not repeatedly used at Family level of soil classification.

5.3.2 Soil Classification at Sub-group Level

A brief introduction related to sub-group level classification has been presented earlier in this section. A key concept in classifying soils at sub-group level is explained by the term 'central concept.' It stands for great group expressed as "Typic"; properties indicating intergradations to other great groups, suborders, and orders; extragradation to identify critical properties common to soils in several orders, suborders, and great groups. This explains partly about the structure of the classification system (Buol et al., 2011). Bionomical nomenclature is used to identify subgroup names, i.e., names carry the great group name as a noun with the main differentiating characteristic of the subgroup used to modify adjective(s) (Smith 1968). A subgroup 'Typic' is a taxon representing the central concept of the great group. This serves as a modifying word in the name of great group, i.e., Typic Hapludoll. Other taxa such as Vertic Hapludoll in which 'vertic' shows the possession of characteristics of other order (Vertisol, in this case). In some situations, other properties may become more apparent and soil may belong to, for example, Fluvent (flooding, Entisol) suborder thus becomes a Fluvaquentic Hapludoll. In this case soil has properties similar to another great group (Fluvaquent), suborder (Aquent) and order (Entisol). These are examples of intergradation. In some situations, certain soil individuals have properties that do not clearly intergrade towards specific defined categories but have one or more properties common to soils in several categories. These soils are identified as extragrade subgroup formative elements such as abruptic, aeric, argic and so on.

5.4 World Reference Base for Soil Resources (FAO)

There are many soil classification systems-French, South African, Australian, Canadian, Russian, and still others. Some of these are limited mostly to soils of that country and do not attempt a comprehensive coverage of world soils. None of them are equated simply to terms in any other classification. The FAO of the United Nations has prepared a world map with described classification units. The FAO world soils are given in approximate comparisons to the 1975 US system. This comparison provides an acquaintance with taxonomic names and approximate relationship of the systems.

The FAO soil classification system is worldwide, but it is not a system of units grouped into higher categories. The units relate most closely to great groups in the US system. The FAO system uses the US system of diagnostic horizons, although they are sometimes more simplified in definition.

Comparisons between USDA and FAO Classification Systems

A tabulation of the FAO system is given as the basis for comparing the systems with 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.

Table 5.5: Comparison between FAO and USDA system of soil classification

FAO Systems and Name Meanings	US Systems (1975)
ACRISOLS Latin acris= very acidic, low base status. Subunits: Orthic, Ferric, Humic, Plinthi	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	Pasmmments Several subgroups
CAMBISOLS Latin cambiare= change Subunits: Eurtic, Dystic, 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 aluminium. Subunits: Orthic Xanthic, Rhodic, Hemic, Acric, Plinthic	Fluvents
GELOSOLS, Greek gelid = very cold, permafrost in part	Gellsols
GLEYSOLS Russian gley= mucky soil mass. Subunits: Eutric, Clacaric, Dystric, Mollic, Humic, Plinthi, Gelic	Aquents, Aquepts, Aquolls
GREYZEMS English grey and Russian zemlja= earth. Subunits: orthic, Gleyic	MOLLISOLS Borolls, Aquolla
HISTOSOLS Greek histos= tissue. Subunits: Eutric, Dystic, Gelic	HISTOSOLS
KASTANOZEMS Latin castanea= Chestnut, Russian zemlja= earth. Subunits: Haplic, Calcic, Luvic	MOLLISOLS Ustolls, Borolls
LITHOSOLS Greek lithos= stone shallow to rock. Subunits: none	Lithic subgroups
LUVISOLS Latin Juo= to wash, Iliuvial clay layer. Subunits: Orthic, Chromic, Calcic, Vertic, Ferric, Albic, Plinthic, Gleyic Brown Wooded, Acid Brown Forest soils	ALFISOLS Many suborders
NITOSOLS Latin nitidus= shiny, shiny ped surface Sub=units: Eutric, Dystric, Humic	Paleudalfs, Many Udults, Tropohumults
PHAEOZEMS Greek phaios= Dusky,	Udolls and Aquolls

Russian zemlja= earth Subunits: Haplic, Calcaric, Luvic, Gleyic	
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. Subunits: Orthic, Leptic, Ferric Humic, Placic, Gleyic	SPODOSOLS Orthods, Humod, Aquods
PODZOLUVISOLS From Podzol and Luvisol Subunits: Eutric, Dystric, Gleyic	MOLLISOLS Udalfs, Boralfs, Aqualfs
RANKERS Austrain rank = steep slope, shallow soils. No sub-units	Lithic Haplumbrepts
REGOSOLS Greek rhegos= blnket, 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-alfs Nadurargids
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 Calcids Gypsids-argids
YERMOSOLS Spanish yermo= desert areas Subunits: Haplic, Calcic	ARIDISOLS Cambids Argids
ACROSOLS Latin acris= very acidic, low base status. Subunits: Orthic, Ferric, Humic, Plinthic	ULTISOLS Hapl-ults Pale-ults Hum-ults Pnth-liults
ANDOSOLS Japanese an= black, do= soil Subunits: Ochric, Mollic, Humic, Vitric	ANDISOLS Several suborders and great groups
ARENOSOLS Lating arena= sand. Subunits: Cabic, Luvic, Ferralic, Albic: CAMBISOL Lating Cambiare= Charge Subunits: Euriric, Dystric, Humic, Gleyic, Golic, Calcic, Chromic, Vertic, Ferralic	Pasamments Several subgroups
CHERNOZEMS Russian chern= black, zemlja= earth. Subunits: Haplic, Calcic,	INCEPTISOLS Many Ochrepts

Luvic	
Glossic FERRALSOLS Latin ferrum= iron and aluminium. Subunits: Orthic, Xanthic, Rhodic, Hemic, Acric, Plinthic	MOLLISOLS Several Borolls, OXISOLS
FLUVISOLS Latin fluvius= river (Alluvial deposits). Subunits: Eutric, Calcaric, Dystric, Thionic	Most suborders Fluvents
GELOSOLS Greek gelid = very cold, permafrost in part	GELISOLS
GLEYSOLS Russian gjey= mucky soil mas. Subunits: Eutric, Calcaric, Dystric, Mollic, Humic, Plinthic, Gelic	Aquents, Aquepts, Aquolls MOLLISOLS Borolls, Aquolla
Aquents, Aquepts, Aquolls MOLLISOLS Borolls, Aquolla	HISTOSOLS MOLLISOLUS Ustolls, Borolls Lithic subgroups
HOSTOSOLS Greekhistos= tissue, Subunits: Eurtic, Dystric, Geli	ALFISOLS Many suborders Paleudalfs, many Udults, Tropohumults Udolls and Aquolls
LITHOSOLS Greek lithos= stone shallow to rock. Subunits: none	Pale-alfs, Albaquults, Aqualfs, Albolls
LUVISOLS Latin Juo= to wash, Iliuvial clay layer. Subunits: Orthic, Chromic, Calcic, Vertic, Ferric, Albic, Plinthic, Gleyic Brown Wooded, Acid Brown Forest soils	SPODOSOLS ORTHODS, ORTHODS, Humods, Aquods

Source: FAO (2006); USDA (2010)

A few terms not presented in Table 5.5 above are as follows:

Orthic: central concept of that soil; Solodic: <6% Na in the CEC

Calcaric: shallow to lime (2-25cm) Takyric: clayey, massive dry

Gelic: permafrost sithin (200cm) Thionic: sulphuric horizon

Gleyic: hydromorphic (anaerobic) Vertic: Vertisol-like properties

Luvic: leached, clay moved downward

5.5 Rating of Soil Fertility Status and Crop Suitability Analysis

Crop suitability has been defined as specific cultivate of crop types based on the requirement of different crops for agriculture and soil attributes pertaining in soil mapping units defined. It has been done for various crops considering for a single clearly defined, reasonably homogenous purpose or practice and suitable appraisal for a list of crops or other activities.

The requirement of a given crop/function (e.g., natural, social, economic or technological etc) needs to be known or alternatively, identify what soil/site attributes influence crops adversely. To identify and delineate land with the desirable attributes suitable for an enterprise while avoiding the effects of undesirable factors, a number of classes are determined according to degree of suitability. The suitability classes are given below:

Highly suitable (S1): Lands with no limitations to suitable application of a given use or minor limitations will not significantly reduce benefits.

Moderately suitable (S2): Lands having limitations in which aggregates are moderately severe for sustained application of a given use or increase inputs to the extent that overall benefits to be gained.

Marginally suitable (S3): Lands having limitations to sustained application of a given use or increase required inputs, marginally justified; costly production; subdivision of S2 and S3. Currently suitable (N1): Refers to the suitability for a defined use of land in its present condition without major improvements. A current suitability classification may refer to the present use of the land either with existing or improved management practices or to a different use.

Permanently not suitable (N2): Refers to the suitability for a defined use of land units in their condition at some future time, after specified major improvements have been completed where necessary.

Suitability analysis based on soil nutrients

An understanding of the terms ‘land capability’ and ‘suitability’ would be worth mentioning here for a general readership. This knowledge provides the land managers with the foundation of proper land uses. Many classification criteria have been developed when the first one was introduced in 1930s by the Soil Conservation Service of the United States. Although capability and suitability are sometimes exchangeable, the former's primary consideration is to prevent land degradation and the latter is to consider the fitness of a given type of land for a defined use (FAO, 1976a).

Soil suitability analysis in the present case was performed based on the soil tests derived from bio-chemical properties of soil samples representing different soil pits in the VDC. This means that soil nutrients analysis could be used to evaluate soil fertility status in order to infer the extent to which soil could be put to a particular use without deteriorating soil quality.

Crop Requirement

Suitability analysis is carried out based on availability of major nutrients in soil and the requirement criteria under optimum condition. As for instance, keeping other things similar, pH 5.5 to 7.5 is desirable range of pH for the successful cultivation of most of the field crops, fruits, and vegetables. However, an average value of 6.5 on pH scale would be taken as an optimum for growing these crops.

Soil Nutrient Rating

Soil suitability ratings with respect to top soil, rooting depth, texture for workability, permeability, acidity, organic matter, including N, P, K status are presented in the tabular forms below.

Table 5.6: Soil depth (cm) rating

Depth	Interpretation	Suitability
>200	Very deep	High
100-200	Deep	
50-100	Moderately deep	
25-50	Shallow	
<25	Very shallow	Low

Table 5.7: Soil workability rating based on texture

Loam	Good	High suitability
Silt loam	Good	
Sandy loam	Good	
Silt loam +loam	Good	
Clay loam	Moderate	
Clay loam over silt loam	Moderate	
Silty clay loam + Silty loam	Moderate	
Silty loam+ Silty clay	Fair	
Silty clay	Fair	
Clay	Fair	Low suitability

Source: Buol et al., 2011

Table 5.8: Soil drainage rating

Well drained	High suitability
Moderately well drained	
Somewhat poorly drained	
Poorly drained	
Very poorly drained	
Somewhat excessively drained	
Excessively drained	Low suitability

Source: Buol et al., 2011

Table 5.9: Soil acidity and alkalinity rating

<5.0	Very strongly acid	Low suitability
5.1-5.5	Strongly acid	
5.6-6.0	Moderately acid	
6.0-6.5	Slightly acid	High suitability
6.6-7.3	Neutral	Most suitable
7.4-7.8	Slightly alkaline	High suitability
7.9-8.4	Moderately alkaline	
8.5-9.0	Strongly alkaline	
>=9.0	Very strongly alkaline	Low suitability

Source: Buol et al., 2011

Table 5.10: Organic matter in soil

Organic matter, %	Interpretation	High suitability
>5.0	High	
2.5-5.0	Medium	
<2.5	Low	Low suitability

Source: Department of Agriculture and NARC

Table 5.11: Total soil N rating

Level of total N, %	Interpretation	High suitability
>0.2	High	
0.1-0.2	Medium	
<0.1	Low	Low suitability

Source: Soil Science Division, NARC

Table 5.12: Available phosphorus in soil

Level of phosphorus, kg/ha	Interpretation	High suitability
>55	High	
30-55	Medium	
<30	Low	Low suitability

Source: Soil Science Division, NARC

Table 5.13: Available potassium in soil

Level of potassium, kg/ha	Interpretation	High suitability
>280	High	
110-280	Medium	
<110	Low	Low suitability

Source: Soil Science Division, NARC

Table 5.14: Available zinc in soil

Level of zinc, mg/kg	Interpretation	High suitability
>1.0	High	
0.5-1.0	Medium	
<0.0-0.5	Low	Low suitability

Source: Soil Science Division, NARC

Table 5.15: Available boron in soil

Level of boron, mg/kg	Interpretation	High suitability
>1.0	Very high	
0.8-1.0	High	
0.41-0.8	Medium	
0.21-0.4	Low	
<0.20	Very low	Low suitability

Source: Soil Science Division, NARC

Chapter 6: Soil Types and GIS Database

6.1 Soil Types

Since early, the Government of Nepal has adopted USDA/NRCS soil classification system. In addition to this, World Reference Base for Soil Mapping –WHO system is also being taught in education sector of Nepal. In USDA system, soil type can be delineated at any level of generalization from Order to Series level, and sometimes up to phase level depending on the purpose of the study. The classification depends on the practical purposes for which these soils will be put forth. In this study, classifications are developed up to Family level which signifies the management options available or limitations these soils offer to an intended use. A subgroup level soil map of this VDC has been presented in Figure 6.1.

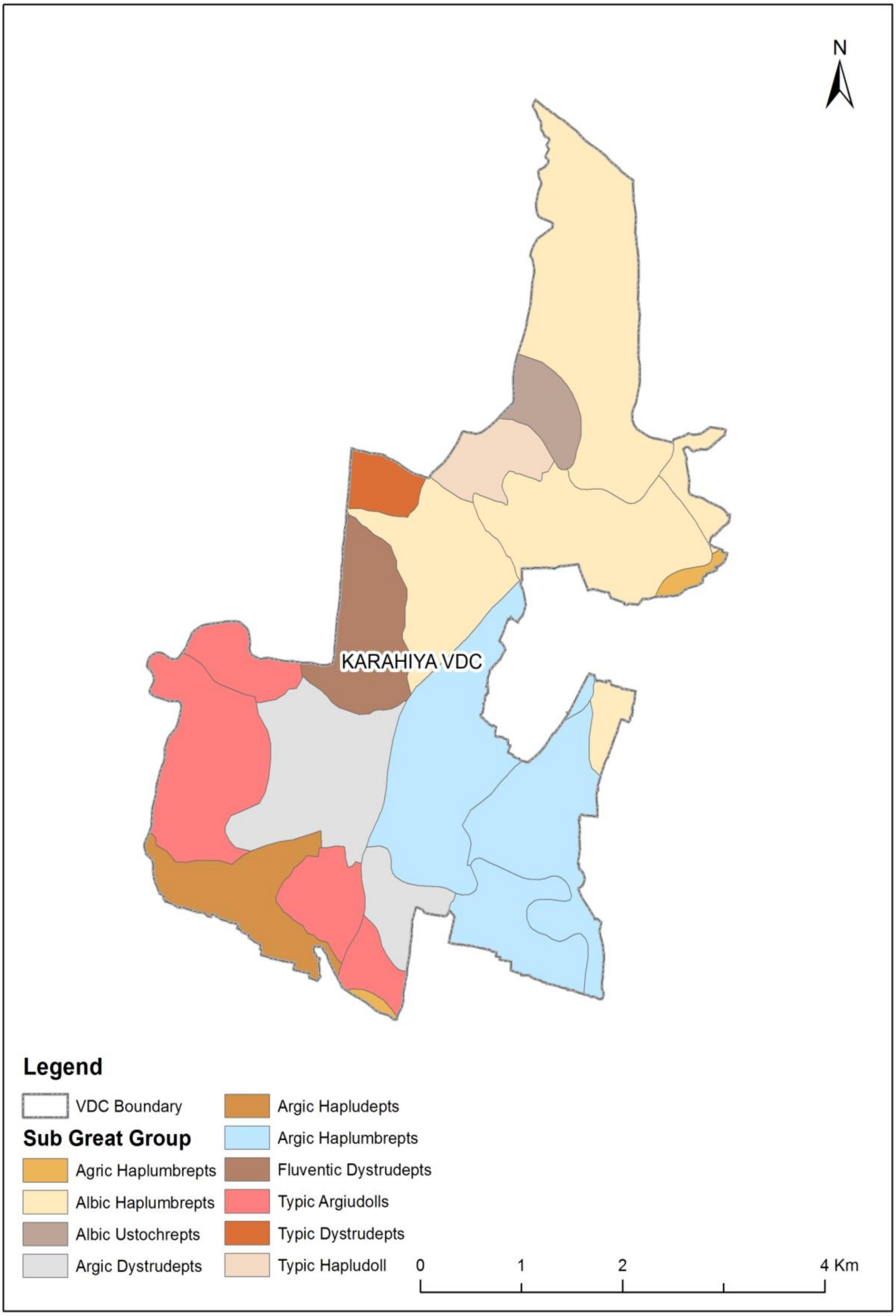


Figure 6.1: Subgroup level of soil classification in Karahiya VDC

Soils presented in Table 6.1 below were derived from the field survey of the VDC. A total of fourteen pits were sampled representing all soil types of this VDC. Soils were described and interpreted using USDA system of soil classification. Only two kinds of soils are found at order level, they are Inceptisols which occupy the largest share of total area (82.5%) followed by Mollisols (17.5%). At sub-order level, two of the dominant types are Umbrepts (56.6%) and Udepts (23.6%). At Great group level, Haplumbrepts (56.6%) followed by Dystrudepts (18.3%) and Argiudolls (14.7%) were found to be the three major soils. At sub-group level, Argic Haplumbrepts (23%) followed by Typic Argiudolls (14.7%) and Argic Dystrudepts (11%) represent the major soils in this VDC. Inceptisols are younger soils than Mollisols in USDA system of soil classification.

Table 6.1: Area covered by soils at different levels of classification, Karahiya VDC

Category		**Area**	**%**	**Category**		**Area**	**%**
Order				**Great-Group**			
	Inceptisol	1719.09	82.54		Argiudolls	306.35	14.71
	Mollisol	363.72	17.46		Dystrudepts	381.20	18.30
					Hapludepts	110.24	5.29
Sub-Order					Hapludoll	57.37	2.75
	Ochrepts	47.64	2.29		Haplumbrepts	1180.0	56.65
	Udepts	491.44	23.60		Ustochrepts	47.64	2.29
	Udolls	363.72	17.46				
	Umbrepts	1180.00	56.65				
Sub-Group				**Family**			
	Agric Haplumbrepts	15.74	0.76		Coarse Loamy Mixed Hyperthermic	92.91	4.46
	Albic Haplumbrepts	684.61	32.9		Fine Loamy Mixed Hyperthermic	660.48	31.7
	Albic Ustochrepts	47.64	2.29		Fine Loamy Mixed Hyperthermic	227.67	10.93
	Argic Dystrudepts	227.67	10.93		Fine Loamy Mixed Hyperthermic	386.74	18.57
	Argic Hapludepts	110.24	5.29		Fine Loamy Mixed Hyperthermic	35.48	1.70
	Argic Haplumbrepts	479.65	23.03		Fine Loamy Mixed Thermic	110.24	5.29
	Fluventic Dystrudepts	118.05	5.67		Fine Silty Mixed Hyperthermic	4.76	0.23
	Typic Argiudolls	306.35	14.71		Fine Silty Mixed Hyperthermic	91.39	4.39
	Typic Dystrudepts	35.48	1.70		Fine Silty Mixed Thermic	215.0	10.3
	Typic Hapludoll	57.37	2.75		Fine Silty Mixed Thermic	57.37	2.75
					Loamy Mixed Hyperthermic	10.98	0.53
					Loamy Mixed Hyperthermic	24.13	1.16
					Loamy Mixed	47.64	2.29

					Hyperthermic		
					Loamy Mixed thermic	118.05	5.67

Source: Field Survey, 2016.

Note: Soil names at family level shown in the right corner belong to sub-groups given in the same line on the left side.

Definition of the terms used for soil classification in Table 6.1, above:

Medium loamy = Loamy soil texture dominated by medium-size particles

Coarse loamy = Loamy soil texture dominated by coarse particles

Fine loamy = Loamy soil texture dominated by fine particles

Fine silty = Fine soil texture dominated by silt size particles

Mixed = Mineralogy of mixed type

Quartzitic = Mineralogy dominated by coarse type of mineral particles

Hyperthermic = mean annual soil temp. (MAST) at 50 cm soil depth is 22^{o}C or higher

Thermic = MAST at 50 cm depth is 15-22^{o}C

Aeric = Aerated/oxidized root-zone area

Agric = Soil property resulting from long term cultivation

Argic = Soil with an indication of argillic horizon

Albic = Soil with an albic horizon

Aquic = Soil dominated by an aquic soil moisture regime

Fluventic = Soil with some reflection of Entisol found near the river system

Lithic = Soil with a hard pan or layer underneath

Typic = No aberrant properties while classifying soil at subgroup level

Udic = Soil moisture regime found in humid and hot regions

Argiudolls = Mollisols with argillic sub-surface horzon and udic moisture soil regime

Haplustept = An Inceptisol with least horizon development in hot and dry areas.

Hapludept = An Inceptisol with least horizon development in hot and humid areas.

Dystrustepts = An Inceptisol with low CEC in hot and dry areas.

Haplochrepts = An Inceptisol with least horizon development and light horizon color

Haplumbrepts = An Inceptisol with least horizon development and umbric horizon

Ustumbrepts = An Inceptisol with umbric horizon developed in hot and dry areas

Dystochrepts = An Inceptisol with low CEC and light colored horizon.

Dystrudepts = An Inceptisol with low CEC in hot and humid areas.

Ustochrepts = An Inceptisol with light colored horizon found in hot and dry areas.

Humaquepts =An Inceptisol with humic horizon found in moist to wet condition.

Udorthents = A commonly found Entisol in hot and humid areas.

6.2 Soil GIS Database

GIS database was prepared at two levels, namely, soil pit and mapping unit. Soil mapping units were delineated based on integration of land system, landform and land units along with micro relief variation in relation to physico-soil characteristics. Individual pit level information was aggregated at mapping unit level database to reflect polypedon characteristics. Soil pits contained site characteristics including physical attributes and also individual horizon information.

GIS database was created and maintained systematically in computer with geo-referenced spatial data linked to attribute data using relational database. Soil maps were created and stored in shape files utilizing Arc GIS platform.

Chapter 7: conclusions

7.1 Conclusions

This report presents information combining data from intensive field survey and laboratory analysis of soil test results – an outcome of the project entitled “Preparation of VDC level land resource maps, database and reports” (Package-11) assigned to Shreeya –KRS JV by National Land Use Project/GoN, in the fiscal year 2072-73. Out of 8 VDCs in Rupandehi district covered under package-11, this report contains information of Karahiya VDC. Soil maps were prepared by integrating GIS, RS and GPS technologies where soil mapping units were identified based on landform, land use and distribution of land types. Guided by zoning concept, cadastral maps also formed the major basis for delineating soil boundaries to increase land utilization because grouping of soils based on similarity is an important task of this project.

Agricultural lands in this VDC are mostly flat to slightly undulating slopes with no risk of soil erosion. Large part of land use is put to agriculture where only one river system and a big community-managed irrigation system named Sorah Chhattis including significant number of shallow tube wells supply water for crop production. Forest is mostly clustered only on one side of the VDC indicating the sustainability of bio-cycling in other areas might be threatened in the future. Geologically, this area seems to have been formed on relatively younger alluvial plain. Inceptisol soil type (82.5%) predominates the VDC area, followed by Mollisols (17.5%) – a highly fertile soil.

Fourteen soil sample pits were dug and used them to obtain information on soil fertility status of the VDC. Although soil reaction (pH) is not objectionable, soil samples representing most areas appear to have low in organic matter, nitrogen, and potassium but high in phosphorus.

7.2 Recommendations

An integrated use of GIS, RS and GPS technologies should be promoted, focusing on producing more reliable data for developing detailed digital soil database for VDC level land use planning.

Soil classification and analysis should also include subsoil properties to increase the utility of national investment so that studies could also provide farmers with broader choices of land application according to their suitability of uses.

Given the soil test results, subsistence farming and other resources observed in the VDC, conservation practices should be encouraged that include legumes, cereals, agro-forestry and animal husbandry that produce more biomass thereby helping restoration of soil quality. Most soils have low nutritional status including macro and micro nutrients (zinc content). Therefore, every effort should be directed to improve land productivity. Results of this study should be used in providing crop zoning initiative for policy intervention in transformation of agricultural economy in the VDC.

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ANNEXES

A sample of soil profile description and classification of Karahiya VDC

USDA Soil Classification	:	Fine-silty, mixed, Thermic, Typic Argiudoll
WRB	:	Chernozems
Family	:	Fine-silty, mixed, Thermic
Soil Profile No/Pit. ID	:	KR-09
Date	:	2072.10.09
Location	:	KARAHIYA VDC, RUPENDEHI
General Instruction		
Coordinates	:	E 448077; N 3055868
Parent Material	:	ALLUVIAL
Physiographic	:	FLAT LAND
Climate	:	SUB-TROPICAL
Erosion Status	:	SPLASH
Land Use	:	AGRICULTURE
Elevation	:	107 m above m.s.l.
Slope	:	1^0C
Slope Direction	:	NORTH-SOUTH
Soil Moisture Condition	:	USTIC
Drainage Class	:	POOR
Depth of Ground Water	:	100-120FT Feet
Min Avg Annual Temp	:	11.2^0C
Max Avg Annual Temp	:	36.7^0C
Cropping Pattern	:	RICE, LENTIL
Stoniness Class	:	
Annual Precipitation	:	185.9 mm
Particle-Size Control Section	:	25-100 cm

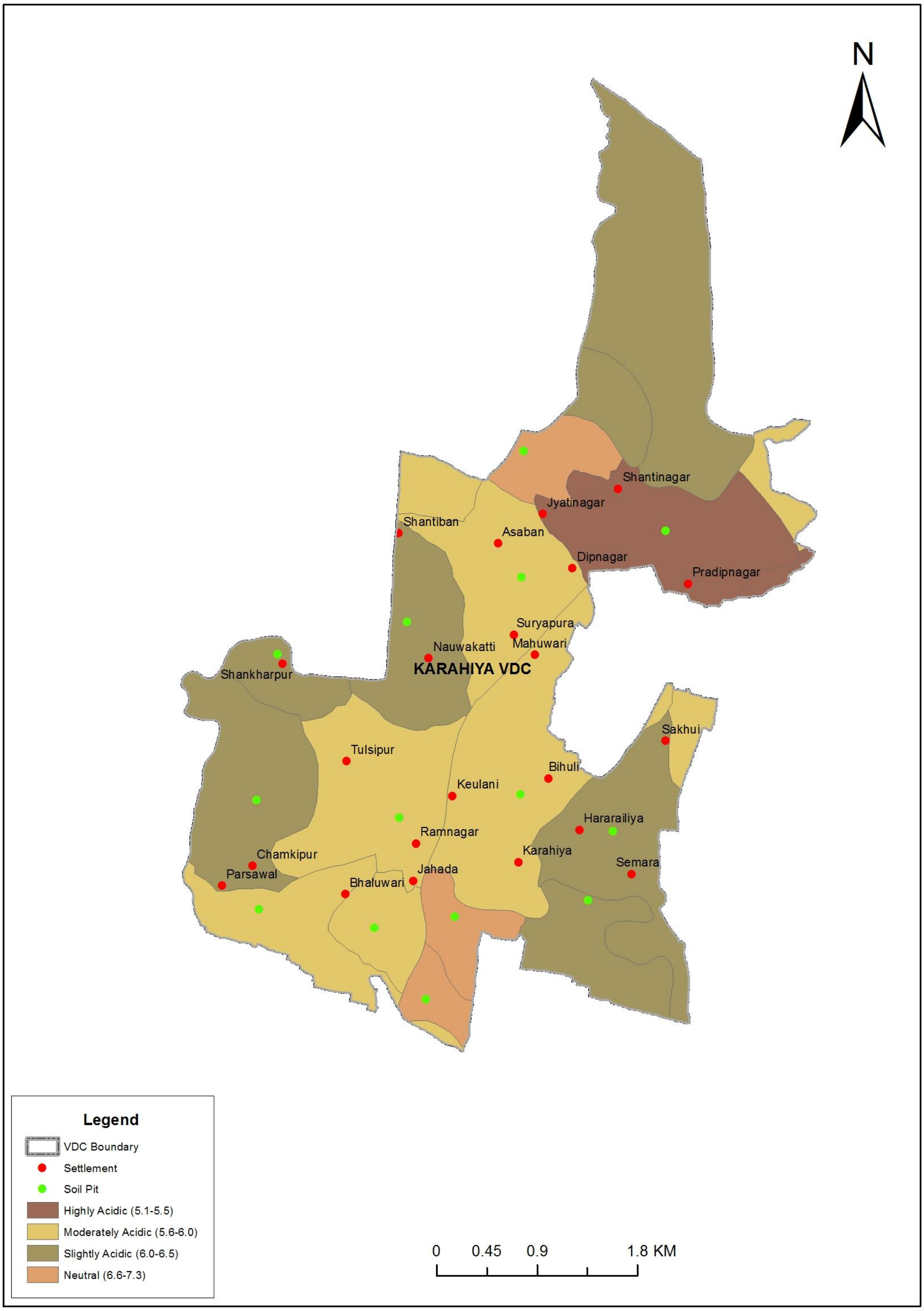
Depth	Horizon	Description
20	AP	*ABRUPT, WEAVY; UMBRIC;LIGHT* BROWNISH GRAY*; 10YR 6/2; SANDY* CLAY LOAM*; STRONG, COARSE, ANGUKLAR BLOCKY; COMMON, MEDIUM; HARD,* FRIABLE, PLASTIC*; ABUNDANT, FINE; MEDIUM ACIDIC*
55	B1	CLEAR, SMOOTH*;* ARGILLIC*; LIGHT* YELLOWISH BROWN*; 10YR 6/4; SANDY* CLAY LOAM*; STRONG, COARSE, ANGUKLAR BLOCKY; COMMON, MEDIUM; HARD,* FRIABLE, PLASTIC*;* ABUNDANT, FINE*;*
100	B2	CLEAR, SMOOTH*;* ARGILLIC*;* YELLOW*;* 10YR 7/6*;* SANDY CLAY LOAM*;* STRONG, COARSE, ANGUKLAR BLOCKY*;* COMMON, MEDIUM*;* HARD, FRIABLE, PLASTIC*;* ABUNDANT, FINE*;*

Soil Properties:

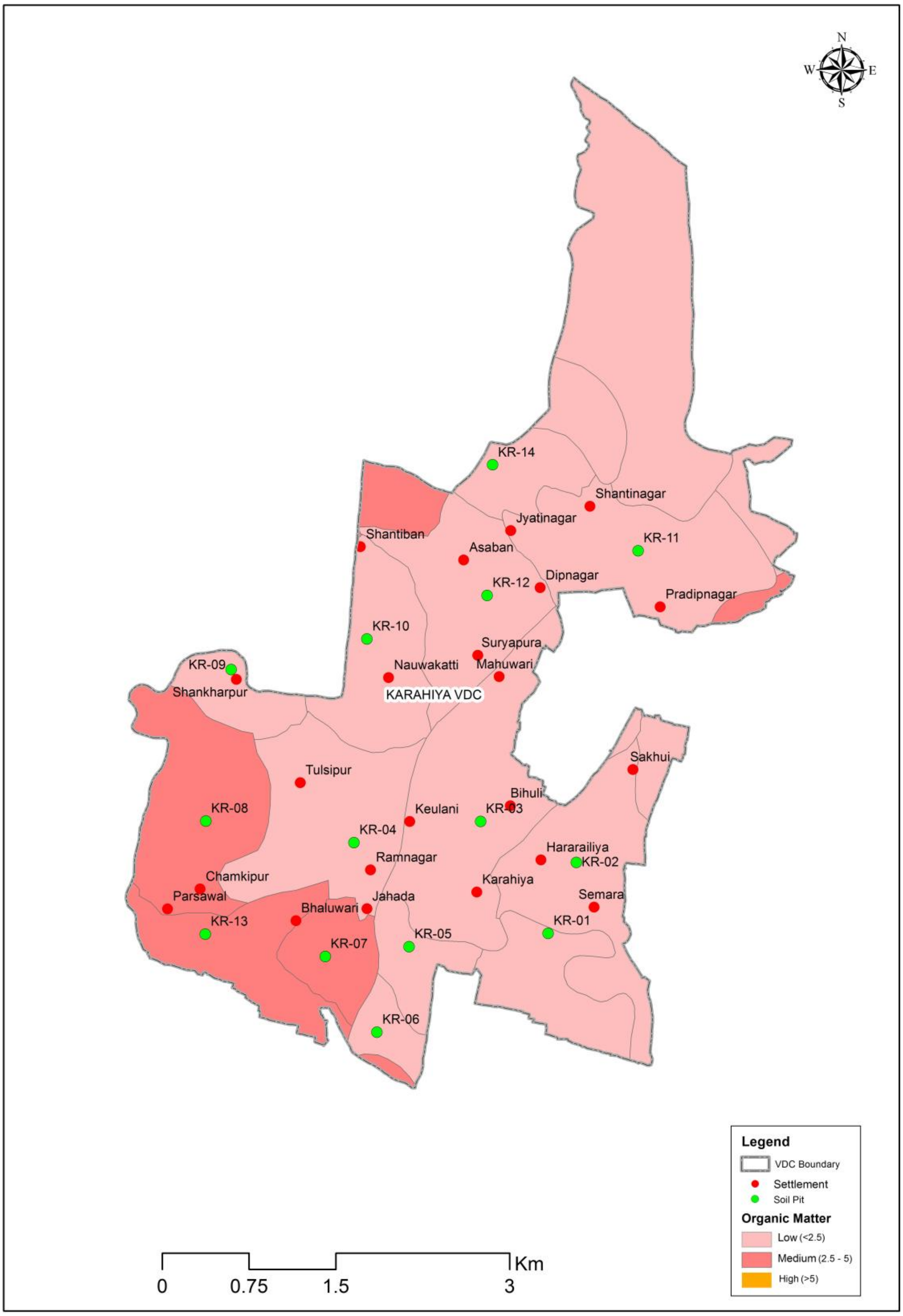
Chemical and physical properties of Ap horizon (fourteen soil pits) of Karahiya VDC

Soil properties	Mean	Std. dev.	Interpretation
pH (1:2 soil water ratio)	6.2	±0.4	Slightly acid
Organic matter (%)	1.77	±1.01	Low
Total nitrogen (%)	0.09	±0.04	Low
Available P_2O_5(kg/ha)	78.5	±53.7	High
Available K_2O (kg/ha)	65.2	±85.7	Low
Available Zn (mg/kg)	0.22	±0.06	Low
Available Boron (mg/kg)	1.36	±0.27	Very high
Texture	Loamy	Medium	

Spatial distribution of **pH** in surface soils of croplands in Karahiya VDC



Spatial distribution of **organic matter** in surface soils of croplands in Karahiya VDC



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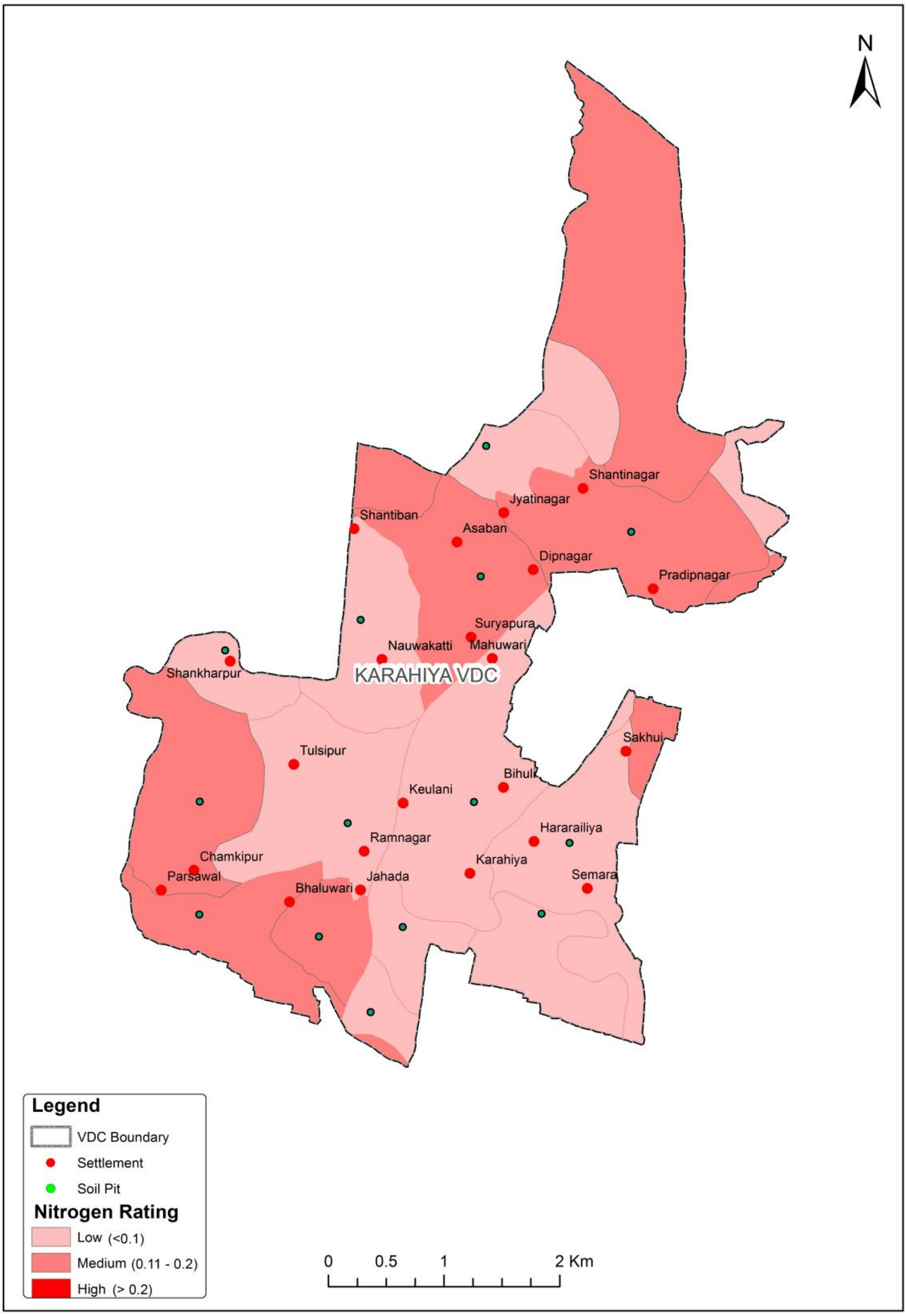

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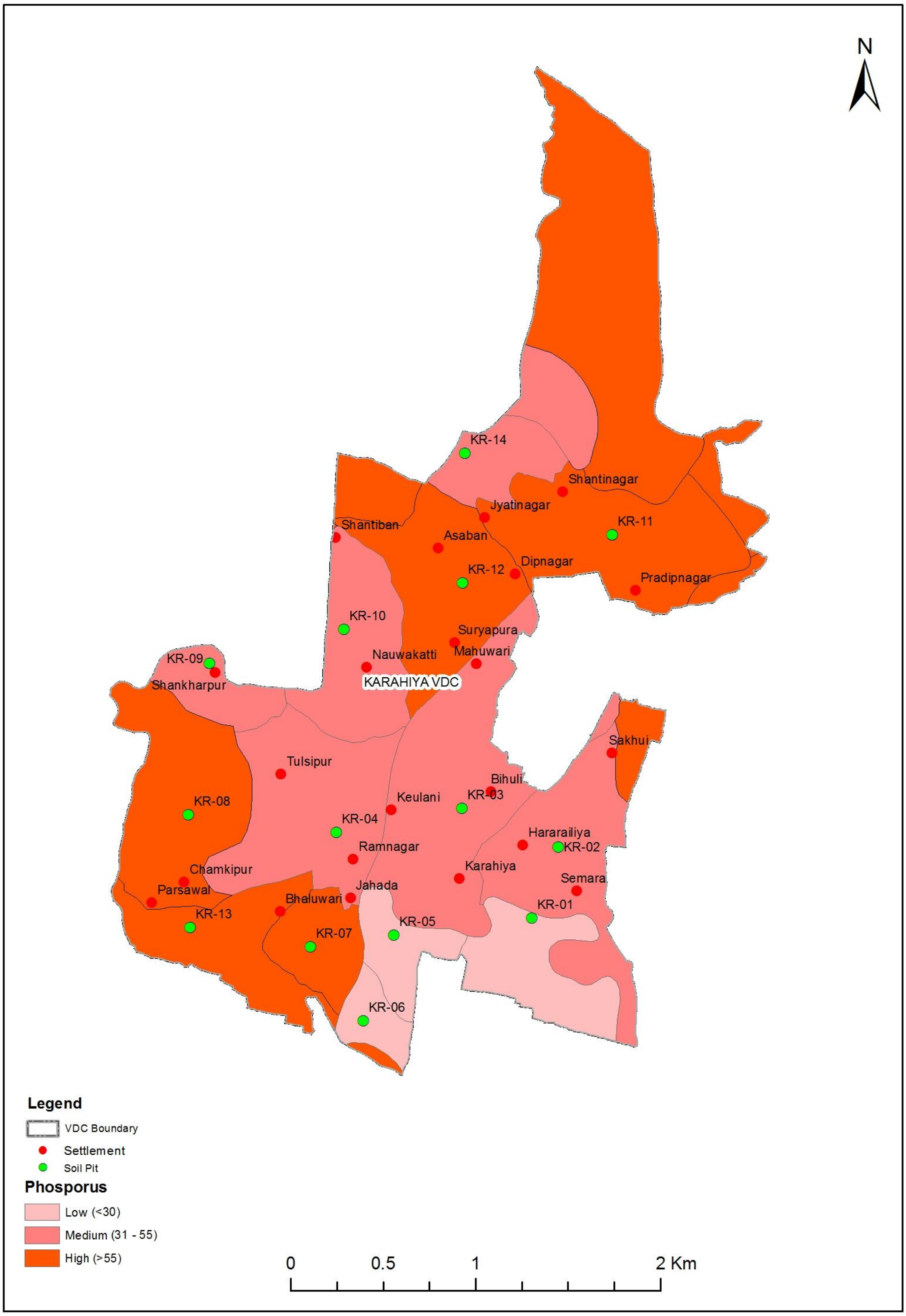
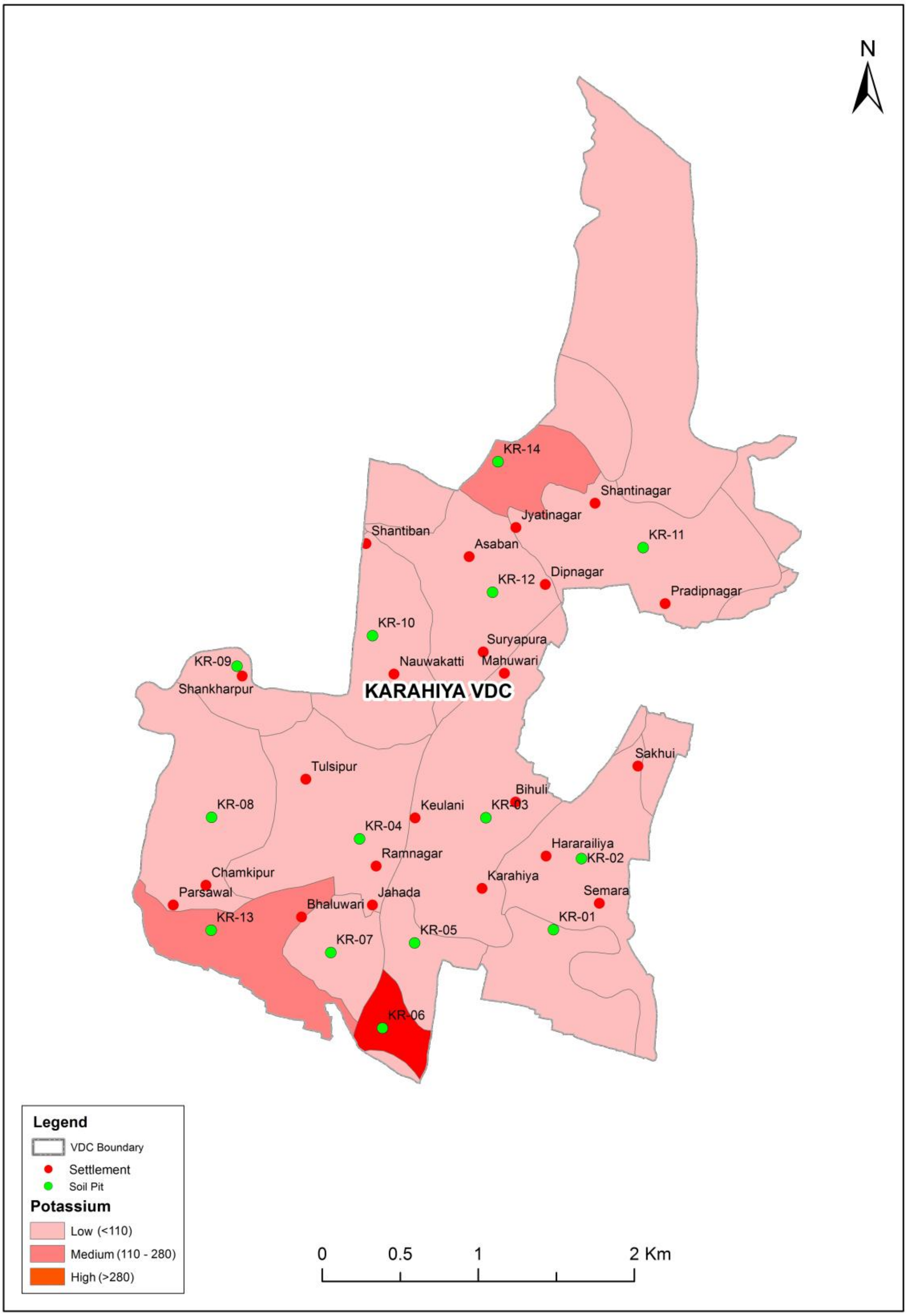
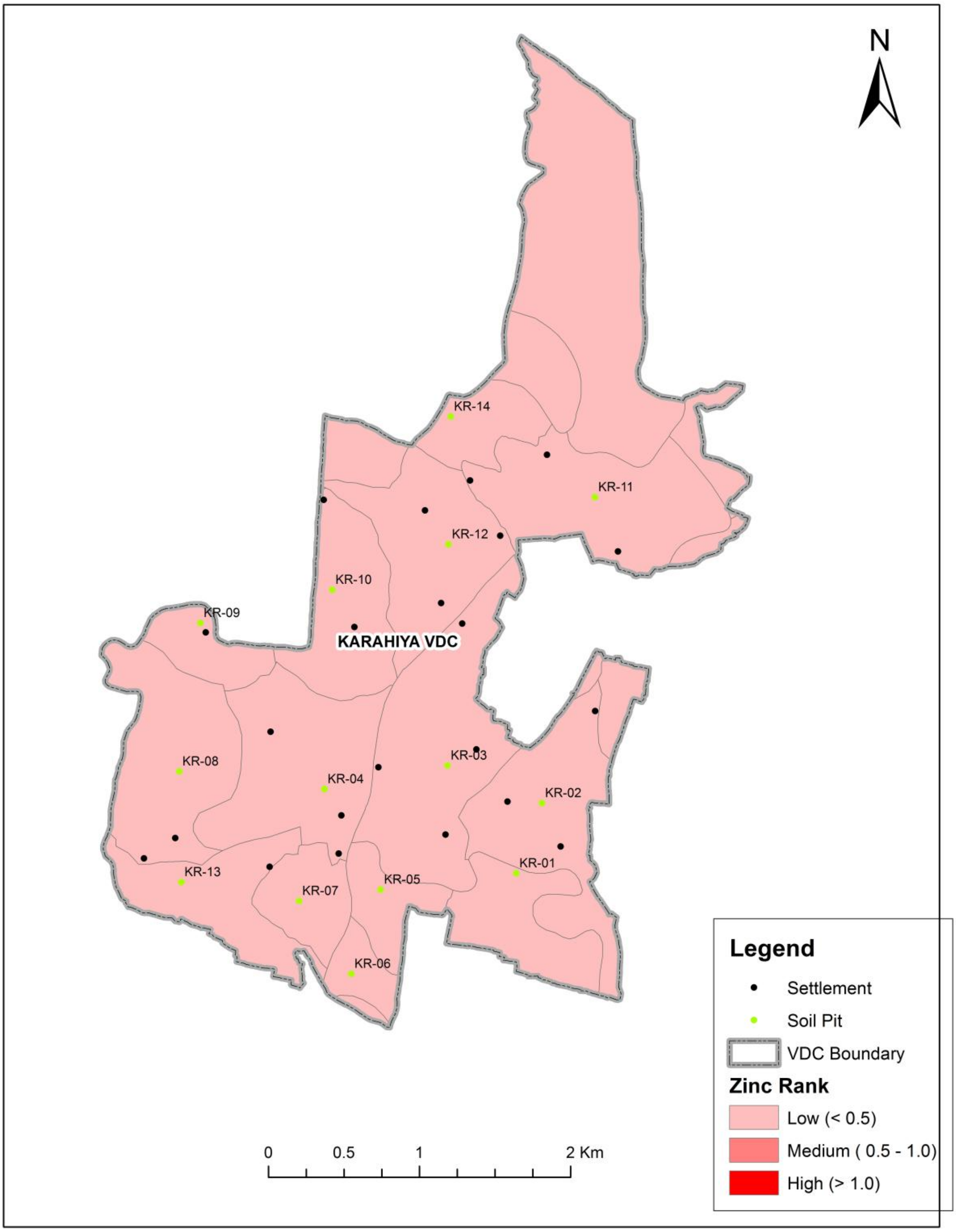


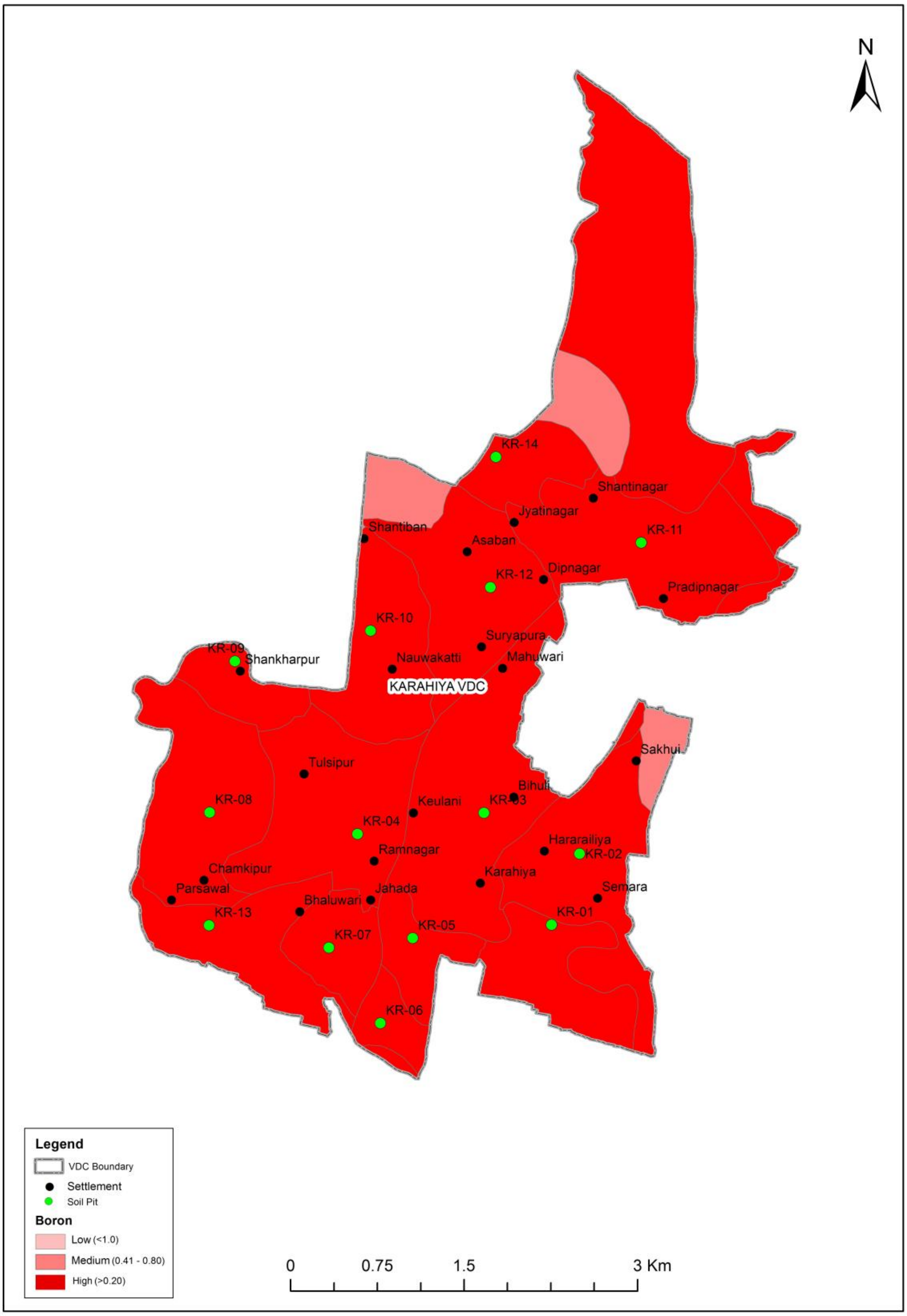
Spatial distribution of **available potassium** in surface soils of croplands in Karahiya VDC



Spatial distribution of **available zinc** in surface soils of croplands in Karahiya VDC



Spatial distribution of **available boron** in surface soils of croplands in Karahiya VDC



Land Capability

FINAL REPORT

Preparation of Land Capability

Karahiya VDC of Rupandehi District

FOR

Consulting Services

For

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

Package No: 11

Anandaban, Devadaha, Karahiya, Kerwani, Madhawaliya, Makrahar, Shankar Nagar, Tikuligadh, of Rupandehi District (8 VDCs)

Preparation of Land Capability
Karahiya VDC of Rupandehi District

This document is one of the outcomes of the project entitled **Preparation of VDC level Land Resource Maps** (Present Land Use Maps, Soil Maps, Land Capability Maps, Land Use Zoning Maps and Cadastral Layer Superimpose and VDC Profile), **Database and Reports** of Package 11 awarded to **SHREEYA-KRS JV** by the Government of Nepal, Ministry of Land Reform and Management, National Land Use Project (NLUP) in Fiscal Year 2072-073. The VDCs covered under this package include eight VDCs of Rupandehi district namely: **Anandaban, Devadaha, Madhawalia, Makrahar, Karahiya, Kerwani, Sankar Nagar and Tikuligadh**.

The VDC areas analyzed for different themes of the NLUP Project are computed from cadastral maps provided by DOLIA Office of Nepal. Therefore, the areas of the VDCs may not be the same as computed from Topographic Database provided by the Survey Department of Nepal.

The consultant is obliged to state that the Imageries, GIS database and other outputs produced for the project is owned by National Land Use Project (NLUP), Mid-Baneshwor, Kathmandu. Therefore, the authorization from the NLUP is required for the usage and/or publication of the data in part or the whole.

ACKNOWLEDGEMENT

The SHREEYA-KRS JV is highly obliged to National Land Use Project (NLUP), for awarding the project **Preparation of VDC level land resource maps** (Present Land Use Maps, Soil Maps, Land Capability Maps, Land Use Zoning Maps and Cadastral Layer Superimpose and VDC Profile)**, database and reports, Package 11 of Rupandehi district**. The consultant would like to extend special thanks to Mr. Nagendra Jha, the Project Chief of NLUP, for his constructive supports during the project period. Similarly, the consultant would also like to highly acknowledge the overall supports of Mr. Nabaraj Subedi, Chief Survey Officer. Likewise, the consultants would like to extend thanks to Mr. Sumir Koirala, Survey Officer, Mr. Ekraj Giri, Account Officer, Mrs. Manju Devi, Store Keeper and the other staffs of the NLUP Office for their supports during the project period.

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CHAPTER 1: INTRODUCTION

1.1 Background and Rationale

The land capability classification is an interpretive grouping made primarily for agricultural purposes (Klingebiel and Montgomery, 1961). This serves as a sound planning tool for guiding landscape level sustainable land management policy. A wise execution of this approach helps to ensure ecological integrity, adequately supply food and fiber and provide cushioning to external shocks and stresses (FRP, 2005).

Land use activities such as clearing forests, practicing subsistence agriculture, intensifying farmland production, or expanding urban centers, have changed the world's landscapes. Although land use practices vary greatly across the world, their ultimate outcome is generally the same: (a) to produce food and fiber and (b) to acquire natural resources for immediate human needs.

Recent decades in Nepal have experienced a trend of rapid urbanizations and the fertile agricultural land being converted into settlements or infrastructure development. The economic and social lifestyles of most of the Nepalese people are intimately related to land resources. Haphazard uses of land resources and faulty plans have decreased the land productivity due to the depletion of natural resources. Hence, land capability classification has become increasingly important task for sound land use planning leading to sustainable land management in Nepal.

Planning is an essential function of rational use of available natural resources for over all development of the nation. FAO (1983) defines land use planning as a systematic assessment of land and water potentials, alternatives for and economic and social conditions in order to select and adopt the best land use options. Except sporadic attempts for the urban areas (NLUP, 2007), Nepal has not practiced land use planning for the country as a whole. However, 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 (VDC) level. The government of Nepal (GoN) has started to look into this problem through the National Land Use Project (NLUP) for collecting detail basic information on land, land resources and the social services at local level. Until now, Nepal has only regional level data base on, land system and land capability produced by earlier Land Resource Mapping Project (LRMP, 1986). On the one hand, these regional level data are already over three decades old and on the other hand, they might not be very useful for local level planning.

In the modern era, space science technologies such as remote sensing (RS) and Geographic Information Systems (GIS) offer real time spatial /and temporal data on land resource which could be used efficiently to prepare digital database. These spatial databases together with data on different land use characteristics can be collected from the field survey even at VDC level and information derived could be used for developing decision making support systems (DSS).

Land can be classified according to its present use and suitability for specific crops under the existing forms of management, its capability for producing crops or combinations of crops under optimum management. A good knowledge of the land capability and suitability combined with good understanding of the soil characteristics and management aspects are the keys to more productive and sustainable use of land resources. Stijns (2006) defined 'land capability classification' as a technique of determining the most suitable use of any area of land. The purpose of land capability classification systems is to study and record all data relevant to combination of agricultural and conservation measures which would permit the most intensive, sustainable and appropriate use of land without significant degradation of the soil resource.

A systematic grouping of the land requires information on existing soil quality, landforms, climate, patterns, irrigation, topography and other aspects of land as well as socio-economic condition of the area. Due to variation in terrain, climate features and human activities, diversities are observed in faunal and floral population and activities. Land capabilities are also affected by the topographic and climatic factors. Greater variation in landforms and soil exists across Nepal. The variability not only poses the problem but also offers enormous opportunities for the development. Increase in population, and industrialization activities as well as increasing disasters in the wake of climatic change always pose threat to the land resources and its management. Therefore, extensive information is needed on land types, land cover and for the formulation of proper land management policies and strategies for the sustainable development of a country. A systematic approach to sustainable land resource management through land utilization planning, zoning and assessment of land could be an appropriate measure for this purpose.

A great spatial and temporal variability in land capability can, thus, be studied only by the use of technologies that encompass the spatial and temporal properties. Remote Sensing (RS) and Geographic Information System (GIS) are the tools available 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 over short time period.

Realizing this fact, the Ministry of Land Reform and Management of GoN established the NLUP in 2057/058 fiscal year to generate the necessary databases on the land resources of the country. In the first phase, the NLUP initiated several projects at district level and prepared Land Resource Maps and Database at 1:50,000 scale for the whole Nepal. It also prepared maps and database for KIrtipur, Madhyapur Thimi and Bhaktapur municipalities at larger scales. Finally, NLUP got a mandate to prepare land resource maps of Village Development Committees (VDCs) of Nepal for local level planning through outsourcing modality.

In the context of the above strategies, the **SHREEYA-KRS JV** has been assigned to carry out the Package-11 project entitled **Preparation of VDC level land resource maps, database and reports** by the Government of Nepal/Ministry of Land Reform and Management, National Project in the Fiscal Year 2072-073. The VDC covered in this Package is of Rupandehi District of Nepal.

The rationale for the preparation of VDC level land capability maps by NLUP are:

a) Preparation of land capability maps of the VDCs for formulating planning according to the quality of land in order to identify areas of Agricultural area, Residential area, Commercial area, Industrial area, Forest area, Public service area and other uses.
b) Identification of the residential and other non-agricultural areas according to the capability of land.
c) Promotion of agricultural productivity as per land capability in comparatively advantageous sub-areas.
d) Conservation of natural resources including forest, shrub, rivers and rivulets and wetland in agricultural/non-agricultural areas.

1.2 Objectives and Scope of the Study

The general objective of this study is to prepare Village Development Committee level land resource maps (Present Map, Soil Map, Land Capability Map, Zoning Map, VDC Profile and Superimpose of Cadastral Layers), database and reports of the selected eight VDCs of Rupandehi district. The Specific objective of this study is to prepare Land Capability Maps, GIS database and Reports for Karahiya VDC.

Scope of the Work

In order to achieve the above mentioned objective, the scope of work includes the following activities:

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

Karahiya VDC lies in Rupendhei district, Lumbini Zone. The VDC has currently included in Tilottama Municipality. And it is known for ward no. 9, 10, 11 & 12 of the municipality. It is located between 83° 27' 50” to 83° 31' 20"E longitude and 27° 35' 20” to 27° 35' 58" N latitude. The VDC is bordered by Makrahar & Gangoliya VDCs to the east, Anandaban VDC to the west, Andandaban & Devadaha VDCs to the north and Madhawaliya & Gangoliya VDCs to the south. The VDC covers a total area of 2082.81 ha. The extension of the VDC is 4.7 km and 8.8 km in east-west and north-south respectively.

According to the population census 2011, the total population of the VDC was 18274 with 4267 households. Of the total population, the percentage of male is six percent lower than the female. The population of this VDC is composed of different caste/ethnic groups. Among them, Brahmin is in majority. The proportion of migrants is significant in the total population. Migrants were mainly from from Palpa, Gulmi, Arghakhachi, Baglung, and Parbat. Ninety-five percent people follow Hinduism. People are involved in many occupations. More than half of the total populations are involved in agriculture. And it is the main source of income. Almost one-third of the total income comes from agriculture sector.

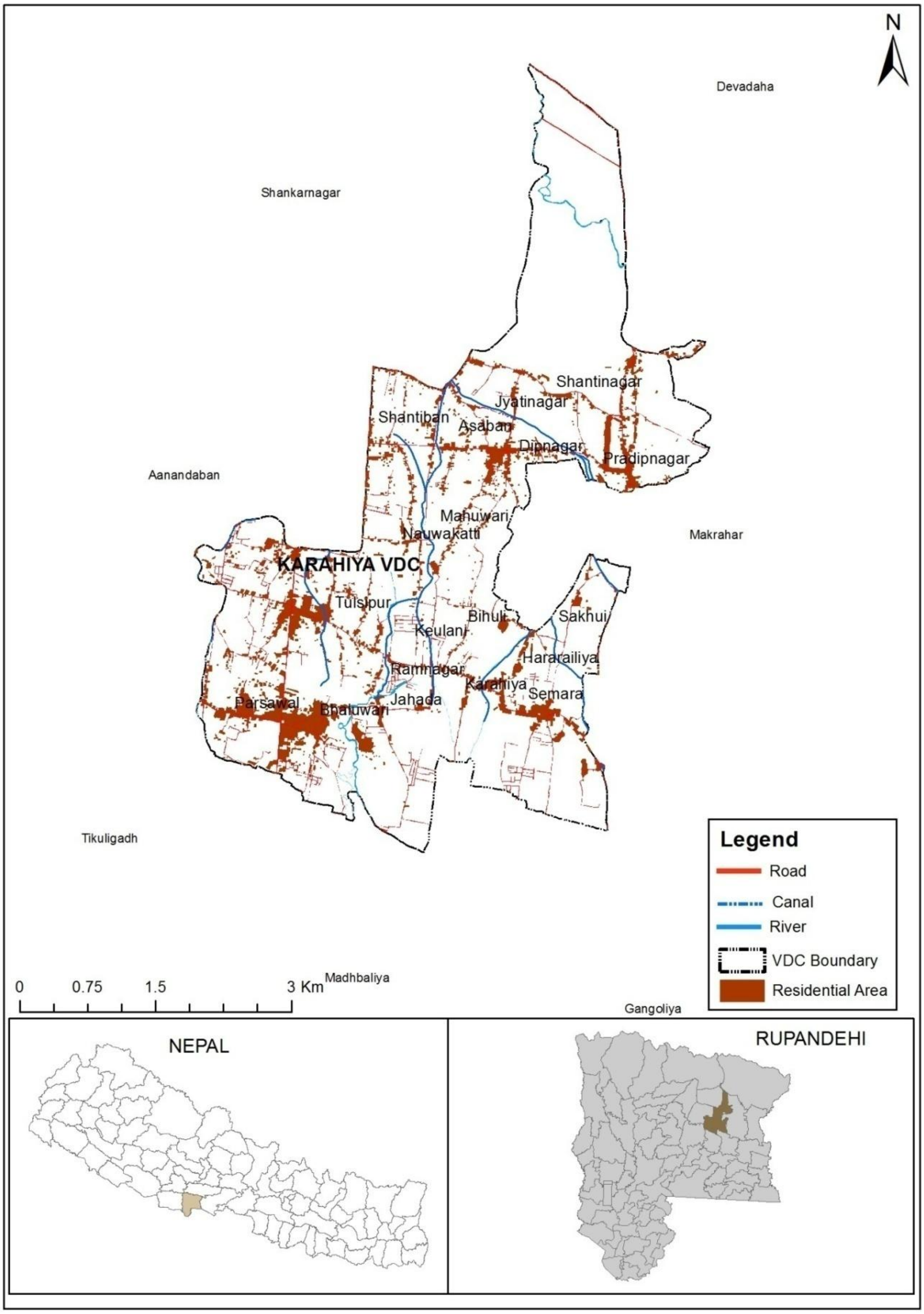

Figure 1.1 Location Map of Karahiya VDC

CHAPTER 2: CONCEPTUAL BASIS OF LAND CAPABILITY CLASSIFICATION

Land capability assessment provides the ranking of the land on the basis of its ability to sustain a range of agricultural s without degradation of land resources on sustainable basis. It was originally developed by United States Department of Agriculture and has been used in identifying appropriate land usages and required management practices that can sustain its productivity for long run. Land capability classification takes into account geology, soils, slope, climate, erosion hazards and land management practices. It also takes into account stoniness, flooding, salinity and drainage conditions of the land. It grades the land for broad scale agricultural uses. Land capability grading at VDC level requires assessment of land for agricultural usages considering land suitability, limiting factors for the use of that land and required management and conservation options to conserve land resources for best productivity. This chapter gives a framework for land capability classification at VDC level. It includes, review of land capability of LRMP, land capability classes, irrigation suitability classes, irrigation suitability sub-class, land capability sub-class, land capability sub-divisions, framework for VDC level land capability classifications and land capability classification hierarchy.

2.1 Review of Land Capability of LRMP

Land capability assessment is an interpretive and somewhat subjective system for evaluating a suite of resource information. It provides a ranking of the ability of an area to support a range of agricultural activities on a sustainable basis. Over the span of human history, man has drawn most of his sustenance and much of his fuel, clothing and shelter from the land. Land has been men's habitat and living space. Vink (1975) indicated that, as circumscribed by the earth, the area of what is considered to be land is finite and fixed in place. s 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 characteristic that makes it more useful than others. These include location and suitability of a particular piece of land for specific use.

Vink (1975) has defined 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. As Spellerberg (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 land degradation. In addition, in western countries, because of industrialization, the invasion of prime agricultural productive land is prominent. 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 limitations posed by permanent or semi-permanent attributes of land to one or more s. 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 is 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, and flood and erosion risk as well as on soil properties are required (Davidson, 1992).

Land capability could be the land to sustain a specified 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 the ability of land. The US Department of Agriculture has been using Land capability widely since the 1950s to assess the appropriate use of various type of land for agriculture usages in identifying s and management practices that can minimize soil erosion, especially induced by rainfall (Brady and Well, 2002).

Land capability assessment is therefore based on the permanent biophysical features of the land (including climate). Land capability assessment is different from 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, drainage, sewage disposal of land (Grose, 1999). Land capability classification gives a grading of land for broad scale agricultural uses drainage, sewage disposal including landfill. The factors affecting on land classification and its limitation is presented in Figure 2.1.

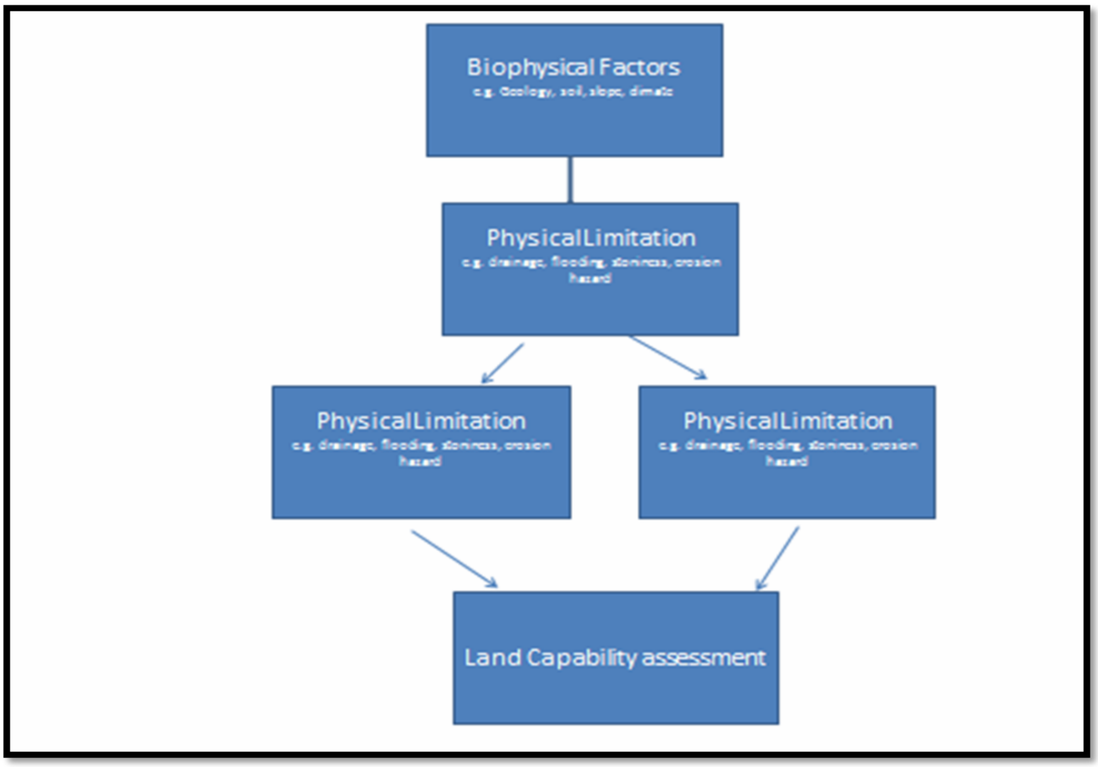

Figure 2.1 Factors Affecting Land Capability Assessment

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 (FAO, 1983). Suitability is a measure of how well the qualities of a land unit match the requirements of a particular form of land. Suitability is assessed for each relevant use and each land unit is identified in the study for the optimum economic benefit.

Land capability classification at VDC level requires assessment of each individual physiographic land unit for agricultural as in the case of present study area. 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 economic productivity. This chapter gives a conceptual basis for the land capability assessment on which the classifications are done at VDC level.

During 1980-1985, 266 Land Capability Maps were made by the LRMP covering entire country. 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’s 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. 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 categorization of classes is 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. Levels (class, sub-class and unit) in land capability are shown in Figure 2.2.

Each land capability unit for Class I and Class II is further designated with irrigation suitability. By applying the United States Bureau of Reclamation 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.

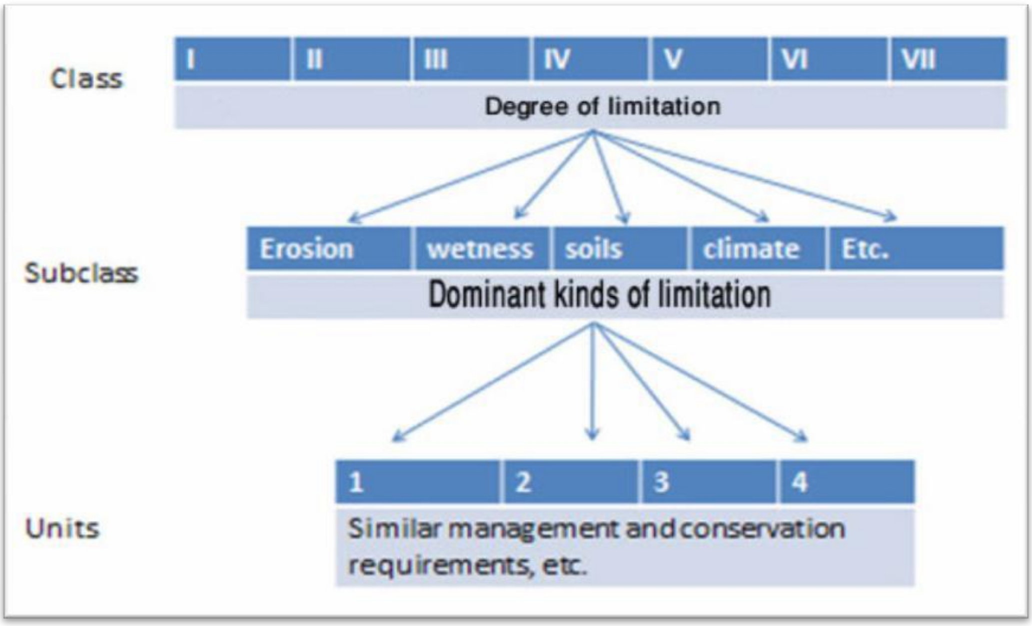

Figure 2.2 Levels of Land Capability Classification System (adopted from Grose, 1999)

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 classification 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 (^{o}C)	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-Division (Moisture regime)
Arid
Semiarid
Sub-humid
Humid
Per-humid

Deficiency Subclass
Soil
Topography
Drainage

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

2.1.1 Land Capability Classes

Land Capability classes are derived from the Land System Map Units. There are seven land classes grouped on the basis of similar geophysical characteristics, reflecting management option (NLUP, 2007). Descriptions of each of seven classes are given below.

Class I

Land in this 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. 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 Terai region, depositing large amount of sediment; but these depositional areas are quickly reclaimed. When flood deposited heavy sediments and debris the capability class may be lowered that is based on the depth and types of debris deposited. 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 control works are required.

Surface drainage pattern and soil moisture affect the capability class. Well to moderately well drain 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 are 1d, 2c, 2d, 3a, 4c, 5a, 6a, 9b, 13b in class I land. 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 lands are characterized as gentle slope (1-5 degrees) and soil stratum is deep and well to moderately well drain. No limitations exist in this class for arable agriculture, terracing and contouring many require 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 irrigation 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, terracing is compulsory to control erosion. Class III land cultivated 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 as in-situ maturing. Mostly, large area of Class III land is available for forestry usages for fodder and fuel wood collection. In terrace farming the irrigation water in leveled bench terraces is extensively used wherever irrigation facility is available. To prevent slope failure and soil erosion in terrace farming a new irrigation system should be developed or modify the cascade system of irrigation .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 (>30^{o} 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 pasture and 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 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 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 s occurs on floods 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. 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. Approximately 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 opportunities under irrigation. The classification follows the USBR land classification framework modified to suite the local conditions of Nepal. The entire Terai 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 below.

Class 1Diversified crops-Arable

The lands highly suitable for irrigated farming and capable of producing sustained and relatively high yields of climatically suited upland crops as well as paddy are classified in Class I.

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 other may not. 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 2R in productivity or more costly to farm and land is moderately to fairly suitable for paddy production under irrigation. The soil deficiencies can be ameliorated. 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. In this report lands under settlements, industries and other non-agricultural uses are included in this section.

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 shown in Table 2.2

Table 2.2 Irrigation suitability rating sub-classes

Major deficiencies for irrigation	Map symbol
Soil deficiency	s
Topography deficiency	t
Drainage deficiency	d

The combinations of any of the above two indicate deficiencies of irrigation of land capability class.

2.1.4 Land Capability Sub-Classes

The land capability classes described above are further classified into sub-classes on the basis of distinct climatic regimes with their altitudinal ranges. The vegetation line is taken as 5000 m as the height increases the climate decrease when altitude increases (Seinfeld and Pandis, 2012).When altitude reaches to 5000 m, the mean air and soil temperature reaches to 0^{o}C. Likewise natural vegetation changes at every 1000 m altitude. At lower altitude the natural vegetation is dominated by Sal forest, Pinus forest is available between 1000 to 2000 m, Quircus forest between 2000 to 3000 m, Betula forest between 3000 to 4000 m and above it there is no forest vegetation. Between 4000 and 4500 m open vegetation is found and above it up to 5000 m Tundra vegetation is available. For agriculture, 1000 m is the limit for the double crops of rice. Rice does not grow beyond 2000 m except Jumli Marshy of Jumla Valley and likewise 3000 m is the limit for maize cultivation. Above 3000 m there are limited valleys where maize, buckwheat, oats and potato can be cultivated. Crop production stops at the limit of forest vegetation where open meadow is available and livestock is raised successfully. Relationship among climate, vegetation and agriculture is shown in Figure 2.3 and land capability subclass climatic zone is shown in Table 2.2.

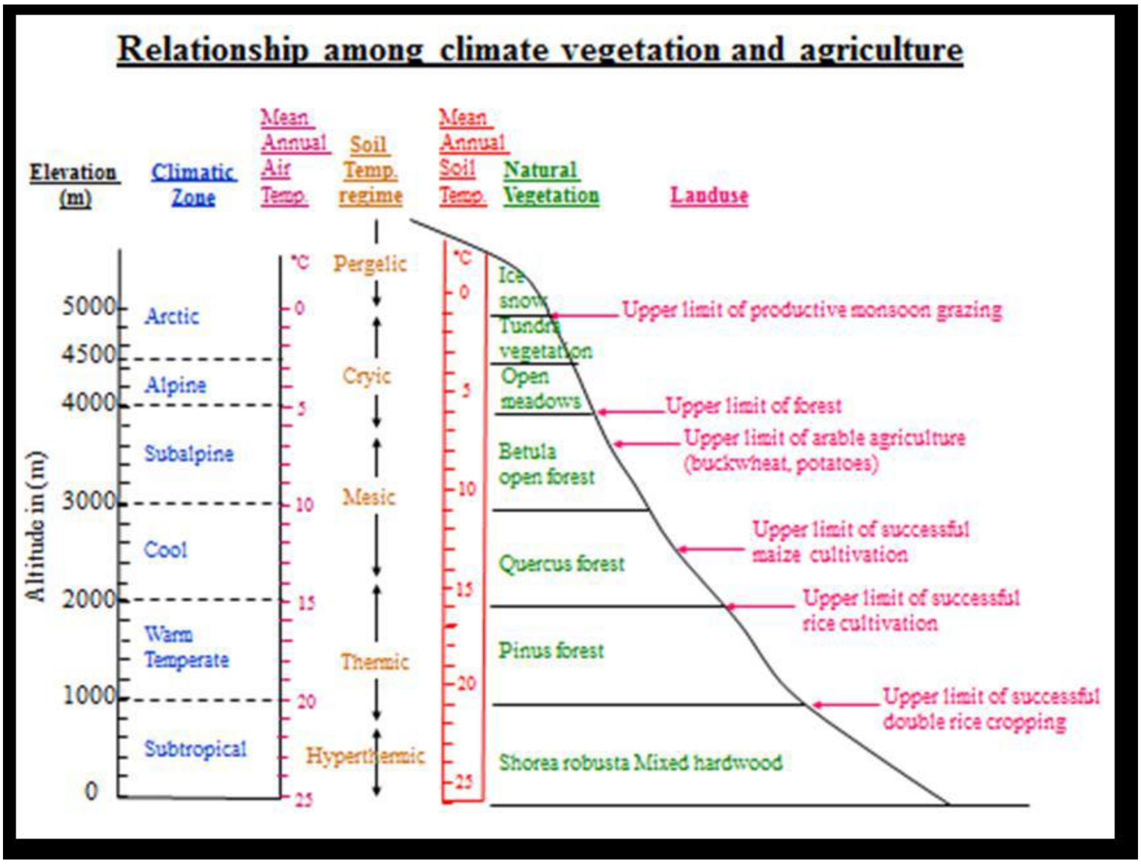

Figure 2.3 The Relation of Climate, Vegetation and Agriculture (adopted from LRMP, 1986)

It summarizes associated farming up to 4500 m and above it no vegetation and also limited sheep and yaks could be raised.

Table 2.3 Land Capability Sub-class Climatic Zones

Climatic Zone	Associated Farming Systems
Subtropical (altitude <1000 meters)	Intensive farming (multi-crops and livestock)
Warm temperate (altitude 1000-2000 meters)	Farming crops and livestock
Cool temperate (altitude 2000-3000 meters)	Livestock, fruits, limited crops farming
Alpine (altitude 3000-4000 meters)	Monsoon Grazing, fruit farming and Yak
Arctic (altitude>4500 meters)	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 shown in Table 2.4.

Table 2.4 Land capability sub-divisions and map symbols

Land Capability Sub Divisions	Map symbol
Semi-arid moisture regime	s
Sub-humid moisture regime	u
Humid moisture regime	h
Per-humid moisture regime	p

2.2 Framework for VDC Level Land Capability Classification

Land capability classification 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 was widely used by State Planning Commission of USDA in 1989 (Grose, 1999) and also adapted in Nepal to suite the context of agricultural soil management.

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 several natural and bio-physical parameters.
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 scope of this study.

2.3 Land Capability Classification Hierarchy

Land Capability is classified into three hierarchical levels 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 Table 2.5.

Table 2.5 Land Capability Hierarchy (adopted from Grose, 1999)

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					

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 compared to any other classes of land. Class II is superior to Classes III to VII but inferior to Class I.

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 above in Section 2.2.2.

Class I

Class I consists of lands with very few or no physical limitations to use. These lands are suitable for wide range of cropping, grazing or forestry. These land are leveled to nearly leveled (<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 slopping to moderately steep (5^{o}-30^{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 (>30^{o} slope) or lie above the altitude limit of agriculture. These lands also include relatively flat to gentle slopping lands with shallow soil depths (>20 cm) and well to imperfectly drained. These lands are suitable for forestry uses and require permanent vegetative 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. The lands having less than 30^{o} slope, soils more than 20 cm deep and in alpine above tree line or are frequently flooded river plains are included in this class. 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 Lesser 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 further be categorized 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

It 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 2.6 Unit Code for Sub-class Soil Deficiency

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

Table 2.7 Unit Code for Sub-class Topography Deficiency

Topography Deficiency	Map symbol
Steep Slope	t1
Surface channel dissection	t2

CHAPTER 3: METHODOLOGY

Village Development Committee level Land Capability Map of Karahiya, Rupandehi district at 1:10000 scale is prepared by analyzing the existing data, maps, field samples and information of lab test using GIS to identify and carry out classification of agricultural land for lucrative (profitable) crop production within the VDC; identify and classify land for non-agricultural purpose; and prepare GIS inventory of current land capability data based on the spatial analysis of soil and terrain parameters, arability class and deficiency type and sub-type unit 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:

- Formulation of multi-criteria weighted rules for soil, topography, erosion and drainage parameters
- Evaluation of rules and ratings from best suited to least suited (high to low)
- GIS based attribute query and spatial analysis of rated parameters
- Classification and designation of suitable land capability class to land type land units
- Classification and designation of deficiency sub-classes and units to land capability classes
- Final land capability map preparation with GIS database creation and use.

3.2 Land Capability Evaluation Criteria

The following criteria are used to derive land capability classification

Soil fertility criteria

Major soil properties that characterize soil fertility include organic matter, soil pH, drainage class, permeability (based on soil texture as explained by USDA 2016) and NPK are given certain numerical points. These properties are pooled and multiplied by the values obtained and weighted average is then taken to evaluate soil fertility. In other words, it involves multi-criteria analysis which is detailed below:

Multi-Criteria Evaluation (MCE): MCE is a decision support tool aiding a choice to be made between alternatives. The basis for a decision is known as a criterion. In a Multi-Criteria Evaluation, an attempt is made to combine a set of criteria to achieve a single composite index for a decision according to a specific objective. Decision need to be made about what areas are the most capable for specific land use type development. In this analysis, criteria or factors affecting capability of crops production include edaphic factors such as soil depth, drainage condition, permeability and soil fertility factors like pH, Organic matter and total Nitrogen (N) available Phosphorus (P) and available Potassium (K). Land capability maps were generated from the MCE process in which parameter weight was derived from the expert knowledge given in table 3.1. Since the land that we evaluate falls on flat plain of Terai and no erosional class is mentioned. Since N is a mobile element and keeps mineralizing continuously, it is rated with the lowest weighted average.

Table 3.1 Parameters used and given weightage for MCE

S. No	Parameters	Weightage
1	Soil depth	4
2	pH	3
3	OM	3
4	Drainage (Texture)	3
5	K_2O	2
6	P_2O_5	2
7	Nitrogen	1

Weighted Composite Score (WCS): Weighted Composite Score (WCS) is a systematic procedure for developing factor weights required for preparing capability map (Table 3.2). The weights assigned to different factors were obtained by subjective to expert judgment. The larger the weight, the more important is the criterion in the overall capability class.

In developing the weights, an individual factor were ranked as low, medium, and high and very high weight are assigned as 1, 2, 3 and 4 respectively as given below. Factors or criteria were rated according to the following 4-point scale. Weighted Composite Score (WCS) was employed based on parameter weight and individual weighted value as 4, 3, 2 and 1 corresponding to very high, high, medium and low rank of concerned factor respectively. The final value of weighted composite score (WCS) for each soil mapping unit was calculated by summing all individual factors value obtained by multiplying individual factor weight rank value with their corresponding weight of parameters. The equation of calculation of WCS is given below:

Weighted Composite Score (WCS) = Soil depth weightage value*4+ pH weightage*3+ Drainage weightage value*3+ OM weightage value*3+ K_2O weightage value*2+ P_2O_5 weightage value*2 + Nitrogen weightage value*1

Total fertility level is 58 and minimum is 18 and hence 45-58 is high 36-44 as medium and below 36 is low fertility.

Table 3.2 Soil Fertility ratting

Fertility Range	Deficiency	Suitability	Mapping Symbol
>18	Very High Deficiency	Very Low Suitability	f1
19-35	High Deficiency	Low Suitability	f2
36-46	Medium Deficiency	Medium Suitability	f3
>46	Low Deficiency	High Suitability	f4

Soil Deficiency Criteria:
Soil had a general connotation to the depth of the soil. Therefore this part is considered in depth rating of soil horizon.

Table 3.3 Soil Rooting Depth

Soil Depth (cm)	Category	Suitability	Deficiency	Mapping Symbols
>54	Deep	High Suitability	Low Soil Deficiency	**s4**
36-54	Moderately Deep	Medium Suitability	Medium Soil Deficiency	**s3**
18-36	Shallow	Low Suitability	High Soil Deficiency	**s2**
<18	Very Shallow	Very Low Suitability	Very High Soil Deficiency	**s1**

Table 3.4 Soil Texture Workability Rating (Manual Farming Tools)

Soil Texture (Workability)	Rating	Suitability
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 3.5 Soil Drainage Rating

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

Table 3.6 Soil Reactions Ratings

Soil Alkalinity and Acidity	Rating	Suitability
<5.0	Very highly acidic	Low Suitability
5.1 – 5.5	Strongly acidic	
5.6 – 6.0	Medium acidic	
6.0 – 6.5	Low (slightly) acidic	High Suitability
6.6 – 7.3	Neutral	Most Suitable
7.4 – 7.8	Low (slightly) alkaline	High Suitability
7.9 – 8.4	Medium alkaline	
> 9.0	Highly alkaline	Low Suitability

Table 3.7 Rating of Soil Organic Matter Content

Organic Matter (%)	Rating	Suitability
>5	High	High Suitability
2.5 – 5	Medium	
1.0 – 2.5	Low	Low Suitability

Table 3.8 Rating of Total Soil Nitrogen Content

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

Table 3.9 Plant Available P_2O_5 Rating

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

Table 3.10 Plant Available K_2O Rating

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

Table 3.11 Water Permeability in Soil Ratings (Hydraulic Conductivity)

Soil Permeability (μm/s)	Suitability
<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

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 Topography Deficiency (in other words, Criteria for slope evaluation)

Description	Dominant slope (^{0})	Suitability	Map symbol
Flat to gently sloping	<3	High Suitability	t1
Sloping to moderately steep	3-14	Medium Suitability	t2
Steep	14-28	Low Suitability	t3
Very steep	>28	Very Low Suitability	t4

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.

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 3.12.

Table 3.13 Soil Erosion Susceptibility

Type of soil erosion	Erosion susceptibility	Map symbol	Suitability
Sheet erosion	Low	e1	High Suitability
Rill erosion	Medium	e2	↓
Rill/Gully erosion	High	e3	↓
Soil slumps / Mass movements	Very High	e4	Low Suitability

Surface Drainage Criteria

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

Table 3.14 Drainage deficiencies

Drainage	Deficiency	Suitability	Map Symbol
Well drained	Very Low Deficiency	Very High Suitability	d1
Moderately Well Drained	Low Deficiency	High Suitability	d2
Imperfect Poorly Drained	Medium Deficiency	Medium Suitability	d3
Poorly Drained	High Deficiency	Low Suitability	d4

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.

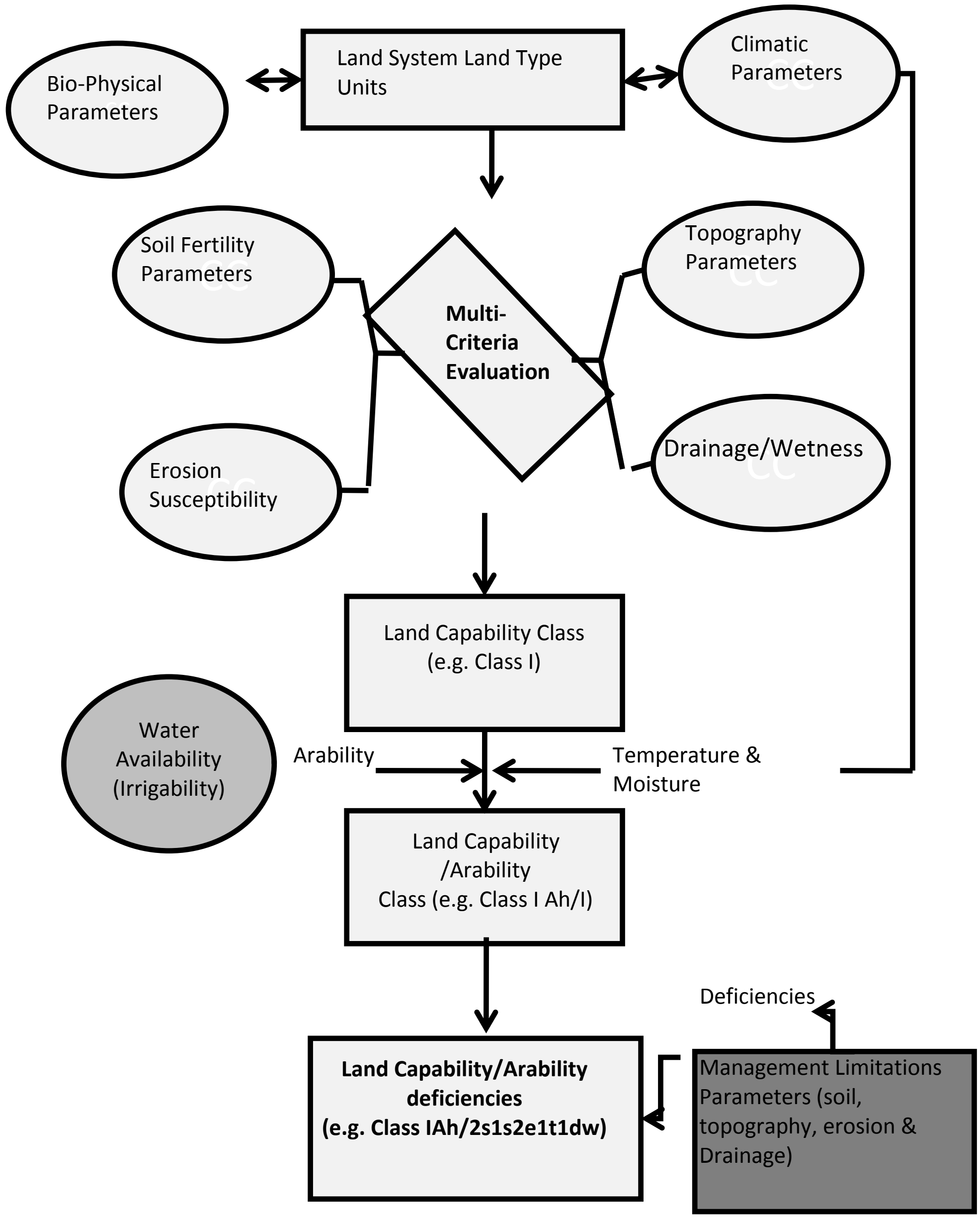

Figure 3.1 Flow Diagram of Land Capability Classification Method

CHAPTER 4: LAND CAPABILITY OF THE STUDY AREA

As presented in earlier section of methodology, land capability classification is carried out on the basis of established criteria of soil quality, deficiencies, arability, climatic and soil moisture conditions. This chapter presents the results of land capability classification framework applied to Karahiya VDC of Rupandehi District.

4.1 Capability Class

The capability classification in Karahiya VDC is done mostly on the basis of land slope, soil rooting depth, soil attributes and other major limitations for crop cultivation (Table 4.1, Figure 4.1). The majority land area of this VDC has almost flat land and relatively deep soil. Based on these standard criteria of land capability classification, whole land area of this VDC is classified broadly in Class I based. The total land area is 1472 ha and all area is nearly flat with <3 degree slope and suitable for diversified crops with few limitations for agriculture and other uses. All lands falling capability class I are highly suitable for agriculture. The land capability classification has been further classified into four classes based on irrigation suitability (Table 4.1, Figure 4.1).

Class I Au/1: Land well suited to a wide range of intensive cropping and grazing activities. It occurs on flat land with deep, well drained soils, and in a climate that favors a wide variety of crops. While there are virtually no limitations to agricultural usage, reasonable management inputs need to be maintained to prevent degradation of the resource. Such inputs might include very minor soil conservation treatments, fertilizer inputs or occasional pasture phases. About 120 ha (5.8%) of land area is estimated under this class in the VDC

Class I Au/1R: The land is highly suitable for Rice based intensive farming. This class is lower than Class I Au/1 because of wet during rainy season for choice of crops. It is estimated about 197 ha (9.4%) of land in the VDC.

Class I Au/2: These lands are ranked lower than Class I in production capacity but these lands are moderately to fairly suitable for irrigated farming. Some areas are suitable diversified crops because of wet condition. About 427 ha (20.5%) of lands have estimated in this class in the VDC.

IAu/2R: The lands in this category are similar to the land under class IAu/2 above, but ranked lower than Class 1R and IAu/2 in terms of productivity or are costlier to do the farm and land management practices (moderately to fairly suitable for paddy production under irrigation). The soil deficiencies can be ameliorated. These lands may possess poor drainage characteristics that affect winter crop production. Area under this land is 432 ha (20.7%).

Class IIAu/1: The land is highly suitable for rice based intensive farming. This class is lower than Class I Au/1 because of wet during rainy season which limits the choice of crops. Estimated area is about 13.6 ha (0.65%) in this class.

Class IIAu/2: These lands could be cultivated with some limitations. They are moderately to fairly suitable for irrigated farming. Some areas are suitable diversified crops because of wet condition. Estimated area is about 179 ha (8.61%) in this class.

Class IIAu/2s: The lands in this category are similar to the land under class IIAu/2 above, but ranked lower in terms of soils deficiency meaning limitations within rooting zones including shallowness or stones, low moisture-holding capacity, fertility difficult to correct. Estimated area in this class is about 76.6 ha (3.68%).

Table 4.1 Land Capability Classes of Karahiya VDC, Rupandehi

Land Capability Class	Area ha	Percent	Arability
IAu/1	121	5.81	High quality land for commercial irrigated agriculture with crop diversification
IAu/1R	197	9.44	High quality land for paddy production (wetland rice arable), crop diversification
IAu/2	427	20.5	Lands are moderately to fairly suitable for irrigated farming. The narrow ranges of diversified crops
IAu/2R	432	20.7	Wetland moderately suitable for arable agriculture (rice).
IIAu/1	13.6	0.65	Lands could be put to diversified cropping system, some limitations occur, requiring conservation measures.
IIAu/2	179	8.16	Lands could be put to diversified cropping system with some limitations, need conservation practices, irrigated crop-arable
IIAu/2s	76.6	3.68	Lands could be put to diversified cropping system with some limitations, need conservation practices, irrigated crop-arable, internal drainage problem which could be corrected.
Non-arable	628	30.2	
River	8.08	0.39	
Total	2083	100	

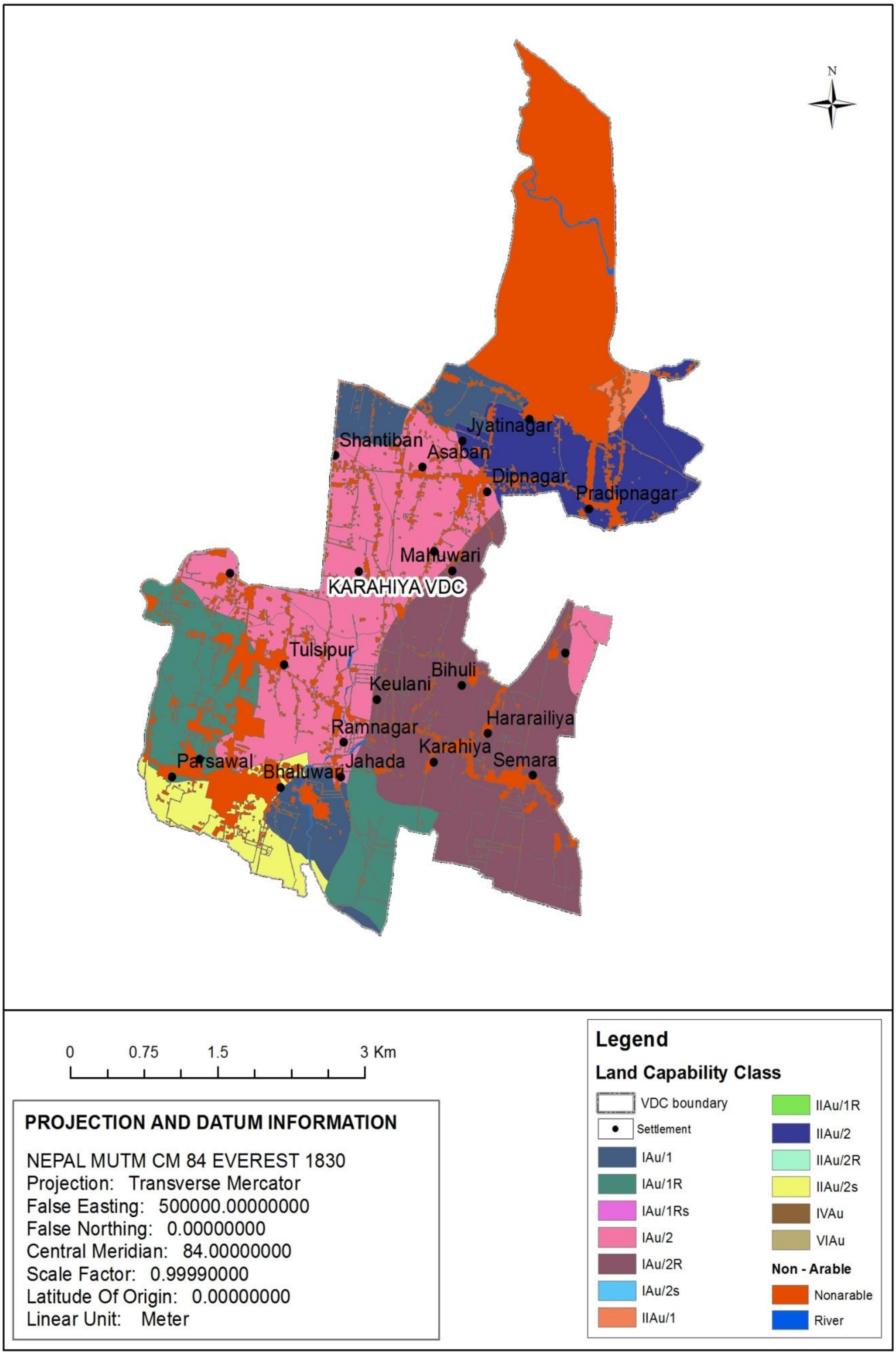

Figure 4.1 Land Capability Classes of Karahiya VDC

4.2 Land Capability GIS Database

The land capability GIS data is prepared 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. N.	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_2O in kg/ha	
27	K_2O_ RATE	String	Associated soil available K_2O rating	
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	

S. N.	Attribute	Data Type	Description	Remarks
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: CONCLUSIONS

5.1 Conclusions

This report presents a land capability classification of Karahiya VDC, Rupandehi district, Nepal. The study was based on USDA Land Capability Classification and also incorporated the modifications received from NLUP/GoN to suit the local conditions. Bio-physical and topographic parameters combined with detailed soils data were used to derive soil mapping units. Part of the major process involved the use of GIS and RS tools for an efficient and reliable data collection, spatial analysis and map outputs generation. Fertility status representing mapping units were derived using laboratory analysis of soil samples. These included properties such as soil texture, soil depth, soil color, organic matter content, soil acidity, and nitrogen, available P_2O_5, K_2O, Zn and B. The total land area was 2083 ha, out of which over 55% was found suitable for low land paddy cultivation. From irrigation point of view, these lands were put to seven sub-classes, i.e., IAu/1, IAu/1R, IAu/2 and IAu/2R, IIAu/1, IIAu2 and IIAu/2s. Crop lands were put to capability class I and II with few to some limitations requiring some kinds of correction measures and irrigation water for diversified agriculture.

5.2 Recommendations

Crop-lands are relatively flat with little or no signs of soil erosion. Farmers grow multiple crops in most areas. Sorah Chhattis Irrigation system alone cannot meet water demand of large areas especially for winter crop diversification. On the other hand, drainage structures would be needed for diversified cropping system in most low-lying areas. Flood protection structures and soil conservation measures are helpful for eliminating topographic and soils deficiencies. Water resource should be developed as multi-functional reservoirs/ponds for future use.

Because there are perennial markets nearby, tremendous potential appears for reliable and increased farm income by agricultural transformation which needs to switch over to cash cropping (vegetables/fish or livestock farming) from cereal based traditional system. One example of rapid rise in rural income by land use change in this VDC could be contemplated by introducing the concept of agro-eco-tourism. This will be a lucrative enterprise for local residents as the international tourists stop by these areas while travelling Buddha's birth place, Lumbini.

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Risk Layers

FINAL REPORT

Preparation of Risk Layer

Karahiya VDC of Rupandehi District

FOR

Consulting Services

for

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

Package No: 11

Anandaban, Devadaha, Karahiya, Kerwani, Madhawaliya, Makrahar, Shankar Nagar, Tikuligadh, of Rupandehi District (8 VDCs)

Preparation of Risk Layer
Karahiya VDC of Rupandehi District

This document is one of the outcomes of the project entitled **Preparation of VDC level Land Resource Maps** (Present Land Use Maps, Soil Maps, Land Capability Maps, Land Use Zoning Maps and Cadastral Layer Superimpose and VDC Profile), **Database and Reports**of Package 11 awarded to SHREEYA-KRS JV by the Government of Nepal, Ministry of Land Reform and Management, National Land Use Project (NLUP) in Fiscal Year 2072-073. The VDCs covered under this package include eight VDCs of Rupandehi district namely **Anandaban, Devadaha, Madhawalia, Makrahar,Karahiya, Kerwani, Sankar Nagar and Tikuligadh**.

Mr. Kul Bahadur Chaudhari is solely credited for the preparation of maps, database and reports on risk themes.

The VDC areas analyzed for different themes of the NLUP Project are computed from cadastral maps provided by DOLIA Office of Nepal. Therefore, the areas of the VDCs may not be the same as computed from Topographic Database provided by the Survey Department of Nepal.

The consultant is obliged to state that the Imageries, GIS database and other outputs produced for the project is owned by National Land Use Project (NLUP), Mid-Baneshwor, Kathmandu. Therefore, the authorization from the NLUP is required for the usage and/or publication of the data in part or the whole.

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CHAPTER 1: INTRODUCTION

1.1 Background and Rationale

Nepal being a mountainous country, four-fifth of its land area is covered by hills and mountains and is characterized by complex geological structure with active tectonic process and seismic activities. The sharp vertical landscape renders the country highly vulnerable and disaster prone due to its fragile geology and steep topography and is highly exposed to multiple hazards, including earthquakes, floods, landslide, droughts, fire, cold waves and disease outbreaks.Increasing evidences of wind storms, cloud burst and hail stones are being common as caused by climate change. Nepal is placed in 20^{th} place in the global hazard while the country is ranked 30^{th} in terms of water-induced hazards such as landslides and floods. In seismic vulnerability ranking, it ranks 11^{th} globally most vulnerable countries to earthquake (GoN, 2009). Fire breakouts in rural Terai remain one of the major problems during the summer season when temperature raises up to 45^{0} C.

The identification of risks and associated hazard is the prerequisite for the proper planning and land management. Thus, the importance of Land Use Planning role in the prevention and the restriction of consequences of major hazard accidents need to be analyzed. Inversely, Land Use planning without due consideration on disaster aspect is not effective. Mainstreaming disaster risk reduction in Land Use Planning can systematically reduce impact of specific hazard. Risk assessment, that identifies the severity and spatial distribution of risk and generates the necessary data/information 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

The main objective of this study is to categorize areas on the basis of risk factorsassociated in land use plan going to be prepared in the study area. The specific objective is to identify and categorize areas which are prone to and secure from potential risks caused by flood, landslide, earthquake, fire and industry for the identification of secure sites for residential use in Karahiya VDC, Rupandehi district.

1.3 Study Area

Karahiya VDC lies in Rupendhei district, Lumbini Zone. The VDC has currently included in Tilottama Municipality. And it is known for ward no. 9, 10, 11 & 12 of the municipality. It is located between 83° 27' 50" to 83° 31' 20"E longitude and 27° 35' 20" to 27° 35' 58"N latitude. The VDC is bordered by Makrahar and Gangoliya VDCs to the east, Anandaban VDC to the west, Andandaban & Devadaha VDCs to the north and Madhawaliya & Gangoliya VDCs to the south. The VDC covers a total area of 2082.81 ha. The extension of the VDC is 4.7 km and 8.8 km in east-west and north-south respectively.

According to the population census 2011, the total population of the VDC was 18274 with 4267 households. Of the total population, the percentage of male is six percent lower than the female. The population of this VDC is composed of different caste/ethnic groups. Among them, Brahmin is in majority. The proportion of migrants is significant in the total population. Migrants were mainly from from Palpa, Gulmi, Arghakhachi, Baglung, and Parbat. Ninety-five percent people follow Hinduism. People are involved in many occupations. More than half of the total populations are involved in agriculture. And it is the main source of income. Almost one-third of the total income comes from agriculture sector.

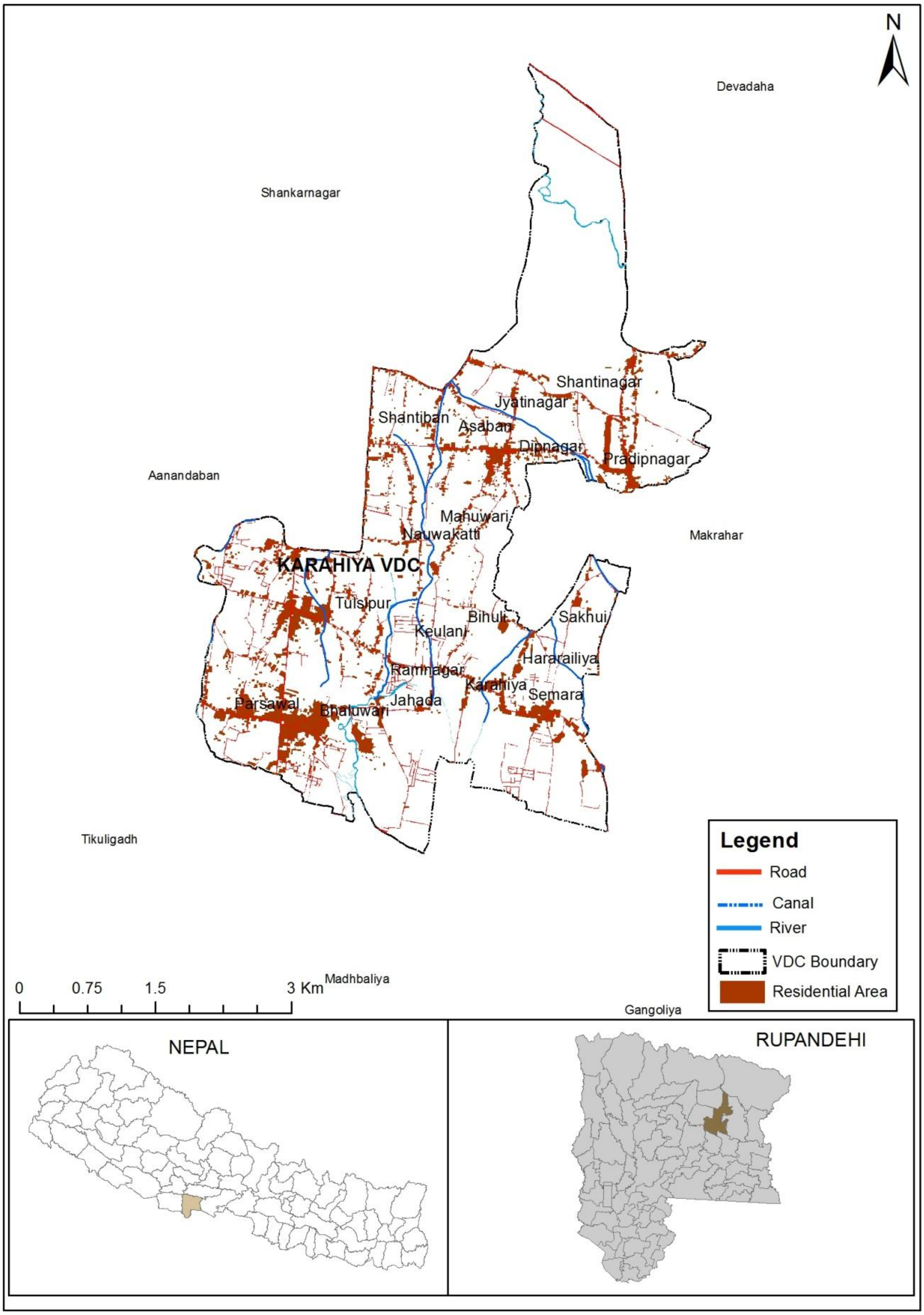

Figure 1.1 Location KarahiyaVDC

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 service 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.

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 adequate building standards during implementation of plan.

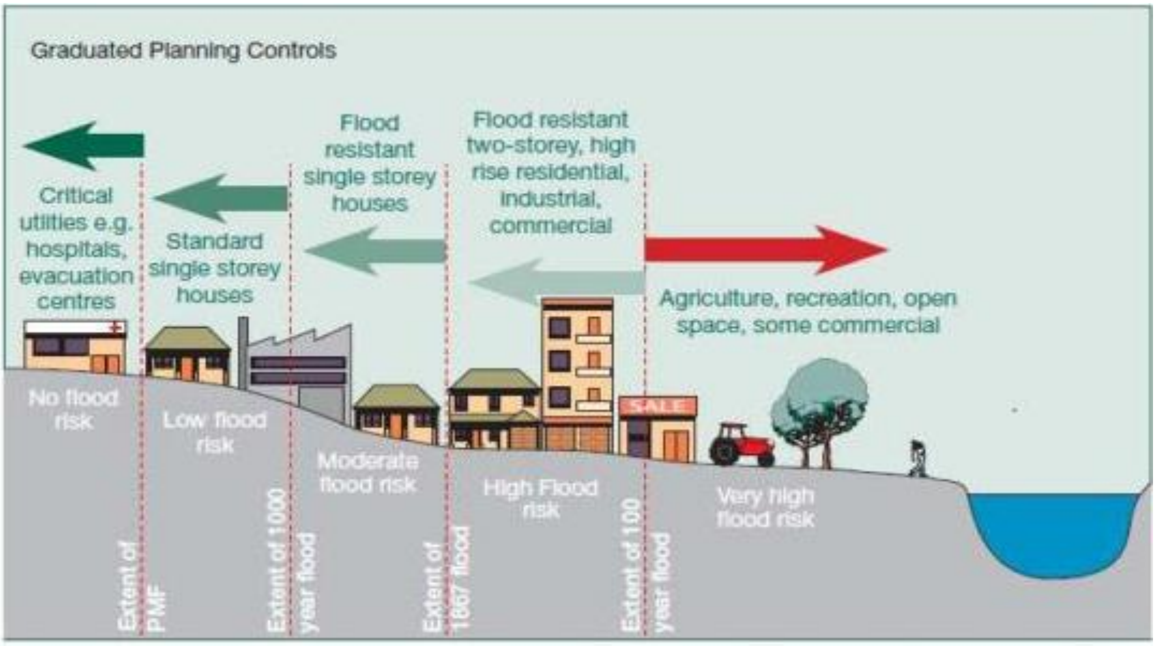

Figure 2.1 Distribution of land use on floodplain to reduce risk

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.

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. 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

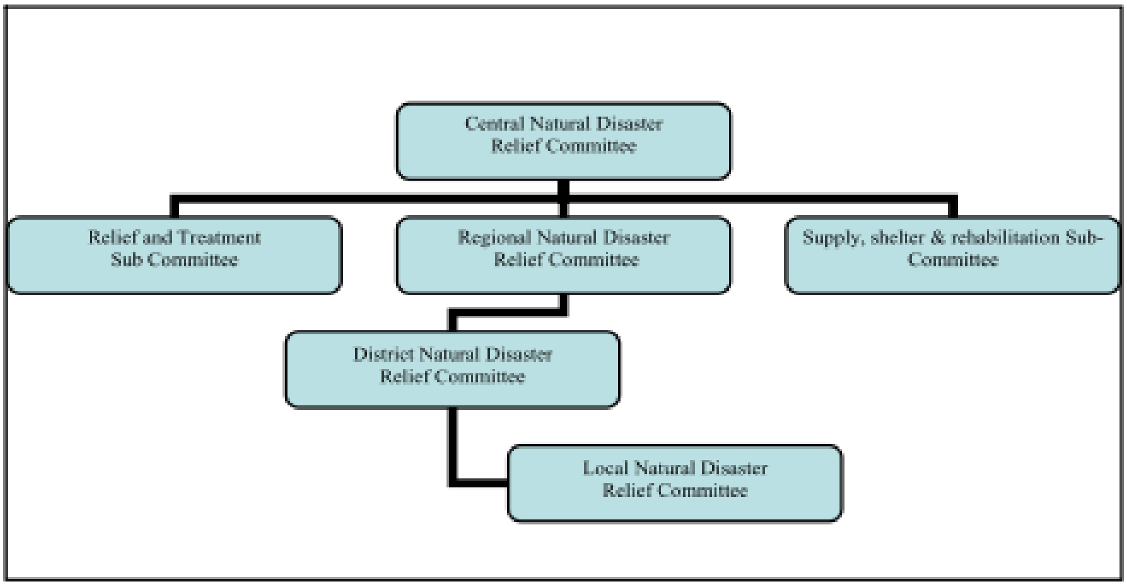

Figure 2.2 Disaster Relief Committee of Nepal

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)

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 depend 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 understood 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.

a) ***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:

i. economic
ii. social
iii. cultural

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.

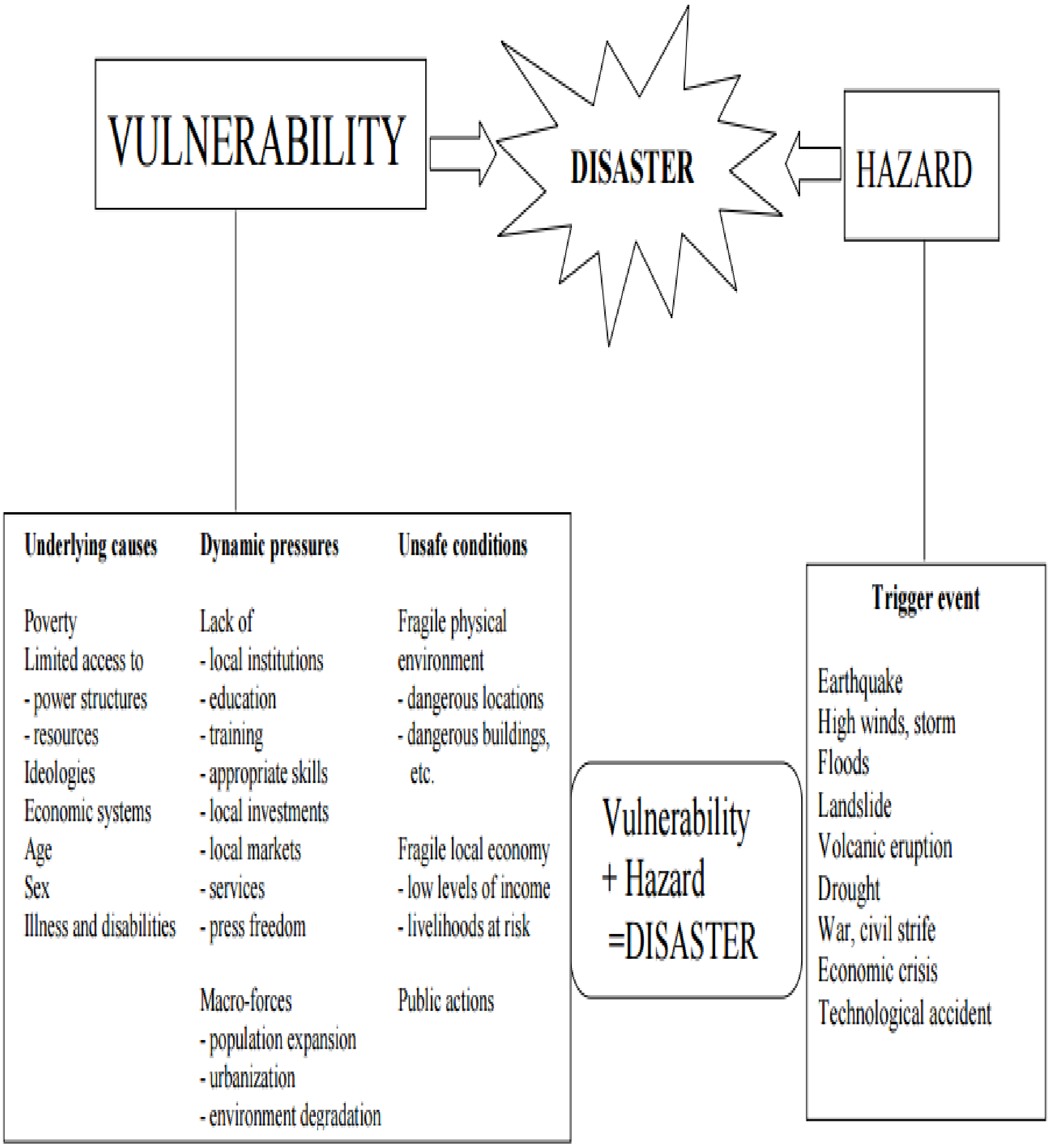

Figure 2.3 Factors of Disaster

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 non-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 have been specified as: i) Flood, ii) Landslide, iii) Fire, iv) Seismicrisk, and v) Industrial hazard.

Flood Risk: According to EU Directive (COM, 2006), '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
.

Four types of flash floods resulting loss of life and properties have been reported from Nepal. Those flash floods are associated with i) extreme local scale precipitation (cloud burst) like in Lele area in 1981 and Syanja in 1998; ii) heavy monsoon precipitation at regional scale like in 1954 and 1955 in many parts of the country; iii) Glacial Lake Outburst Floods (GLOFs) like Balephi in 1982 and Larchakhola in 1996 and iv) landslide dam outburst flood like in Jure-Sunkoshi, Sindhupalchowk in 2014 and Kaligandaki, Myagdi in 2015 (Khanal et.al, 2015).

Fire Risk: Fire hazard is one of the prominent hazards of the Tarai areas particularly during the dry months. There are very few studies on hazard risk mapping in Nepal. NEST carried out a study incorporating fire hazard mapping in Bhimdutta Municipality of Kanchanpur District for DUDBC. The study identified types of building materials, proximity to the neighboring buildings, proximity to roads, proximity to forest, and proximity to hazardous elements (petrol pump and gas stations etc.) and socio-economic status and awareness of the local people on the hazard as the major parameters for identifying fire hazard risk areas in the Tarai areas of Nepal.

Fire risk 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 lightning strikes, suffers from numerous fire outbreaks mainly during the process of cooking. In the winter, the major cause of fires is the short circuit of electrical appliances, particularly heaters. In both urban and rural areas where houses are built in close proximityare vulnerable, as fires easily leap from one house to the next. Fires cause great loss of life and property and can have a devastating impact on local economies.

Similarly, forest fires also occur 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 are affected by fire albeit the magnitude varies. Community forests and leasehold forests are less affected as compared to protected forests and government managed forests. Forest fire is considered as a problem in forest management systems in Nepal since we have not been able to manage it efficiently. The fire management is an important initiation to safeguard forest, biological resources, environment and public heath, by reducing fire damages through mobilizing government, non-government, private sector, civil society and local people.

Landslide Risk: A landslide is the gravitational movement of a mass of rock, earth or debris down a slope. Landslide hazards are usually classified on the basis of the material involved (rock, debris, earth, mud) and the type of movement (fall, topple, avalanche, slide, flow, spread). Thus, the generic term landslide also refers to mass movements such as rock falls, mudslides and debris flows. Landslide hazard zonation is defined by the mapping of areas with an equal probability of occurrence of slope failure within a specified period of time. Slope failure is largely controlled by two different factors; i) Intrinsic factors (bedrock geology, geomorphology, depth and type of soil, slope gradient and aspect, land use pattern, drainage pattern etc.), and ii) Extrinsic factors (rainfall, earthquakes and volcanoes).

There are varieties of techniques for landslide hazard analysis. These include Heuristic qualitative approach, Statistical approach, and Deterministic approach. These are GIS base techniques for landslide hard assessment. According to Van Westen (2000), in a GIS-based technique, it is also necessary to be sure that any selected factor is functional (has a certain degree of affinity with previous occurrences of landslides), complete (is reasonably represented all over the study area), no uniform (remarkable spatial variation), measurable (can be expressed by nominal, ordinal, interval, ratio scales), and non-redundant, i.e., outcome of selected factors should not account for double effects in the final result.

The present study is based on deterministic approach which generally applied for detailed studies at large scale (1:2,000 to 1: 10,000), without entering at the level of the engineering geological site investigation, which can be used for the detailed planning of infrastructural works. For this, basically, it will be based primarily on the inventory of landslides in the area from the Google image.

Seismic Risk: Nepal experienced a major earthquake with magnitude of 7.6 on 25 April, 2015. The catastrophic earthquake had resulted over 8,800 casualties and over 22,000 injuries together with displacement of 100,000 people. It is estimated that the lives of eight million people, almost one-third of the population of Nepal, have been impacted by these earthquakes (NPC, 2015). 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 (Terai) and the Lesser Himalaya.

There are several methods to evaluate the seismic hazard in a particular area; however, no one is termed as the best because of the uncertainty and ignorance of the internal parts of the earth. HAZUS (Hazard US) and RADIUS (Risk Assessment for Diagnosis of Urban Areas against Seismic Disasters) are also used in such analysis. However, the variables such as PGA, MMI and Liquefaction parameters should be identified for such analysis and certainly these are time and resource consuming jobs. Further, it should be acknowledged that the problems of seismo-tectonic events of Himalaya are not fully understood and the knowledge is increasing with more and more accumulation of research results and data analysis. However, now-a-day a simple method of preliminary investigation of maximum credible earthquake and peak ground acceleration for an assessment of seismic hazard is also popular. The analysis is basically made by deterministic evaluation of earthquake sources in the vicinity with the state of art consideration of attenuation for the Himalayan terrain.

The result of micro seismic investigation, geodetic monitoring and morpho-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 rupture the whole ramp-flat system up to the Main Boundary Thrust (MBT) of the Sub-Himalaya (Pandey et al., 1995).

Industrial Risk: Industrialization is one of the indicators of development. However, it has negative consequences too, as industrialization is the basic cause of pollution. To fulfill the unlimited demand of population growth, industrialization is going rapidly. This has led to the environmental changes that have become harmful to all living beings and environment. Proper steps are necessary to reduce the industrial pollution from both, public and government sectors. The industrial pollution has greater impacts in a wide variety of sectors.

The industrial pollution has greater impacts on the native fauna and flora. It could lead 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 lead decrease in surface and ground water quality near to the industrial sites.

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 are also found around the industrial areas. In Nepal, the soil is also harmed by fugitive effluent from the cement factories. Anecdotal evidences indicate 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.

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. Heavy industrial equipments such as fans, engines and generators cause noise 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. Other forms of pollution are light, visual, thermal, plastic and pesticides pollution.

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, 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, 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, 2013).

Natural Hazard and Flood events are part of nature which have always existed and will continue to exist. Floods are climate related 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.

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).

$$\{R\} = \{H\} \square \{V\}$$

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

$$R = \{H\} \times \{V\}$$

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 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

3.1.1 Data

Data for the Flood Risk study can be classified into various groups 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 centre line etc.
- Discharge data at strategic points, manning's constant, river boundary information etc.

3.1.2 General Approach and Methodology Framework

Various methodological frameworks exist in Nepal for flood modeling. It is generally accepted 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 are mainly driven by the need of cultural heritage protection and also by the socioeconomic conditions of the area concerned. In this context, 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. 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 report, a comprehensive way for defining and assessing flood risk and vulnerability in the flood-prone areas is proposed. 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).

Based on the ANCOLD Guidelines 2003, there is a basic consensus towards the methodological framework of risk identification and estimation. In this context, the general methodological framework for risk assessment can be, more or less, determined and it is given by the following steps:

1. **Risk identification**: refers to the identification of the hazard source.

2. **Risk analysis or risk estimation**: refers mostly to the probabilistic quantification of the average annualized risk and it is measured in the same units as hazard. It involves the estimation of the probability of occurrence of the hazardous phenomenon, the estimation of the actual consequences and the vulnerability estimation of the affected system over the selected hazard scenarios.

3. **Risk evaluation**: refers to the identification of the local society's tolerable risk policies and criteria as well as to the comprehension of the local society's perception of the hazard impacts by the decision makers. One's willingness to pay for risk reduction is controlled by the perceived and not the actual risk. Simultaneously the perceived risk reflects the human attitude towards various kinds of risks and it is therefore of high importance to assess it.

4. **Risk assessment**: refers to the evaluation of the tolerability of the estimated risks based on the local society's acceptability criteria. The comparison of the estimated risks with acceptable ones results in the decision of what risk will be acceptable in the particular affected system and what risk reduction measures will be applied; if needed.

The methodology aims to assist water managers and stakeholders in devising rational flood protecting strategies. Figure 3.1 depicts the applied methodological framework for flood risk assessment.

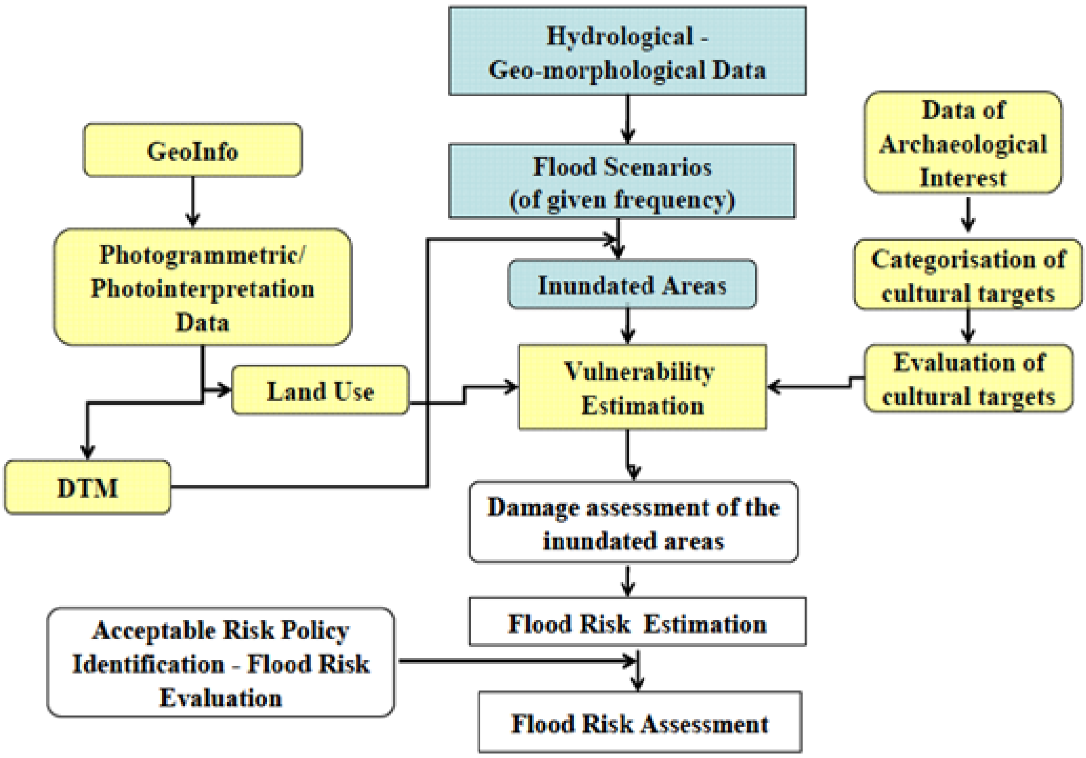

Figure 3.1 Methodological Framework for Flood Risk assessment

Flood modeling: Flood modeling is an engineering tool that provides accurate information regarding flood profile. The governing factors causing flood are rainfall, run off, catchment characteristics and return period. 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. There are various methods for calculating flood discharges: i) Rational Method, ii) Empirical Formula (Modified Dickens's formula), iii) Flood- Frequency Method, andiv)Water and Energy Commission Secretariat (WECS) Approach. The rational method is applied for the peak flow calculation of smaller basin (below 25 km^2) 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 Empirical Formula uses the catchment area as a single parameter affecting the flood peak and other factors are constant based on the specific region. For best results, this formula is applicable only in the region from which they were developed (Subramanya, 2006).Flood frequency method is more time consuming and it needs data of minimum 30 years. The WECS/DHM (1990) method considers whole country as single hydrological region and regionalization can be done for low flows, long term flows and flood flows. It is the modified form of WECS approach of 1982 which was jointly developed by WECS and DHM (Shresthaet al., 2010).The following equations is used for flood flow of any river of catchment area ‘A’ below 3000 m (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 in number of years.

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

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

The WECS/DHM method is found to be appropriate in this study for the calculation of flood discharge for the return periods of 2years and 100 years.

The Manning’s roughness coefficient, n, is commonly used to represent flow resistance. The friction parameters have been considered as the form of Manning's roughness coefficient (n).

Steady flow water surface profile:The steady flow analysis has been done for the flood simulation as required for the project considering the lack of unsteady flow data of the rivers of the project area. 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). Thus, the 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.

3.1.3 Methods

In order to obtain the set objectives defined in ToR regarding flood risk, both spatial and non-spatial data were collected and both qualitative and quantitative approaches were adopted for data generation. Primary data were acquired through interview with the local people residing in flood prone areas and relevant government officials. For this, altogether 10 persons were interviewed in the study area. In addition, secondary data were collected from varieties of sources including the project document of National Land Use Project.

Watershed area determination and water discharge calculation: All the nine rivers (Bhaluhi, Bodhar, Gahigaire, Ghadha, Jymire, Rohini, Saran, Sukauna, Tinau) of the package 11 were digitized from the WorldView-2 image. Digital elevation model, shown in figure below 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 below (Figure 3.2) using flow direction and flow accumulation.

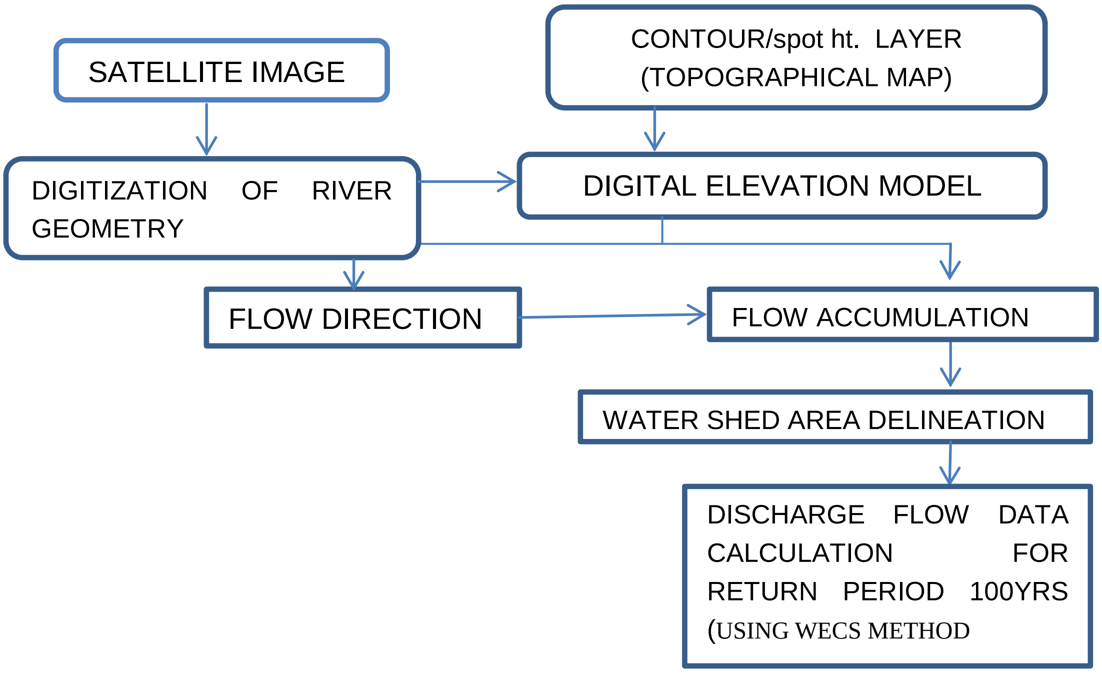

Figure 3.2 Process for Watershed area determination and discharge calculation

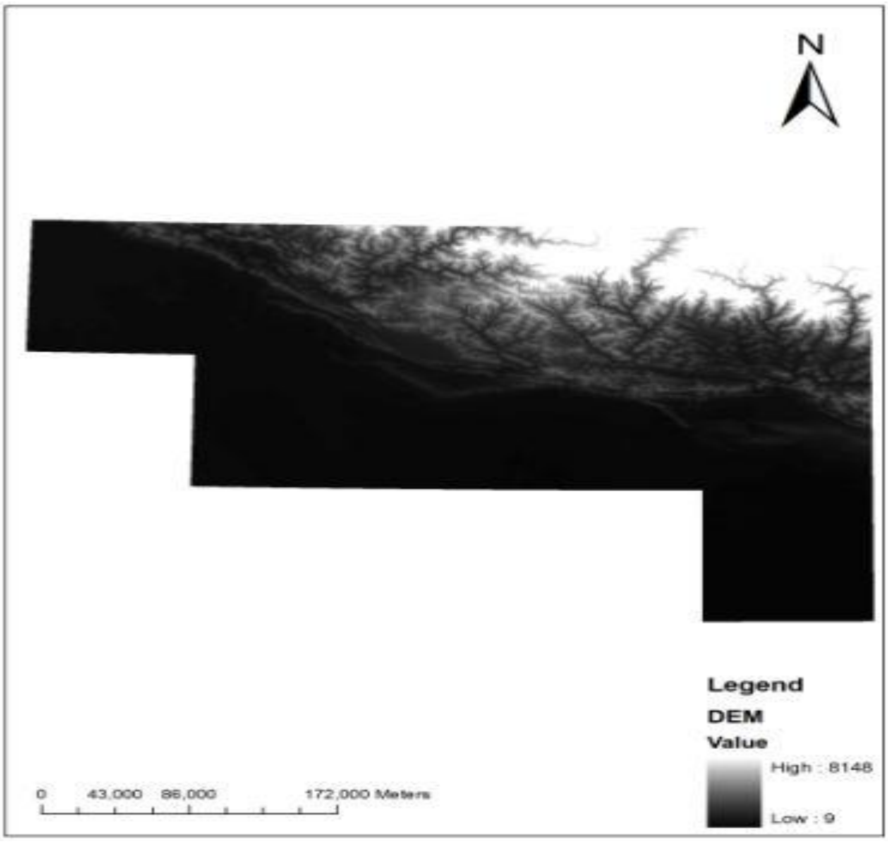

Figure 3.3 Catchment Area

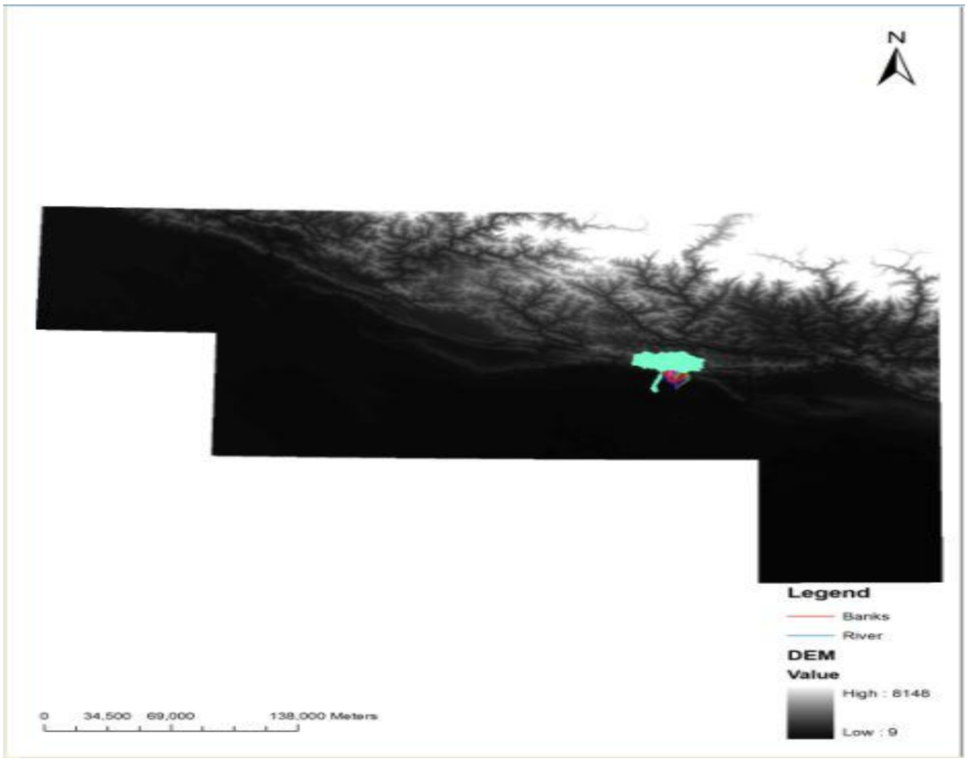

Figure 3.4 Digital Elevation Model

Calculated flow discharge of the nine rivers/streams of the study area for the 100 years of return period is given in Table 3.1.

Table 3.1 Discharge calculation for given Return Periods

River	Station (m)	Catchment Area (Sq.km)	100 years
Bhaluhi	2500	4.8686	53.6417
Bhaluhi	500	1.1943	26.051
Bodhar	4000	0.9948	24.2902
Bodhar	500	1.8843	31.8424
Gahigaire	11500	0.9964	24.3045
Gahigaire	471.91	5.0271	54.7016
Ghadha	3500	1.0031	24.3643
Ghadha	500	1.7374	30.6435
Jymire	4500	1.0182	24.4990
Jymire	500	2.6709	38.0102
Rohini	8000	26.3017	165.842
Rohini	1999.99	41.2373	228.471
Rohini	141.49	42.3002	232.678
Saran	8500	1.0009	24.3447
Saran	5000	4.2287	49.2821
Saran	500	5.9855	60.9613
Sukauna	8500	3.0161	40.6030
Sukauna	500	7.1866	68.4928
Tinau	15000	138.5370	549.3820
Tinau	112.37	147.2540	574.3760

The flood related data were processed in three phases: i) Pre-processing in GIS environment, ii) HEC-RAS processing, and iii) HEC GOO RAS post processing.

Pre-processing in GIS environment: In pre-processing phase, RAS layers of stream centerline, river banks, flow path centerlines and cross sections were created in GIS environment. Finally, RAS-GIS import file was created which was ready for processing in Hec-Ras.

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 period 100 years was calculated from WECS/DHM method entering 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 in steady flow analysis. Then the generated data is exported in GIS format. Water surface profile for return periods of 100 years is given in the Figures 3.5.

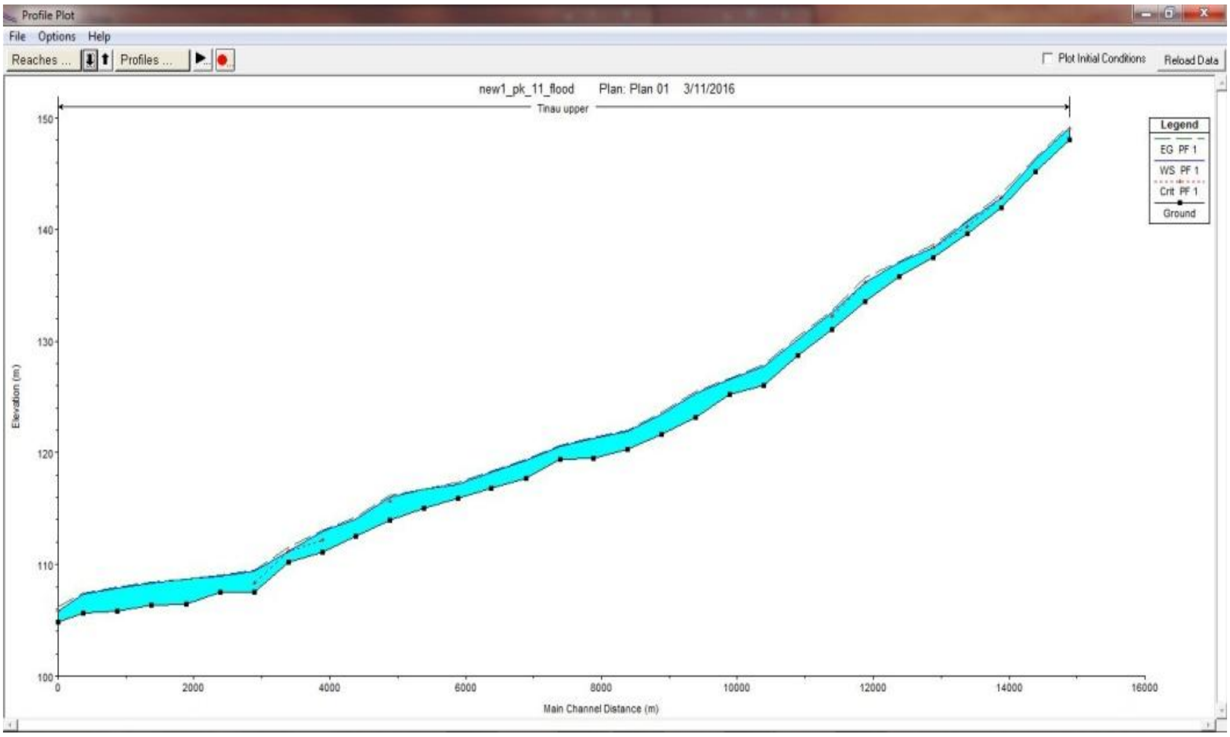

Figure 3.5 Water Surface Profile of TinauKhola for 100 Years

HEC GEO RAS Post Processing: In the third HEC GEO RAS post processing phase, inundation mapping was performed with the generation of water surface which was later followed by flood plain delineation.

3.1.4 Result

As reported by the local people, flood is not frequent in Karahiya VDC. Bank cutting is quite common in the northern parts of the VDC. This VDC was flooded in 1993. Mainly forest area was flooded..

Preparing Flood Hazard Map: Flood hazard map provides information on type and extentof flood; depth of water, flow velocity,and water flow direction. This can be the basis for determining land use control, flood proofing constructions and flood awareness and preparedness. This has given clear picture of possible flood that can affect land use of the area.

The delineated flood model is used for the evaluation of land use planning by using overlay analysis in GIS environment. The present land use of the study area is given in Table 3.2.It is found that almost 70 percent area of this VDC is covered by agricultural land. The second important land use category is forest, which occupies about 16.30 percent of the total land.

Flood hazard map was prepared by overlaying land use map with flood area polygon for return period of 100 years. Total land by different use categories and land liable to flood for 100 years of return period is summarized in Table 3.2.According to flood assessment for return period 100 years, out of 2082.81 ha of classified land use zone, 51.65 ha is found to be flood prone. Out of total flood prone area, forest constitutes 84.4 percent. The proportion of probable inundated agricultural land is negligible (Figure 3.6).

Table 3.2 Present Land Use and area liable to flood

Zone Type	**Present Land Use**		**Probable Inundate are (100 yrs)**	
	Area (ha)	**Percent**	**Area (ha)**	**Percent**
Agriculture	1440.33	69.15	0.0035	0.01
Commercial	11.41	0.55	0.00	0.00
Cultural and Archeological	0.29	0.01	0.00	0.00
Excavation Area	0.28	0.01	0.00	0.00
Forest	339.46	16.30	43.5904	84.40
Riverine and Lake Area	14.22	0.68	4.1852	8.10
Industrial	8.88	0.43	0.00	0.00
Public Service	72.48	3.48	0.3972	0.77
Residential	186.28	8.94	0.00	0.00
Other	9.17	0.44	3.4762	6.73
Total	**2082.81**	**100.00**	**51.65**	**100.00**

Flood Depth for Return Period 100 years: Flood can be grouped as low flood, medium flood and high flood on the basis of degree of flooding or depth of flood water. Table 3.3 provides the detail information regarding areas liable to flood by land use classes. From the overlay of flood model with Land use plan of KarahiyaVDC, it was found that 43.59 ha of forest land, 4.19ha of riverine and lake area and 3.48 ha of land used for other purposes is liable for inundation(Table 3.3).

Table 3.3 Flood Depth for return period 100years as per Landuse class

Land use Class	**Low**	**Medium**	**High**	**Total**
	(< 0.5 m)	**(0.5 m - 1.5 m)**	**(>1.5 m)**	
Agriculture	0.0035	0.00	0.00	0.00
Commercial	0.00	0.00	0.00	0.00
Cultural and Archeological	0.00	0.00	0.00	0.00
Excavation Area	0.00	0.00	0.00	0.00
Forest	36.36	7.17	0.07	43.59
Riverine and Lake Area	2.07	2.02	0.09	4.19
Industrial	0.00	0.00	0.00	0.00
Public Service	0.40	0.00	0.00	0.40
Residential	0.00	0.00	0.00	0.00
Other	3.10	0.37	0.00	3.48
Total	**41.94**	**9.56**	**0.16**	**51.65**

A total of 41.94 ha of different types of land is liable to low flood while only 9.56 ha of land becomes medium flooded and very few are is liable to high flood (Table 3.3 and Figure 3.6).

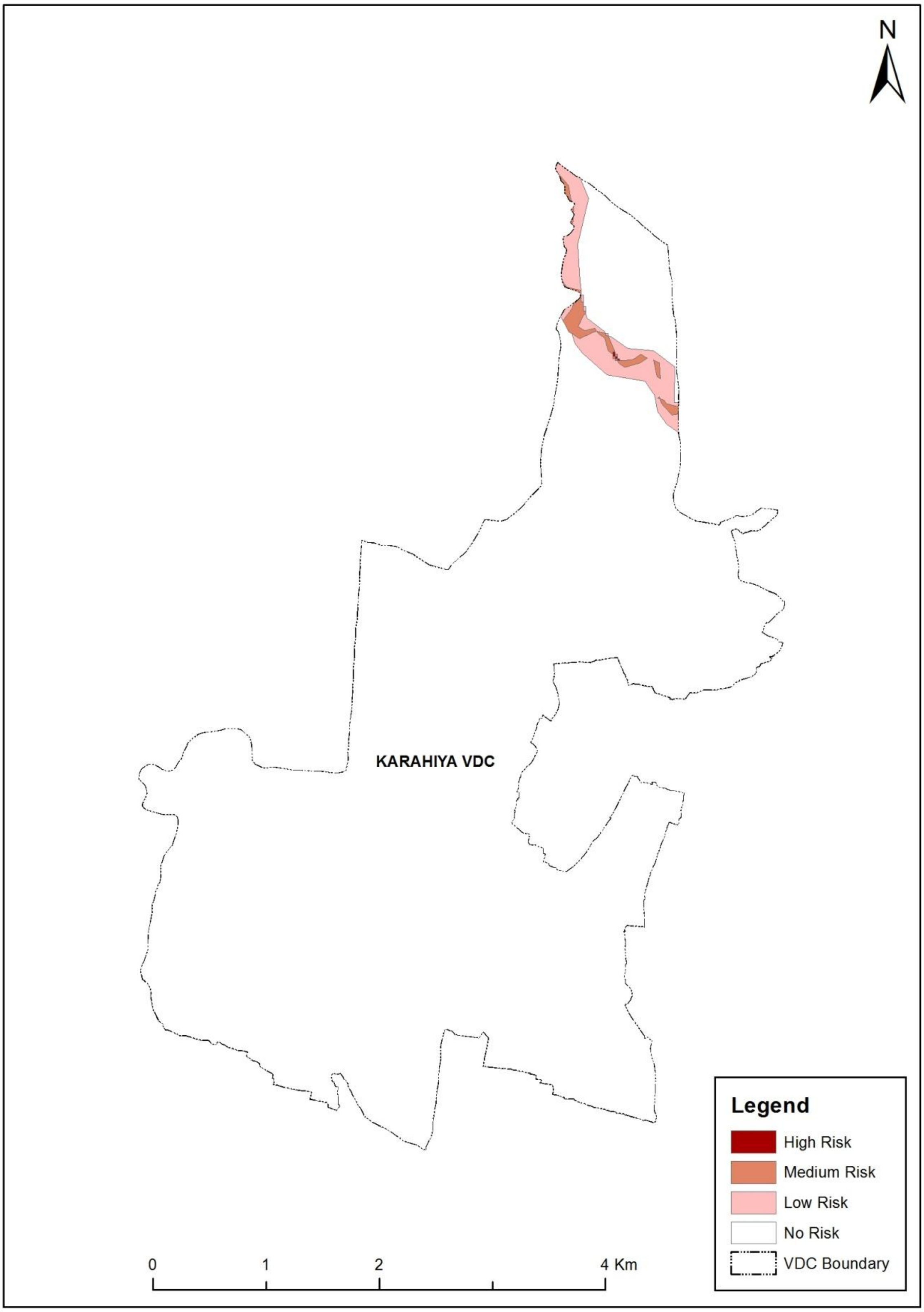

Figure 3.6 Flood Risk Rreas, Karahiya VDC

3.1.5 Discussion

The result acquired through the analysis reveals the fact that in this VDC a small area is flood prone.Settlements nearby River are prone to floods. The people in such area are at risk of flood hazard.

3.2 Fire Risk

Fire is a common phenomenon occurring in Nepal during the dry stormy summer season and hazards take place. Fire Hazard is a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage. The major factor for the increasing fire risk is the lack of a favorable policy and legal environment commensurate with the present-day situation, needs, opportunities and resource availability.

Rupandehi district also suffers from fire event. Fire takes place in the settlements, in agriculture fields and most importantly in the forests. Almost all VDCs of this district are sensitive to fire risks and hazards. Forest fire is considered as one of the major causes of destruction and degradation of forest ecosystems. Recurrent uncontrolled forest fires have serious negative impacts on biodiversity, rural livelihoods and the natural environment including regional climate. Every year forest fires wipe out considerable forest resources in Nepal resulting in the loss of biodiversity and deterioration of forest condition. The analysis of satellite imagery of the last one decade shows that the fire incidences in Nepal are in increasing trend. Besides, fire burn houses made of thatched grasses in particular and result into loss of lives and property of the people. Smokes due to burning of houses, forest leaf litters and aerial parts create hazy environment and drab throughout the year in country side where there is forest and villages/hamlets adjoining or nearby to the forest.

Forest fires starts from mid-March in Taraiforests and ends in May. In the Terai belts particularly during the dry, stormy season between April and June when temperatures exceed 35°C, wooden and thatched roofs houses in the Teraiare extremely vulnerable to incendiary lighting strikes, suffers from numerous fire outbreaks mainly during the process of cooking. During this period usually 1 to 3 times forest fire takes place and burns the vegetation. All fires are surface fires, although, no exact data are available on the number of fires, severity and amount of losses. This fires cause great loss of life and property and can have a devastating impact on local environment and economies.

3.2.1 Data

Though, identification of fire risk areas is a difficult process, attempts have been made to identify the risk areas based on the past occurrences, consultation with different stakeholders, observation of building materials and building density, and socio-economic status of localpeople. The present analysis tried to evaluate the fire risk areas by collecting data through the extensive consultation with local people, experts and officials district forest and community forest user groups. Besides, intensive field observation was during the field visit.

3.2.2 General Approach and Methodology Framework

The general approach is participatory, in situ observation and interview with individual and in groups with different stakeholders. Figure 3.7 highlights the general approach and methodological framework for fire risk analysis.

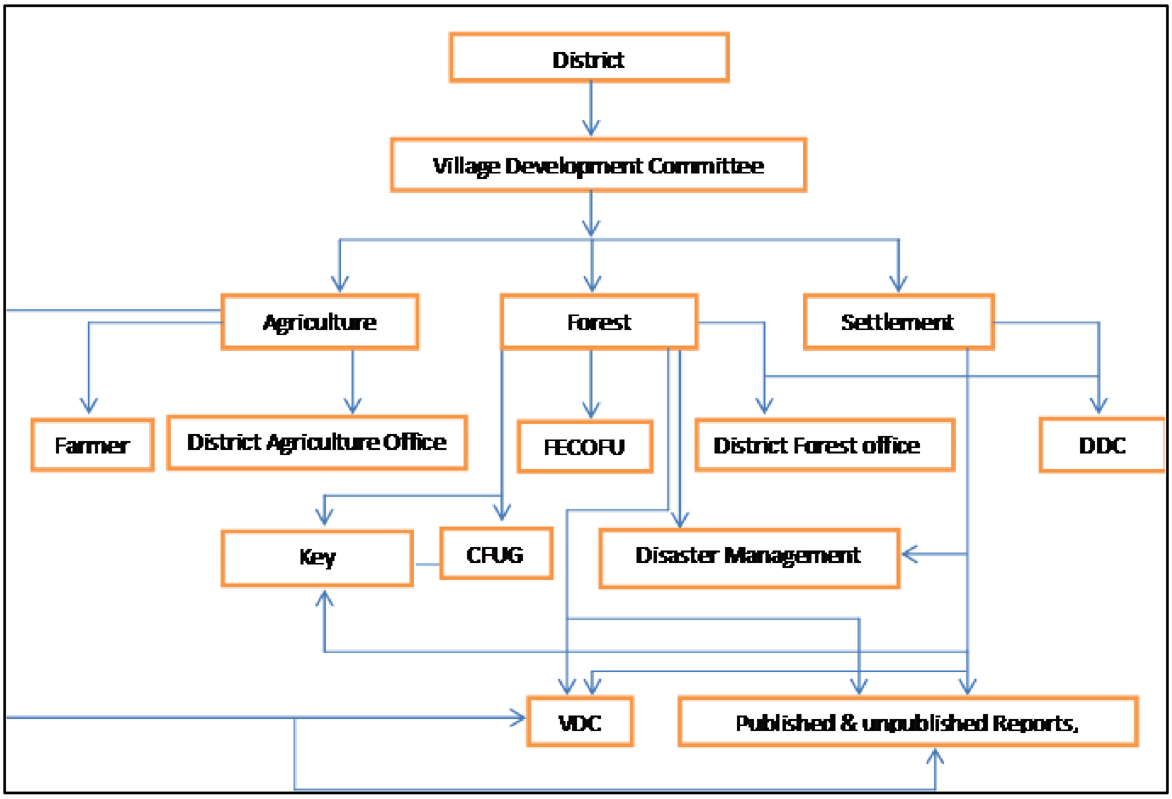

Figure 3.7 Methodological Framework for Fire Risk Analysis

3.2.3 Methods

The information on forest fires were collected from the extensive consultation with government representatives at various levels, experts and professionals, local communities, and key informants. Participatory appraisal methods were carried out among different stakeholders, including district forest office staff, CFUGs and also by field observation. Besides, secondary data and information were collected from published and unpublished reports and from articles on websites. The details have been given in methodological frame work mentioned above.

3.2.4 Result

Fire takes place in the village houses, in agriculture fields and most importantly in the forests. Almost all VDCs of Package 11 of the Rupandehi district are sensitive to fire risk and hazards. The main causes of forest fires are anthropogenic due to negligence and occasionally by deliberate burning to induce succulent grass growth for domestic animals.The means of fire are cooking outside houses, unmanaged fire during winter season for heating the body, burning cigarettes and bidi throwing, lack of awareness and less access to helping organizations. Besides, improper management of crop residue, use of mechanical threshers, feeding cooking stoves with rich husks and packed long cow dung, cooking outdoor throughout the day are other causes of firing.

In Terai, houses for residential purpose are developed on clusters which are more susceptible to catching fire and spreading over there immediately due to close connectivity especially in the dry season. Since study area is located in Terai plains,this area is susceptible to fire hazards.The settlements located nearby forest areas are more prone to firing. Likewise, cluster settlement having houses made with wood and thatch roofs are more susceptible for fire hazard.

3.2.5 Discussion

Every year fires destroy considerable forest resources and large number of settlements in Nepal. Such destruction includes timber and non-timber forest products, lives and huge amount of properties. Fires also reduce the biological diversity of the forests to a great extent and also cause soil erosion and induce floods due to the destruction of natural vegetation. The area specific quantitative information regarding the number of fires, severity and the amount of loss are not available.Reportedly, most incidences of fires occur in the dry summer season, festivities, crop harvesting, and load-shedding time. Poor handling of fire for cooking and other purposes, electrical short circuits, poor wiring, poor handling of gas cylinders and stoves, human negligence and lack of adequate fire safety measures are the major factors contributing to the outbreak of fires.

3.3 Landslide Risk

Nepal being a mountainous country, landslide is recognized as one of the major hazards of the country. Each year a large volume of loss and damage takes place as caused by the landslide hazards. The landslide hazards are concentrated especially in the elevated parts of the country. The present study area is located in the Terai plain with virtual or no elevation, the chance of landslide hazard is almost nilexcept the bank cutting.

3.3.1 Data

The analyzed data has been taken from the secondary data as well primary data. The secondary data has been collected from the Google Earth. The bank undercutting along the river bank has been studied in filed visit.

3.3.2 General Approach and Methodology Framework

Landslide hazard assessment is an important step towards landslide hazard and risk management. There are several methods of Landslide Hazard Zonation (LHZ) viz. heuristic, semi quantitative, quantitative, probabilistic and multi-criteria decision making process. However, no one method is accepted universally for effective assessment of landslide hazards. In recent years, several attempts have been made to apply different methods of Landslide Hazard Zonation and to compare results in order to find the best suited model. The advanced multivariate techniques are proved to be effective in spatial prediction of landslides with high degree of accuracy. Physical process based models also perform well in Landslide Hazard Zonation mapping even in the areas with poor database. Multi-criteria decision making approach also play significant role in determining relative importance of landslide causative factors in slope instability process. Remote Sensing and Geographical Information System (GIS) are powerful tools to assess landslide hazards and are being used extensively in landslide researches since last decade. Aerial photographs and high resolution satellite data are useful in detection, mapping and monitoring landslide processes. GIS based Landslide Hazard zonation models helps not only to map and monitor landslides but also to predict future scope.

Geomorphological hazard mapping and analysis of landslide inventories are two basic experts knowledge based qualitative landslide hazard mapping techniques. Geomorphological mapping of landslide hazard is a direct, qualitative method that relies on the ability of the investigator to estimate actual and potential slope failures. When making use of GIS techniques, the following methodological approaches can be differentiated:

Heuristic qualitative approach: particularly suited for small-scale regional mappings and suitable for regional scale planning.

Statistical quantitative approach: are used by consulting firms or planning agencies for the preliminary planning of infrastructural works, such as the definition of road corridors and use the range of 1:25,000 - 1:50,000 scales. This scale can be sub differentiated as data driven multivariate statistical analysis and experience driven bivariate statistical analysis.

Deterministic approach: for detailed studies at large scale (1:2,000 - 1:10,000), without entering at the level of the engineering geological site investigation. Such small-scale studies are used by consulting firms or local planning agencies for the detailed planning of infrastructural works.

3.3.3 Methods

In this study, MRE (1991) has been adopted for Landslide Hazard Zonation. Based on weight of the structural, landuse, slope, Lithological, Hydrogeology, seismo-tectonic and rockslides components for the Rock Hazard and Soil type with slope, hydrogeological, hydrodynamics, thickness of soil, seismo-tectonic, slides and erosional features components are for the soil hazards has been applied for landslide hazard zonation. Table 3.4 shows weight of each component and Table 3.5 Shows the hazard level.

Table 3.4 Weight of the hazard components

Rock slope Hazard Rating

Component	Characteristics	Rating
Geo-mechanical (Lithological)	High rock mass strength Medium rock mass strength Weak rock mass strength	5 7 10
Hydrological	Dry or rain induced No springs, seepage Permanent springs and streams	5 8 10
Seismo-tectonic	Minor fault or fold axis Major fault or fold axis	10 20
Landuse	Forest Cultivated land Dry barren land	0 5 8
Rockslide	Rockslide	12

Soil Slope Hazard Rating

Component	Characteristics		Rating
	Type of Soil	Slope	
Soil type/Slope	Alluvium	< 25 degrees 25-40 degrees > 40 degrees	8 10 12
	Colluviums	< 25 degrees 25-40 degrees > 40 degrees	9 11 13
	Residual	< 25 degrees 25-40 degrees > 40 degrees	10 12 15
Depth	Thick (>6 m) Medium 3-6 m) Shallow (1-3 m)		10 12 15
Hydrological	Dry Rain induced No springs, seepage Rare spring and seepage Permanent springs and streams		5 7 10 12 15
Hydro-dynamical	Low gradient Medium gradient High gradient		5 10 15

Landuse	Forest Dry cultivated land Dry barren land Wet cultivated land	0 5 8 10
Seismo-tectonic	Minor fault or fold axis Major fault or fold axis	8 15
Landslide and erosional gully	Presence of landslides and erosional gullies	15

Table 3.5 Hazard Level

Hazard level	Total rating
Low Medium High	$\leq$ 45 45-65 $\geq$ 66

3.3.4 Result

Because of the flat topography, there is no possibility of landside in Karahiya VDC. The possibility of bank undercutting is common along the riverside especially in the northern parts of the VDC.

3.3.5 Discussion

There is no risk of landslides in Karahiya VDC. But due to the loose nature of the soil there is possibility of bank erosion or bank undercutting. Bank undercutting effect can be seen along sides of the river in the northern parts of the VDC.

3.4 Seismic Risk

Nepal is characterized by complex geological structure with active tectonic process and seismic activities. In seismic vulnerability ranking, it ranks 11th globally most vulnerable countries to earthquake. 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.

3.4.1 Data

The analyzed data has been used from the secondary sources. The data has been produced by maps of Epic centre 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 morphotectonic 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 rupture 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 methods 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: i) Simplest Method, ii) Empirical Method, and iii) 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 Dynamic Analysis Method using the dynamic modelis considered to be the 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).

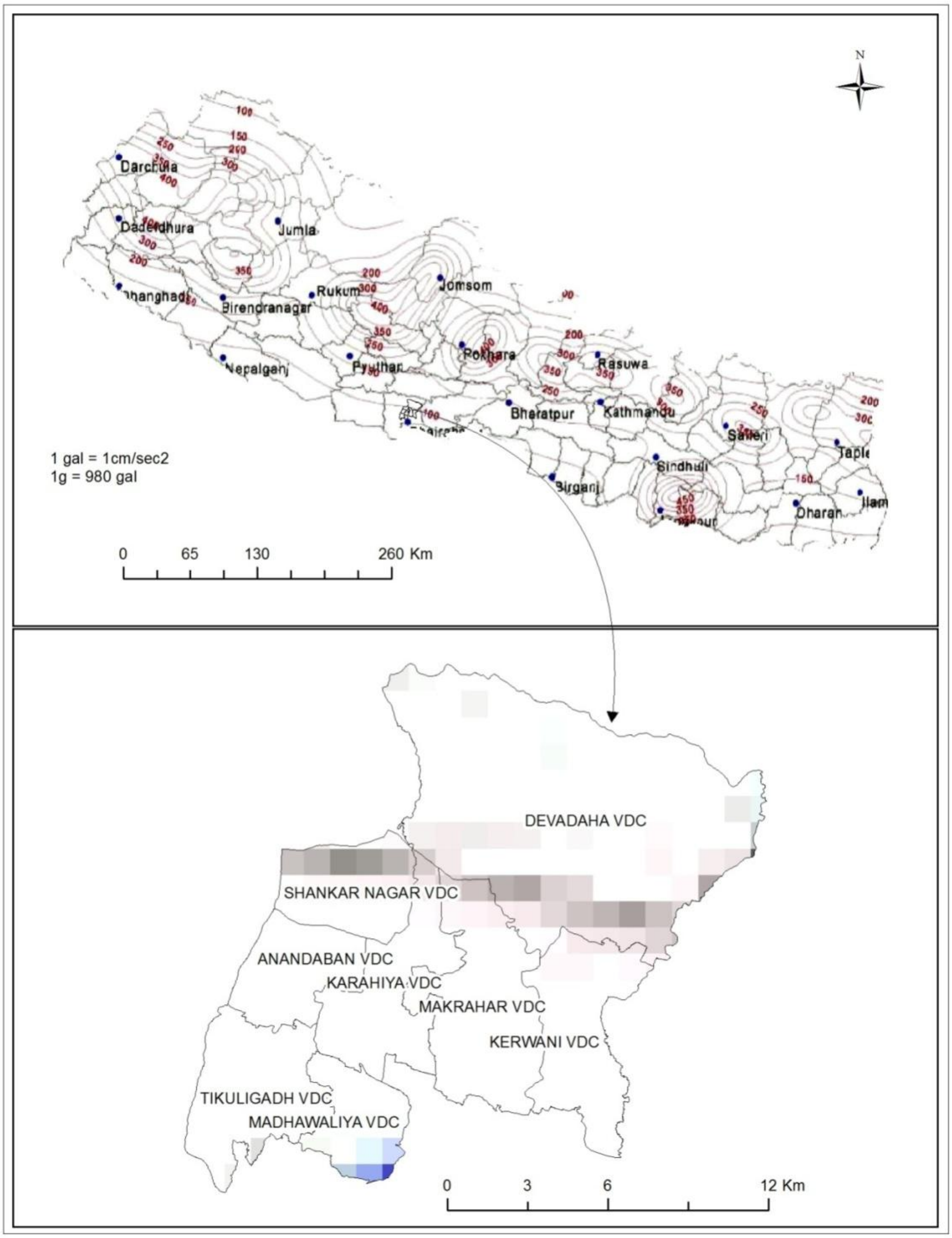

Figure 3.8 Probabilistic Seismic Hazard Assessment Map of the Nepal Himalaya

3.4.4 Result

For the minimum acceleration of 50 gal, reduction factor of 0.50 the calculated effective design seismic coefficient is approximately 0.02.

For the maximum acceleration of 100 gal, reduction factor of 0.50 the calculated effective design seismic coefficient is approximately 0.05. Hence, the design horizontal seismic coefficient ranges from 0.02 to 0.05 (calculated values).

3.4.5 Discussion

Karahiya VDC area falls in the seismic zone of 4, high seismic hazard area.The seismic coefficient in bedrock of the VDC area is considered as 0.020 to 0.050. But the area is composed of fluvial soil so amplification in soil is higher than 20 percent. Therefore, the seismic coefficient is considered as 0.024 to 0.060.

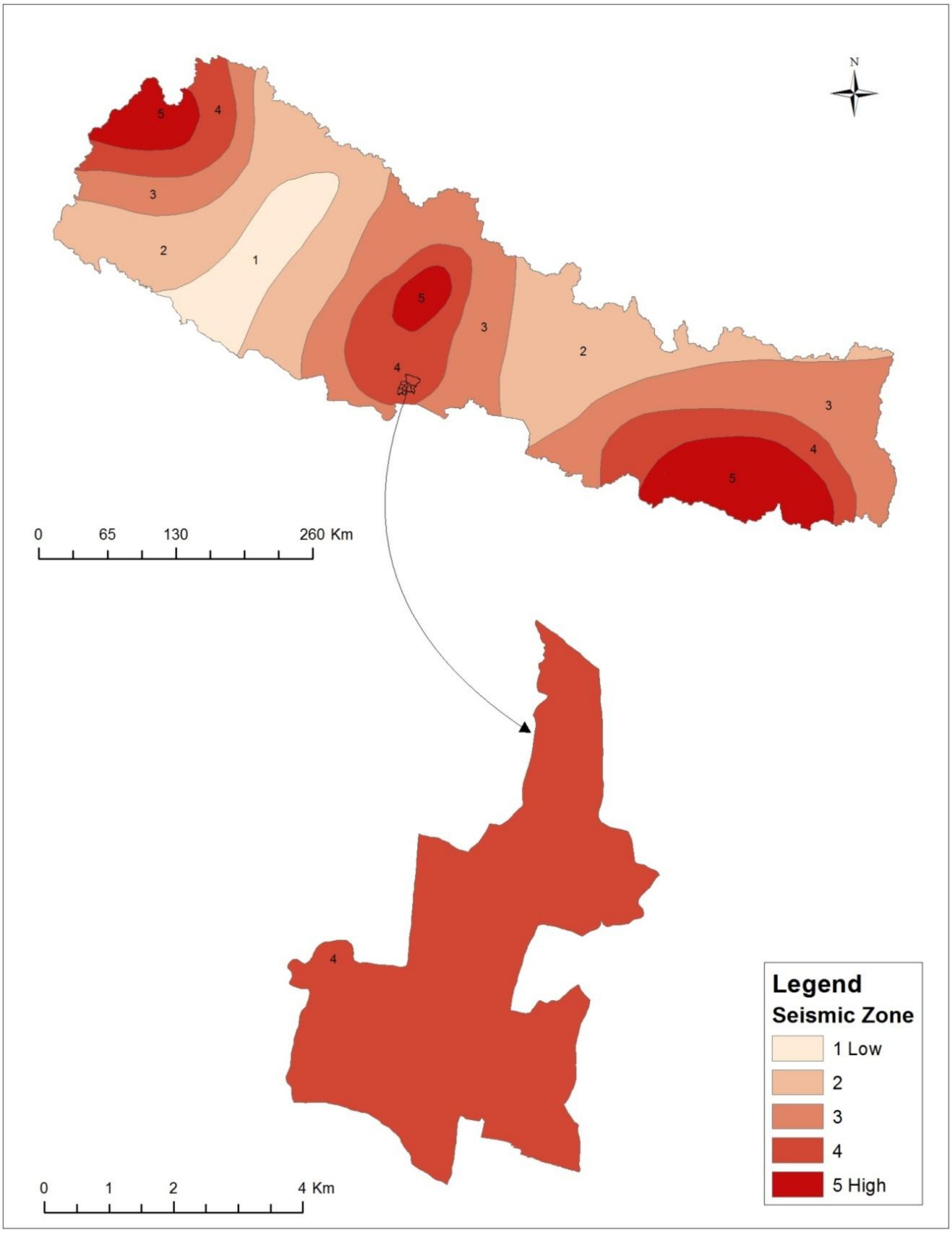

Figure 3.9 Seismic hazard Map of KarahiyaVDC

3.5 Industrial Risk

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 areas nearer to the industries are in high risk in all aspect such as health, environmental, water ecology, agricultural productivity etc.

3.5.1 Data

The relevant data/ information for assessing the industrial risk of the VDC were collected from both primary and secondary sources. Relevant primary data were collected through field survey. The secondary data were collected from published and unpublished sources from official documents, reports, maps including internet sources.

3.5.2 General Approach and Methodology Framework

The general approaches for the industrial risk layer data collection includes the following:

- Identification of Industrial area
- Identification of Industrial type and category
- Identification of environmental risk, risk characterization and environmental effects.
- Identification of probable industrial area risk area

The following methodological framework was applied for the analysis of industrial risk

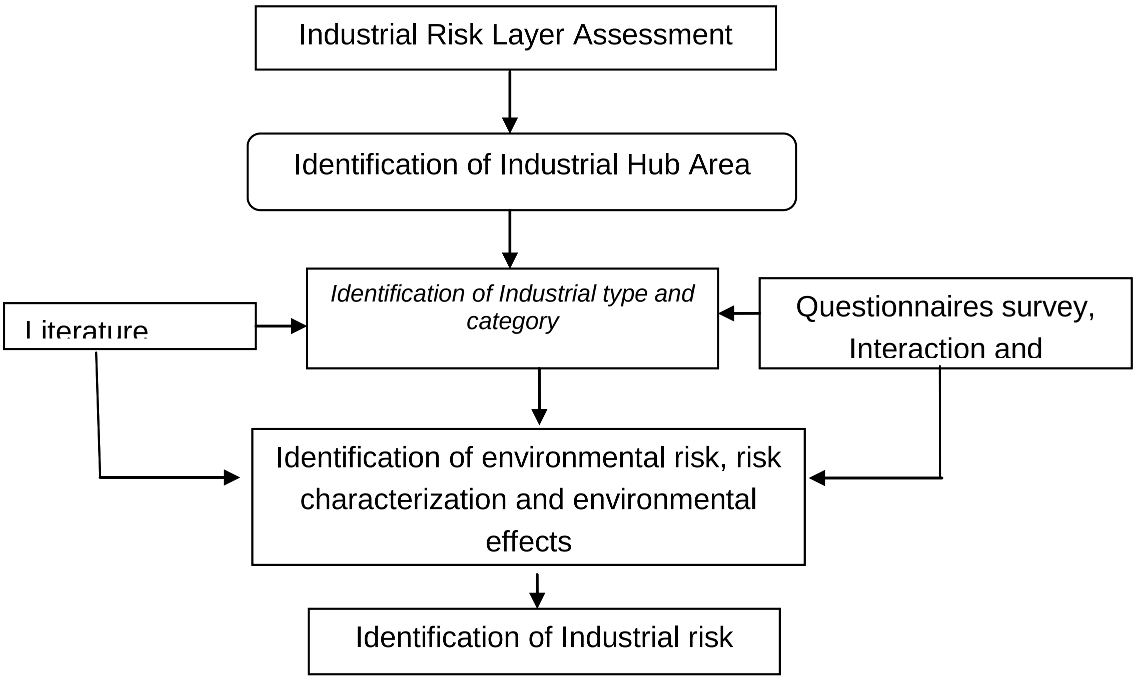

Figure 3.10 Methodological Framework for Industrial Risk assessment

3.5.3 Methods

The relevant information for assessing the industrial risk was collected from both primary and secondary sources. Relevant primary data were collected through field survey. Consultation with government representatives at various levels, experts and professionals, local communities and industrial stockholders were made during field visit. Likewise, information regarding impact status and extent of impact was collected from community forestry user groups and local communities using interactive methods. Extensive field observation was made and visible environmental impacts created by the industry were observed. In addition, varieties of secondary sources were also reviewed. These sources include books, unpublished reports, Journals etc. Similarly, different types of maps such as topographical map and images were also used. Relevant information has also been drawn from different internet Web Pages.

3.5.4 Result

In this Karahiya VDC, there arethree industries including Siddhababa distillery industry. This may cause air and water pollution and impact on different sectors of human life directly or indirectly.

Table 3.6: List of industries with major pollution type in Karahiya VDC

Industry	Probable Major Pollution Type	Probable Risk areas (from centre)
Arun food pvt	-	-
Lumbini Concrete Pvt. Ltd	-	-
Siddhababa distillery	Air and water pollution	400m

3.5.5 Discussion

The distilleryindustrylocatedin this VDC is the main source of different types of pollution causing various types of environmental impacts. The magnitude of industrial risk is higher at the production site and vice versa. The risk due to air pollution depends on meteorological parameters especially of wind direction and velocity, temperature, humidity, rainfall, cloud coverage and solar radiation which determine the dispersion, diffusion and transportation of particulate matter and emissions into the atmosphere. The industrial growth in the future, could lead further degradation of environment. The proper control measures should be adopted to minimize the risk of industrial pollution in the surrounding area.

3.6 Other Risk in the Study Area

As noted above, Nepal is characterized by complex geological structure with active tectonic process and seismic activities. The sharp vertical landscape renders the country highly vulnerable and disaster prone due to its fragile geology and steep topography. Nepal is highly exposed to multiple hazards- earthquakes, floods, landslide, and fire including industrial hazards. Besides,in recent years, increasing evidences of wind storms, draughts, and hot and cold waves are being common as caused by climate change. Disease outbreak is also evident in the country. However, except the five risks discussed above no other area specific risks were identified within the VDC studied.

CHAPTER 4: RISK IN THE STUDY AREA

4.1 Existing Risk in the Study Area

The existing risks in the Kahariya VDC area are analyzed through the composite mapping of the all five possible hazards. The present analysis revels that the whole VDC area falls under the high seismic risk zone but there is no risk of landslides at all except few bank cutting in the northern parts of the VDC along the river. Some parts of this VDC is liable to flood; however, as reported, flooding is not frequent in the VDC. The flood discharge for return period 100 years was calculated using WECS/DHM method entering steady flow datashows that a total of 51.65ha of different types of land are liable to inundate during high flood period. However, high flood in this VDC is not common.This VDC is not free from fire hazards;however, it was not possible to identify the VDC wisehot spots for fire risk.Both natural and anthropogenic factors are responsible for fire hazards. Theimproper management ofcrop residue,feeding cooking stoves withrich husks and packed long cow dung,outdoorcooking throughout the day and other causes are the main reasons for firing in this area. Houses made with wood and thatches are more prone to fire disaster. Concrete buildings are also in risk of firing because of the defective electric wiring and equipments, and improper management of LPG gas and ignorance, however, the risk is low as compared to houses mentioned above.Similarly, the areas resided by poor peopleare always in the high risk of firing. On the other hand, the settlements near by the forest areas are also proneto fire hazard. The industrial risk is not prominent in this VDC.Areas within the perimeter of 400m from center of the distillery industry are prone to industrial hazard. The composite risk map (Figure 4.1) shows the general scenario of existing risk status of the Karahiya VDC.

The result acquired through the analysis reveals that the areas along the rivers and nearby industrial establishments are risks prone. Construction of River embankment is essential to protect the settlements more prone to floods and preventive measures needs to apply to reduced industrial risks.

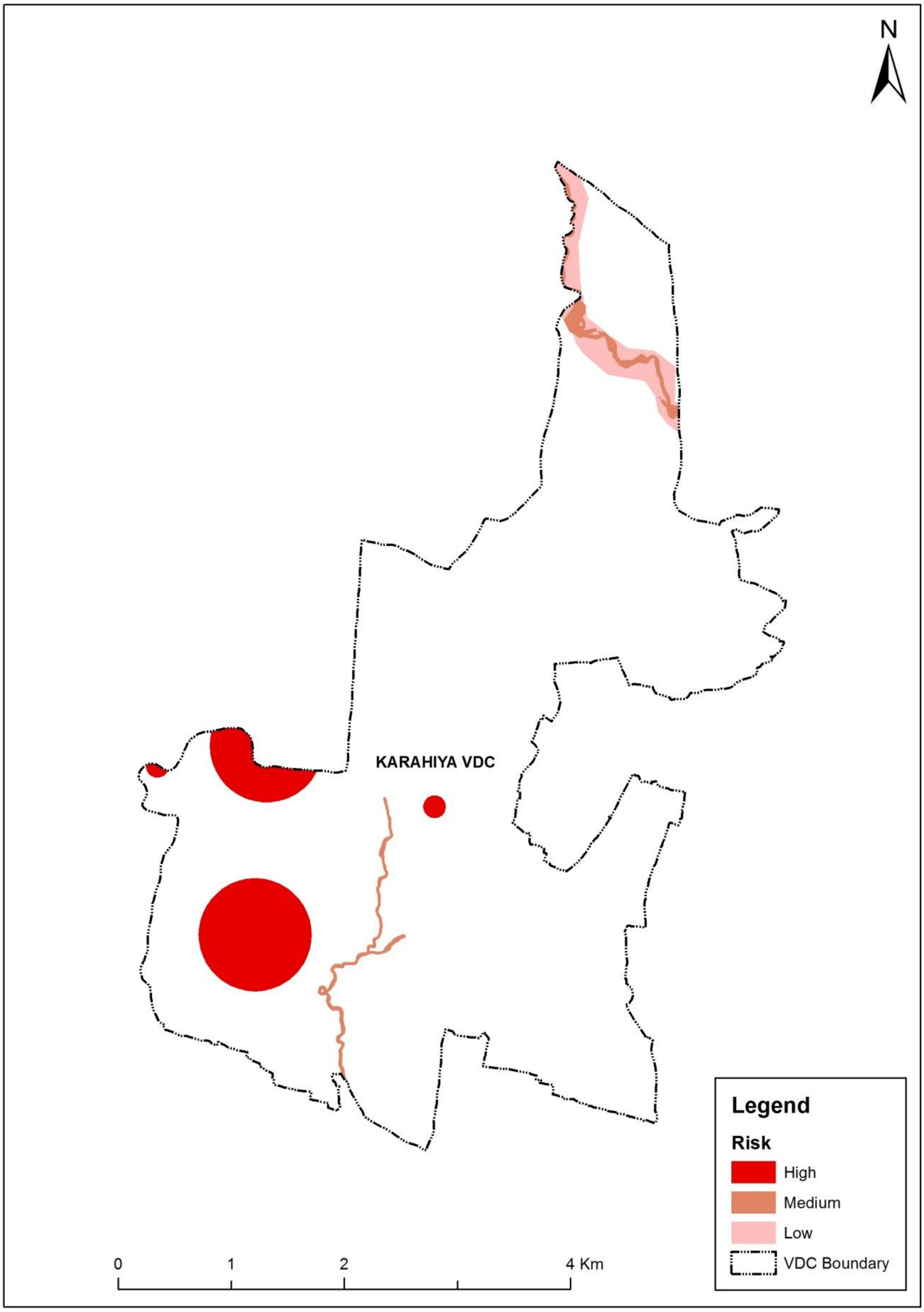

Figure 4.1 Composite of risk layers in Karahiya VDC

4.2 Potential Risk in the Study Area

The identification of potential risk in the study area is the prime importance with a view of land use management. However, this task is not easy because of uncertainty of the nature as nature may not follow the hazard/risk model developed by the human beings.The modeling of the existing risk areas can help to estimate or predict the potential risk areas and implement precaution measures that help reducing potential loss and damages to some extent. Based on the existing assessment of the risk factors in the project areas it can be concluded that the existing areas prone to hazards are prone to future potential risks as well. However, the existing risk areas identified through the mapping of available informationmay not be sufficient for future land use zoning especially for residential, commercial or public service areas. These hazard risk areas could be suggested for forests, plantations or as the open spaces.

4.3 Risk Data Model

The structure of model developed for Risk data is shown in Table 4.1. The data model includes data fields, data types and their description. Necessary remarks are also provided for clarification of the subject.

Table 4.1 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

The different components or attributes of risk GIS database is shown in 4.2. GIS database for risk factors was prepared at two levels: risk factors at level 1 and their level of intensity by VDC at level 2. With this geo-database, the risk layers and maps were generated. GIS database was created and maintained systematically in computer with geo-referenced spatial data linked to attribute data. Hazards maps were created and stored maintaining shape files in Arc GIS platform.

Table 4.2 Risk GIS Database

Description	Level 1	Level 2	VDC	District	Remarks
Fire	Fire	High Medium Low	Name of VDC	Name of District	
Flood	Flood	High Medium Low	Name of VDC	Name of District	
Landslide	Landslide	High Medium Low	Name of VDC	Name of District	
Seismic	Seismic	High Medium Low	Name of VDC	Name of District	
Industrial	Industrial	High Medium Low	Name of VDC	Name of District	
Other	Other	High Medium Low	Name of VDC	Name of District	

CHAPTER 5: CONCLUSIONS

5.1 Conclusions

Nepal is highly exposed to multiple hazards as earthquakes, floods, landslide, and fires including industrial development are the common hazards in Nepal. Besides,in recent years, increasing evidences of wind storms, draughts, and hot and cold waves are being common as caused by climate change. However, except the five risks discussed above no other area specific risks were identified within the VDC studied. The present studyhas attempted for risk mapping of the VDC area based on the available data and the data generated from the field visit. Based on the types of factors causing an area to expose into vulnerability and hazard associated within it, risk can be classified into various categories. However, for the present land use mapping process, five main risk factors maintained aboveare analyzed.

Existing risks in the project areas are analyzed through the composite mapping of the all possible hazards. So far as the seismic risk of the project area is concerned, the whole project area falls under the high seismic risk zone. Firing is the common hazard of Terai area; however, it was not possible to identify the VDC wise hot spots for fire risk.Main reasons identified for firing in this area are both natural and anthropogenic especially the ignorance of the people. Houses made with wood and thatches are more prone to fire disaster. Poor handling of fire for cooking and other purposes, electrical short circuits, poor wiring, poor handling of gas cylinders and stoves, human negligence and lack of adequate fire safety measures are the major factors contributing to the outbreak of fires.Concrete buildings are also in risk to firing; however, the risk is low as compared to houses made with wood and thatches.Likewise, the areas resided by poor people are always in the high risk of firing because of the use of thatch and wood as the building materials. The settlements near by the forest areas are also prone to fire hazard.Though there is adistillery industry in the VDC, the industrial risk is not found prominent. Likewise, thisVDChas no risk of landslide as it is located entirely in the flat plain but bank cutting in the northern parts of the VDC is liable however, flooding is not frequent in the VDC.

The identification of potential risk areas are predicted based on the assessment of existing hazard/risk areas of the studied VDC. The existing risk areas identified through the mapping of risksmight not be appropriate for zoning residential, commercial or public use purposes. These hazard risk areas could be suggested for forests, plantations or as the open spaces.

The database prepared from the present exercise could be used for planning; analyzing and decision making process on the sustainable, equitable and economic use of the precious land resources and land development of the VDC.

5.2 Recommendations

Based on the present experience and the exercise, the following recommendations are made.

- Considering the firing risk of this area, settlement area must be built in clumped pattern with appropriate spacing which will reduce the firing risk in the whole area. Along with this, artificial ponds, wells must be built to use water for controlling fires if it occurs suddenly.

- The present exercise produced preliminary results on the risk areas of the selected hazards. These outputs could be used for the purpose of the present exercises for delineating the land use zoning of the VDCs.

- Future users of the data set are recommended tocarefully notice the limitations of the datasets and use accordingly for analyzing in depth studies of their researches based on the present data sets for the analysis of the risk areas.

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Land Use Zoning

FINAL REPORT

Preparation of Land Use Zoning

Karahiya VDC of Rupandehi District

FOR

Consulting Services

for

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

Package No: 11

Anandaban, Devadaha, Karahiya, Kerwani, Madhawaliya, Makrahar, Shankar Nagar, Tikuligadh, of Rupandehi District (8 VDCs)

Preparation of Land Use Zoning
Karahiya VDC of Rupandehi District

This document is one of the outcomes of the project entitled **Preparation of VDC level Land Resource Maps** (Present Land Use Maps, Soil Maps, Land Capability Maps, Land Use Zoning Maps and Cadastral Layer Superimpose and VDC Profile), **Database and Reports** of Package 11 awarded to SHREEYA-KRS JV by the Government of Nepal, Ministry of Land Reform and Management, National Land Use Project (NLUP) in Fiscal Year 2072-073. The VDCs covered under this package include eight VDCs of Rupandehi district namely: **Anandaban, Devadaha, Madhawalia, Makrahar, Karahiya, Kerwani, Sankar Nagar and Tikuligadh**.

Mr. Kul Bahadur Chaudhari was involved and solely credited for the preparation of maps, database and reports on risk themes.

The VDC areas analyzed for different themes of the NLUP Project are computed from cadastral maps provided by DOLIA Office of Nepal. Therefore, the areas of the VDCs may not be the same as computed from Topographic Database provided by the Survey Department of Nepal.

ACKNOWLEDGEMENT

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The consultant would also like to thank the local people, members of the different political parties and staffs of the VDCs and local institutions of **Karahiya VDC** of Rupandehi District for providing their valuable time to the study team in discussing different aspects of the project. Without their support this work would not have been completed.

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CHAPTER 1: INTRODUCTION

1.1 Background and Rationale

1.1.1 Background

Land is a basic resource and livelihood base for almost tree-fourth of the population in Nepal. Lack of physical infrastructure like irrigation facilities, scattered small sized land parcels and subsistence farming practices have resulted in low agricultural productivity. Increasing demand of agricultural production as caused by population growth cannot be fulfilled due to low rate of agricultural production resulted in food deficit and insecurity in the future. High rate of migration from hilly region to fertile land of Terai has created unplanned settlement and increasing loss in agricultural area and production. At the same time, encroachments on public and government lands (like forests) for squatter farming and settlement have been alarming.

Nepal being a developing nation, massive urban land has been encroached as slums and real estate markets. This activity has been flourished in Nepal since last two decades specifically in large municipalities and fringe areas. As land is the pivotal for economic development, almost all economic activities in these areas depend on lands. There has also been rising unsystematic and unhealthy real estate business in the absence of effective land use planning and zoning. The provisions of utility services are very poor in the developmental areas due to lack of updated planning and monitoring. All these facts have resulted in serious problems on settlement pattern and have resulted in environmental deterioration. The state being the guardian of development, it needs to pay serious attention to face, overcome and tackle the ever growing problems.

The Government of Nepal 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 and 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. Improper use of lands in many places have been causing varieties of disasters such as landslides and flooding. If situation continues, Nepal has a serious threat to face varieties of problems including food insecurity and hunger 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 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.

1.1.2 Rationale

Government of Nepal has identified land use zoning as an important device to design a detailed land use plan and devise its policy. This policy is expected to be implemented 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 rationales of the 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.

The Government of Nepal has approved the National Land Use Policy, 2069 on the 4th Baisakh of 2069. It has intended to manage land use according to land use policy of the Government of Nepal and had outlined six zones such as *Agricultural area, Residential area, Commercial area, Industrial area, Forest area and Public use area*. However, based on the scenario developed after the major earthquake of 12th of Baisakh2072, the Government of Nepal has re-directed for possible amendment on the existing Land Use Policy, 2069 which possibly may also emphasize the safe and secure settlement along with the environmental protection and ensuring of food security. Moreover, the Land Act 2021 (Sixth amendment) have mandated for designation of more than six land use classes, some of which obviously differs from what exist in the National land use policy, 2069. NLUP at present endeavors on the same to maintain the essence of the proposed amendment on the National Land Use Policy and as mandated by the Land act 2021 (Sixth Amendment) at the same time with the strategy of completion of land use mapping within 5 years to come as directed by the parliamentary committee in 2071.

The different land use zones as per the Land Use Policy, 2072 are made in appropriate hierarchy as per the requirement of the data model provided by the NLUP Office. As per the Land Use Policy - 2072, the hierarchy of 11 types of fundamental land use zones are such as Agricultural Zone, Residential Zone, Commercial Zone, Industrial Zone, Mining and Mineral Zone, Cultural and Archaeological Zone, Riverine and Lake Area, Forest Zone, Public Service Zone and Others.

In the context stated above, the JV of Shreya Consultancy (P) LTD- K.R.S. Engineering (P) LTD has been commissioned to pursue the project entitled *Preparation of VDC level land resource maps, databases and reports for Package 11* (Anandaban, Devadaha, Karahiya, Kerwani, Madhawaliya, Makrahar, Shankar Nagar and Tikuligadh, Eight VDCs of Rupandehi District) by National Land Use Project (NLUP) Office, Kathmandu.

1.2 Objectives and Scope of the Study

1.2.1 Objectives

The main objective of the study is to carryout land use zoning; prepare land use zoning maps, GIS database and reports of Karahiya VDC of Rupandehi district of Nepal. The specific objectives of this study are:

- To perform land use zoning of Karahiya VDC by using different available data sources 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 National 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.

1.2.2 Scope

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.

1.3 Study Area

Karahiya VDC lies in Rupendhei district, Lumbini Zone. The VDC has currently included in Tilottama Municipality. And it is known for ward no. 9, 10, 11 & 12 of the municipality. It is located between 83° 27' 50” to 83° 31' 20"E longitude and 27° 35' 20” to 27° 35' 58" N latitude. The VDC is bordered by Makrahar & Gangoliya VDCs to the east, Anandaban VDC to the west, Andandaban & Devadaha VDCs to the north and Madhawaliya &

Gangoliya VDCs to the south. The VDC covers a total area of 2082.81 ha. The extension of the VDC is 4.7 km and 8.8 km in east-west and north-south respectively.

According to the population census 2011, the total population of the VDC was 18274 with 4267 households. Of the total population, the percentage of male is six percent lower than the female. The population of this VDC is composed of different caste/ethnic groups. Among them, Brahmin is in majority. The proportion of migrants is significant in the total population. Migrants were mainly from from Palpa, Gulmi, Arghakhachi, Baglung, and Parbat. Ninety-five percent people follow Hinduism. People are involved in many occupations. More than half of the total populations are involved in agriculture. And it is the main source of income. Almost one-third of the total income comes from agriculture sector.

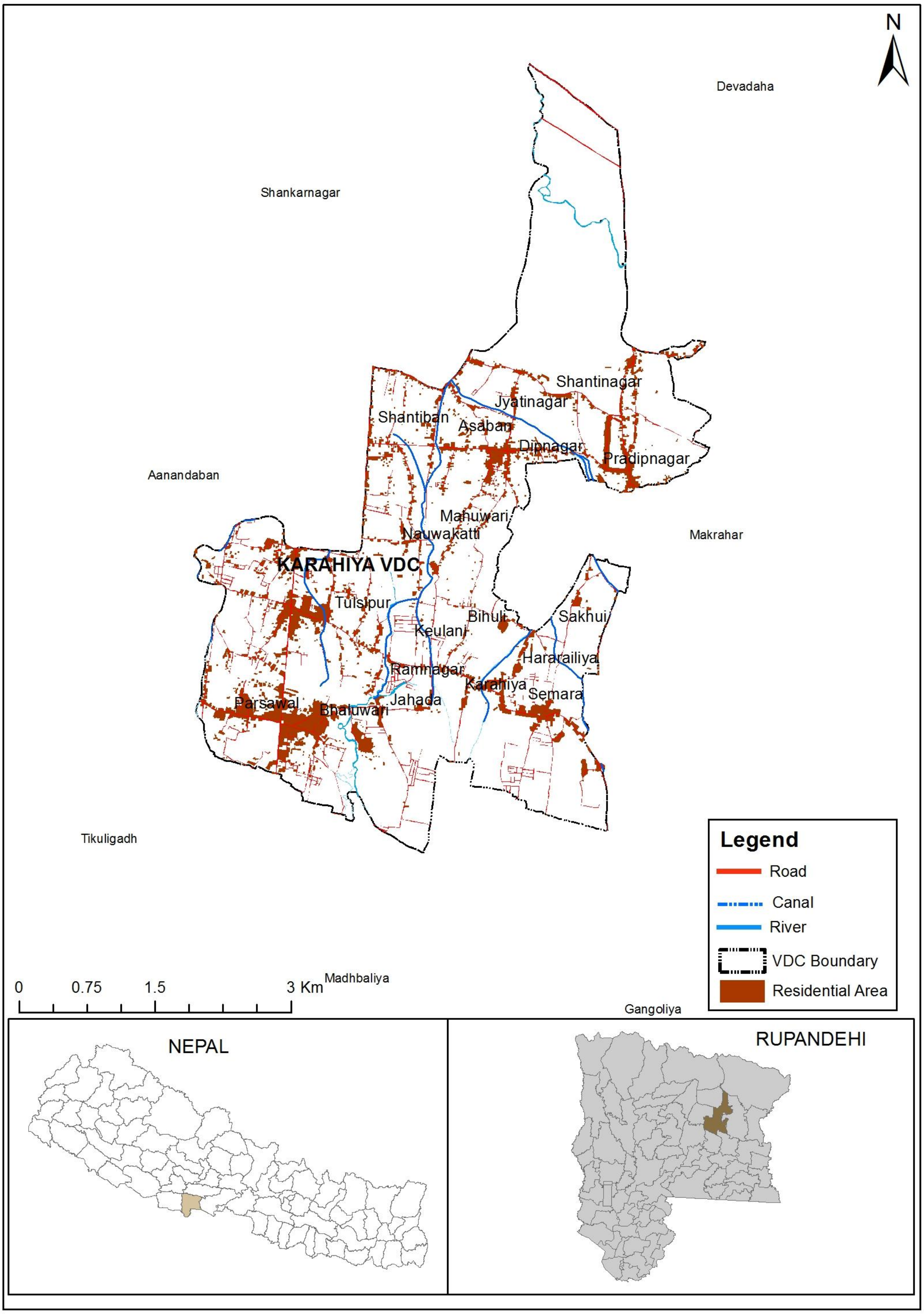

Figure 1.1 Location of Karahiya VDC

CHAPTER 2: CONCEPTUAL BASIS OF LAND USE ZONING

This chapter presents the conceptual basis and principles of land use zoning. It explains the land use zones and their detailed description as mentioned in the National Land Use Policy 2072 and also highlights on the general criteria used for land use zoning.

2.1 Land Use Zoning, Principles and Criteria

2.1.1 Land Use Zoning

Zoning is a technique of land use planning used mainly by the local governments in most of the developed countries. It is the practice of assigning permitted uses of land based on official zoning record which separate one set of land uses from another. Land zoning is how local institution, such as Village/ Municipal/ District Councils restrict the physical development and use of specific parcels of land.

Land use zoning determines the types of activities (such as agricultural, residential, commercial or industrial) that can occur on the land. Theoretically, the primary purpose of zoning is to separate land uses that are thought to be incompatible to each other. A detailed map or plan may be prepared showing different allocated use on the particular land or territory. As such, the zoning map portrays and reflects both current conditions and anticipated conditions.

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 on the basis of land capability and suitability analysis. The zonation of land is further supported and regulated by specific regulations which ensure designated use of each particular zone category.

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.

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 specific legislation.

2.1.2 Land use Zoning Principles

The main principles adopted for land use zoning are as follows:

- Promotion of complementary land use
- Maintain competitive land use
- Avoid conflicting land use

Moreover, land use zoning process specifically adopts the following spirit and follows these principles:

- Identification and protection of prime land areas for suitable agricultural crop production.
- Development of stable, attractive, safe and secured residential neighborhoods which contain a range of supportive commercial, institutional, and public facilities
- Development of stable and functional commercial centers based on site suitability and compatibility with adjacent land uses.
- Identification, development and protection of prime land areas for future quality industrial growth based on site suitability and compatibility with adjacent land uses.
- Protection of natural resources and environment for green and eco-friendly society
- Protection and conservation of cultural, religious and archeological heritages for future generations
- Appropriate management of river, water bodies, wetlands and watersheds for sustainable future use
- Provision of appropriate location and distribution of public facilities such as transportation, parks and schools throughout the community.
- Promotion of rehabilitation and improvement of the living environment in older neighborhoods and areas characterized by conflicting patterns of land use.
- Promotion of land use activities appropriate to the features and characteristics of the natural landscape.
- Appropriate management of mines, minerals and other land based resources for optimum use and support sustainable development
- Support and promote consistency between the Land Use Plan and current land use pattern.
- Provision of adequate transitioning and buffering between residential/ commercial uses and industrial uses.
- Promote growth in areas adjacent to existing urban development so that public services and facilities may be provided efficiently and economically.

2.1.3 Land use Zoning Criteria

Based on the above mentioned objectives, principles and description of land use zones, zoning is carried out adopting the following broad guidelines:

- The zoning of the VDCs should not contradict with the essence of the National Land Use Policy, 2072.
- In identifying potential residential zone a model based on the growth of built-up area in last ten years and infrastructure development within the area should be used.
- The existing forest land should be kept intact in the zoning.
- Based on the soil suitability analysis the prime agricultural lands should be preserved for future food reserve.
- Emphasis should be made to allocate less or unproductive barren lands and areas of marginal productivity for future residential, industrial, commercial and public service zone.
- Analysis of hazard risk must be done before working on zoning. Mainly the flood, landslide, erosion, seismic, fire and industrial hazard should be taken into account. Zoning should be done in such a way that the land use zones with human activities should be restricted to the areas with low hazardous or hazard free area as much as possible.
- Sufficient land should be zoned at appropriate locations throughout the study 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. 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 development 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.

Based on the above guidelines, the general criteria for zoning are as following:

1. Agricultural Area

a. Most of the agricultural areas are kept intact but it is almost impossible to retain all agricultural areas as some of the newly proposed residential, commercial, industrial and public use areas are proposed on the agricultural land. It is essential to address the needs of housing, marketing, employments, public utility development and other economic activities besides agriculture for the growing population. Therefore, the agricultural areas may be slightly decreased. However, we need to retain the most arable agricultural land and marginally capable lands should be used for infrastructure development.

b. Within the agricultural land, the area of comparative advantage can be identified on the basis of land capability, land system, temperature, irrigation and drainage system, and other physical, chemical parameters of soil. Extensive discussions are done with agriculture experts and their opinion is taken to do further sub classification of agricultural land.

2. **Residential Area**

a. The existing residential area is kept intact if they are risk free or at low risk. Generally, the settlements in the local area or villages are established on the basis of inherent indigenous knowledge, they are generally safe and the infrastructures are already available in many of the areas. Therefore, these settlements are kept intact.

b. Keeping the local population growth and flow of internal migration to the area in mind and looking at the rate of built-up development in the area during last 10 years, some new settlements are proposed. Some of the criteria to identify appropriate land for new settlements are:

i. The land should be free from or at low hazard risk as much as possible
ii. The area should be in the neighborhood of the existing settlement, if possible
iii. Availability of road and infrastructures if possible
iv. The area should not in the flood plain of any river
v. The area should be geologically stable
vi. The area should not be in the vicinity of dense forests, petrol pump, transmission lines, fault line and industrial areas as much as possible
vii. The land should be of marginal utilization, i.e. the land should be less capable for agricultural crop production

3. **Commercial Area**

a. The existing commercial area is kept intact as they are already establishes according to the necessity of the local people in or near residential areas.

b. For the future planning, the land is allocated for the new commercial and business areas including government institution on the basis of the following criteria:

i. The land should be free from or at low hazard risk as much as possible
ii. The areas should be in the neighborhood of residential area, number of household and population should be considered
iii. Availability of road and infrastructures if possible
iv. The area should not in the flood plain of any river
v. The area should be geologically stable
vi. The area should not be in the vicinity of dense, petrol pump, transmission lines, fault line and industrial areas as much as possible
vii. The land should be of marginal utilization, i.e. the land should be less capable for agricultural crop production

4. **Industrial Area**

a. Most of the existing industries in the rural area are small and are agriculture based. The impacts of these industries on human activities are not much prominent. Therefore, the existing small industries are kept intact. Most of the heavy industries are already either far from settlement or they are managed in such a way that the impact should be less on the human activities. Such kind of industries, if found affecting human life, will be recommended to relocate.

b. For the proposed industrial areas, the following criteria are chosen:

i. The land should be free from or at low hazard risk as much as possible

ii. It should be in the neighborhood of existing industrial area (if it is already suitable)

iii. It should not be in the vicinity of residential and commercial area but within the approachable distance from market and settlements with infrastructures

iv. The area should have accessibility to roads if possible

v. The area should not be in the vicinity of rivers, ponds or any other water sources and dense forest as well as in the vicinity of petrol pump, transmission and fault lines

vi. The land should be of marginal utilization, i.e. the land should be less capable for agricultural crop production

vii. Geologically stable

viii. The proposed industrial area should not be in the international boundary but can be in the bordering area of two or more administrative units (VDC/Districts) so that there would be opportunity to share benefits of the resources of both administrative units

5. Forest Area

a. Existing forests are kept intact

b. New forests or plantation are proposed mainly on the basis of the following criteria:

i. Barren lands, Wetlands, Abandoned lands

ii. Slopping land, watershed, high mountains

iii. Flood and erosion prone river banks

iv. Other lands of marginal utilization

v. Sides of roads, canals etc., if possible

vi. Near or around industrial areas to make natural protection from pollution

vii. On the land under high or medium hazard risk

viii. Other suitable areas for agro-forestry or timber production etc.

6. Public Use zone

a. Existing public use areas are kept intact

b. Some of the new public use areas such as Health, Education, open area etc are proposed on the vicinity of existing and proposed residential/commercial/industrial areas wherever appropriate.

c. Mostly, these types of service areas are located on the basis of the necessity and requirement of the local people. Therefore, this category is suggested to be planned after discussion with local community using participatory approach.

7. Mining and Minerals Zone

a. Existing Mining and Minerals areas as defined and described by National Land use Policy 2072

b. Identified and prescribed areas as potential Mining and Minerals area in future

8. **Cultural and Archaeological Zone**
    a. Existing religious, cultural, archeological areas as defined and described by National Land use Policy 2072
    b. Area defined as cultural heritage and their master plans
9. **Riverine and Lake Area Zone**
    a. Existing Riverine and Lake Area as defined and described by National Land use Policy, 2072

10. **Excavation (Construction Material) Zone**
    a. Existing areas as defined by National Land Use Policy, 2072
    b. Areas prescribed and allocated by the national/local government for such use
    c. Areas found appropriate from expert's study for such use in future

11. **Other Zone prescribed as required**
    a. As per the prescription of experts and decision of the government
    b. If any land use cant not be fit in any class mentioned above

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 Zone**

The agricultural zone means the area where there is a presence of agro products (food grains, cash crops, horticulture, etc.), animal husbandry, fisheries, agro and forest products or orchards in a private land. This word also indicates a region prescribed by the government as an agricultural zone.

2. **Residential Zone**

Residential zone means the land used by people for shelter or housing and the word also includes animal shed, food container, garage, stable, well, tap, orchard, backyard, courtyard or land with any other use whether joined with the house or separate. This word also denotes a collective housing or apartment built by a business company or institution, and also to a specific land declared by the government for housing purposes.

3. **Commercial Zone**

Commercial zone means the land occupied by or allocated for shops, hotels, exhibition stalls, petrol pumps, warehouses, health and information facilities, commodities trade centre, an organization providing any literary, scientific or technical service or advice, fair venues, discos, clubs, swimming pools, cinema halls opened for business purposes, entertainment joints or any other building meant for commercial use. This word shall also include a commercial building built in a trade zone by a business company or institution and the land occupied by the same. Moreover, this word shall also indicate an area declared by the government to develop a city for market expansion and commercial use in a definite geographical region.

4. **Industrial Zone**

Industrial zone means the land occupied by or allocated for any workshop, goods manufacturing industry, the associated buildings and sheds. This word also denotes an industrial corridor, industrial village, cluster, special export zone and special economic zone declared by the government for industrial promotion in a definite geographical region.

5. **Mine and Minerals Zone**

Mining and minerals zone means a land being used for mining, production or processing of minerals or area declared by the government as a mining and quarrying zone definite geographical region. This word also includes any area where mineral deposit is discovered or a mine is operational, where industries for mining, production, processing and purification of minerals are being located as well as the associated buildings, sheds as the land being used for the operation of such industries as well.

6. **Cultural and Archaeological Zone**

Cultural and archaeological zone means the forts, palaces, buildings, temples, shrines, mosques, monasteries, Manes, with a historical and archaeological significance as well as other pilgrimage sites and places of worship. This word also implies an area declared by the government as a historical, cultural, religious and archaeological place in a definite geographical region.

7. **Riverine and Lake Area Zone**

Riverine and Lake Area zone means an area where rivers, rivulets, streams, canals, lakes, ponds, long-holding swamps or wetlands are existent.

8. **Forest Zone**

Forest zone means an areas being covered with public, community, leasehold forests in part or entirety, national parks, wildlife reserves, conservation areas, bushes, shrubs, plains, all types of jungles and places designated by the government as a forest regardless of whether there are trees or not. This term also infers an area nominated by the government for the expansion of forests or green areas, in a definite geographical region.

9. **Public Use Zone**

Public utilities and open zone means land occupied by schools, colleges, vocational educational centers, academic institutions including the universities, security agencies, health centers, health posts, private or community hospitals, telecom, drinking water, government agencies involved in providing electricity or other energy, community buildings, libraries, old age homes, child protection homes, other buildings, sheds, platforms erected for public use. This term also includes the hills, meadows, cliffs, mountains, snow covered areas, pastures. The word also denotes playgrounds, parks, stadiums, grounds, platforms, picnic spots, open places having no special use, district roads, rural roads, bus parks, airports, cargo areas, dry ports, railways, ropeways, waterways, cable cars, electricity transmission lines, ports and the places designated as public utilities zone by the government or prevailing laws.

10. Excavation (Construction Materials) Zone

Excavation (Construction Material) zone means the area designated for quarrying, production or processing of stones, pebbles and sand as per the determined standards, or any other place designated by the government as an aggregate quarrying zone (stones, pebbles and sand) in a definite geographical region.

11. Other Zone Prescribed as Required

Other Zones prescribed as required mean the areas that do not fall under any of the above land use zones but which need to be mentioned as an exclusive land use zone. This term also implies an area with mixed characteristics. Mixed zone means the areas where the residential and business zones have merged so seamlessly that they cannot be bifurcated as is seen now in various cities, towns, highway areas. This zone shall be applied only for regulating settlements and market areas that have been since the past.

In this study, the instructions of National Land Use Policy 2072 are followed and categorized the study area on the following zones and sub-zones as shown in the table 2.1.

Table 2.1 Land use zoning scheme of the study area

Class	Zone	Zone Type	Code	Sub zone	Description	Remarks
1	Zone 1	Agricultural Zone	AGR	Zone 1A	Cereal crop production area	
				Zone 1B	Cash crop area	
				Zone 1C	Horticultural area	
				Zone 1D	Animal husbandry area	
				Zone 1E	Fish farming area	
				Zone 1F	Agro forestry area	
2	Zone 2	Residential Zone	RES	Zone 2A	Existing residential zone	
				Zone 2B	Potential area for residential zone	
3	Zone 3	Commercial Zone	COM	Zone3A	Governmental institutions and service areas	
				Zone 3B	Business area	
4	Zone 4	Industrial Zone	IND	Zone 4A	Areas under industrial use	
				Zone 4B	Potential area for Industrial zone	
5	Zone 5	Forest Zone	FOR	Zone 5A	Existing forest	
				Zone 5B	Potential area for forest including barren lands, wet lands etc.	
6	Zone 6	Public use Zone	PUB	Zone 6A	Areas under roads, railways, bus parks, airport and land fill site etc.	
				Zone 6C	Open spaces, picnic spots, playing grounds and stadiums etc.	
				Zone 6E	health/education/library, police station, fire station, telephone /electricity areas etc.	
				Zone 6F	Grazing Land	
7	Zone 7	Other area	OTH	Zone 7	as per requirement	if necessary

Class	Zone	Zone Type	Code	Sub zone	Description	Remarks
8	Zone 8	Mining and Minerals Zone	MIN	Zone 8A	Existing Mines and mineral area	
				Zone 8B	Potential areas for Mines and mineral	
9	Zone 9	Cultural and Archeological Zone	CULARCH	Zone 9A	Existing cultural and archeological area	
				Zone 8B	Potential cultural and archeological areas	
10	Zone 10	Riverine and Lake Area zone	HYD	Zone 10A	Existing rivers and riverine area	
				Zone 10B	Potential hydrographic areas	
11	Zone 11	Excavation (Construction Materials Zone	EXC	Zone 11A	Existing quarrying and excavation area	
				Zone 11B	Potential areas for quarrying and excavation	

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

Various data sources are used in this land use zoning exercise. The major data sources include:

- Ortho-rectified very high resolution satellite image World View-2 of the study area,
- GIS vector data (shape file) of mainly land capability, land system, present land use, risk areas and administrative boundary (VDC, Ward),
- Various maps (Land system, Capability) data, and reports from LRMP, and
- Socio economic data and village profile

3.2 General Approach and Methodology Framework

Government of Nepal has enacted the National Land Use Policy 2072. According to the policy the overall land mass of nation shall be divided into 11 land use zones as mentioned above. These zones shall be further sub-divided into sub-zones as required.

Since earthquakes, landslides of devastating nature and other natural calamities negatively affect more than one land use zones, the risk prone areas shall be identified through geological review and such risk spots shall be marked in the land use maps so as to sustainably secure the development of settlements, townships and infrastructure in an earthquake and other risk resistant manner.

The primary bases of land use zoning are as follows:

a) The basis of land composition, capability and appropriateness

The indicator of geographical and geological land composition, capability and appropriateness shall be the primary basis for determining land use zoning.

b) The basis of present land use

The land use zone for a particular area shall be determined on the basis of present land use of that area, if it is in accordance with its land composition, capacity and appropriateness.

c) The basis of necessity

In case the state has to use any particular land for a use other than it is directed for public good and development of physical infrastructure, then the land use zone shall be assigned in a manner so as to facilitate its utilization as per the need.

The zoning map is prepared keeping the objective of the policy in mind. Therefore, the following main principles are adopted:

- Agricultural land should be kept intact as much as possible
- Forest cover should not be decreased, but can be increased. Wetlands should be preserved.
- Natural disasters such as flood risks should be minimized
- Appropriate housing and residential areas should be identified for planned settlement
- Appropriate land should be allocated to commercial, business and industrial areas for economic activities
- Area of comparative advantage should be identified within agricultural crop production

To achieve the aforementioned objectives, the following basis is taken for land use zoning:

- Existing land use
- Capability and suitability of the land
- Socio economic data
- Expert's opinion
- Subjective analysis

3.3 Methods

Mainly two methods are applied for land use zoning in this study.

a. Multi-criteria Analysis

Land use zoning is carried out by considering various criteria as mentioned in the previous section. These criteria are translated in GIS software and analysis is done. This is a scientific process and individual judgments cannot be made while applying the process. The suitability of certain use is judged by the software based on the provided criteria. An example of such criteria is the potential residential area should not lie in a flood prone-risky land, highly productive agricultural land and in a slopping terrace of more than 30°. These kinds of multiple criteria are evaluated and suitable land for particular use is identified with the help of GIS software.

b. Subjective Analysis

Subjective analysis on the basis of requirement and expert's opinion is carried out. As an example, if a small piece of land is found suitable for agricultural use, it is surrounded by residential area, then it is placed in the residential area. Similarly, if the land is found suitable for agricultural purpose but it is in the flood plain of the river and high risk of flooding, then it can be used for forest and plantation to control the flood.

General approach and methodology used for the land use zoning is shown on the following schematic diagram (Figure 3.1).

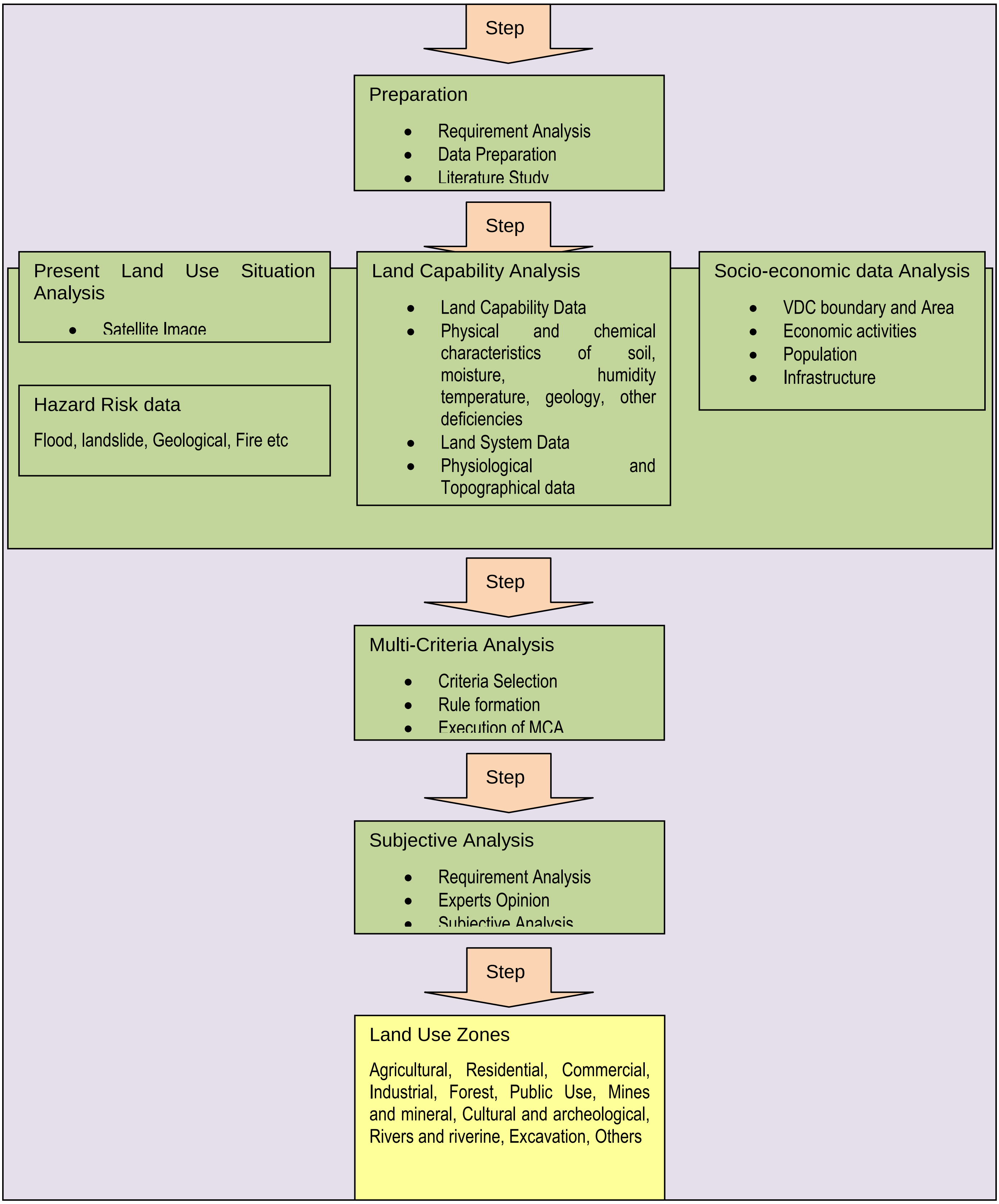

Figure 3.1 Methodology used for land use zoning

3.4 Result

The methods described in the previous section are applied and GIS analysis is performed on the various steps for land use zoning. The land use zones identified in this VDC are summarized on the Table 3.1.

Table 3.1 Land use zones of the study area

Class	Zone	Zone Type	Code	Sub zone	Description	Area of sub zone type (Ha)	% of individual zone	Area of zone type (Ha)	% of total area
1	Zone 1	Agricultural	AGR	Zone 1A	Cereal crop production area	1248.99	96.69	**1291.79**	62.02
				Zone 1B	Cash crop area	32.03	2.48		
				Zone 1C	Horticulture	8.34	0.65		
				Zone 1D	Animal Husbandry	0.12	0.01		
				Zone 1E	Fish farming area	2.31	0.18		
				Zone 1F	Agro-forestry	0.00	0.00		
2	Zone 2	Residential	RES	Zone 2A	Existing residential zone	178.94	64.50	**277.43**	13.32
				Zone 2B	Potential area for residential zone	98.50	35.50		
3	Zone 3	Commercial	COM	Zone3A	Governmental institutions and service areas	11.98	60.69	**19.74**	0.95
				Zone 3B	Business area	7.76	39.31		
4	Zone 4	Industrial	IND	Zone 4A	Areas under industrial use	8.26	100.00	**8.26**	0.40
				Zone 4B	Potential area for Industrial zone	0.00	0.00		
5	Zone 5	Forest	FOR	Zone 5A	Existing forest	336.93	90.38	**372.81**	17.90
				Zone 5B	Potential area for forest including barren lands, wet	35.88	9.62		

					lands etc.				
6	Zone 6	Public use	PUB	Zone 6A	Areas under roads, railways, bus parks, airport and land fill site etc.	82.09	83.68	**98.10**	4.71
				Zone 6C	Recreation, picnic spot	0.00	0.00		
				Zone 6E	Health, education etc. institutions	4.45	4.53		
				Zone 6F	Grazing land	9.17	9.35		
				Zone 6G	Government Institutional Area	0.00	0.00		
				Zone 6H	Open spaces	2.40	2.45		
7	Zone 7	Other area	OTH	Zone 7	as per requirement	0.00	0.00	**0.00**	0.00
8	Zone 8	Mine and Minerals	MIN	Zone 8A	Existing Mines and mineral area	0.00	0.00	**0.00**	0.00
				Zone 8B	Potential areas for Mines and mineral	0.00	0.00		
9	Zone 9	Cultural and Archeological	CULARCH	Zone 9A	Existing cultural and archeological area	0.27	100.00	**0.27**	0.01
				Zone 9B	Potential cultural and archeological areas	0.00	0.00		
10	Zone 10	Riverine and Lake Area	HYD	Zone 10A	Existing rivers and riverine area	14.19	100.00	**14.19**	0.68
				Zone 10B	Potential hydrographic areas	0.00	0.00		
11	Zone 11	Excavation (Construction Materials)	EXC	Zone 11A	Existing quarrying and excavation area	0.22	0.00	**0.22**	0.01
				Zone 11B	Potential areas for quarrying and excavation	0.00	0.00		
Total								**2082.81**	100.00

Agricultural land use zone covers 62.02 percent of Karahiya VDC. Similarly, Forest land use zone has 17.90 percent coverage. While residential zone occupies 13.32 percent, Public use zone covers 4.71 percent only. Distribution of land use zones of the VDC is depicted in Table 3.1.

More than 96 percent of agricultural land is occupied by cereal crop production and cash crops occupy only 2.48 percent of the total agricultural lands of the VDC (Table 3.1 and Figure 3.2). Less than one percent of agricultural land is occupied by fruits and orchards. Animal husbandry and fish farming are almost negligible by area. Agro-forestry zone does not exist in the VDC.

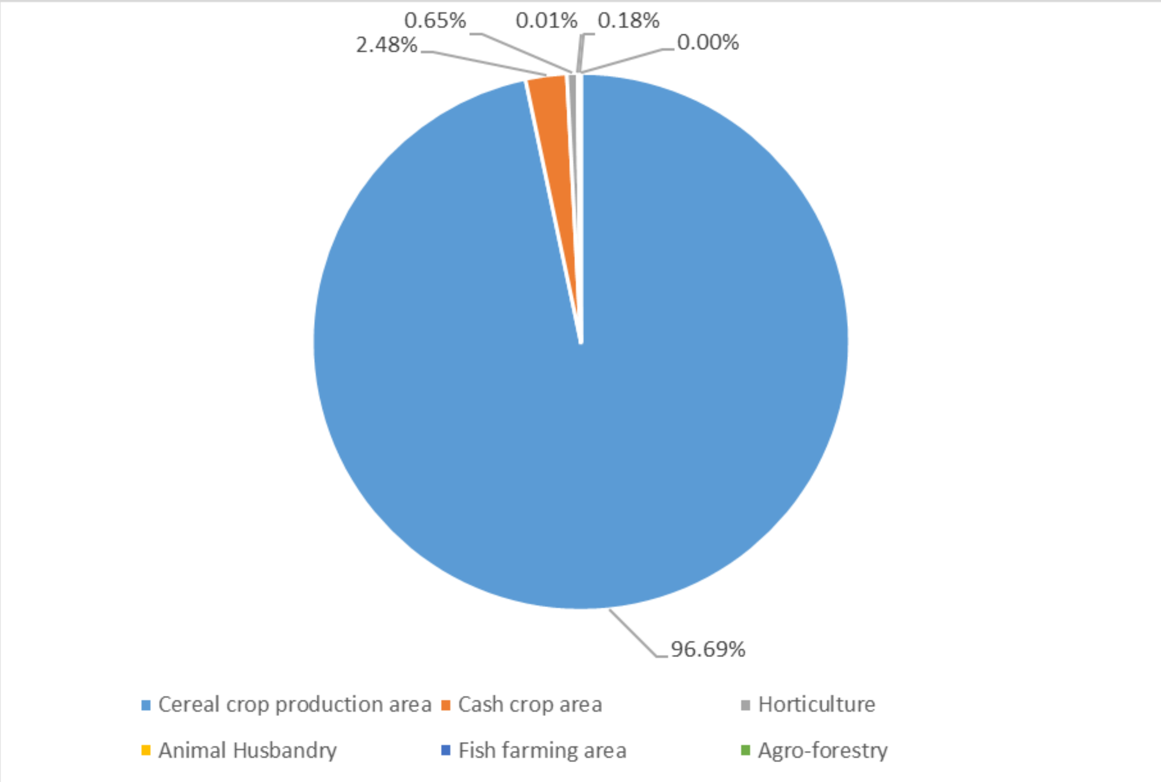

Figure 3.2 Distribution of agricultural sub-zones, Karahiya VDC

Present land use areas used for different purposes are shown in Table 3.2 and Figure 3.3. Agriculture is the dominant land use type in the study area which covers almost 69 percent of the total area followed by forest (16.30 percent), residential area (8.94 percent), public service area (3.48 percent) and riverine and lake area (0.68 percent). The area used for commercial, industrial, excavation, cultural and archeological purposes are not significant in terms of area occupied by these categories in the VDC. The mines and mineral sites do not exist.

Table 3.2 Present land use area distribution

Land use Type	Present land use (Ha)	Percent
Agricultural	1440.33	69.15
Commercial	11.41	0.55
Cultural and Archeological Area	0.29	0.01
Excavation Area	0.28	0.01
Forest	339.46	16.30
Riverine and Lake Area	14.22	0.68
Industrial	8.88	0.43
Public Service	72.48	3.48
Residential	186.28	8.94
Mines and Minerals	0.00	0.00
Others	9.17	0.44
Total	2082.81	100.00

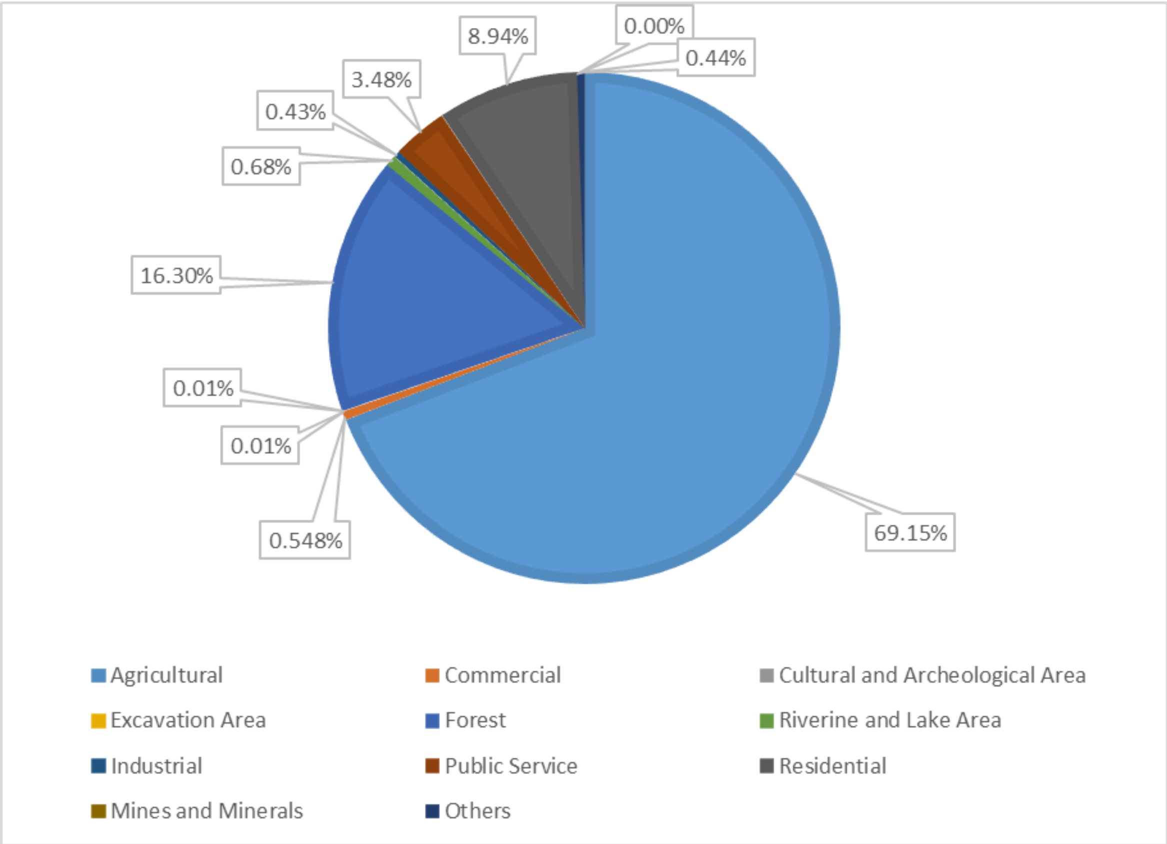

Figure 3.3 Status of existing land use in Karahiya VDC

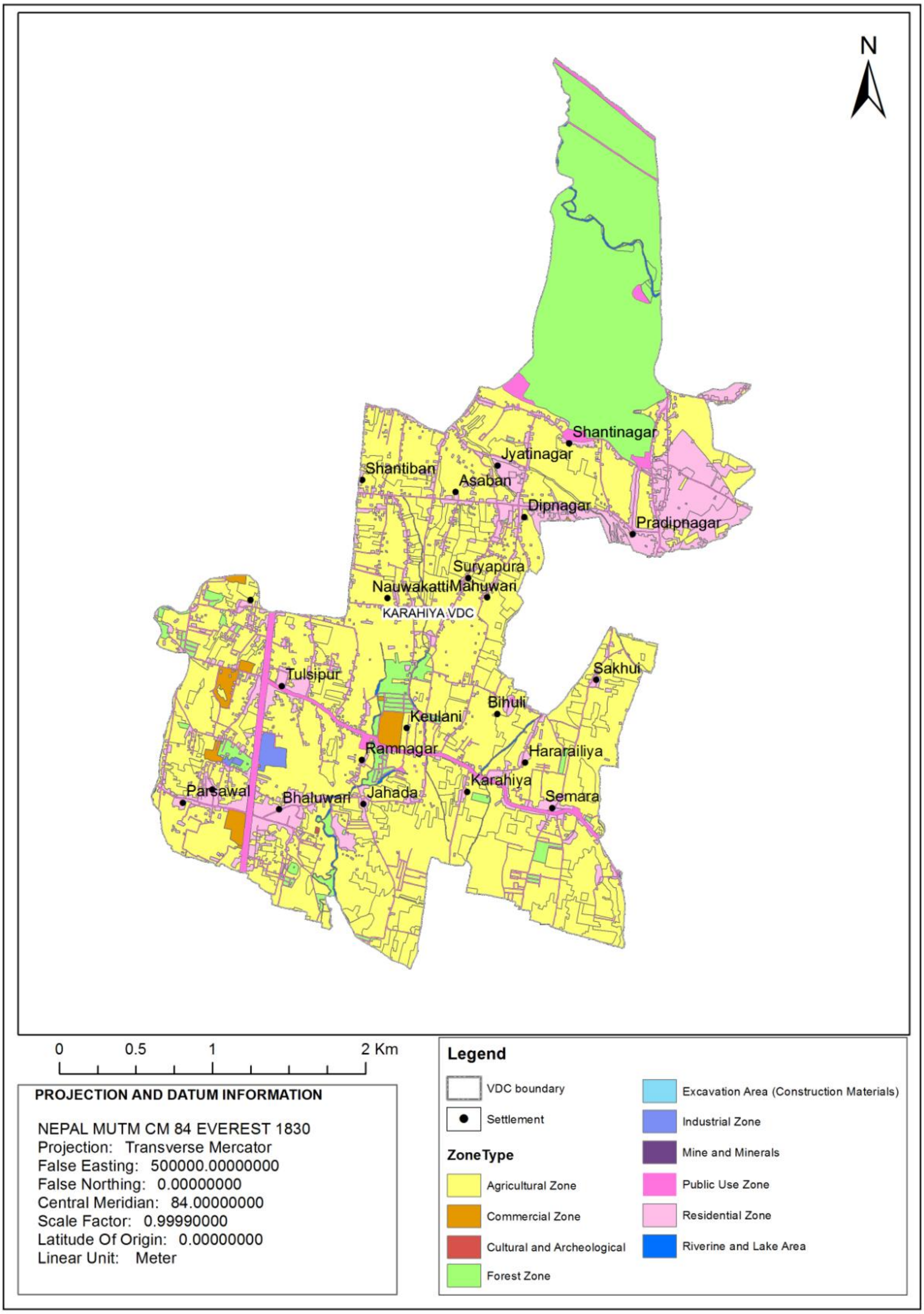

Figure 3.4 Land Use Zoning Map of Karahiya VDC

3.5 Discussion

As noted above, almost 69 percent of the total VDC area is occupied by agricultural lands (Present Land Use), the existing agricultural area declines with the new zonation of the lands. Some lands are proposed for residential, commercial and public uses considering the increasing demand of such lands and some for plantation forest area. Obviously, this needs extra lands and they are proposed in existing agricultural lands of the VDC. For this allocation, land suitability analysis was done using land capability data. Lands of marginal utilization with low capability of agricultural production as well as areas with poor drainage are allocated for residential and commercial areas as far as possible. Likewise, the land areas, categorized as Other land use in present land use are proposed for forest area, grazing land and open space depending on its surrounding land use types. These newly proposed forest can be used for wood and timber production. New industrial area is not proposed in the VDC as space suitable (areas with transport infrastructure, far away from existing forest, residential and commercial area as well as away from riverine and lake area) for industrial establishment is unavailable in the VDC.

According to the CBS data, the rate of population growth is almost three and half percent in this area during the decades 1991 to 2011. It has been observed that the present settlement has been developed gradually in last 50 years. But in last 10 years, the rate of urbanization is very high. The main reasons behind this include internal migration from the hills as well as rural areas of the Tarai region to this area, increasing investment of remittance earned from foreign employment on housing lands in urban areas, increasing social trend of unitary small family. Since, this VDC area is currently annexed as a part of Tilottama Municipality, population growth is expected to rise further due to inflow of migrants from rural VDCs in search of better education and employment opportunities. Therefore, significant growth can be seen in the residential and commercial zoning in the VDC.

This area has very low economic and commercial activities. There are very few small markets where commercial activities take place. Buildings in this area are used for mixed purposes i.e. residential and commercial purposes. This is the reason why the commercial area is shown very low in proportion. However, some new commercial and business areas are proposed considering the future demand of increasing size of population in this area. The population in this area has been rising tremendously in recent years.

The land used for industrial purpose is limited in the VDC. There are only five industrial establishments. These include small to large industries with agro-processing industries, distillery, and others. No area is proposed for future industrial development as the suitable land (with transport infrastructure, far away from existing forest, residential and commercial area as well as away from riverine and lake area) for industrial establishment is unavailable in the VDC.

Although most of the land is used for agricultural purposes, the optimum utilization of land is not observed in the VDC. Most of the fertile land has been left uncultivated and barren after harvesting rice. The main reason behind this as pointed are lack of irrigation facility (though some canals exits, they are not sufficient enough), working labor, and high production cost (high cost of fertilizers, seeds and other production requirements). The benefit as compared to investment is very low. That is why people are not excited for second crops and left fallow after rice. This could be a very serious problem for food security in future. Considering the situations the government should identify appropriate solutions to address the problem.

Regarding crops, both cereal and cash crops are mostly grown in this area. Rice and wheat are the main cereal crops whereas pulses and oilseeds are the major cash crops grown in this area. Few people have shown their interest to horticulture, specially, fruits. Though fish farming area is considerable (in number rather than area) in the area, the soils are very fertile so they are more suitable for cereals. Animal husbandry is almost negligible in the VDC. Agro-forestry zone does not exist in the VDC.

The area is mostly safe for human settlement as it is located in the flat plain, the risk of landslide doesn't exist. The risk of bank cutting and flooding is limited and liable especially in northern part of the VDC. However, the situation is not much severe. Moreover, some Northern part of the VDC falls under vicinity of transmission line and fault line. However, the area is covered by forest and no major human activities exist in such area. Nonetheless, many houses are made of woods and other inflammable material, thus, risk of fire outburst is high in some areas. Furthermore, one petrol pump exist in the VDC which possess fire risk to nearby settlements.

CHAPTER 4: LAND USE ZONES OF THE STUDY AREA

4.1 Risk Areas within the study area

There is no much risk for human activities in this area. The most prominent risk observed in the area is because of flood in rainy season. Tinau River and other streams which may cause destruction of human life and livelihood base of the local people when they flood. As the study area lies in the Terai, the risk of landslide is not present. However, bank cutting and erosion of fertile land has been observed.

To identify such flood prone area and the extent of flood, flood modeling has been carried out. The flood prone area has been classified as high, medium and low risk areas for flooding. The high and medium risky area has not been allocated to those land use zones which may have higher human interactions such as residential, commercial and industrial areas. It is recommended to make river embankment for controlling flood and bank cutting.

No major industrial area exists in the VDC. However, the consultant proposed not to build any residential or commercial structures within a periphery of 500m (1000m in case of brick industry) from the existing industrial area of the VDC and neighboring VDCs.

Fault line and one petrol pump exist in the VDC. The other risk in the area is because of fire spreading in summer. In rural settlement, some houses are made of wood and other combustible materials. These houses are in cluster and attached to each other. Further, many of the households used to store fuel woods, straw and other inflammable material inside or adjoining to houses for daily use. In this situation, if one of the house or surrounding catches fire accidently, there is a huge risk of spreading fire all over the settlement. The detailed description of risk and risk prone area in the study site is separately described and delineated in risk study.

4.2 Analysis of Present Land Use and Potential Land use Zone

Table 4.1 clearly shows that agricultural area is the dominant land use type followed by forest, residential area, public use area, and riverine and lake area. The lands occupied for commercial, industrial, and cultural and archeological purposes are not significant in terms of area. The mine and minerals sites do not exist in the VDC except for excavation of some construction materials. Table 4.1 shows the present and potential land use of the VDC.

Table 4.1 Present Land Use and Potential Land use Zone

Land use Type	Present land use (Ha)	Percent	Zoning (Ha)	Percent	Difference (Ha)	Rate of change (%)
Agricultural	1440.33	69.15	1291.79	62.02	-148.55	-7.13
Commercial	11.41	0.55	19.74	0.95	8.33	0.40
Cultural and Archeological Area	0.29	0.01	0.27	0.01	-0.02	0.00
Excavation Area	0.28	0.01	0.22	0.01	-0.06	0.00
Forest	339.46	16.30	372.81	17.90	33.34	1.60
Riverine and Lake Area	14.22	0.68	14.19	0.68	-0.03	0.00
Industrial	8.88	0.43	8.26	0.40	-0.63	-0.03
Public Service	72.48	3.48	98.10	4.71	25.62	1.23
Residential	186.28	8.94	277.43	13.32	91.16	4.38
Mines and Minerals	0.00	0.00	0.00	0.00	0.00	0.00
Others	9.17	0.44	0.00	0.00	-9.17	-0.44
Total	2082.81	100.00	2082.81	100.00	0.00	0.00

The agricultural area is decreased by 148.55 ha while zoning. The proposed allocation of new sites for residential and commercial use needs extra land. Around 91 ha of agricultural land have been allocated for new residential sites and 8 ha for commercial areas. Around 33 ha land is proposed for forest. The proposed lands were allocated after suitability analysis was done using land capability data. Land of marginal utilization with low capability of agricultural production and poor drainage facility is allocated for residential and commercial use as far as possible.

4.3 Analysis of Safe Settlement Areas and Open Areas

Existing settlement in the area are mostly safe. However, some settlements or individual houses lies in the flood prone area and few are within the risk of industrial pollution. The areas under potential hazard in this VDC have been shown in the risk maps in the risk analysis report.

According to the CBS data, the rate of population growth is almost three and half percent in this area during the decades 1991 to 2011. It has been observed that the present settlement has been developed gradually in last 50 years. But in last 10 years, the rate of urbanization is very high. The main reasons behind this include internal migration from the hills as well as rural areas of the Tarai region to this area, increasing investment of remittance earned from foreign employment on housing lands in urban areas, increasing social trend of unitary small family. Since, this VDC area is currently annexed as a part of Tilottama Municipality, population growth is expected to rise further due to inflow of migrants from rural VDCs in search of better education and employment opportunities. Therefore, significant growth can be seen in the residential and commercial zoning in the VDC.

This area has very low economic and commercial activities. There are very few small markets where commercial activities take place. Buildings in this area are used for mixed purposes i.e. residential and commercial purposes. This is the reason why the commercial area is shown very low in proportion. However, some new commercial and business areas are proposed considering the future demand of increasing size of population in this area. The population in this area has been rising tremendously in recent years.

The potential residential areas for future settlement are proposed after thorough study of possible hazards in the area. New settlements are not proposed in flood prone area, area under industrial pollution and other risks. Therefore, the residential and commercial areas are almost at minimum risk. Because of the limitation of available techniques, the seismic hazard and its occurrences cannot be studied and couldn't be considered for proposing new residential, as well as commercial zones. However, geological stability is studied and considered during the process.

Regarding open area, the study site is rural area which means most of the land is agricultural. The residential and other construction areas are limited. So, most of the areas are open in nature. However, open area left for recreation purpose, parks and playgrounds are negligible except some open area used for grazing, flooded riverbeds and unused /uncultivated lands as well as separate open space.

4.4 Land Use Zone in the Study Area

The following land use zones are identified in this study area. The Mine and Minerals area are not identified in this VDC. The detailed description of land use zone in the study area has been provided in section 3.4.

Table 4.2 Land use zoning of Karahiya VDC

Land use type	Zoning Area (Ha)	Percent
Agricultural	1291.79	62.02
Commercial	19.74	0.95
Cultural and Archeological Area	0.27	0.01
Excavation Area	0.22	0.01
Forest	372.81	17.90
Riverine and Lake Area	14.19	0.68
Industrial	8.26	0.40
Public Service	98.10	4.71
Residential	277.43	13.32
Mines and Minerals	0.00	0.00
Others	0.00	0.00
Total	2082.81	100.00

4.5 Land Use Zoning GIS Database

The following database schema is used for preparation of GIS database of land use zoning. The GIS database of land use zoning includes data field, data types, feature descriptions and remarks.

Table 4.3 Database schema used for land use zoning

Field	Data Type	Description	Remarks
FID	Feature Id	Feature	
SHAPE	Geometry	Geometric Object type	
ID	Integer	Unique Object ID	
ZONE NO	String	Zone No	
ZONE TYPE	String	Zone type	
SUB ZONE TYPE	String	Subzone Type	
VDC	String	VDC/Municipality Name	
DISTRICT	String	District Name	

CHAPTER 5: CONCLUSIONS

5.1 Conclusions

Karahiya VDC has covered significantly by agricultural land suitable for both cereal and cash crop production. Urbanization is getting increased and hence the agricultural land is being rapidly converted into residential and commercial purposes. Industrial and commercial activities in the VDS are not significant. Since, there is predominance of agricultural lands; most of the fertile land has not been utilized as per its capacity because of various management reasons which could be a serious problem in the future with a view of food security as well. Most of the areas are safe for residential purpose.

5.2 Recommendation

- The zoning categories are too many which are overlapping and confusing. It is recommended to review and make them clear.
- Zoning criteria are subjective, which may lead to ambiguous zoning and inconsistency amongst different consultants. Therefore, it is recommended to have a discussion and develop scientific guideline as much as possible.
- The land use in this VDC is still not deteriorated so far. Therefore, land use planning should be started on the basis of this study as soon as possible.
- The implementation should be initiated through local government to address the local needs. Some of the local needs and aspiration could not be judged by this study as it lacks wide consultation to the local people. This study has suggested a potential place based on spatial analysis. But actual location should be ultimately finalized by the local people on the basis of available land and other circumstances.
- It is suggested to develop a micro zoning by the local government on the basis of this report/maps/database/document for further implementation.
- Land use act is the most important tool to take this policy in action. Therefore, it is recommended to formulate land use act and enact it as soon as possible.

Cadastral Superimposed on Land Use Zoning

FINAL REPORT

Preparation of Cadastral Layer Superimpose

Karahiya VDC of Rupandehi District

FOR

Consulting Services

For

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

Package No: 11

Anandaban, Devadaha, Karahiya, Kerwani, Madhawaliya, Makrahar, Shankar Nagar, Tikuligadh, of Rupandehi District (8 VDCs)

Preparation of Cadastral Layer Superimpose Karahiya VDC of Rupandehi District

This document is one of the outcomes of the project entitled **Preparation of VDC level Land Resource Maps** (Present Land Use Maps, Soil Maps, Land Capability Maps, Land Use Zoning Maps and Cadastral Layer Superimpose and VDC Profile), **Database and Reports** of Package 11 awarded to SHREEYA-KRS JV by the Government of Nepal, Ministry of Land Reform and Management, National Land Use Project (NLUP) in Fiscal Year 2072-073. The VDCs covered under this package include eight VDCs of Rupandehi district namely **Anandaban, Devadaha, Madhawalia, Makrahar, Karahiya, Kerwani, Sankar Nagar and Tikuligadh**.

Mr. Kul Bahadur Chaudhari was involved and solely credited for the preparation of maps, database and reports on risk themes.

The VDC areas analyzed for different themes of the NLUP Project are computed from cadastral maps provided by DOLIA Office of Nepal. Therefore, the areas of the VDCs may not be the same as computed from Topographic Database provided by the Survey Department of Nepal.

The consultant is obliged to state that the Imageries, GIS database and other outputs produced for the project is owned by National Land Use Project (NLUP), Mid-Baneshwor, Kathmandu. Therefore, the authorization from the NLUP is required for the usage and/or publication of the data in part or the whole.

ACKNOWLEDGEMENT

The SHREEYA-KRS JV is highly obliged to National Land Use Project (NLUP), for awarding the project **Preparation of VDC level land resource maps** (Present Land Use Maps, Soil Maps, Land Capability Maps, Land Use Zoning Maps and Cadastral Layer Superimpose and VDC Profile)**, database and reports, Package 11 of Rupandehi district**. The consultant would like to extend special thanks to Mr. Nagendra Jha, the Project Chief of NLUP, for his constructive supports during the project period. Similarly, the consultant would also like to highly acknowledge the overall supports of Mr. Nabaraj Subedi, Chief Survey Officer. Likewise, the consultants would like to extend thanks to Mr. Sumir Koirala, Survey Officer, Mr. Ekraj Giri, Account Officer, Mrs. Manju Devi, Store Keeper and the other staffs of the NLUP Office for their supports during the project period.

The consultant would also like to thank the local people, members of the different political parties and staffs of the VDCs and local institutions of **Karahiya VDC** of Rupandehi District for providing their valuable time to the study team in discussing different aspects of the project. Without their support this work would not have been completed.

Similarly, the consultant is highly obliged to Dr. Suresh Kumar Shrestha (forest expert) Fuleshwor Singh (horticulturist), Prajwal Thapa (environmentalist), Bhupati Neupani (geologist) Dr. Deepak Kumar Rijal.(agriculture expert), Mohan Krishna Balla (hydrologist), Ganesh Raj Acharya (natural resource manager), and Umesh Agrawal (land use planner) worked diligently in their own specialized area. Special thanks go to soil scientists Dr. Keshav Raj Adhikari with the team of soil sample collectors - Sunil Pokhrel and Laxman Bhandari for their tedious and untiring tasks at the field. Thanks are due to Mrs. Parbati Chaudhary and Mr. Kul Bahadur Chaudhary, for their excellent job as Remote Sensing and GIS experts. Similarly, the inputs of Mr. Sachindra Kumar Deo in collecting the socio-economic information from the VDC and preparing VDC profile are highly appreciable. Support staffs Mr. Jivan Kutu and Mr. Mahendra Shrestha worked diligently in different capacities to make the project work successful. The consultant would like to thank all the team members as well as **Team Leader** Dr. Shiba Prasad Rijal, for planning a successful field work and accomplishing the project work as per the ToR and the Specification, 2015.

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List of Abbreviations

DGPS	Differential Global Positioning System
DEM	Digital Elevation Model
DOLIA	Department of Land Information and Archive
GCP	Ground Control Point
GIS	Geographical Information System
GoN	Government of Nepal
Ha	Area in hectare
Hqs	Headquarters
LRMP	Land Resources Mapping Project
MoLRM	Ministry of Land Reform and Management
MSS	Multispectral Scanner
NLUP	National Land Use Project
RS	Remote Sensing
VDC	Village Development Committee
Km	Kilometer
m	Meter
mm	Millimeter
RMSE	Root Mean Square Error

CHAPTER 1: INTRODUCTION

1.1 Background and Rationale

1.1.1 Background

Land is one of the important and precious natural resources of the earth surface. The demands for arable land, grazing, forestry, wildlife, 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).

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. 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.

Nepal has only regional level database on land use, land system and land capability which were produced by Land Resource Mapping Project (**LRMP**, 1986). Realizing this fact, the Ministry of Land Reform and Management, Government of Nepal established the **National Land Use Project** (**NLUP**) in 2057/058 fiscal year to generate the necessary database 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 and Nawalparasi district and one VDC each for Kavre (Panchkhal VDC) and Tanahu (Anbu Khaireni VDC) District as well. These digital database include VDC level present land use, soil, land capability, land use zoning, cadastral layers and VDC profile with bio-physical and socio-economic database.

On the 4th Baishakh of 2069, the Government of Nepal has approved the National Land Use Policy, 2069. Recently, this policy was modified by amendment in 2072 and introduced National Land Use Policy, 2072. It has intended to manage land use according to land use zoning policy of the government of Nepal and outlined eleven zones such as Agricultural area, Residential area, Commercial area, Industrial area, Mining and Mineral area, Cultural and Archaeological area, River, Lake and Water bodies area, Excavation area, Forest area, Public Use area and Others. 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, 2072 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.

In the context stated above, the NLUP in the Fiscal Year 2072-073 has commissioned the JV of Shreya Engineering Consultancy (P) LTD- K.R.S. Engineering Consultancy (P) LTD to carry out the project entitled "Preparation of VDC level land resource maps (Present Land Use Maps, Soil Maps, Land Capability Maps, Land Use Zoning Maps and Cadastral Layer Superimpose and VDC Profile), database and reports" for Package XI of Rupandehi District. The VDCs covered under the Package XI are Anandaban, Devdaha, Karahiya, Kerwani, Madhawaliya, Makrahar, Shankar Nagar and Tikuligadh (total 8 VDCs) of Rupandehi District.

1.1.2 Rational of the Study

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 proposed land use. For all land related decision making, land ownership and land tenure information provides essential ingredient. The implementation of land use plan cannot succeed 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 is necessary for the following:

i. Delineation of land parcels according to land use zoning viz. Agricultural area, Residential area, Commercial area, Industrial area, Mining and Mineral area, Cultural and Archaeological area, River, Lake and Water bodies area, Excavation area, Forest area, Public Use area and Others.
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

1.2.1 Objectives

The broad objective of National Land Use Project (2069/070 fiscal year) is to prepare VDC Level Land Resource Maps, Database and Reports for Package 11 VDCs of Rupandehi District of Nepal. The specific objective of the present study is to prepare maps of Cadastral Layer Superimpose on Land Use Zone, GIS database and Reports for the Karahiya VDC of Rupandehi district at 1:10,000 scales.

1.2.2 Scope of the Study

Scope of this study includes the following activities:

- Collect and prepare cadastral geo-database from existing cadastral map.
- Collect land use zoning maps and present land use maps at 1:10,000 scale
- Overlay of cadastral layer on present land use and land use zoning and prepare cadastral superimposed map at 1:10,000 scale.
- Classify the cadastral parcels according to present land use and land use zoning.
- Maintain GIS database on cadastral parcels with zoning characteristics and current land use as per the specification provided by NLUP.
- Analyze the accuracy, reliability and consistencies of data, and
- 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

Karahiya VDC lies in Rupendhei district, Lumbini Zone. The VDC has currently included in Tilottama Municipality. And it is known for ward no. 9, 10, 11 & 12 of the municipality. The VDC is bordered by Makrahar & Gangoliya VDCs to the east, Anandaban VDC to the west, Andandaban & Debdaha VDCs to the north and Madhabaliya & Gangoliya VDCs to the south. The VDC covers a total area of 1984.24 ha. The extension of the VDC is 4.7 km and 8.8 km in east-west and north-south respectively. The total population of the VDC is 18274 with 4267 households, CBS (2011). Of the total population, the percentage of male is six percent lower than female. However the total number of households and population is differ in VDC profile. According to the VDC profile (2067), there are 3360 households with a total population of 24398. Of the total population, the percentage of male and female are equal. All wards have different in size in terms of area and population. Ward no. 8 has the largest population size population of 8145. And ward no. 5 has smallest population of 556. Different caste/ethnic groups are living in the VDC. Among them, majority is Brahmin. It is followed by Indigenous. Some people came to the VDC from other districts mainly from Palpa, Gulmi, Arghakhachi, Baglung, and Parbat. There are four religions such as Hindu, Buddhist, Muslim and Isai. Among them, almost all 95 percent are Hindu. There is no information of literacy rate of the VDC. People are involved in many occupations. More than half of the total populations are involved in agriculture. And it is the main source of income. Majority 32 percent of the total income comes from agriculture/livestock.

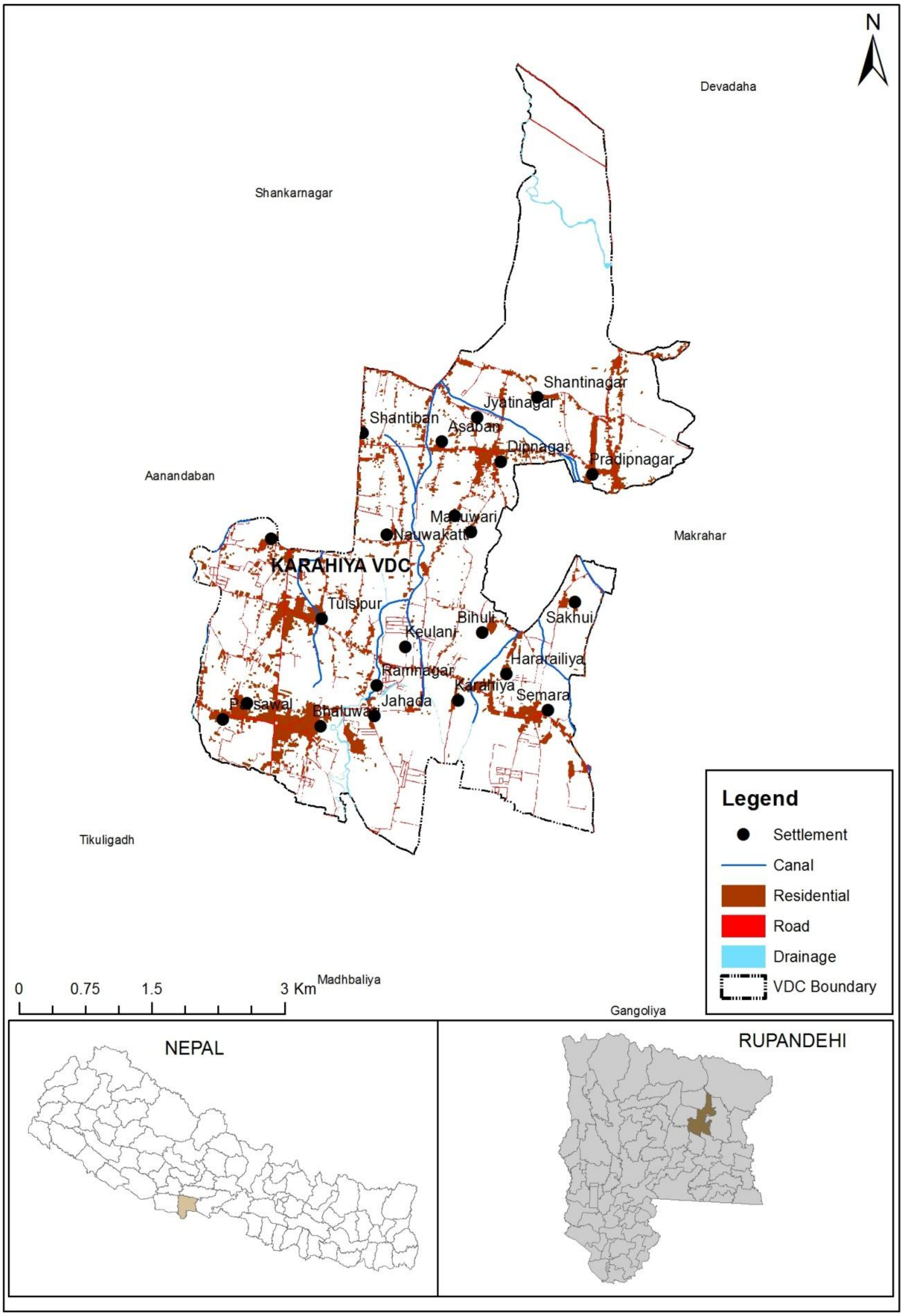

Figure 1.1: Location Map of Karahiya VDC

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 (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 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,1985). 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 1:10,000 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 and 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 a 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 percent 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 area, heavy industrial area, waste storage, and so forth so that people get a clear visual impression of how land in a particular 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.

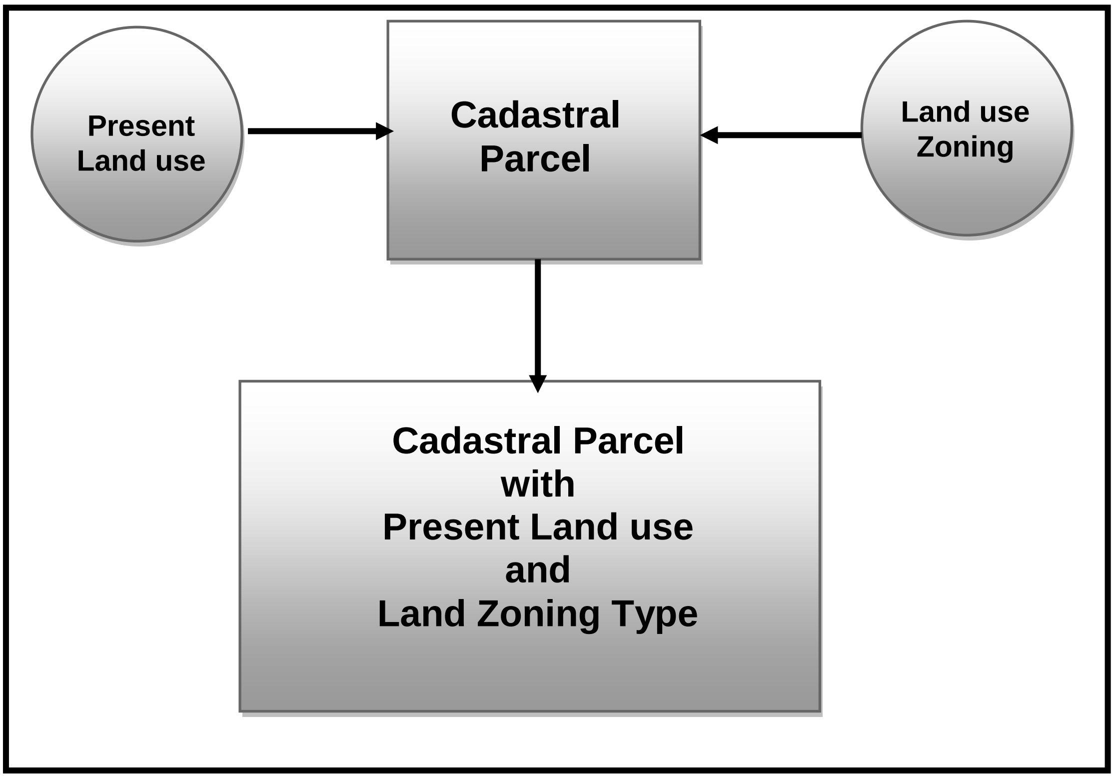

Figure 2.1: Spatial Function Related to Spatial Databases

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 provides information on proposed use of the particular parcel. The overlay function provides information on the proposed change of parcel wise use, and also provides 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. These 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 the land use and land use zoning 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. The method adapted to superimpose cadastral parcel on land use zoning map for the prescribed VDC area is shown in Figure 3.1.

3.1 Acquisition of Cadastral Maps

The original source of cadastral data for the VDCs of Rupandehi district was the Survey Office who maintains the original cadastral maps and records, and those cadastral maps were digitalized by DOLIA and stored as sheet wise geo-database. 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.

The present land use and land use zoning maps for the study area were prepared by the JV of Shreya Engineering Consultancy (P) LTD- K.R.S. Engineering Consultancy (P) LTD 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, 2072 of Government of Nepal.

3.2 Scanning

Although a digital cadastral database was made available in compatible data format by NLUP, some digital cadastral maps were missing. Therefore, the consultant visited the District Survey Office, Rupandehi, Bhairahawa and collected the Ammonia Print of the missing cadastral maps. These collected ammonia print of cadastral maps were scanned in 300dpi with large format scanner with high radiometric quality.

3.3 Georeferencing of Cadastral Data

As sheet wise free-sheet digital cadastral database was available for the project there was necessity of geo-rectification. The geo-rectification process makes the cadastral maps geometrically oriented and corrected to ground scale as well as to the national reference frame. The geo-rectification of free sheets of digital cadastral database and scanned cadastral images was carried out with the help of ortho-rectified satellite image of the project area. 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.

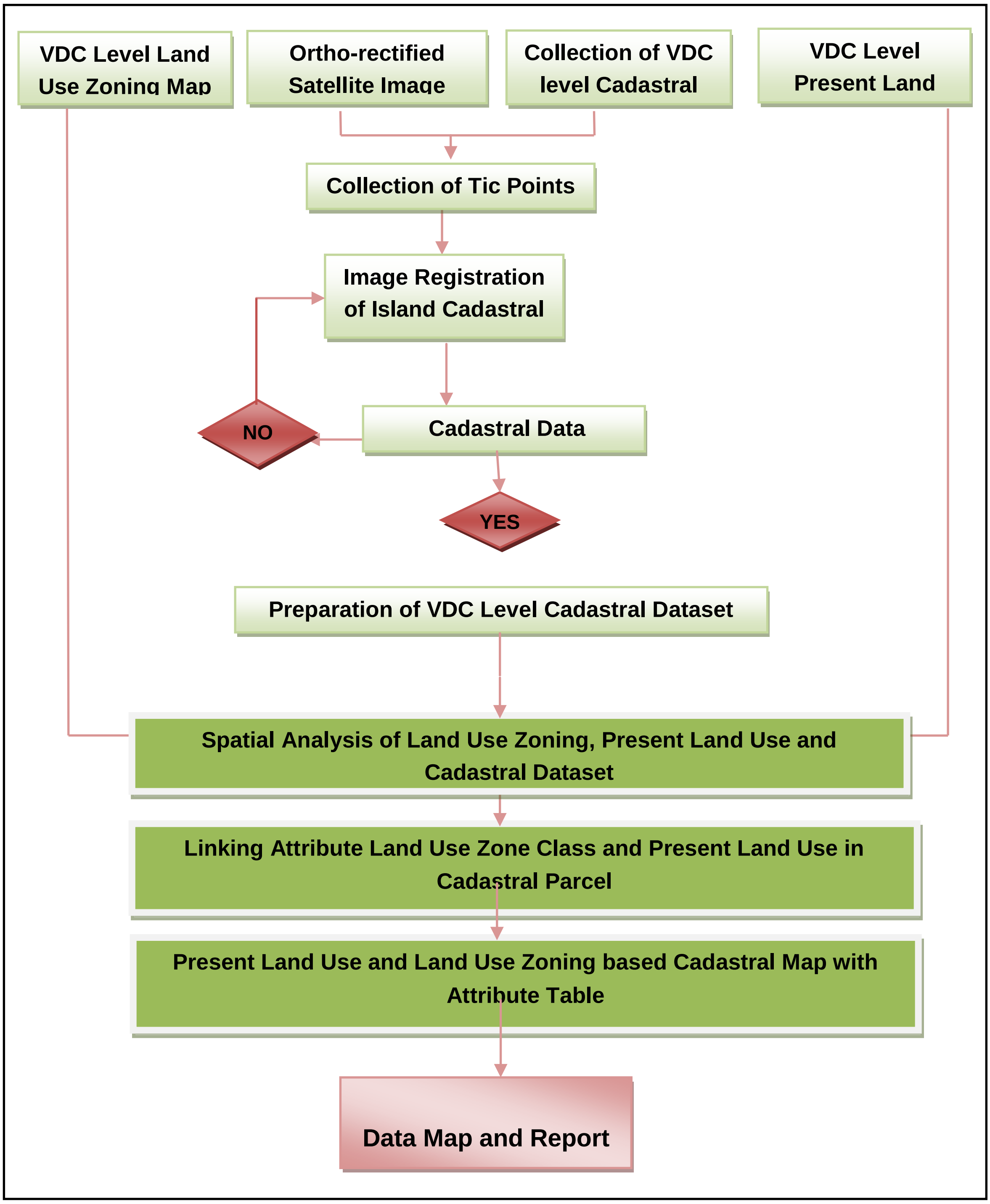

Figure 3.1: Schematic Diagram of Methods Adopted

- A team of surveyors visited project areas for carrying out survey of Tic Points
- The geo-referencing was carried out matching the sharply identifiable common points (Tic Points) in the cadastral map and the ortho-rectified image map. Geo-correction of vector layer of cadastral data need Tic Points at least on the four corners of the map sheet, however, to maintain the accuracy, and ensure even distribution of errors, 16 to 20 Tic Points in one cadastral map sheet were used for geo-referencing. A 3rd degree polynomial transformation was applied for rectification of the vector layer of cadastral dataset after assigning the required Tic Points. Due to larger errors in source data, mainly due to the method of plane tabling using limited local controls, 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 (1:10,000). 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.

Geo-referencing and matching with the ortho-rectified images provides a common geodetic framework for all related maps. and therefore; provide a common basis for overlay and other GIS operation functions.

3.4 Digitization and Preparation of Digital data

Scanned cadastral maps were digitized to convert analog format into digital format of cadastral datasets. These datasets were stored as sheet-wise cadastral geo-database in

.gdb format. These geo-database has used for preparation of seamless cadastral database of Ward or VDC. The complete digital vector cadastral data set is shown in Figure 3.2.

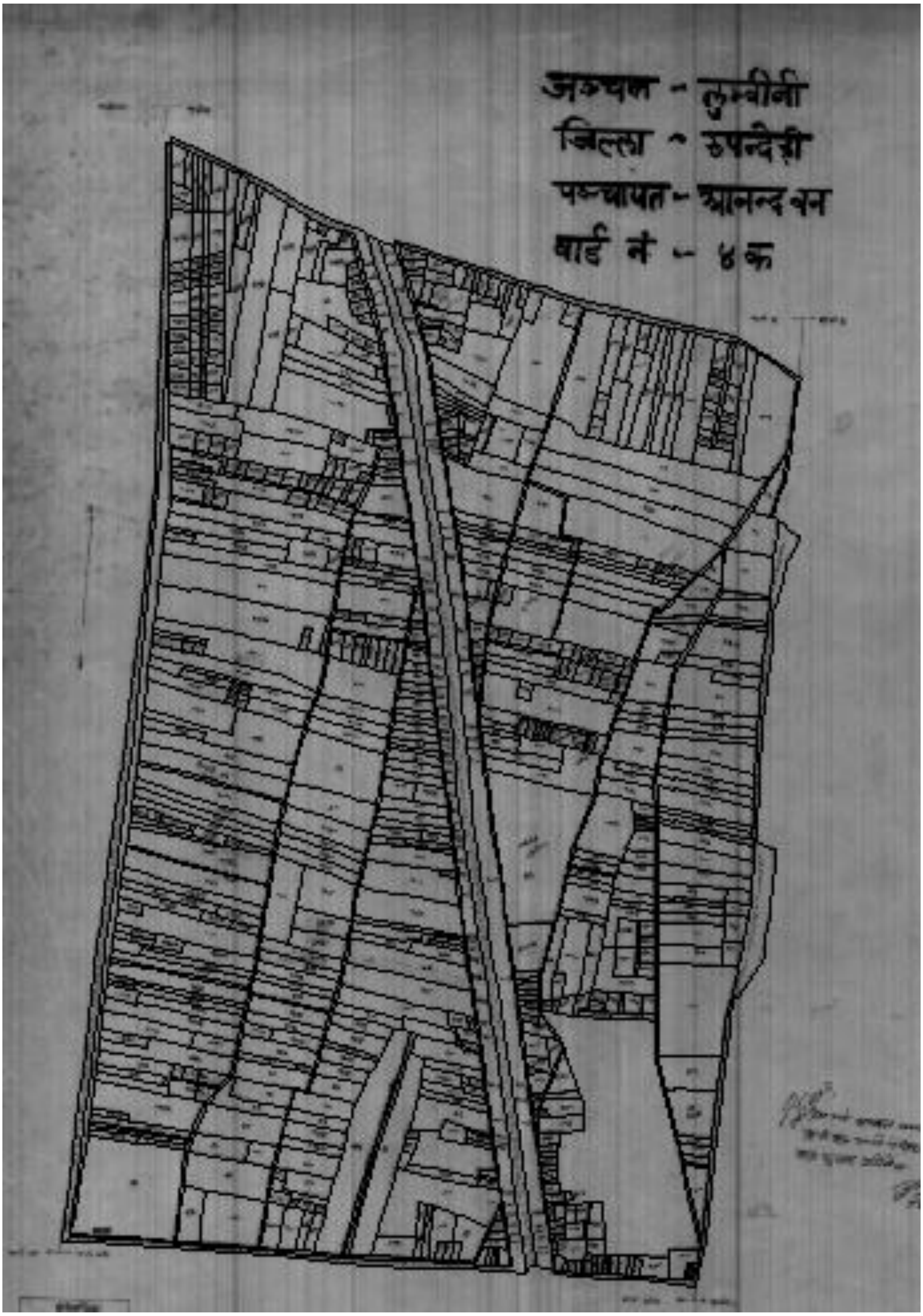

Figure 3.2: Vector Cadastral Layer overlaid on Scan Image

The transformed cadastral vector layer overlaid on ortho-rectified satellite image is shown in Figure 3.3.

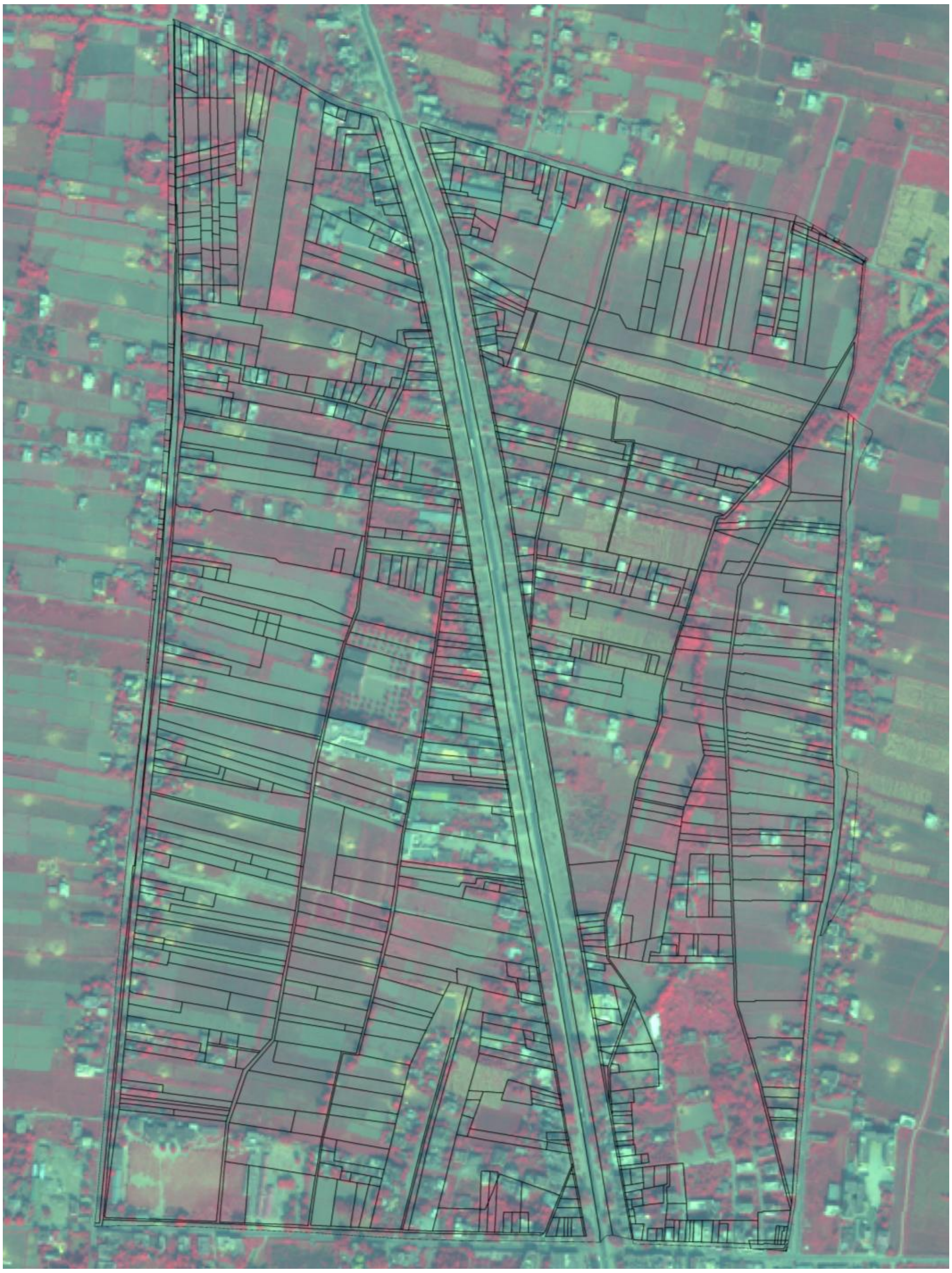

Figure 3.3: Vector Cadastral Layer overlaid on Ortho-rectified Satellite Image

3.5 Preparation of VDC level Seamless Cadastral Dataset

A ward level and subsequently VDC level seamless cadastral datasets 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 un-surveyed 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

The chapter four illustrates some analysis of the superimposition of cadastral maps over the present land use and the land use zoning map. 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 2021-2026 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. However, the Karahiya VDC had 10064 land parcels and area covered in the survey was 1679 ha.

4.1 Cadastral Parcel Superimpose on Present Land Use

Table 4.1 shows the present characteristics of cadastral parcels that falls in Karahiya VDC of Rupandehi district of Nepal. In the cadastral area of the VDC, out of the designated 11 classes, 9 land use classes do exist excepting the Mining & Mineral and undersigned other land use zone classes. It is significant that there are only 6 land parcels for cultural and archeological land use class. The predominant land use was the agriculture land use that covers with a total of 1423 ha (84.8%) having 11103 land parcels out of the total 14847 land parcels in the VDC. The coverage of the residential land parcels covered 165 ha (9.8%) having 2684 land parcels. The coverage of the forest land parcels covered 6 ha (0.4%) having 77 land parcels and the public service land parcels covered 56 ha (3.3%) having 717 land parcels. Similarly, the hydrographic feature (riverine, lake and water bodies) land class is significant of about 8.36 ha (0.5%) having 93 land parcels. About 0.03% (0.42ha) area fall on the cultural and archeological land use class, which is as well significant. The distribution of land parcel on present land use is shown in Figure 4.1.

Table 4.1 Parcel Characteristics of Present Land Use

S.N.	Description	Area (ha)	Percentage	No. of Parcel
1	Agriculture	1423.33	84.77	11103
2	Residential	165.08	9.83	2684
3	Public Service	55.33	3.30	717
4	Commercial	13.44	0.80	114
5	Riverine & Lake Area	8.36	0.50	93
6	Industrial	6.90	0.41	41
7	Forest	5.93	0.35	77
8	Cultural & Archeological	0.42	0.03	6
9	Excavation Area	0.24	0.01	12
	Grand Total	**1679.02**	100.00	**14847**

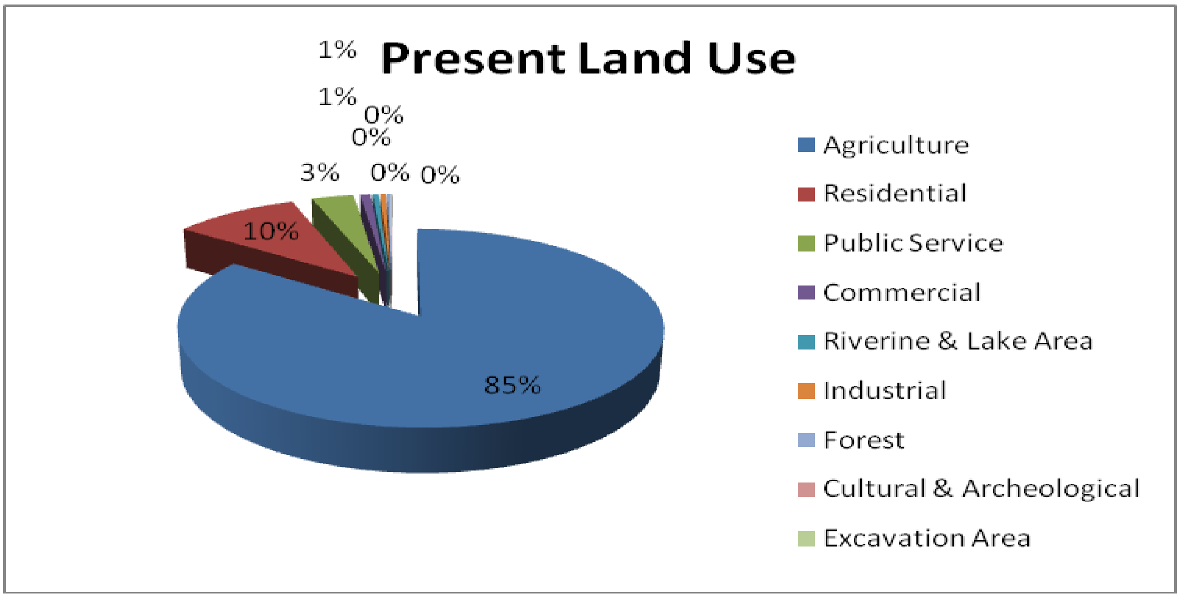

Figure 4.1: Distribution of Cadastral Parcel on Present Land Use

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 Karahiya VDC of Rupandehi district of Nepal. The land use zoning shows a restructuring on the existing land use. In the cadastral area of the VDC, out of the designated 11 classes, zoning for nine classes is made thus avoiding only the Mining & mineral and undersigned the other zone. Agriculture land parcels is reduced from 1423 ha to 1308 ha a significant loss of 8% in terms of areal extent where as agriculture land parcels is reduced from 11103 to 9828 land parcels. The significant change in the existing agriculture land use land parcels allocation has converted into residential, commercial industrial and public service land use. Similarly, other land use parcels changes into forest and public service. Further, riverine and lake area some cadastral parcel converted into forest mostly along the river. Prominent change of Residential land parcels has increased by 101 ha (89% of conversion area) and increased by 1035 land parcels. Commercial land parcels has increased by 8 ha (7% of conversion area) and increased by 60 land parcels. There is marginal increase in public service land parcels by 5ha (5% of conversion area). The distribution of cadastral parcel in land use zoning classes is shown in Figure 4.2.

Table 4.2 Parcel Characteristics of Land Use Zoning

S.N.	Description	Area (ha)	Percentage	No. of Parcel
1	Agriculture	1308.85	77.95	9828
2	Residential	256.18	15.26	3528
3	Public Service	72.42	4.31	1100
4	Commercial	18.97	1.13	165
5	Riverine & Lake Area	8.03	0.48	82
6	Industrial	7.68	0.46	44
7	Forest	6.24	0.37	84
8	Cultural & Archeological	0.42	0.03	6
9	Excavation Area	0.23	0.01	10
	Grand Total	**1679.02**	**100.00**	**14847**

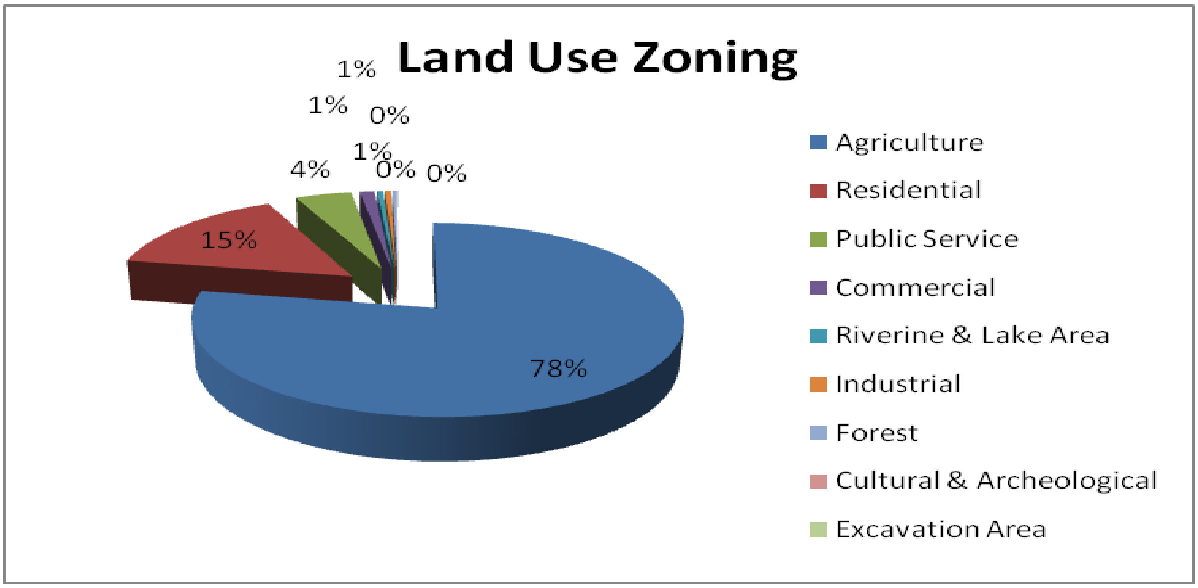

Figure 4.2: Distribution of Cadastral Parcel on Land Use Zoning

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

S.N.	Description	Area (ha)	Percentage	No. of Parcel
1	Agriculture /Agriculture	1308.85	77.95	9828
2	Residential /Residential	155.23	9.25	2493
3	Agriculture /Residential	100.96	6.01	1035
4	Public Service /Public Service	55.33	3.30	717
5	Commercial /Commercial	11.06	0.66	105
6	Residential /Public Service	9.85	0.59	191
7	Riverine & Lake Area /Riverine & Lake Area	8.03	0.48	82
8	Agriculture /Commercial	7.91	0.47	60
9	Industrial /Industrial	6.88	0.41	35
10	Forest /Forest	5.93	0.35	77
11	Agriculture /Public Service	4.82	0.29	171
12	Commercial /Public Service	2.38	0.14	9
13	Agriculture /Industrial	0.80	0.05	9
14	Cultural & Archeological /Cultural & Archeological	0.42	0.03	6
15	Riverine & Lake Area /Forest	0.31	0.02	7
16	Excavation Area /Excavation Area	0.23	0.01	10
17	Industrial /Public Service	0.02	0.00	6
18	Riverine & Lake Area /Public Service	0.02	0.00	4
19	Excavation Area /Public Service	0.01	0.00	2
	Grand Total	**1679.02**	**100.00**	**14847**

The change comes for all classes from agriculture. Out of the total 1679 ha of land parcel currently 1565 ha remains constant and 114 ha of the total cadastral land parcel area were converted from agriculture, other and riverine & Lake Area into the residential, forest, commercial, public service and industrial land use classes. The most prominent among them is to residential 101ha (89%), commercial 8ha (7%) and public service 5ha (5%). The new characteristics of the VDC is now more homogeneously structured, and looks to be restructured with sufficient allocation for industrial and commercial use, preserving in the same time the parcels and areas under forest and public use.

CHAPTER 5: CONCLUSIONS

5.1 Conclusions

Due to the involvement of many stakeholders directly and indirectly the land use planning and management is a cross-sectoral issue. Therefore, a single measure may 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, 2069.

The present exercise is fruitful and it produced required maps, data base and reports on the theme, which will be helpful in providing 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 the 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. During field work, ortho-rectification and geo-referencing, some 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 the 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.

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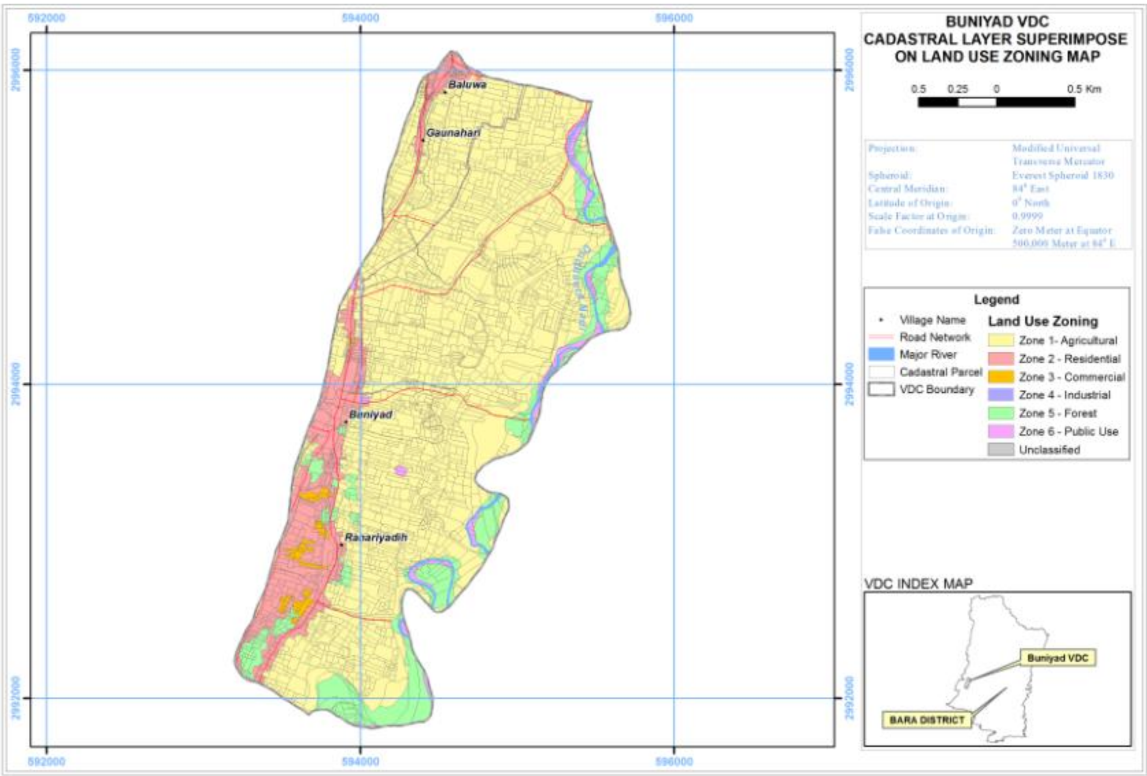
Appendix

Superimpose Map



VDC Profile

FINAL REPORT

Preparation of Profile of the Study Area

Karahiya VDC of Rupandehi District

FOR

Consulting Services

For

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

Package No: 11

Anandaban, Devadaha, Karahiya, Kerwani, Madhawaliya, Makrahar, Shankar Nagar, Tikuligadh, of Rupandehi District (8 VDCs)

Preparation of Profile of the Study Area
Karahiya VDC of Rupandehi District

This document is one of the outcomes of the project entitled **Preparation of VDC level Land Resource Maps** (Present Land Use Maps, Soil Maps, Land Capability Maps, Land Use Zoning Maps and Cadastral Layer Superimpose and VDC Profile), **Database and Reports** of Package 11 awarded to SHREEYA-KRS JV by the Government of Nepal, Ministry of Land Reform and Management, National Land Use Project (NLUP) in Fiscal Year 2072-073. The VDCs covered under this package include eight VDCs of Rupandehi district namely **Anandaban, Devadaha, Madhawalia, Makrahar, Karahiya, Kerwani, Sankar Nagar and Tikuligadh**.

Mr. Kul Bahadur Chaudhari was involved and solely credited for the preparation of maps, database and reports on risk themes.

The VDC areas analyzed for different themes of the NLUP Project are computed from cadastral maps provided by DOLIA Office of Nepal. Therefore, the areas of the VDCs may not be the same as computed from Topographic Database provided by the Survey Department of Nepal.

The consultant is obliged to state that the Imageries, GIS database and other outputs produced for the project is owned by National Land Use Project (NLUP), Mid-Baneshwor, Kathmandu. Therefore, the authorization from the NLUP is required for the usage and/or publication of the data in part or the whole.

ACKNOWLEDGEMENT

The SHREEYA-KRS JV is highly obliged to National Land Use Project (NLUP), for awarding the project **Preparation of VDC level land resource maps** (Present Land Use Maps, Soil Maps, Land Capability Maps, Land Use Zoning Maps and Cadastral Layer Superimpose and VDC Profile)**, database and reports, Package 11 of Rupandehi district**. The consultant would like to extend special thanks to Mr. Nagendra Jha, the Project Chief of NLUP, for his constructive supports during the project period. Similarly, the consultant would also like to highly acknowledge the overall supports of Mr. NabarajSubedi, Chief Survey Officer. Likewise, the consultants would like to extend thanks to Mr. SumirKoirala, Survey Officer, Mr. EkrajGiri, Account Officer, Mrs. Manju Devi, Store Keeper and the other staffs of the NLUP Office for their supports during the project period.

The consultant would also like to thank the local people, members of the different political parties and staffs of the VDCs and local institutions of **Anandaban VDC** of Rupandehi District for providing their valuable time to the study team in discussing different aspects of the project. Without their support this work would not have been completed.

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CHAPTER 1: AN OVERVIEW OF KARAHIYA VDC

1.1 Context/Naming and Origin of the VDC

Karahiya VDC is one of the VDCs (currently a part of Tilottama Municipality) of Rupandehi district. People started to live in the VDC many years before, especially after malaria eradication in the Terai region during 1950s. As reported in the VDC profile 2067, there is a belief about naming and origin of the VDC. There was a village named*Karaiya* where Tharu people used to live. There was a temple of *DiharBaba* in the village and the temple still exists. Tharu people go to the temple during their festivals to worship and ask to fulfill their wishes from the *Baba*. Traditionally, they used to do *puja* before they plant their crops. In that day, they used to make *Prasad* in big pan (*Karai*). Tharu people say '*Karahi*' in their language for the*big pan*. They started to say *Karahi*to the place where they cook '*Prasad*'. This name later became famous among villagers and neighboring villages. Then after, during the formation of the VDC,Nepal government named the VDC as Karahiya.

1.2 Location

Karahiya VDC located at almost middle part of Reupendehi district in Lumbini Zone, Western Development Region. Geographically, it is located between 83° 27' 50" to 83° 31' 20"E longitude and 27° 35' 20" to 27° 35' 58"N latitude. The VDC is bordered by Makrahar & Gangoliya VDCs to the east, Anandaban VDC to the west, And andaban & Debdaha VDCs to the north and Madhabaliya & Gangoliya VDCs to the south (Figure 1.1). The VDC is in northern side from Bhairahawa, the district headquarter. The VDC has a total area of 2082.81 ha. The extension of the VDC is 4.7 km and 8.8 km in east-west and north-south respectively. Almost all land of the VDC is plain.

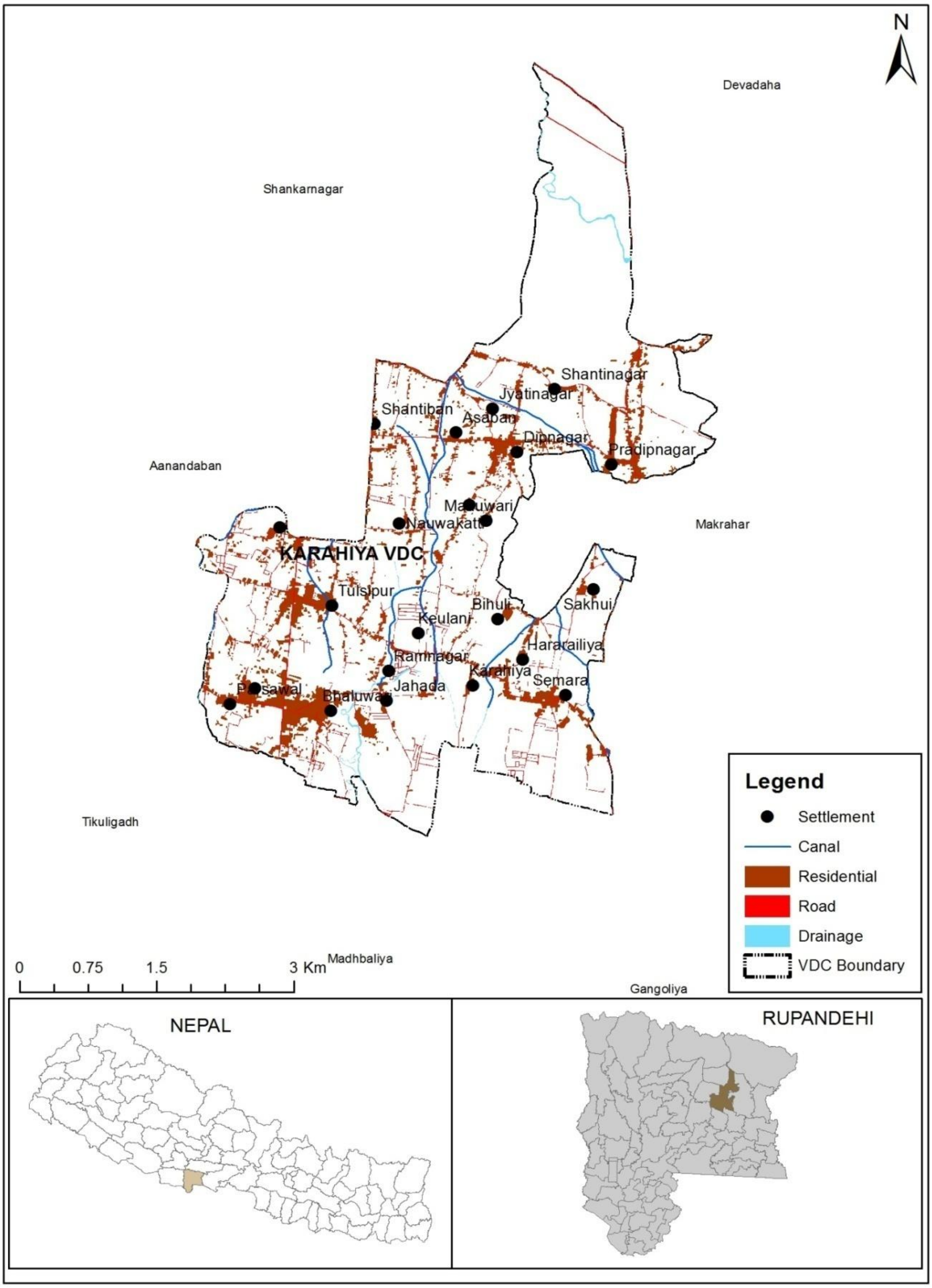

Figure 1.1: Location Map of the Karahiya VDC

1.3 Administrative Units and Settlements

As reported by Ministry of Federal Affairs and Local Development, Government of Nepal, currently, there are 50 VDCs and 6 Municipalities in Rupandehi district. Karahiya VDC is no more exists as a separate entity of VDC; it is a part of Tilottama Municipality after the decision of Nepal Government in 2071 BS (2014). Now, the VDC area is known for ward number 9, 10, 11 and 12of the Tilottama Municipality.

According to the population census 2011, there were 4267 households with a total population of 18274. According to the VDC profile (2067), there are 3360 households with a total population of 24398. **Number of households by major settlement is given in Table 1.1. Households were** not evenly distributed across the ward/settlement**. Largest number of households were concentrated in ward number eight, accounting for 1099 households**. Ward number five accounts for minimum number of households 101.The average household size of the VDC is 4.2,which is lower than national average of 4.88.

Table 1.1: Ward wise Distribution of Settlements and Households

Ward No.	**Settlements**	**Households**
1	Tulsipur, Shankarpur, Teulani, Butikot, Jhimaldanda, Sainikkot	220
2	Mangalapur, SunthaiyaPath, PuranoSadak	219
3	Bhalawadi, Chamkipur, Pasathor, TharuGaon, Musiyatole, Manakamana Path, Parbhat Path, Samabesitole, Maya Debi Marga, Namuna Path, Engineering Marga	703
4	Jahada, Dalka, Shri Deba Path, Bhalwadidanda	188
5	Karaiya, Ramnagar	101
6	Barag Daba, Sakhui, Haraiya, Simara	280
7	Simara Bazar, Darsantole, SimaraGaon	225
8	Char No., Shantinagar, Jyotinagar, Tallo Suryapura	1099
9	Tin No, Tin No. Dakshintole, Premnagar, Keulani	325
Total		**3360**

Source: VDC Profile,2067

CHAPTER 2: PHYSICAL SETTINGS

2.1 Physiography

The Indo-Gangetic Plain is situated south of the foothill (Siwaliks) and elevation ranges from 100 to 200 m. The plain is developed due to activation of the thrust (e.g., Main Frontal Thrust; MFT). This thrust is considered as evolution before 1 million years ago. The quaternary sediments are deposited by the river in geological past time. Physiographically, the proposed study area is located the Indo-Gangetic Plain (Terai Plain). External process as denudation consists of alluvial deposits and internal physiographic process as tectonic movements are responsible for making land froms such as active and recent alluvial plain, alluvial fans and terraces and depositional basins which have affected the soil formation. Topography of the basin is nearly flat.

2.2 Gemorphology

The Indo-Gangetic Plain is east-west trending basin and distributed in the southern part of the Himalaya. The plain is extended just down to the foothills of the Siwaliks. Geomologically, the Indo-Gangetic Plain is divided into the Bhabar, Middle Terai (Marshy land) and Southern Terai zones. The Bhabar zone is located just down to the Siwalik Hills and composed of the boulders to cobble, pebbles and represents highly rechargeable area for the hydrogeological phenomenon. The Middle Terai is characterized by presence of thick sands and pebbly sand beds. Southern Terai is composed of thick beds silty sand and clay as well as thin layers of coarse sands also. The age of the sediments deposition of the Indo-Gangetic Plain is Pleistocene to Holocene (recent).

On the basis of the sediments, the unconsolidated sediments of the Terai Plain or Indo-Gangetic Plain are subdivided into 1a and 1b units. The 1a unit consists of loose, thick alluvial deposits, deposited or reworked by Ancient River including river terraces. The 1b unit is characterized by presence of alluvial fans, tallus and colluvial deposits. The study has been covered by unconsolidated sediments of 1a of the Indo-Gangetic Plain. According to the geomorphology, the study area (**Karahiya VDC**) falls in the sediments Middle Terai zone (Marshy land) that is related to sediments of 1a.

2.3 Geology

Geologically, **Karahiya VDC** belongs to the Indo-Gangetic Plain or Terai. The VDC is covered sediments of Middle Terai zone of the Indo-Gangetic Plain (1a). The Middle Terai zone is composed of thick beds of silty sands to coarse sands and some layers of pebbly sands. These sediments were deposited by the ancient river and deposited in alluvial plain or ancient basin. Thickness of the sediments of the Middle Terai is more than 500 m. The topography of the VDC is more or less flat.

The sediments of Middle Terai zone (Figure 2.1) cover about 95 percent area of the VDC whereas the 1b unit has covered 5 percent area. The sediments of the 1b are distributed in the eastern part of the VDC whereas the sediments of the 1a is distributed in the central and western parts of the VDC. The 1a unit is characterized by presence of the unconsolidated sediments contents of sands with cobble and pebbles. Lithologically, it consists of sub rounded to rounded, well sorted cobble and pebble interbeds with sands and silty clay layers. The sediments either fine or coarse sediments are derived from the Lesser Himalaya rocks. The cobble and pebble are composed of quartzite, sandstone, gneiss. The loose beds of sands and gravel are roughly horizontal and show fining upward succession with cobble pebble with loose sands and silty sands at base and silty clay and clayey silt and clay as the residual soil on top. Some planar bedding structures are observed in sandy layers. The top layers are covered by thick residual soils contents of silty sands and clayey sands. The 1b unit is composed of the alluvial fans, talus and colluvial deposits. The sediments were deposited along the ancient river valley in geological past. The fineness of the sediments increases towards south of the VDC area.

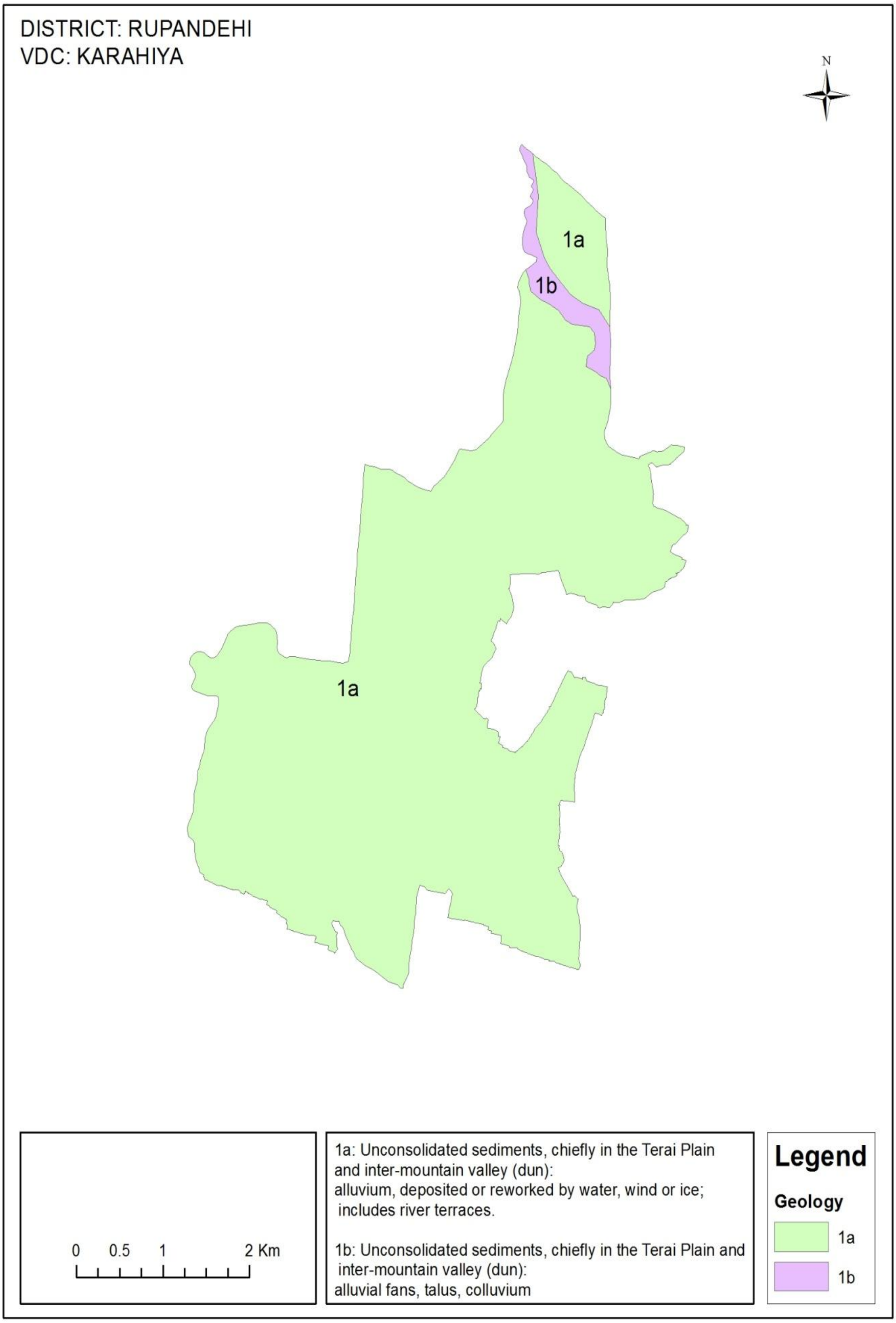

Figure 2.1: Geology Map of the Karahiya VDC

2.4 Drainage

The VDC area is endowed with historic farmers managed irrigation system called SorahChhattis(Figure 2.2). Water is therefore not a scarce commodity, although irrigation management is not very efficient. Rivers network seem to be found on the south part in very small area but branches of SorahChhattis irrigation system as shown in the Figure covers large spatial area of the VDC. The branching of this irrigation system indicates that water flows in N-S fashion of the VDC. No other irrigation canals of prominence are seen to supply water in this VDC. Farmers reported that it is not hard to find groundwater aquifers (commonly 20 – 30 ft) down from the land surface. A large number of farmers also depend partly on private shallow tube-wells or dug-wells for supplying water for growing cereal crops, and culinary or household purposes.

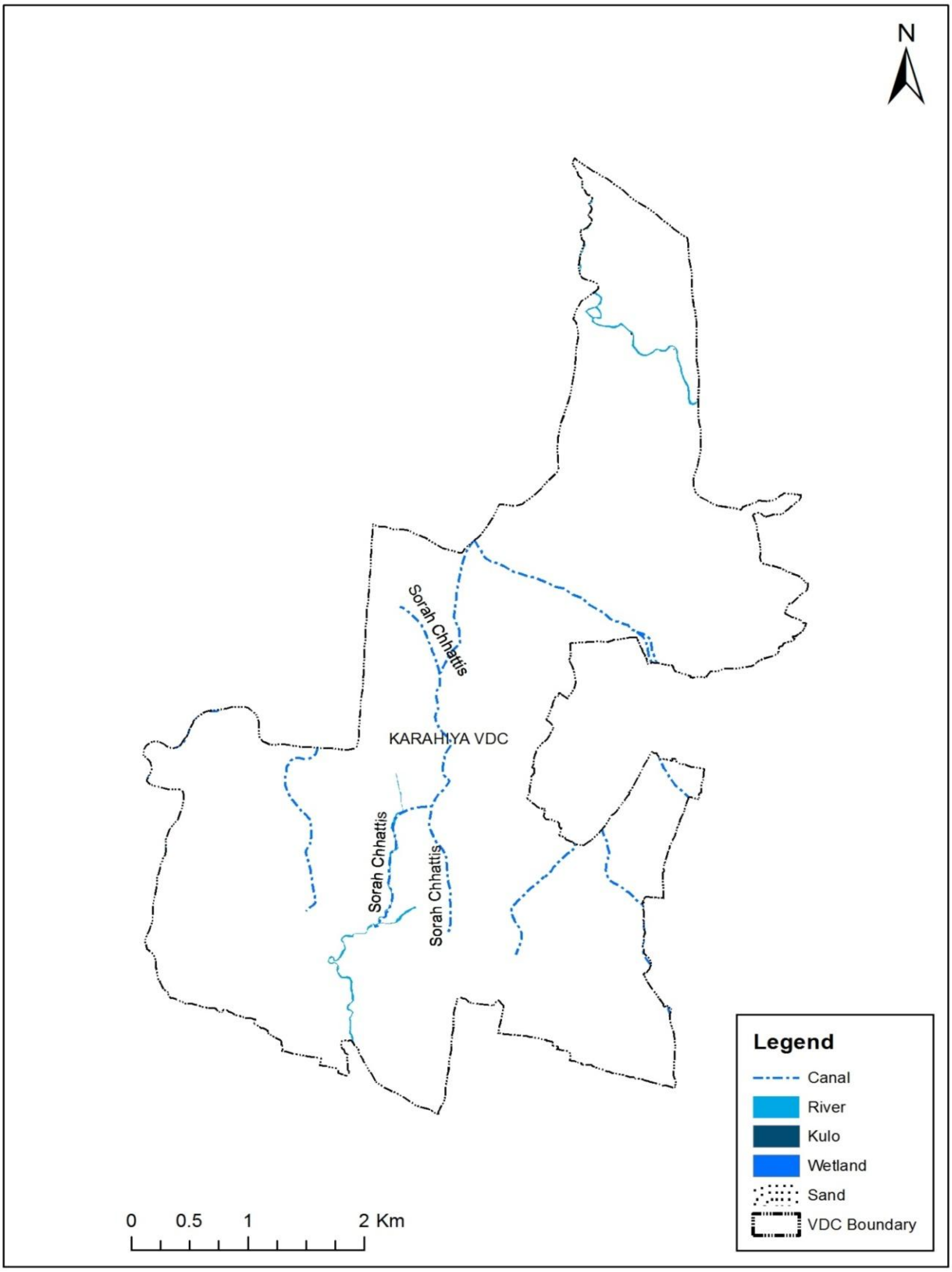

Figure 2.2: Drainage Pattern of the Karahiya VDC

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 land surface of the VDC is entirely flat. However, it is not homogenous, and dissected by surface run-off, small streams and river flowing south from the little elevated parts of the north.

2.5.1 Slope

Slope is an important topographic factor affecting landform and soil development process. That is why soils appearing at different slope positions (i.e., summit and back slope or toe slope or flat areas) along a slope transaction exhibit great variability in soil fertility and productivity. Slope generally is expressed as a percentage that is calculated by dividing the difference in elevation between two points by the horizontal distance and multiplying by 100. In Karahiya VDC, nearly 99 percent areas occur on simple slopes 0-3 degree slopes meaning to be nearly level (Figure 2.3). This is a clear indication that unlike in neighboring hills, these plain areas do not have land degradation problem due to erosion. Here the rate of deposition of natural sediments should be greater than the rate of sediment removal.

Slope also forms an important criteria for soil classification. The slope of the project area is mostly found to be less than 3 degree and 3-5 degrees slope are found in very small quantity. The classified slopes are presented in Table 2.1.

Table 2.1: Soils distribution in the VDC area based on slope classes

Slope description	Slope (in degree)	Symbol
Nearly level	<1	S1
Gentle slope	1-3	S2
Gentle slope	3-5	S3

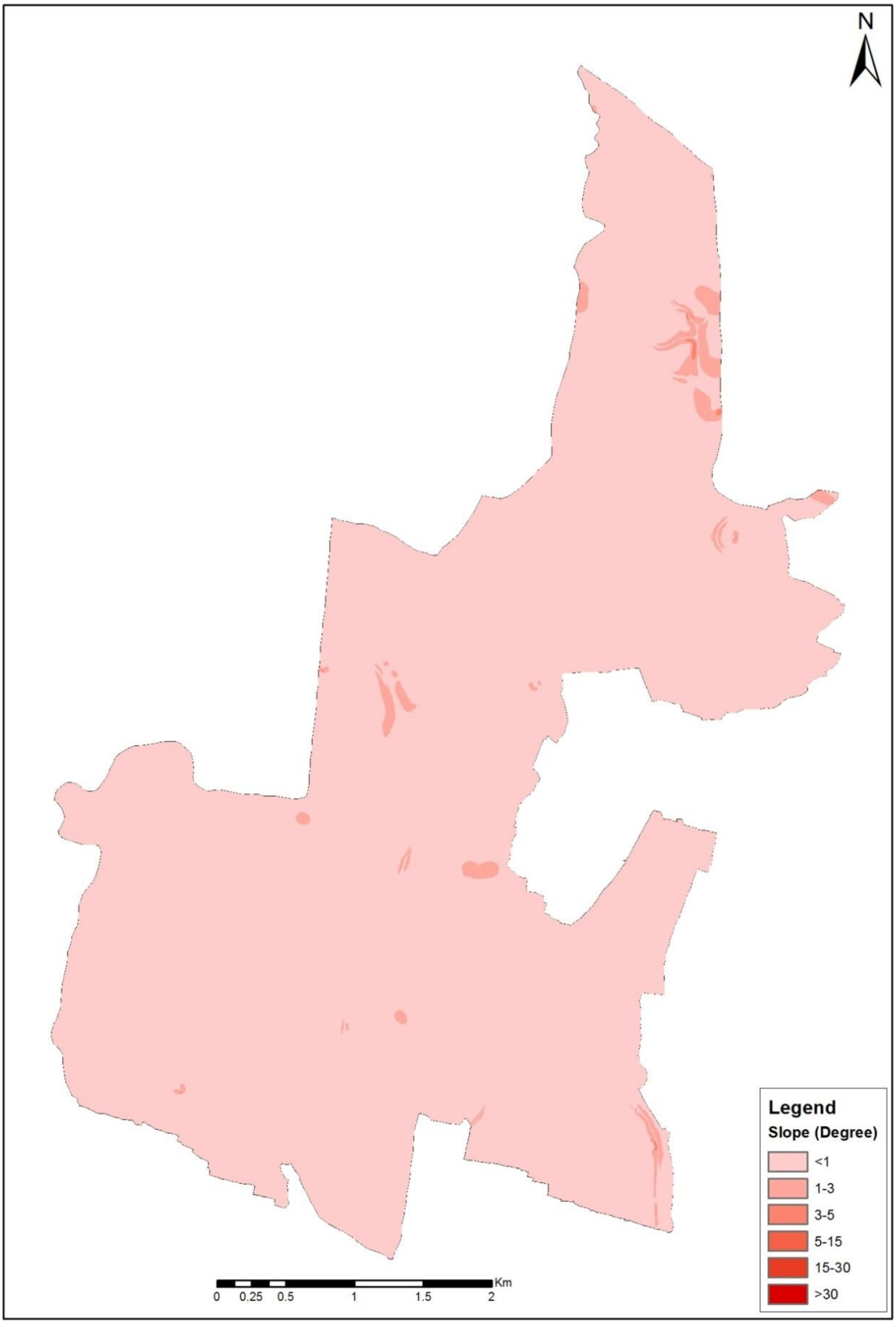

Figure 2.3: Slope Map of the Karahiya VDC

2.5.2 *Elevation*

Elevation plays determining role in the utilization of land for different purposes. It is the important criterion for dividing the land surface into different physical divisions. It also governs to a large extent the formation of soil profiles, soil depth and soil nutrients.

Soil development is greatly influenced by elevation on which soils occur, the plant and animal life which they support and the amount of time which they have been exposed to these conditions. Shallow soils on the sloping lands and deeper soils on flat areas downstream are typical examples of how elevation controls formation and distribution of soil types on the landscape. Based on elevations, recorded using GPS receiver at 14 soil pit locations in this VDC, average elevation of these pits was found to be 108.5 m above msl (± 4.3m). This means that land systems within this VDC occur at very low elevation and differences across the locations is not big. According to digital elevation model (DEM), the VDC elevation varies from 104 to 125m msl(Figure 2.4). The northern region of the VDC map with gray tone indicates the region of higher elevation whereas the southern region with darker tone signifies the lower elevation.

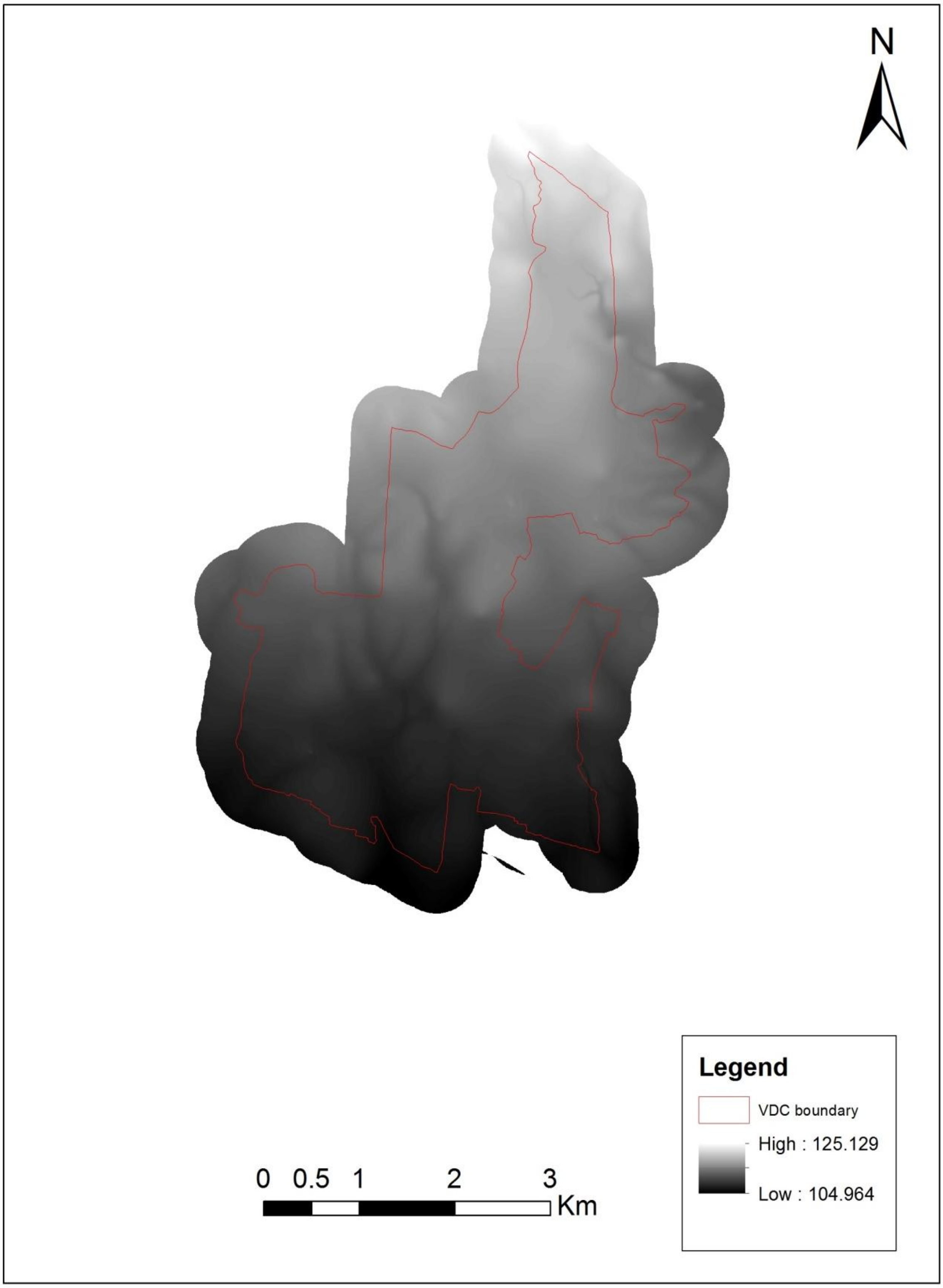

Figure 2.4: Elevation Map of theKarahiya VDC

2.6 Climate

The monthly average maximum and minimum temperature for the period of 10 years (2005 and 2014) measured at the nearest weather station at Butawal is shown in Figure

2.5. Differences in maximum and minimum temperatures through the months from January to December as seen on the figure in these years remained fairly homogenous. Maximum monthly average temperature ranged between 21-37^{o}C with April being the hottest month, whereas minimum monthly average temperature ranged between 11-24^{o}C with December being the coldest month of the year. The range within which these temperatures are distributed across months is the range suitable for biochemical processes in the pedosphere and also for favorable growth of most of crop plants.

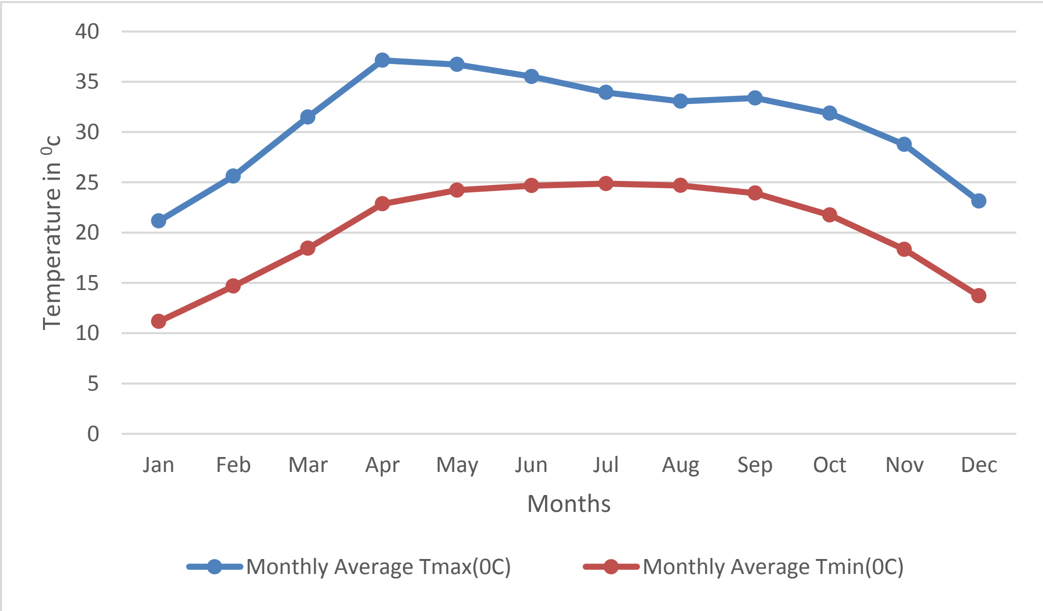

Figure 2.5: Monthly average maximum and minimum temperatures recorded at the Butwal weather station of Rupandehi district for the years from 2005 to 2014.

Annual total rainfall (2005 - 2014) of the VDC is shown in Table 2.2. Minimum (1224 mm) was recorded in 2012 and maximum (2907 mm) in 2010. This clearly shows a tendency of great year to year variation in annual rainfall pattern which in a way poses risk in crop production facing scarcity of water in some years and flooding in other years. Looking at more details, Figure 2.6 shows a greater variation in monthly average rainfall in these years. Monthly average rainfall increased sharply from April, peaked in the month of July (619 mm), dropped sharply after August and remained below 80 mm towards October. Such a seasonal distribution of rainfall shows that rainfall alone would not be enough to recharge soil profile for profitable crop production. Hence, irrigation development is necessary to improve soil fertility for food production in this area.

Table 2.2: Annual rainfall (mm) at the Butwal weather station for the year from 2005 to 2014

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total	1496	2769	2532	2173	1614	2907	2061	1224	2035	2726

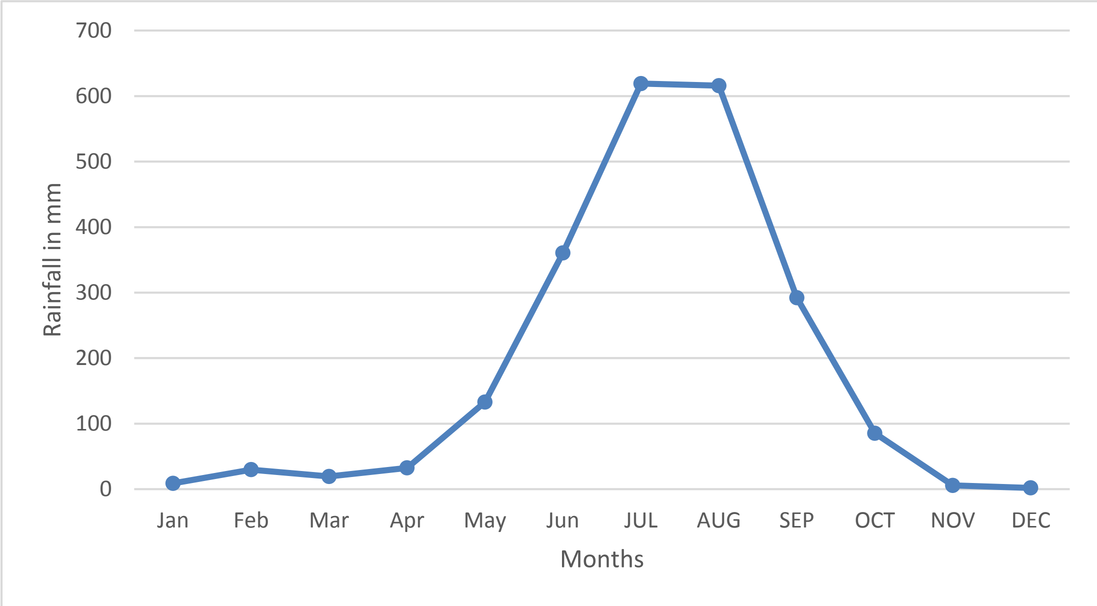

Figure 2.6: Monthly average rainfall at Butwal weather station for the years from 2005 to 2014.

2.7 Forest and Biodiversity

Rupandehi is agriculturally important south western district of Nepal bordering India in South, and Palpa, Nawalparasi and Kapilvastu in the North, East and West respectively. More than half of the land in the district (58.45 % or 82,622ha) is under cultivation agriculture (Census, 2013). The diverse geography of the district attributed to a combination of Terai plain and Chure hills region. The elevation of the district lies between 100m to 1229m from sea level. The total area of the district is 1,360 km^2 with 16.1 percent in Churia Range and rest in the Terai region.

Forest land is covered by 25528 ha(District Profile). This district is highly important from the rich Natural resources and biodiversity point of view. The forest types have been categorized as Community Forests (15234.92 ha), Public Land management Group(216.8 ha), Collaborative Forest management (2048.04 ha),Religious forest(113.05 ha),Private forest (92.2 ha),other organizational government forest(1565.64) and Government managed forest (6357.35 ha)(District Forest Office).The package 11 covers 8 VDCs namely Devdaha, Kerwani, Makrahar, Shankar Nagar, Ananadban, Karahiya, Tikuligadh and Madhbaliya. The number of community forests handed over and having constitution and forest operation plans are 31 in these 8 VDCs.

The major forest area is dominated by *Sal* species and most of the community forests have been supported by Bakaino, *Masala, Kadam,Khair, Sissoo* plantation in the gaps and open areas of community forests. There are few forests having *matured* species but most of the forests have *immature* and few are in the reproduction stage. The crown density in most of the community forests belongs to *sparse* i.e. 40 to 70 percent and the remaining less than 40 percent. There are two forests that are within agricultural land in the form of agro-forestry. Besides private tree plantation in the private lands can be regarded as private forest and this can be considered in the agriculture land. These plantations on private land either in small patches or on the bunds of agriculture fields can be taken as agro-forestry. The trees are commonly for the use of small timber, pole and fuel wood purpose to reduce the pressure on the forests.

All these forests characterize by *Tropical Climatic Zone* comprising of either *hardwood* or *Terai mixed hardwood*.

The following are the plant biodiversity, NTFPs and wild animals found within the forest areas of eight VDCs of Package 11:

Plant biodiversity: The plant biodiversity within the area covers Sal, Karma, Banjhi, Sissoo, Khair, Asna, Bot-dhangero, Harro, Barro, Jamun, Kusum, Dhouti, Bel, Rohini, Simal, Tendu,Bans Pate, Bhellar, Sagon, Arjun, Acacia Auriculiformis, Kachari, Masala, Dabdabe, Bair, Mainkanda, Piyari, Vijaysal and Gular etc.

NTFPs: Kurilo. Tarul, Pipala, Chyau, Raj brikchha, Bel, Jamun, Harro, Barro, Amala, Shikakai, Ritha, Karaunda, Tanki , Setomusali, kalomusali, Bhanti, Bent, Gurjo.

Wild animals: Nilgai, Chittal, ,Jackle, Purcupine,Gohoro, Sungohoro,Leopard, Monkey, Kharayo, Bandar, Bandel, Syal, Ban-kukhura, Titra, Mayur, Lokharke, other Birds, Dhukur, Suga, Ajingar etc.

The status of forest in Karahiya VDC is not very much different in terms floral diversity, non-timber forest products and use of forest products. **Forest land** has been observed as the dominant land use category among the groups under Level-1. As the Karahiya VDC lies within the Tarai plain in the district, the forest is of **Tropical climatic vegetation** in hierarchical level 2 characterized by **Hardwood** in hierarchical level 3. Similarly, the Forest in the VDC is characterized as hardwood type on species such as **Sal** at Level 4 hierarchy**.** Within **Level 5,** all forest covers were found in **dense** crown density. All type of forest covers were found in Mature and Immature Phase based on the Maturity class at **Level 6**. The forest covers were kept in **Government and Community** category because of the ownership right for its use.

The present status of faunal and floral diversity and available NTFPs of the Karahiya VDC is shown in Table 2.3. There is only one community forest in ward number 11 of the municipality.

Table 2.3: Distribution of forest with faunal/floral diversity and NTFPs

Name of Forest	Name of VDC	Ward No.	Area(Ha)	Main plant species	NTFPs	Wildlife Animal biodiversity
karaihiya CF	Karaihiya (Tilotma)	11	265	Sal, Asna, Karma, Banjhi, Botdhangero, Mahuwa, Jamun, Sissoo, Teak, Simal, Rohini, Mashala	Harro, Barro, Amla, Bel, Sikakai, Pipala, Kurilo, Sindure, Thakal, Bamboo, Bet, Sikakai, Sitalchinni	Leopard, Fox, Deer, Monkey, Bandel, porcupine, Jackle, Neelgai

Source: Field Survey, 2016

The VDC has only one community forest.

2.8 Natural Hazards and Environment

The region has a subtropical monsoon climate with a warm wet season from mid-June to September a cool dry season from October to February, and a hot dry season from March to mid-June. The annual rainfall is about 1700 mm of which 85 percent falls during the monsoon season. The mean temperature is about a maximum 45 ^{0} C during May and a minimum of 10.5 ^{0} C from December to January.

Agriculture system in this VDC seen traditional as well as modern practice has been applied for sustain their life. Having improved their irrigation facilities, many farmers have changed their cropping patterns from subsistence grain cultivation to cash crop and vegetable cultivation. This change in cultivation patterns contributes to increased incomes and nutritional improvement of people. People have started to earn more from their cash crops.

The communities in the region are still involved in farming but rapid changes are creating an extremely hazardous situation for all forms of biodiversity.

CHAPTER 3: SOILS AND LAND CHARACTERISTICS

3.1 Land System and Soil Characteristics

3.1.1 Land System

Land systems are areas or regions with recurring patterns of component parts, in geographical, geological, and ecological terms. They are generally seen in terms of landform, underlying geology, vegetation and can also have other components that may be recurrent across regional landscapes. They are used extensively in surveys of land use planning and land management (Speck, 1960). The land system of the VDCs presented in this report was seen as fairly homogeneous and in accordance with LRMP (1986), it falls under land systems 2 characterized by recent alluvial plain, depositional and erosional lower piedmont.

Within the physiographic regions, land systems are characterized as landform types based on recurrent pattern and processes of landform, geologic materials, terrain slopes, and limit of arable lands. The landforms affect soil formation and profile development. They could be named variously depending on the location they are formed. They might be mountain landform, continental landform, river landform, fluvial landform, glacial landform, aeolian landform, slope landform and so on. Strong interactions are seen between landform, topography and vegetation to influence the process of soil formation and development.

The VDC reported herein, falls under the Terai Physiographic Region, is an alluvial plain - a largely flat landform mostly created by the deposition of sediment over a long period of time by one or more rivers coming from highland regions in the north and a big Tinau River in the West, from which this alluvial soil is formed. Other terms like 'floodplain' may also appear in this manuscript which may mean that this plain is formed a part of the land forming process, denotes the smaller area over which the rivers flood at a particular period of time, whereas the 'alluvial plain' is the larger area representing the region over which the floodplains have shifted over geological time. The landform of this VDC is defined as recent alluvial plain, depositional and erosional lower piedmont.

This study underlines the importance of soil-landform relationship and uses this concept as a scientific approach to form soil mapping units. LRMP (1986) divided physiographic regions of Nepal into distinct land systems following the recurrent pattern of landforms, geology, slope, and limits to arable agriculture. In LRMP report, Carson (1985) assigned land units to different land systems, and defined the boundaries based on position, slope, direction, and drainage pattern of landscape features and considered these features particularly important for local level project designing. The soils within the land types were classified based on detailed field survey. This study report also used these observations and experiences as a guide for soil association level classification. DEM technique proved to be helpful to delineate boundaries for landforms, land units and land types for detailed soil survey.

In developing map units, landform is further subdivided into land units basically defined by the mapable size of land surface aided by topographical variation. The description of soil mapping unit and the symbol was formed with the integration of land system, landform, land type with geological map and land use/land cover. The whole VDC area under study comes under 2b land unit which is predominantly a recent alluvial plain with position level and dominant slopes < 2 degrees.

Based on shape, size, tonal, color variation and relative elevation of the location, the landform and land types were identified on satellite imagery and DEM. The color variation ranging from light to dark represented the soil differences associated with degrees of soil wetness. Soil association as the universally accepted parameter for soil mapping was adopted in orders to correlate the soil pit with soil mapping units because these two spatial entities are geometrically different. Thus classifications were made based on soil association. Definitions of land system units of Karahiya VDC and associated map are shown in Table 3.1 and Figure 3.1, respectively.

Table 3.1: Definitions of land system, landform and land units of Karahiya VDC

Region	**Land system**	**Landform**	**Land unit**	**Dominant slopes$^{(0)}$**
A. Tarai	1	Active Alluvial Plain (depositional)	1a. present river channel	
			1b. sand & gravel bars	<1
			1d. higher terrace	<1
	2	Recent Alluvial Plain lower piedmont(depositional and erosional)	2b. intermediate position level	<1/2
			2c. intermediate position undulating	<1
	3	Alluvial Fan complex, upper piedmont (erosional)	3b. gentle slopes	1-3

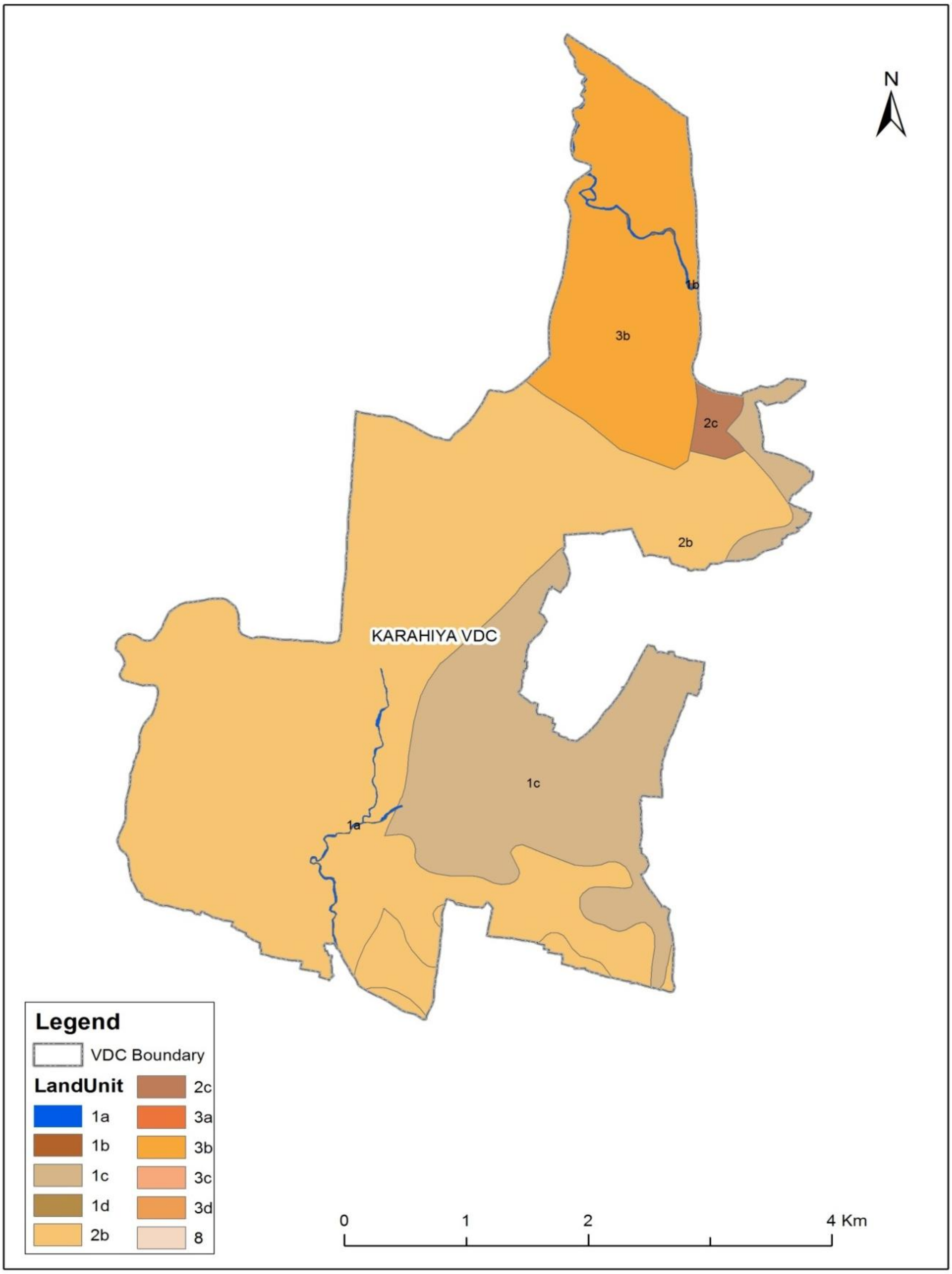

Figure 3.1: Distribution of Land units in Karahiya VDC

3.1.2 Soil Characteristics

Since early, the Government of Nepal has adopted USDA/NRCS soil classification system. In addition to this, World Reference Base for Soil Mapping –WHO system is also being taught in education sector of Nepal. In USDA system, soil type can be delineated at any level of generalization from Order to Series level, and sometimes up to phase level depending on the purpose of the study. The classification depends on the practical purposes for which these soils will be put forth. In this study, classifications are developed up to Family level which signifies the management options available or limitations these soils offer to an intended use. A subgroup level soil map of this VDC has been presented in figure 3.2.

Soils presented in table 3.2 below were derived from the field survey of the VDC. A total of fourteen pits were sampled representing all soil types of this VDC. Soils were described and interpreted using USDA system of soil classification. Only two kinds of soils are found at order level, they are Inceptisols which occupy the largest share of total area (82.5%) followed by Mollisols (17.5%). At sub-order level, two of the dominant types are Umbrepts (56.6%) and Udepts (23.6%). At Great group level, Haplumbrepts (56.6%) followed by Dystrudepts (18.3%) and Argiudolls (14.7%) were found to be the three major soils. At sub-group level, Argic Haplumbrepts (23%) followed by TypicArgiudolls (14.7%) and Argic Dystrudepts (11%) represent the major soils in this VDC. Inceptisols are younger soils than Mollisols in USDA system of soil classification.

Table 3.2: Area covered by soils at different levels of classification, Karahiya VDC

Category		**Area**	**Percent**	**Category**		**Area**	**Percent**
Order				**Great Group**			
	Inceptisol	1719.09	82.54		Argiudolls	306.35	14.71
	Mollisol	363.72	17.46		Dystrudepts	381.20	18.30
					Hapludepts	110.24	5.29
Sub-Order					Hapludoll	57.37	2.75
	Ochrepts	47.64	2.29		Haplumbrepts	1180.0	56.65
	Udepts	491.44	23.60		Ustochrepts	47.64	2.29
	Udolls	363.72	17.46				
	Umbrepts	1180.00	56.65				
Sub-Group				**Family**			
	AgricHaplumbrepts	15.74	0.76		Coarse Loamy Mixed Hyperthermic	92.91	4.46
	Albic Haplumbrepts	684.61	32.9		Fine Loamy Mixed Hyperthermic	660.48	31.7
	Albic Ustochrepts	47.64	2.29		Fine Loamy Mixed Hyperthermic	227.67	10.93
	Argic Dystrudepts	227.67	10.93		Fine Loamy Mixed Hyperthermic	386.74	18.57
	Argic Hapludepts	110.24	5.29		Fine Loamy Mixed Hyperthermic	35.48	1.70

	Argic Haplumbrepts	479.65	23.03		Fine Loamy Mixed Thermic	110.24	5.29
	FluventicDystrudepts	118.05	5.67		Fine Silty Mixed Hyperthermic	4.76	0.23
	TypicArgiudolls	306.35	14.71		Fine Silty Mixed Hyperthermic	91.39	4.39
	TypicDystrudepts	35.48	1.70		Fine Silty Mixed Thermic	215.0	10.3
	Typic Hapludoll	57.37	2.75		Fine Silty Mixed Thermic	57.37	2.75
					Loamy Mixed Hyperthermic	10.98	0.53
					Loamy Mixed Hyperthermic	24.13	1.16
					Loamy Mixed Hyperthermic	47.64	2.29
					Loamy Mixed thermic	118.05	5.67

Source: Field Survey, 2016.

Note: Soil names at family level shown in the right corner belong to sub-groups given in the same line on the left side.

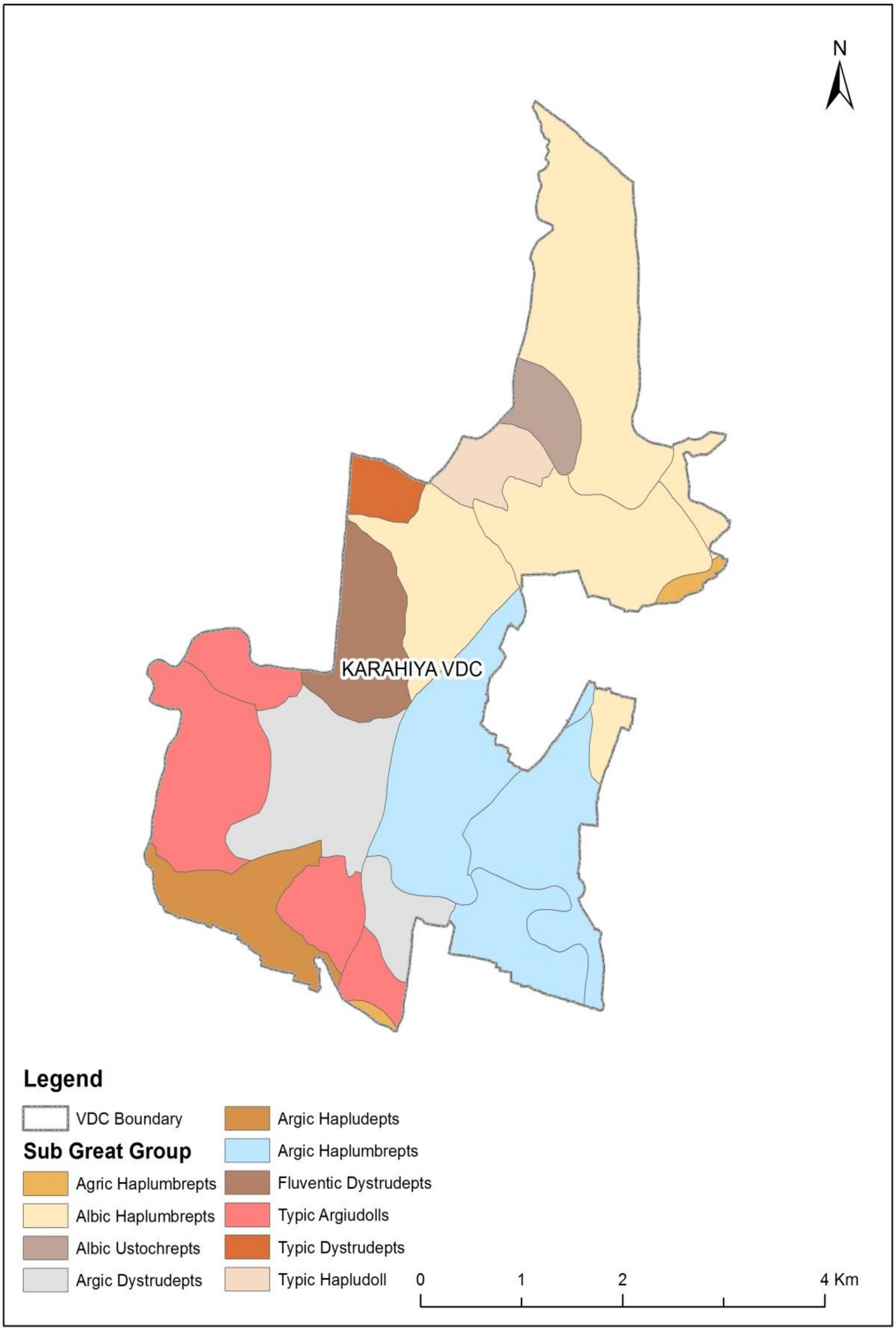

Figure 3.2: Subgroup level of soil classification in Karahiya VDC

3.2 Land Capability

The capability classification in Karahiya VDC is done mostly on the basis of land slope, soil rooting depth, and soil attribute sand other major limitations for crop cultivation (Table3.3, Figure3.3).The majority land area of this VDC has almost flat land and relatively deep soil. Based on these standard criteria of land capability classification, whole land area of this VDC is classified broadly in Class I based. The total land area is 1472 ha and all area is nearly flat with<3degreeslope and suitable for diversified crops with few limitations for agriculture and other uses. All lands falling capability class I are highly suitable for agriculture. The land capability classification has been further classified into four classes based on irrigation suitability (Table3.3,Figure 3.3).

Class I Au/1: Land well suited to a wide range of intensive cropping and grazing activities. It occurs on flat land with deep, well drained soils, and in a climate that favors a wide variety of crops. While there are virtually no limitations to agricultural usage, reasonable management in puts need to be maintained to prevent degradation of their source. Such in puts might include very minor soil conservation treatments, fertilizer inputs or occasional pasturephases.About120 ha (5.8%) ofland area isestimated underthisclassin theVDC

ClassIAu/1R:The land is highly suitable for Rice based intensive farming. This class is lower than ClassIAu/1 because of wet during rainy season for choice of crops. Itis estimated about197ha (9.4%) ofland inthe VDC.

ClassI Au/2: These lands are ranked lower than Class I in production capacity ut these lands are moderately to fairly suitable for irrigated farming. Some areas are suitable diversified crops because of wet condition. About 427 ha (20.5%) of land shave estimated in this class in the VDC.

IAu/2R: The lands in this category are similar to the land under class IAu/2 above, but ranked lower thanClass1R and IAu/2 in terms of productivity or are costlierto do the farmand land management practices (moderately to fairly suitable for paddy production under irrigation). The soil deficiencies can be ameliorated. These lands may possess poor drainage characteristics that affect winter crop production. Area under this land is 432 ha (20.7%).

ClassIIAu/1: The land is highly suitable for rice based intensive farming. This class is lower than ClassIAu/1 because of wet during rainy season which limits the choice of crops. Estimated area is about13.6ha (0.65%) in this class.

Class IIAu/2: These lands could be cultivated with some limitations. They are moderately to fairly suitable for irrigated farming. Some areas are suitable diversified crops because of wet condition. Estimated area is about179ha (8.61%) in this class.

Class IIAu/2s: The lands in this category are similar to the land under class IIAu/2 above, butrankedlower in terms of soils deficiency meaning limitations within rooting zones including shallowness or stones, low moisture-holding capacity, fertility difficult to correct.

Table 3.3: Land Capability Classes of KarahiyaVDC, Rupandehi

Land Capability Class	Area in ha	Percent	Arability
IAu/1	121	5.81	Highqualitylandforcommercial irrigated agriculture withcropdiversification
IAu/1R	197	9.44	Highqualitylandforpaddyproduction (wetland rice arable),cropdiversification
IAu/2	427	20.5	Landsaremoderatelytofairlysuitableforirrigatedfarming.Thenarrowrangesofdiversifiedcrops
IAu/2R	432	20.7	Wetland moderately suitable for arable agriculture (rice).
IIAu/1	13.6	0.65	Lands could be put to diversified cropping system, some limitations occur, requiring conservation measures.
IIAu/2	179	8.16	Lands could be put to diversified cropping system with some limitations, need conservation practices, irrigated crop-arable
IIAu/2s	76.6	3.68	Lands could be put to diversified cropping system with some limitations, need conservation practices, irrigated crop-arable, internal drainage problem which could be corrected.
Non-arable	628	30.2	
River	8.08	0.39	
Total	**2083**	**100**	

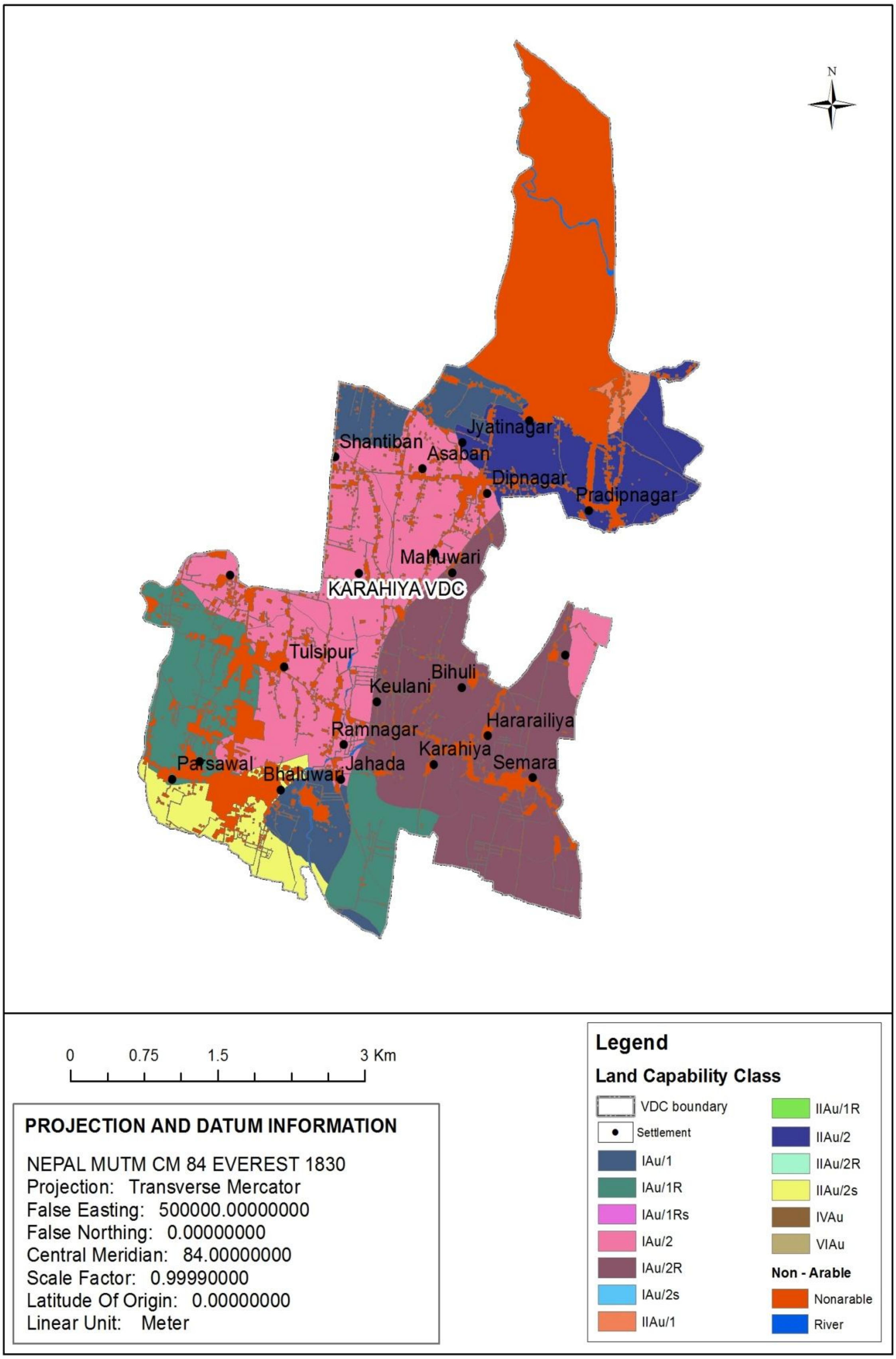

Figure 3.3: LandCapabilityClassesofKarahiyaVDC

3.3 Present Land Use

The general land use pattern of KarahiyaVDC at the broad hierarchical classification Level 1 has been provided in the (Table 3.4.)

Table 3.4: Land use Pattern at Classification Level 1

Description	Area (ha)	Percent
Agriculture	1440.33	69.15
Forest	339.46	16.30
Residential	186.28	8.94
Public Services	72.48	3.48
Riverine & Lake	14.22	0.68
Commercial	11.41	0.55
Industrial	8.88	0.43
Cultural & Archeological	0.29	0.01
Excavation	0.28	0.01
Others	9.17	0.44
Total	**2082.81**	**100.00**

Karahiya VDC covers a total of 2083 hectares (approximately 20.83sq. km) of land. Table 3.4 shows that the Agricultural land is the dominant land use category which covers1440 haof land with 69.15 percent of the total areal extent. Similarly, Forestland is 339 ha (16.30percent of the total extent). Likewise, the coverage of Residential, Public Service area, River line and lake area,Commercial,Industrial,Cultural and Archeological landExcavation land use covers 8.94 percent, 3.48 percent, 0.68 percent, 0.43 percent, 0.01 percent and 0.01 percent respectively. The other category covers 0.44 percent of the total area.

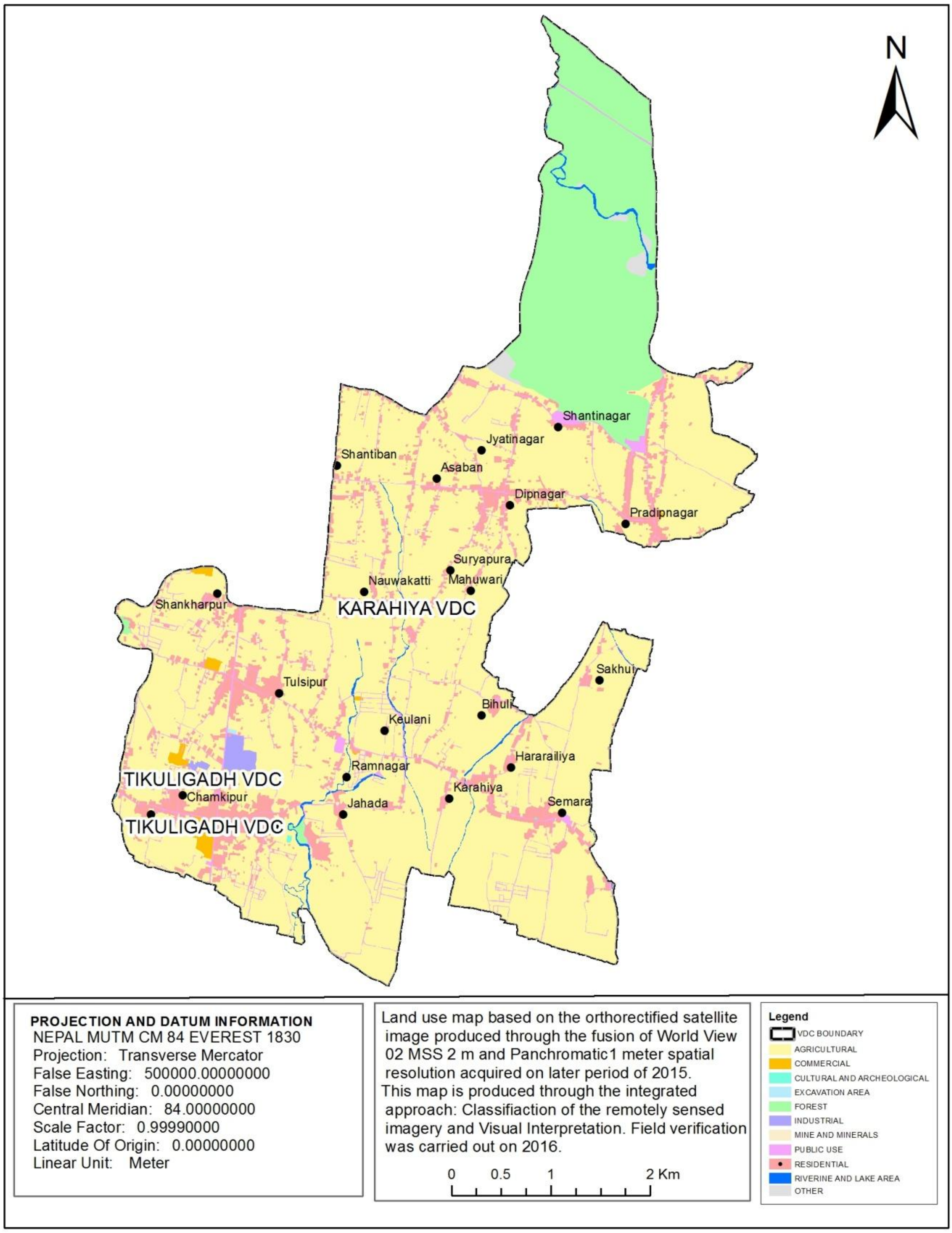

Figure 3.4: Present Land Use Map of the Karahiya VDC

3.4 Agriculture Pattern

All the agricultural land of the KarahiyaVDC is categorized as TeraiCultivation based on the physiographic region at the hierarchical classification Level 2. At the hierarchical classification Level 3, all the agricultural land in the VDC was categorized as Wet land cultivation andDry landcultivation based on the land form and land system. The agriculture land use pattern at the hierarchical Level 3 has shown in the Table 3.5.

Table 3.5: Agriculture Land use Pattern at Classification Level 3

Description	Area (ha)	Percent
Wet Land Cultivation	1095.88	76.09
Dry Land Cultivation	344.45	23.91
Total	**1440.33**	**100.00**

The total agriculture land of the VDC was about 1440ha in which Wet land and Dry land cultivationcombination covers1096haand 344harespectively. The distribution pattern of agriculture land is shown in Figure 3.5.

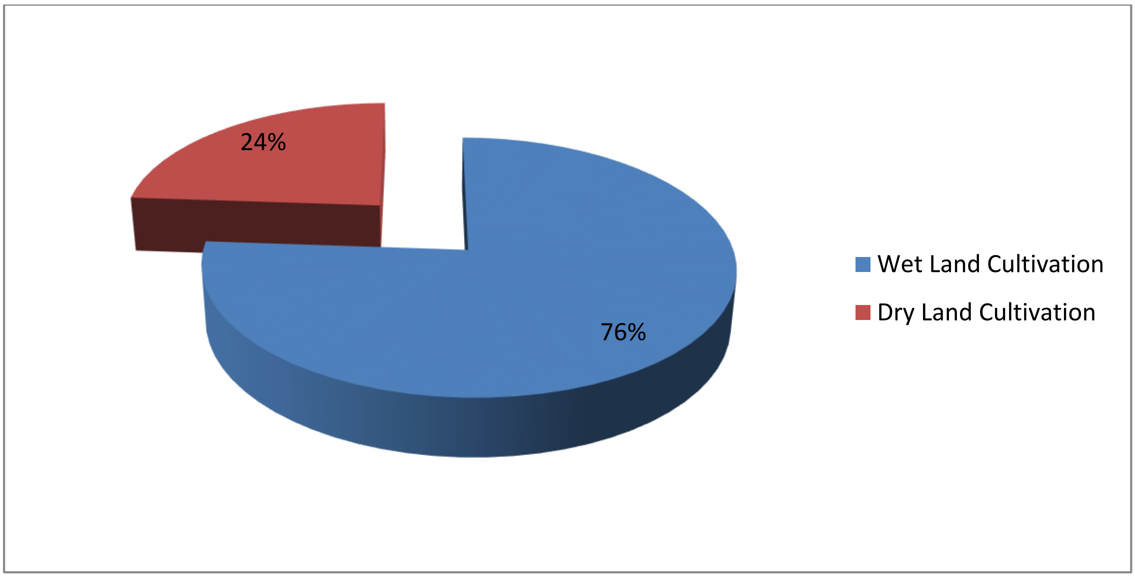

Figure 3.5: Agriculture Land by Types of Cultivation

Similarly, at Level 5, based on the cropping pattern the agricultural land use pattern in the VDC has been found under Rice-Pulse, Rice-Wheat-Pulses,Rice-Wheat, Rice-Oilseed, Rice-Fallow, Rice-Rice, Pulses-Others, barren Cultivable Land, Bamboo, Fruits, Pond for Fish Farming, Pulses-Fallow and Livestock/Cattle/buffalo Farm. The agriculture land use pattern at the hierarchical Level 5 has shown in the Table 3.6.

Table 3.6: Agriculture Land use Pattern at Classification Level 5

Description	Area (ha)	Percent
Rice-Pulses	401.46	27.87
Rice-Wheat-Pulses	365.38	25.37
Rice-Oilseed	319.96	22.21
Rice-Wheat	151.26	10.50
Rice-Fallow	80.65	5.60
Barren Cultivated Land	43.34	3.01
Rice-Rice	30.81	2.14
Pulses-Others	22.31	1.55
Maize-Pulses	8.40	0.58
Bamboo	6.66	0.46
Fruits	6.06	0.42
Pond for Fish Farming	2.31	0.16
Pulses-Fallow	1.58	0.11
Livestock, Cattle, Buffalo Farm	0.12	0.01
Total	**1440.33**	**100.00**

The total agriculture land of the VDC was 1440ha in which Rice-Pulses combination was dominating with 401ha followed byRice-wheat-pulsescropping pattern. The area under other crop combination was less dominating cropping pattern in the VDC (Table 3.6).Cropping pattern is mostly intense in types.

3.5 Land Use Zones

The methods described in the previous sectionare applied and GIS analysis is performed on the various steps for land use zoning. The land use zones identified in this VDC are summarized on the Table 3.7.

Table 3.7: Land use zones of the study area

Class	Zone	Zone Type	Code	Sub zone	Description	Area of sub zone type (Ha)	% of individual zone	Area of zone type (Ha)	% of total area
1	Zone 1	Agricultural	AGR	Zone 1A	Cereal crop production area	1248.99	96.69	1291.79	62.02
				Zone 1B	Cash crop area	32.03	2.48		
				Zone 1C	Horticulture	8.34	0.65		
				Zone 1D	Animal Husbandry	0.12	0.01		
				Zone 1E	Fish farming area	2.31	0.18		

				Zone 1F	Agro-forestry	0.00	0.00		
2	Zone 2	Residential	RES	Zone 2A	Existing residential zone	178.94	64.50	277.43	13.32
				Zone 2B	Potential area for residential zone	98.50	35.50		
3	Zone 3	Commercial	COM	Zone3 A	Governmental institutions and service areas	11.98	60.69	19.74	0.95
				Zone 3B	Business area	7.76	39.31		
4	Zone 4	Industrial	IND	Zone 4A	Areas under industrial use	8.26	100.00	8.26	0.40
				Zone 4B	Potential area for Industrial zone	0.00	0.00		
5	Zone 5	Forest	FOR	Zone 5A	Existing forest	336.93	90.38	372.81	17.90
				Zone 5B	Potential area for forest including barren lands, wet lands etc.	35.88	9.62		
6	Zone 6	Publicuse	PUB	Zone 6A	Areas under roads, railways, bus parks, airport and land fill site etc.	82.09	83.68	98.10	4.71
				Zone 6C	Recreation, picnic spot	0.00	0.00		
				Zone 6E	Health, education etc. institutions	4.45	4.53		
				Zone 6F	Grazing land	9.17	9.35		
				Zone 6G	Government Institutional Area	0.00	0.00		
				Zone 6H	Open spaces	2.40	2.45		
7	Zone 7	Other area	OTH	Zone 7	as per requirement	0.00	0.00	0.00	0.00

8	Zone 8	Mine and Minerals	MIN	Zone 8A	Existing Mines and mineral area	0.00	0.00	0.00	0.00
				Zone 8B	Potential areas for Mines and mineral	0.00	0.00		
9	Zone 9	Cultural and Archeological	CULARCH	Zone 9A	Existing cultural and archeological area	0.27	100.00	0.27	0.01
				Zone 9B	Potential cultural and archeological areas	0.00	0.00		
10	Zone 10	Riverine and Lake Area	HYD	Zone 10A	Existing rivers and riverine area	14.19	100.00	14.19	0.68
				Zone 10B	Potential hydrographic areas	0.00	0.00		
11	Zone 11	Excavation (Construction Materials)	EXC	Zone 11A	Existing quarrying and excavation area	0.22	0.00	0.22	0.01
				Zone 11B	Potential areas for quarrying and excavation	0.00	0.00		
Total								2082.81	100.00

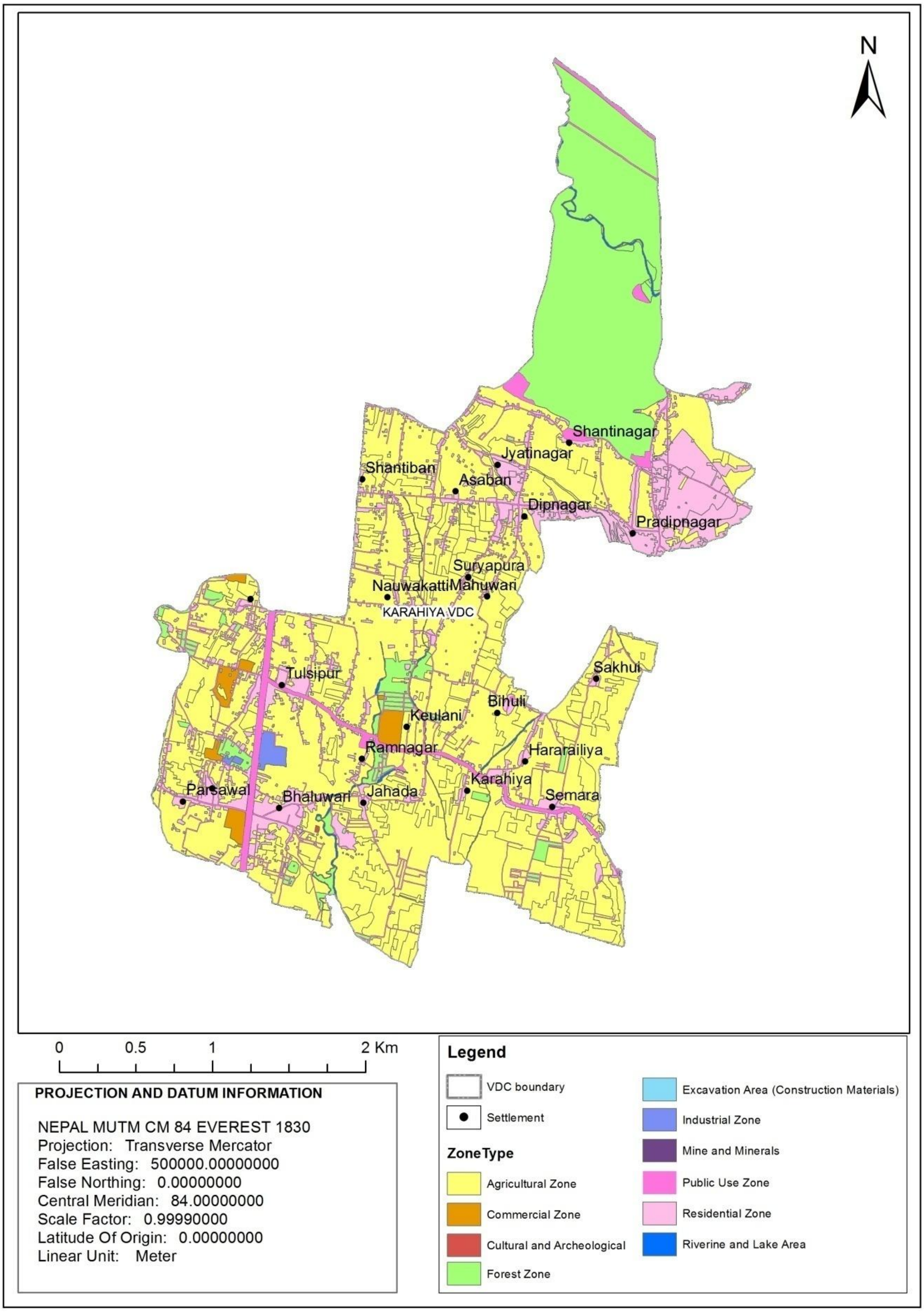

Figure 3.6: Land Use Zoning Map of the Karahiya VDC

3.6 Cadastral Data

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 2021-2026 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. However, the Karahiya VDC had 10064 land parcels and area covered in the survey was 1679 ha.

3.6.1 Cadastral Land Parcel based on Land use

Table 3.8 shows the present characteristics of cadastral parcels that falls in Karahiya VDC of Rupandehi district of Nepal. In the cadastral area of the VDC, out of the designated 11 classes, 9 land use classes do exist excepting the Mining & Mineral and undersigned other land usezone classes. It is significant that there are only 6 land parcels for cultural and archeological land use class. The predominant land use was the agriculture land use that covers with a total of 1423 ha (84.8%) having 11103 land parcels out of the total 14847 land parcels in the VDC. The coverage of the residential land parcels covered 165 ha (9.8%) having 2684 land parcels. The coverage of the forest land parcels covered 6 ha (0.4%) having 77 land parcels and the public service land parcels covered 56 ha (3.3%) having 717 land parcels. Similarly,the hydrographic feature (reverine, lake and water bodies) land class is significant of about 8.36 ha (0.5%) having 93 land parcels. About 0.03 percent (0.42ha) area fall onthe cultural and archeological land use class, which is as well significant. The distribution of land parcel on present land use is shown in Figure 3.7.

Table 3.8: Parcel Characteristics of Present Land Use

S.N.	Description	Area (ha)	Percent	No. of Parcel
1	Agriculture	1423.33	84.77	11103
2	Residential	165.08	9.83	2684
3	Public Service	55.33	3.30	717
4	Commercial	13.44	0.80	114
5	Riverine & Lake Area	8.36	0.50	93
6	Industrial	6.90	0.41	41
7	Forest	5.93	0.35	77
8	Cultural & Archeological	0.42	0.03	6
9	Excavation Area	0.24	0.01	12
	Grand Total	**1679.02**	100.00	**14847**

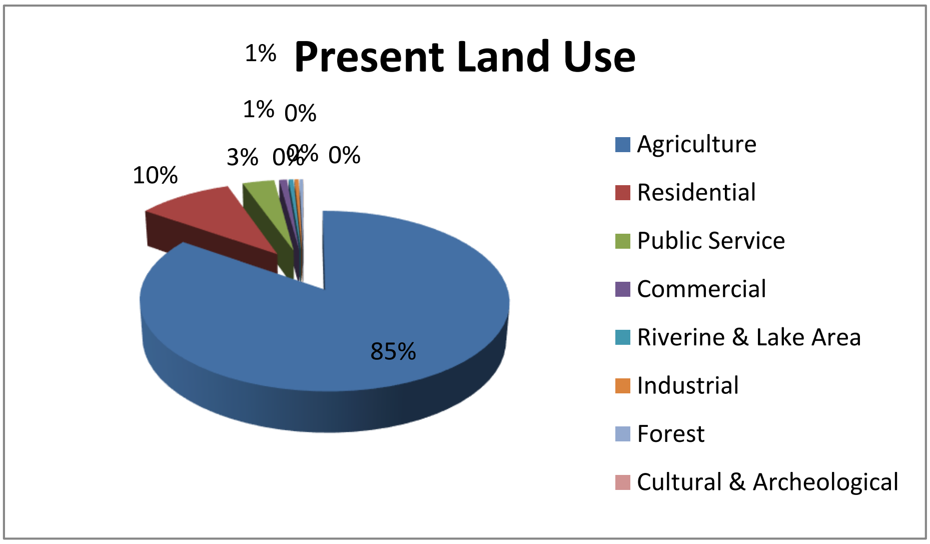

Figure 3.7: Distribution of Cadastral Parcel on Present Land Use

3.6.2 Cadastral Land Parcel based on Land use Zoning

Table 3.9 shows the characteristics of cadastral parcels superimposition on Land Use Zoning for the Karahiya VDC of Rupandehi district of Nepal. The land use zoning shows a restructuring on the existing land use.In the cadastral area of the VDC, out of the designated 11 classes, zoning for nine classes is made thus avoiding only the Mining& mineral and undersigned the other zone. Agriculture land parcels are reduced from 1423 ha to 1308 ha a significant loss of 8 percent in terms of areal extent whereas agriculture land parcels is reduced from 11103 to 9828 land parcels. The significant change in the existing agriculture land use land parcels allocation has converted into residential, commercial industrial and public service land use. Similarly, other land use parcels changes into forest and public service. Further, riverine and lake area some cadastral parcel converted into forest mostly along the river. Prominent change of Residential land parcels has increased by 101 ha (89% of conversion area) and increased by 1035 land parcels. Commercial land parcels has increased by 8 ha (7% of conversion area) and increased by 60 land parcels. There is marginal increase in public service land parcels by 5ha (5% of conversion area). The distribution of cadastral parcel in land use zoning classes is shown in Figure 3.8.

Table 3.9: Parcel Characteristics of Land Use Zoning

S.N.	Description	Area (ha)	Percent	No. of Parcel
1	Agriculture	1308.85	77.95	9828
2	Residential	256.18	15.26	3528
3	Public Service	72.42	4.31	1100
4	Commercial	18.97	1.13	165
5	Riverine & Lake Area	8.03	0.48	82
6	Industrial	7.68	0.46	44
7	Forest	6.24	0.37	84
8	Cultural & Archeological	0.42	0.03	6
9	Excavation Area	0.23	0.01	10
	Grand Total	**1679.02**	100.00	**14847**

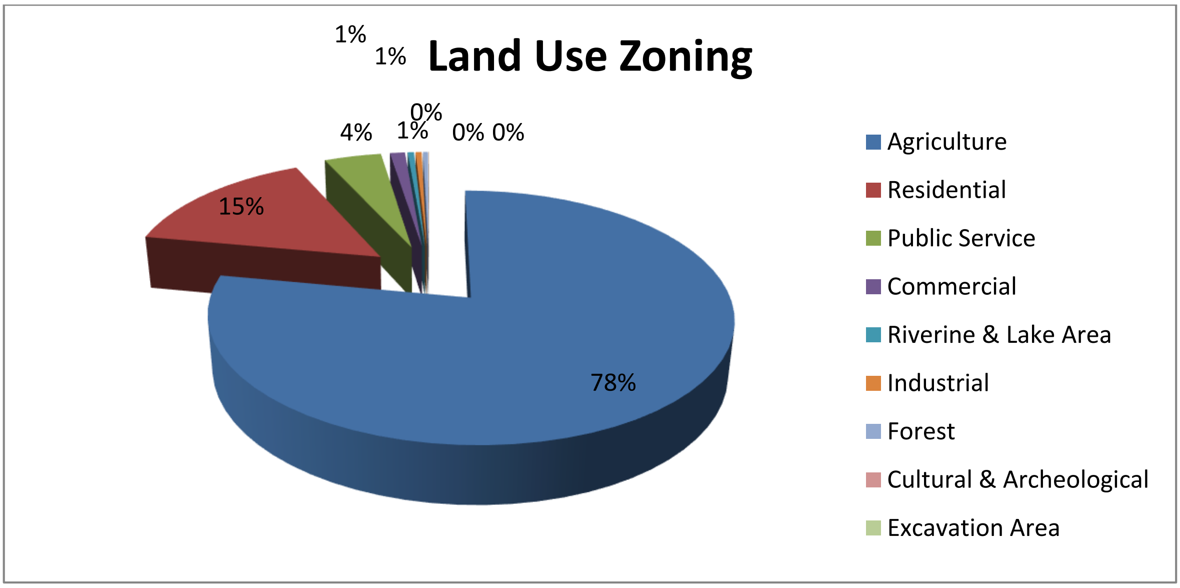

Figure 3.8: Distribution of Cadastral Parcel on Land Use Zoning

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 3.10 gives the details.

Table 3.10: Parcel Characteristics of Present Land Use Land Use Zoning Superimposition

S.N.	Description	Area (ha)	Percent	No. of Parcel
1	Agriculture /Agriculture	1308.85	77.95	9828
2	Residential /Residential	155.23	9.25	2493
3	Agriculture /Residential	100.96	6.01	1035
4	Public Service /Public Service	55.33	3.30	717
5	Commercial /Commercial	11.06	0.66	105
6	Residential /Public Service	9.85	0.59	191
7	Riverine & Lake Area /Riverine & Lake Area	8.03	0.48	82
8	Agriculture /Commercial	7.91	0.47	60
9	Industrial /Industrial	6.88	0.41	35
10	Forest /Forest	5.93	0.35	77
11	Agriculture /Public Service	4.82	0.29	171
12	Commercial /Public Service	2.38	0.14	9
13	Agriculture /Industrial	0.80	0.05	9
14	Cultural & Archeological /Cultural & Archeological	0.42	0.03	6
15	Riverine & Lake Area /Forest	0.31	0.02	7
16	Excavation Area /Excavation Area	0.23	0.01	10
17	Industrial /Public Service	0.02	0.00	6
18	Riverine & Lake Area /Public Service	0.02	0.00	4
19	Excavation Area /Public Service	0.01	0.00	2
	Grand Total	**1679.02**	100.00	**14847**

The change comes for all classes from agriculture. Out of the total 1679 ha of land parcel currently 1565 ha remains constant and 114 ha of the total cadastral land parcel area were converted from agriculture, other and riverine & Lake Area into the residential, forest, commercial, public service and industrial land use classes. The most prominent among them is to residential 101ha (89%), commercial 8ha (7%)and public service 5ha (5%). The new characteristics of the VDC is now more homogeneously structured, and looks to be restructured with sufficient allocation for industrial and commercial use, preserving in the same time the parcels and areas under forest and public use.

CHAPTER 4: SOCIO-ECONOMIC SETTINGS

4.1 Social Settings

The social condition such as population distribution and density pattern, caste/ethnicity and religious composition and literacy status of Karahiya VDC has beendiscussed in this section.

4.1.1 Population Distribution and Density

The total population of Karahiya VDC is 24398 (VDC Profile, 2067). Ward wise population distribution by sex shows in table 4.1.Of the total population, percentage of male and female is similar. The table shows that ward number eight has the largest population size due to large area of land. Ward number five has the small population size because the total area of ward is smaller than other wards.

Table 4.1: Ward wise Population Distribution by Sex in Karahiya VDC

Ward No.	Male	Female	Population
1	823	817	1640
2	774	771	1545
3	2849	2829	5678
4	497	517	1015
5	263	293	556
6	983	983	1965
7	898	921	1819
8	4094	4051	8145
9	1050	985	2035
Total	**12230 (50)**	**12168 (50)**	**24398**

Source: VDC Profile, 2067

Note: Figure in the parentheses is the percentage of total male and female.

Density of population varies sharply by the wards. Population density varies between 251 per square kilometer to more than 1001 per square kilometer in all wards. Highest density is found in 1, 2, 3 and 7 wards as compared to the other wards. Lowest density (251-500) is found in ward number 4, 5, 6 and 8.

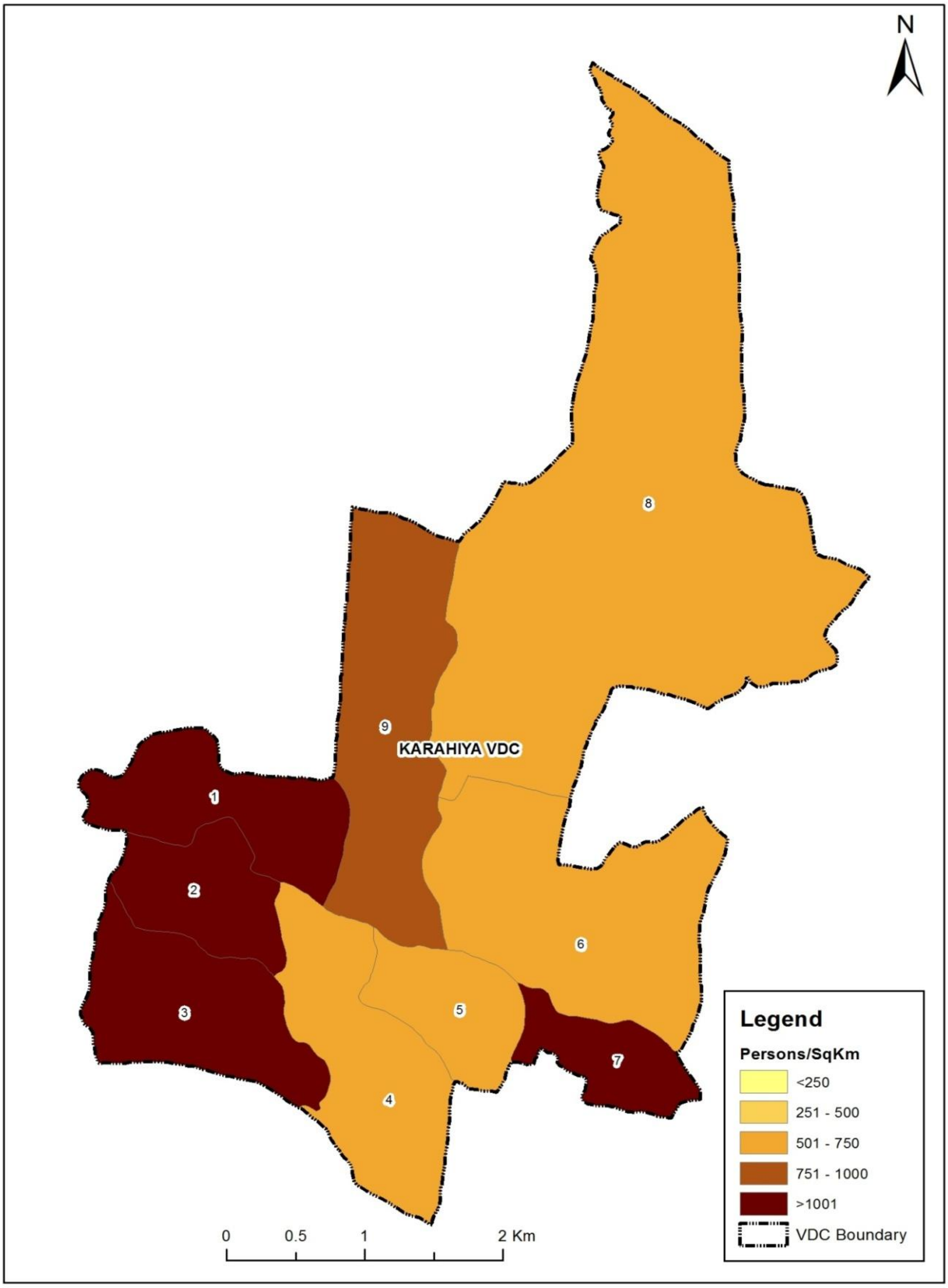

Figure 4.1: Density Map of theKarahiyaVDC

4.1.2 Population by Caste/ethnicity

Karahiya VDC is inhabited by different caste and ethnic groups. Chhetri, Brahmin, Indigenous, Madheshi, Dalit, and Muslim are the main caste. Among them, majority is Brahmin. It is followed by Indigenous. There are few Madheshi who live in all wards except ward number one. Muslim is even lower and they live in six wards except in ward number 2, 5, and 7. Population distribution by caste/ethnicity has shown in table 4.2.

Table 4.2: Ward wise Population Distribution by Caste/ethnicity in Karahiya VDC

Ward No.	Chhetri	Brahmin	Indigenous	Madheshi	Dalit	Muslim	TotalPopn
1	213	494	861	-	68	4	1640
2	102	639	612	59	133	-	1545
3	654	2247	2274	216	278	9	5678
4	60	264	502	15	165	9	1015
5	79	150	261	54	12	-	556
6	96	703	770	233	116	47	1965
7	17	516	1066	141	79	-	1819
8	713	3823	2720	66	620	3	8145
9	37	1782	72	105	31	8	2035
Total	**2171**	**10618**	**9138**	**889**	**1502**	**80**	**24398**

Source: VDC Profile, 2067

4.1.3 Population by Religion

Nepal has many religious groups, as there is no any restriction for religion. However, Nepal has the majority of Hindu people. In Karahiya VDC, there are four religionssuch as Hindu, Buddhist, Muslim and Isai. Population distribution by religion shows in table 4.3.Among them, almost all 95 percent of the total population follows Hinduism. Proportion of population following Buddhist, Muslim, Isai and others is just five percent.

Table 4.3: Population Distribution by Religion in Karahiya VDC

Religion	Population	Percent
Hindu	23281	95.4
Buddhist	982	4.02
Muslim	80	0.3
Isai	12	.0.04
Others	43	0.1
Total	**24398**	**100**

Source: VDC Profile, 2067

4.1.4 Literacy Status

Education is one of the most important components for alleviating poverty and for increasing living standard of people. The educational status of the people directly or indirectly influences the economic status of family. Education is an important factor in life and contributes to the decision-making process. It plays a vital role for the development of the community, the nation and the economy. It is a central to the process of empowering both men and women. Thus, education is the first step towards creative thinking and development. However, there is no detail information of literacy rate of male and female.

4.2 Economic Setting

Economy is very important component to make humanlife better. There are different income sources in Karahiya VDC. Major income sources are remittances, government and private services, agriculture, labor work, livestock and business.Cash crop agriculture is common among farmers. The VDC is nearby Butwal, Bhairahawa and Sunauli, thus the involvement of people in cash crop agriculture is increasing. Besides agriculture, some of the households run their own business for their livelihood.

4.2.1 Agriculture

Agricultural land is defined broadly as land used primarily for production of food and fiber crops. 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 largely due to physical (e.g. climatic condition, moisture, topography, soil) and social/cultural settings 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 cultivation. Hill cultivation is further sub-divided into level terraces and sloping terraces. The Mountain cultivation is further divided into Level terraces, Upland cultivation and Sloppy upland. Similarly, Valley cultivation is divided into four groups: 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 of the Taraiis further sub-divided into Low khet land cultivation and Upper khet land cultivation-torikhet. Different cropping patter is presented in level five, whereas cropping intensity is also resented in level six category. Based on above information, NLUP has provided hierarchy of agricultural land (Table 4.4).

Table 4.4: Hierarchy of Agricultural Area

Level 1	Level 2	Level 3	Level 4	Level 5 Cropping Pattern Monsoon- Winter- Dry season	Level 6 Cropping Intensity
Agricultural Land Use	**Terai Cultivation**	• **Wet Land Cultivation**	• **Low Khet Land Cultivation** (Poorly drained with High bond) -------------------- • **Upper Khet Land Cultivation- TariKhet** (Intermediate land between wet and dry land with well drain soil bonds are lower)	Rice-Wheat Rice-Rice Rice-Maize Rice-Pulses Rice-Wheat-Pulses Rice-Maize-Veg. Rice-Potato-Veg. Rice-Veg.-Veg. Rice-Pulses Maize-Oilseeds Maize-Pulses Pulses-Fallow Fruit-fruit Sugarcane-Sugarcane Rice-Pulses Maize-Oilseeds Maize-vegetables Rice-Veg. Pulses-fallow	Intense (75%-100% cultivated) medium(50%-75% cultivated) Light (25%-50% cultivated) Not Applicable
		• **Dry Land Cultivation** (Upland Pakho/ Bhith land Cultivation, Drained, smallest bond height)	Unclassified		
Agricultural Land Use		• **Mixed Land Cultivation** (Commonly found near River where River have change the course)	Unclassified		Light-1 Medium-2 Intense-3
	Hill Cultivation	**Level Terraces**	• **Level Terraces Khet Land Cultivation** (level khet land with small bond)		

Level 1	Level 2	Level 3	Level 4	Level 5 Cropping Pattern Monsoon- Winter- Dry season	Level 6 Cropping Intensity
Agricultural Land Use			• **Level Terraces Upland/Pakho Land Cultivation** (level upland with no bond)		Light-1 Medium-2 Intense-3 Not Applicable -4
		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 Cultivation	• **Valley slope upland/Pakho cultivation** (Cultivated on natural slopes) ---------------------- • **Valley Riverbeds(Lower footslope) Alluvial Fans Cultivation** (alluvial riverbed fans)	Unclassified		

4.2.1.1 Food Production

Rice, wheat, maize, millet, pulse and oil are the main food produce in the Karahiya VDC. Total area under rice cultivation is 1349.52 ha, wheat 335.81 ha, maize 8.40ha, pulses 39.03 ha, oil seeds 25.59 ha respectively. Average productivity of major cereal crops like paddy, wheat, maize, pulses, and oil seeds are 2.6 mt/ha, 2.49 mt/ha, 3.70 mt/ha, 0.9 mt/ha, and 1.00 mt/ha respectively Productivity of the crops is low and there is ample scope to increase the productivity by using modern technologies.

Presently inputs used are low and timely availability of immigration is also not assured. Improved seeds are not sufficiently available especially in case of wheat.

4.2.1.2 Production of High Value Crops

Production of high value crops is the basis of commercialization of agriculture and improvement of level of living of farmers. In this VDC the main crop is food crops. Vegetable and fruits such as potato, cauliflower, cabbage, tomato, Okra, eggplant, onion, garlic, mango, Litchi, banana, jack fruit, and lime are produced in small quantity in the VDC. Area under Mango, litichi, banana, jack fruit, lime and others are 19 m/ha, 5 m/ha, 28 m/ha, 0.50 m/ha, 3 m/ha and 4 m/ha respectively in the VDC. If such products are produces in large quantity it will definitely improve the level of living of the farmers.

Main markets (by markets) are Butwal and Bhairhawa both the markets are accessible to the farmers as the VDC is linked with the fair weather roads/black top roads. Market is not a problem for the farmers. They put concern on the price of the produces as per them; they are not getting good prices. So it seems to make them aware about pricing concept of the commodities/ produces. Technicians can assist them for this.

There are three Agriculture Service Centers (ASC), in the VDC to cater the technical need of the farmers. But during the field survey, farmers complained that technicians are not available most of time when they visit ASC to seek their technical advice.

Major Problems

Major problems identified during field visit in the VDC are as follows:

1) Timely availability of inputs: Inputs line seeds, irrigation and chemical fertilizers are not available on time and even the quantity of availability especially in case of chemical fertilizers and seeds are not enough.
2) Availability of improved seeds on time: Every time farmers have to face this problem as they do not get recommended quality seeds.
3) Inadequate technical know-how for improved cultivation. There are not sufficient numbers of technical human resources to support the farmers technologically.
4) Inadequate Integrated Pest Management (IPM) practices in the field especially in rice.
5) Use of plant protection chemicals is not as per recommendation. It is not used wisely.
6) Inadequate knowledge on post-harvest technology.
7) Lack of production planning so farmers are not getting benefits as they want.

8) Cost of production is high as compared to the neighboring county India because input costs are higher than those of India. Moreover, availability of labour is becoming acute problem as young generation is going out of country for employment.

Recommendation

1) In the designated VDCs of Rupandehi districts it is found that there is still room to improve the productivity of the crops by using modern technology ensuring timely availability of required inputs.
2) Assured quality seeds which are pre-requisite for higher production.
3) Availability of quality fertilizers, Soil testing facilities and recommendations based on it for the fertilizers doses can improve the fertilizer use efficiency.
4) Integrated Pest Management (IPM) should be promoted as regular production activities.
5) Irrigation facilities should be available on time as per requirement of the crops
6) Post-harvest related facilities should be made available to the farmers.
7) Low cost production technology should be encouraged to ensure competitiveness.

4.2.1.3 Livestock

Livestock is an integral part of the farming system of Karahiya VDC. Cow, buffalo, goat, pig, chicken, and duck are the domesticated animals of the VDC. They are raised for various purposes. They play a crucial role in agriculture. Animals can contribute to income from selling their products like milk, ghee, meat and other products. The importance of manure on agriculture is high. Livestock in this area is used for draught power too. Moreover, cow/buffalo dung is used for fuel in some households. Although people use ox to plough their field, tractor has also been widely used to plough land agricultural land.There is no ward wise detail of livestock in the VDC.

4.2.1.4 Poultry and Fish Farming

The cities likeButwal, Bhairawa, Sunauli and Indian boarder are located close to this VDC. Large population in these cities indicates a large demand of meat and fish products.There are 20 poultry firms, and 1 fish farm.These firms produce especially egg and meat to fulfill the demand people and economic generation for their livelihoods. Considering the demand and market of these products there is god potentials for further development of both poultry and fish farming in the VDC.

4.3 Employment/occupation

People of Karahiya VDC adopted varieties of occupations for their livelihoods. These include agriculture, business, services, labor, and industries.Among these, involvement of people in agriculture is high, accounting for about 55 percent of economically active population.Slightly more than one fifth of total population (27.6%) is engaged in non agricultural activities. Non agricultural activities include labor work, services in private and government offices, different types of business and industries. It plays vital role for increasing economic condition of people. Table 4.5shows the occupational distribution of the population.

Table 4.5: Population Distribution byOccupation in Karahiya VDC

Types	Population	Percent
Agriculture	7583	54.7
Business	581	4.2
Services	1848	13.3
Labor	3824	27.6
Industries	10	0.07
Total	**13846**	**100**

Source: VDC Profile, 2067

4.4 Industry

Since the VDC is in Terai region and near from big cities with easy access to road,and market,there are many industrial establishments.There are 22 small and cottage industries such as grill industries, furniture, rice mills and so on.Many local people are employed in these industries in different capacities. Its contribution on local economy is significant. However, the extent of contribution is yet to be known.

4.5 Remittances

Remittance is one of the main sources of Nepalese economy; no doubt, it is main source of local economy as well. As reported, currently about 250 young working age people are migrated to different countries in search of job. The major destination of abroad includes Malaysia, Omen, Dubai, Qatar, America, London, Australia, and Israel. In addition, a large portion of these migrants go to India for temporary work when they become free especailly after harvesting crops and involved in different sectors like salesman, industrial worker, driver, scaffold, security guard, and so on. Migrants send a huge amount of money every year in their areas through differrnt banking and non-banking channels. The contribution of remittance on household economy can clearly been seen, which they have invested on housing land, construction of houses, and household goods. About 18 core69 lakhrupees enter as a remittance each year.

4.6 Sources of Income

As noted above,agriculture/livestock, business/industries, labor work, services, remittances, and soon are major sectors for employment, household income is largely depends on these sources. The contribution of these sources on household income is significent. Major sources of income shows in table 4.6According to the table, agriculture/livestock are the main sources of income, accounting for about32 percent of the total income. It is followed by remittances by (22.2%) and business/industries (19.3%) respectively.

Table 4.6: Major Sources of Income of Karahiya VDC

Types	Income (in Rs)	Percent
Agriculture/Livestock	269130410	32.0
Business/Industries	162079720	19.3
Services	121302071	14.4
Remittances	186994632	22.2
Labor	69932240	8.3
Others	31406865	3.7
Total	**840845938**	**100**

Source: VDC Profile, 2067

4.7 Potential Income Opportunities

The agriculture land in this VDC is very fertile. In addition, climate is suitable for agriculture and livestock farming. Thus, there are lots of potentialities for generating income from cash crop farming especially in commercial scale. As this VDc is well connected by roods, there will be no problem regarding marketing of produced goods. Livestock farming can also become another option for income generation. Another potential sector is industrial development. Large scale factories can also be established. It can generate employment opportunities on the one hand and reduces the foreign dependency through replacement of goods to be imported.

CHAPTER 5: INSFRASTRUCTURE AND SERVICES

In this chapter, infrastructure and services available in Karahiya VDC are discussed. The main infrastructure and services include road, electricity, health facility, communication, financial and educational institutions.

5.1 Road

Karahiya VDC is locatedat a distance of 6 km eastfromButwal city. It is the main place to connect all cities of Nepal and is known as main gate to India. The Karahiya VDC is well connected by networks of roads.And all the wards are internally connected either by black topped or by graveledand earthen roads. Since some of the roads are gravelled and earthen, people have been facing problem of dust during dry season and mud during rainy season. All types of vehicle such as bus, truck, jeep, tractor, van, car, and motorcycle etc are the major means of transportation in the VDC.

5.2 Health

There are some health institutions and medical shops in the VDC. There is ahealth service centre in the VDC that provides general treatment and medicine to the residents of the VDC such as minor injuries and diseases.People have to visit either nearby areas (Butwal, Bhairawa) or other areas having good facilities for specialized services.

Human activities always generate waste. The waste management is very important for people to be healthy. Every household manages the waste in their own way especially in the rural areas. People dump their waste in agricultural field, which can be used as compost manure and they burn plastic materials. Since this VDC being a part of Municipality, there is a provision of waste collection and municipality collects household waste once a week.

The toilet facility in a household is one of the indicators of a health and sanitary situation. Table 5.1 shows the household sanitary situation in terms of availability of toilets in the Karahiya DVC.

Table 5.1: Ward wise Distribution of Toilet in Karahiya VDC

Ward No.	Households with Permanent Toilet	Households with Temporary Toilet	Households without Toilet	Total Households
1	184	21	15	220
2	174	18	27	219
3	641	25	33	703
4	128	14	46	188
5	73	13	15	101
6	216	26	38	280
7	151	8	66	225
8	770	120	209	1099
9	233	57	35	325
Total	**2570 (76)**	**302 (8.9)**	**484 (14.4)**	**3360**

Source: VDC Profile, 2067

Note: Figure in parentheses indicates percentage of different types of toilet.

The table shows nearly four fifth of the total households, 76 percent have permanent toilet, few households have temporary toilet and 14.4 percent do not have toilet in their house. This indicates that open defication is still common in some communities.

5.3 Drinking Water

People use different sources of drinking water in Karahiya VDC. There is not so much scarcity of water for drinking and other purposes. The condition of drinking is water is not bad butthe supply of pure and safe water is insufficient. People drink water mainly from tap and tube well. Table 5.2 shows ward wise distribution of different sources of drinking water.

Table 5.2: Sources of Drinking Water in Karahiya VDC

Ward No.	Public/ PrivateTap	Tube Well
1	218	2
2	219	-
3	278	20
4	188	-
5	101	-
6	263	17
7	225	-
8	1035	64
9	325	-
Total	**3252**	**103**

Source: VDC Profile, 2067

The above table shows ward wise distribution of different types of water for drinking. According to the table, the main source of water is public tap. Most of the households have tap in their own house. They drink water directly from the tap. Of the total households, 3252 households use tap, and few households use drinking water from tube well.

5.4 Electricity

Electricity is the main source of lighting in the VDC. The VDC is well connected to national transmission grid and most of the households in the VDC have electrified. Of the total, 3075 households have used electricity as a main source from national transmission line and remaininghouseholds use other sources of light such as bio gas, kerosene, and solar light. Frequent loadsheding is the common problems in this area too. This make difficult not only in production activities, but overall activities as well.

5.5 Educational Institution

The education institution is the place where people get opportunity to acquire knowledge that helps to lead individuals and society towards creative thinking and development. In Karahiya VDC, there are 15 schools. Of the total schools,threeare primary schools, twoare lower secondary schools, two are secondary schools and one higher secondary school.

Table 5.3: Ward Wise Distribution of Educational Institution of Karahiya VDC

Ward No.	Primary School	Lower Sec. School	Secondary School	Higher Sec. School
1	1			1
2			1	
3		1	2	1
4				
5				
6				
7			2	
8	1	1	2	1
9	1			
Total	**3**	**2**	**7**	**3**

Source: VDC Profile, 2067

5.6 Finalcial Institutions

The financial institutions available in the VDC include banks, cooperatives and others. There are five banks in the VDC. They are Sine Resunga Development Bank, NMB Bank, Mission Bank, Nepal Arab Bank and Purnima Development Bank. Besides bank, there are 35 cooperatives as well. Manjari Saving and Credit SahakariSastha, Samabesi Saving and Credit SahakariSastha, NariJagriti Saving and Credit SahakariSastha, and Panchami Saving and Credit SahakariSastha are some of the name of the cooperatives. The cooperatives mainly work for saving and credit, and also for multipurpose work such as distribution of seeds, training for different knowledge and skills development. They also work for awareness program for local people. If villagers need loan, they take from bank, cooperative, community group and also from individual peoplefrom the village. When they take loan from the bank or cooperative ltd, they pay about 13-21 percent interest and about 20 percent interest to individual people. Of the total, 21 percent households take loan from bank, 13 percent from cooperative, 20 percent from sahumahajan and rest households do not take loan.

CHAPTER 6: HERITAGE, CULTURE AND TOURISM

6.1 Heritage

Nepal is known for cultural heritage in the world. Karahiya VDC is no exception. There are a number of temples that have religious importance. Mainly there are four temples. Hindu people perform worship in these temples regularly. Mostly people go to temple during religious ceremonies and festivalsto worship and ask god to fulfill their wishes. There is no detail information of temples.

6.2 Culture

Population of this VDS is composed of diverse caste and ethnic groups. Hinduism is the main religion of the people of Karahiya VDC however, some people folow other religions too. People of diffeent ethnic background and religion follow their own customs, traditions, and religions.They have their own rituals too. Hindu Pahadi celebrate different festivals like Dashain, Tihar, Teej, MagheSakranti, Janaipurnima, Nag panchami, Shivaratri, ChataiDashain, Holi and (BadakiAaitabar and Sabaniyaespecially Tharu). Hindu Madheshi celebrateKarkatSakranti, Naagnagin Puja, Gudiya (Naghpanchami), RakshaBandhan, Chhatthi Puja, Krishna Janmasthami, KajariTeej, Dashahara (Dashain), KarawaChautha, Dipwali, BhurkiPujan, Dithawan Puja (HaribodhaniAakadashi), Sankat Puja, Khichadi (MagheSakranti) and Holi. Buddhist people also celebrate Dashain, Tihar and SonamLoshar but do not sacrifice animals and they use white tika instead of red. Muslim people celebrate BararabiAbal, Subarat, Eid, BakrEid and GyarahiSarif. Christian people celebrate Christmas and Easter.

6.3 Tourism

Nepal is unique for many things such as nature, culture and adventure. Due to uniqueness, tourism is one of the important sectors for economy development. People from different countries can easily enjoy, spend time and gain different experiences those who are nature and culture lover. The prospect of tourism in Karahiya VDC is low.There are not any places that have historical and religious importance.

CHAPTER 7: RISK IN THE STUDY AREA AND SAFE AREAS FOR SETTLEMENT

7.1 Flood Risk

As reported by the local people, flood is not frequent in Karahiya VDC. Bank cutting is quite common in the northern parts of the VDC. This VDC was flooded in 1993. Mainly forest area was flooded.

Table 7.1: Flood Depth for return period 100years

Land use Class	Total	Percent
Low (<0.5)	41.94	81.20
Medium (0.5m-1.5m)	9.56	18.50
High (>1.5m)	0.16	0.30
Total	**51.65**	**100**

A total of 41.94 ha of different types of land is liable to low flood while only 9.56 ha of land becomes medium flooded and very few are is liable to high flood (Table 7.1 and Figure 7.1).

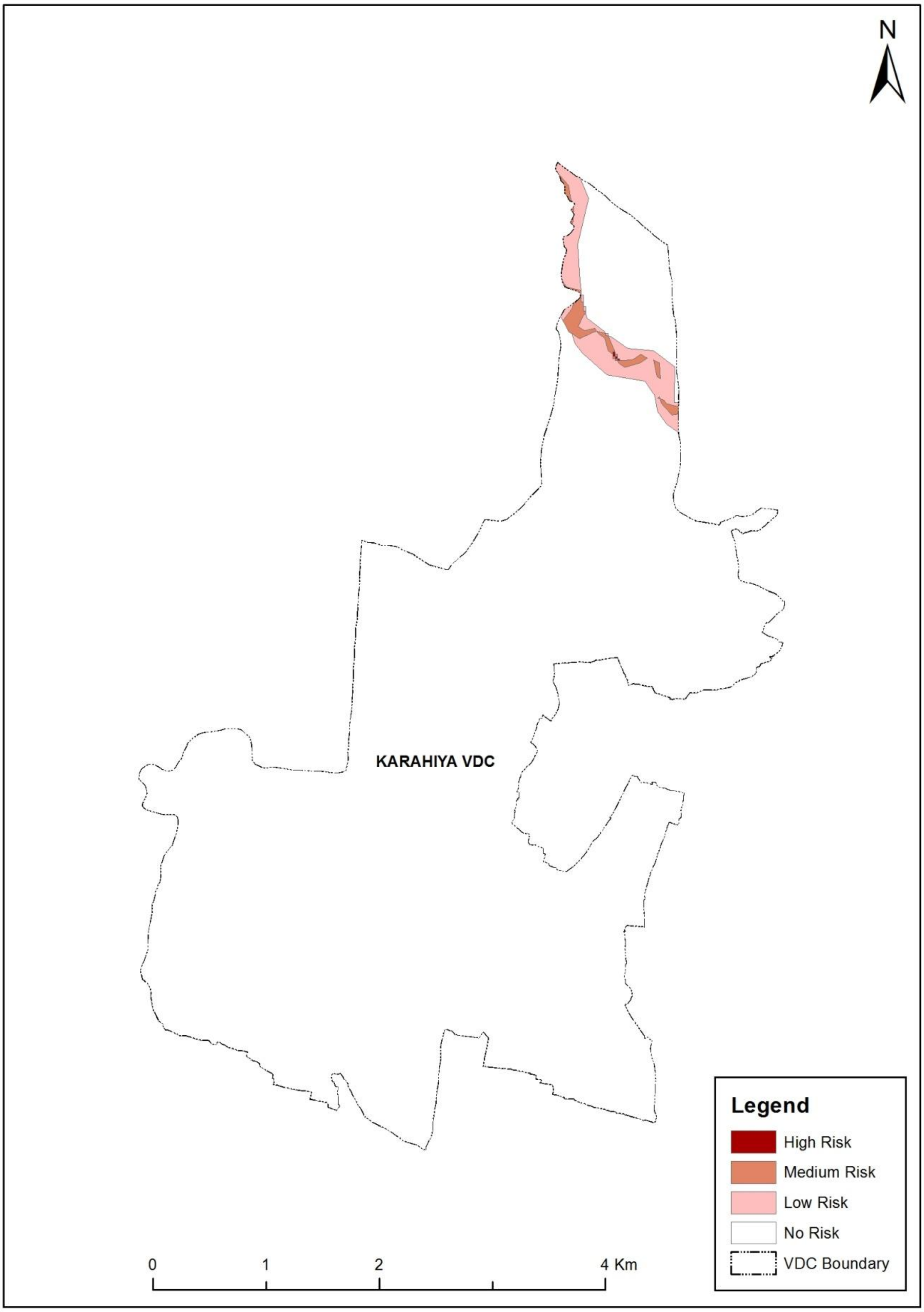

Figure 7.1: Flood Risk Areas of the Karahiya VDC

The result acquired through the analysis reveals the fact that in this VDC a small area is flood prone. Settlements nearby River are prone to floods. The people in such area are at risk of flood hazard.

7.2 Fire Risk

Fire is a common phenomenon during the dry stormy summer season and hazards take place. Fire Hazard is a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage. The major factor for the increasing fire risk is the lack of a favorable policy and legal environment commensurate with the present-day situation, needs, opportunities and resource availability.

Fire takes place in the village houses, in agriculture fields and most importantly in the forests. Almost all VDCs of Package 11 of the Rupandehi district are sensitive to fire risk and hazards. The main causes of forest fires are anthropogenic due to negligence and occasionally by deliberate burning to induce succulent grass growth for domestic animals.The means of fire are cooking outside houses, unmanaged fire during winter season for heating the body, burning cigarettes and bidi throwing, lack of awareness and less access to helping organizations. Besides, improper management of crop residue, use of mechanical threshers, feeding cooking stoves with rich husks and packed long cow dung, cooking outdoor throughout the day are other causes of firing.

In Terai, houses for residential purpose are developed on clusters which are more susceptible to catching fire and spreading over there immediately due to close connectivity especially in the dry season. Since study area is located in Terai plains,this area is susceptible to fire hazards.The settlements located nearby forest areas are more prone to firing. Likewise, cluster settlement having houses made with wood and thatch roofs are more susceptible for fire hazard.

Every year fires destroy considerable forest resources and large number of settlements in Nepal. Such destruction includes timber and non-timber forest products, lives and huge amount of properties. Fires also reduce the biological diversity of the forests to a great extent and also cause soil erosion and induce floods due to the destruction of natural vegetation. The area specific quantitative information regarding the number of fires, severity and the amount of loss are not available.Reportedly, most incidences of fires occur in the dry summer season, festivities, crop harvesting, and load-shedding time. Poor handling of fire for cooking and other purposes, electrical short circuits, poor wiring, poor handling of gas cylinders and stoves, human negligence and lack of adequate fire safety measures are the major factors contributing to the outbreak of fires.

7.3 Landslide Risk

Because of the flat topography, there is no possibility of landside in Karahiya VDC. The possibility of bank undercutting is common along the riverside especially in the northern parts of the VDC.The VDC area is located in the Terai plain with virtual or no elevation, the chance of landslide hazard is almost nil except the bank cutting.

There is no risk of landslides in Karahiya VDC. But due to the loose nature of the soil there is possibility of bank erosion or bank undercutting. Bank undercutting effect can be seen along sides of the river in the northern parts of the VDC.

7.4 Seismic Risk

For the minimum acceleration of 50 gal, reduction factor of 0.50 the calculated effective design seismic coefficient is approximately 0.02. For the maximum acceleration of 100 gal, reduction factor of 0.50 the calculated effective design seismic coefficient is approximately 0.05. Hence, the design horizontal seismic coefficient ranges from 0.02 to 0.05 (calculated values).

Karahiya VDC area falls in the seismic zone of 4, high seismic hazard area.The seismic coefficient in bedrock of the VDC area is considered as 0.020 to 0.050. But the area is composed of fluvial soil so amplification in soil is higher than 20 percent. Therefore, the seismic coefficient is considered as 0.024 to 0.060.

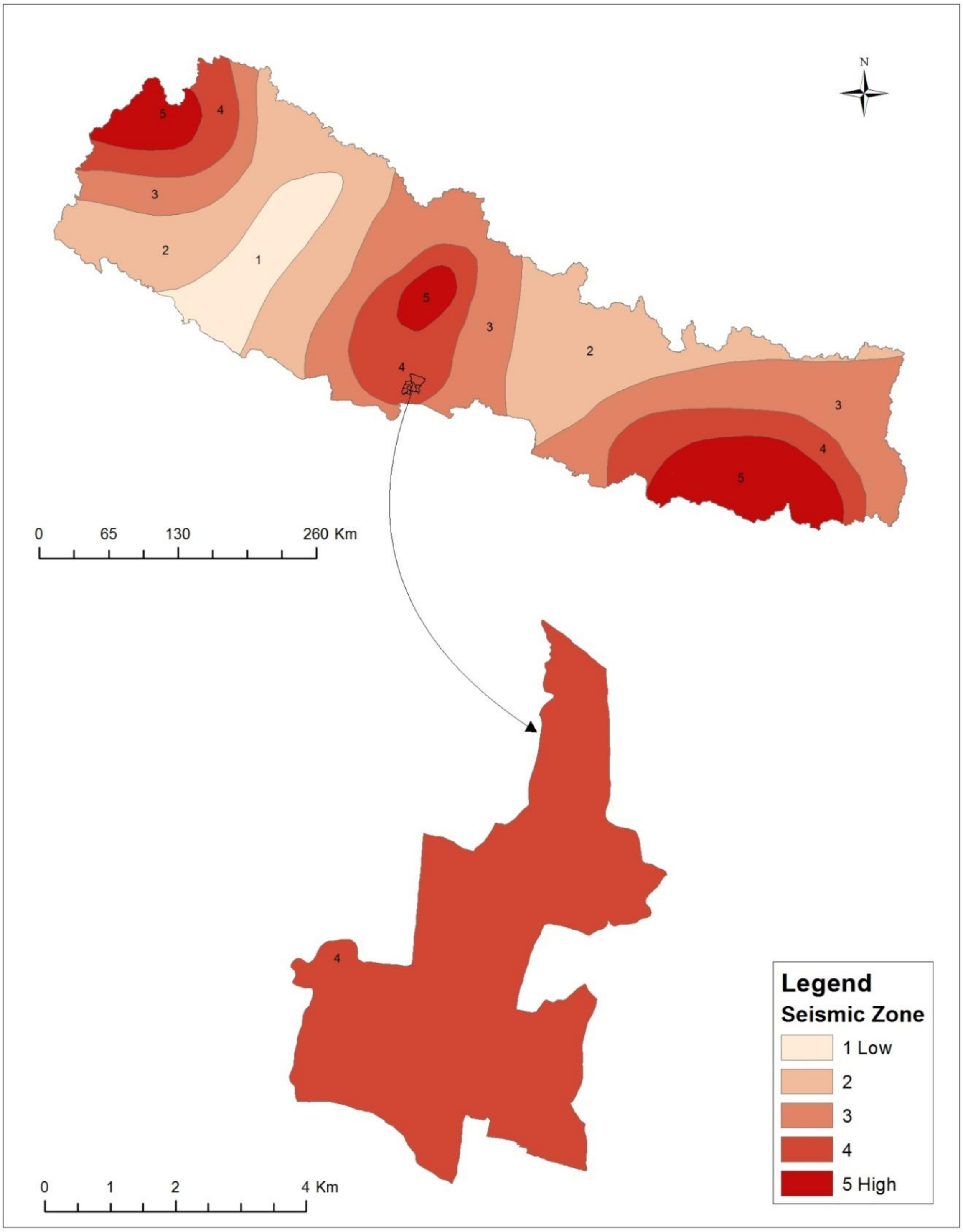

Figure 7.2: Seismic Zone of the Karahiya VDC

7.5 Industrial Risk

In this Karahiya VDC, there arethree industries including Siddhababa distillery industry. This may cause air and water pollution and impact on different sectors of human life directly or indirectly.

Table 7.2: List of industries with major pollution type in Karahiya VDC

Industry	Probable Major Pollution Type	Probable Risk areas (from centre)
Arun food pvt	-	-
Lumbini Concrete Pvt. Ltd	-	-
Siddhababa distillery	Air and water pollution	400m

The distillery industrylocatedin this VDC is the main source of different types of pollution causing various types of environmental impacts. The magnitude of industrial risk is higher at the production site and vice versa. The risk due to air pollution depends on meteorological parameters especially of wind direction and velocity, temperature, humidity, rainfall, cloud coverage and solar radiation which determine the dispersion, diffusion and transportation of particulate matter and emissions into the atmosphere. The industrial growth in the future, could lead further degradation of environment. The proper control measures should be adopted to minimize the risk of industrial pollution in the surrounding area.

7.6 Other Risk

As noted above, Nepal is characterized by complex geological structure with active tectonic process and seismic activities. The sharp vertical landscape renders the country highly vulnerable and disaster prone due to its fragile geology and steep topography. Nepal is highly exposed to multiple hazards- earthquakes, floods, landslide, and fire including industrial hazards. Besides,in recent years, increasing evidences of wind storms, draughts, and hot and cold waves are being common as caused by climate change. Disease outbreak is also evident in the country. However, except the five risks discussed above no other area specific risks were identified within the VDC studied.

7.7 Safe Areas for Re-settlement

Existing settlement in the area are mostly safe. However, some settlements or individual houses lies in the flood prone area and within the risk of industrial pollution. The areas under potential hazard in this VDC have been shown in the risk maps in the risk analysis section.

According to the CBS data, the rate of population growth is almost three and half percent in this area during the decades 1991 to 2011. It has been observed that the present settlement has been developed gradually in last 50 years. But in last 10 years, the rate of urbanization is very high. The main reasons behind this include internal migration from the hills as well as rural areas of the Tarai region to this area, increasing investment of remittance earned from foreign employment on housing lands in urban areas, increasing social trend of unitary small family. Since, this VDC area is currently annexed as a part of

Tilottama Municipality, population growth is expected to rise further due to inflow of migrants from rural VDCs in search of better education and employment opportunities. Therefore, significant growth can be seen in the residential and commercial zoning in the VDC.

This area has very low economic and commercial activities. There are very few small markets where commercial activities take place. Buildings in this area are used for mixed purposes i.e. residential and commercial purposes. This is the reason why the commercial area is shown very low in proportion. However, some new commercial and business areas are proposed considering the future demand of increasing size of population in this area. The population in this area has been rising tremendously in recent years.

The potential residential areas for future settlement are proposed after thorough study of possible hazards in the area. New settlements are not proposed in flood prone area, area under industrial pollution and other risks. Therefore, the residential and commercial areas are almost at minimum risk. Because of the limitation of available techniques, the seismic hazard and its occurrences cannot be studied and couldn’t be considered for proposing new residential, commercial as well as industrial zones. However, geological stability is studied and considered during the process.

Regarding open area, the study site is rural area which means most of the land is agricultural. The residential and other construction areas are very less. So, most of the areas are open in nature. However, open area left for recreation purpose, parks and playgrounds are negligible except some open area used for grazing, flooded riverbeds and unused /uncultivated lands as well as separate open space.

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Appendices

Photo 1: Karahiya VDC Office

Photo 2: One of the Buffalo Suppliers of the VDC

Photo 3: Land Use Pattern of the VDC

Photo 4: One of the Schools of the VDC

Photo 5: One of the Temples of the VDC