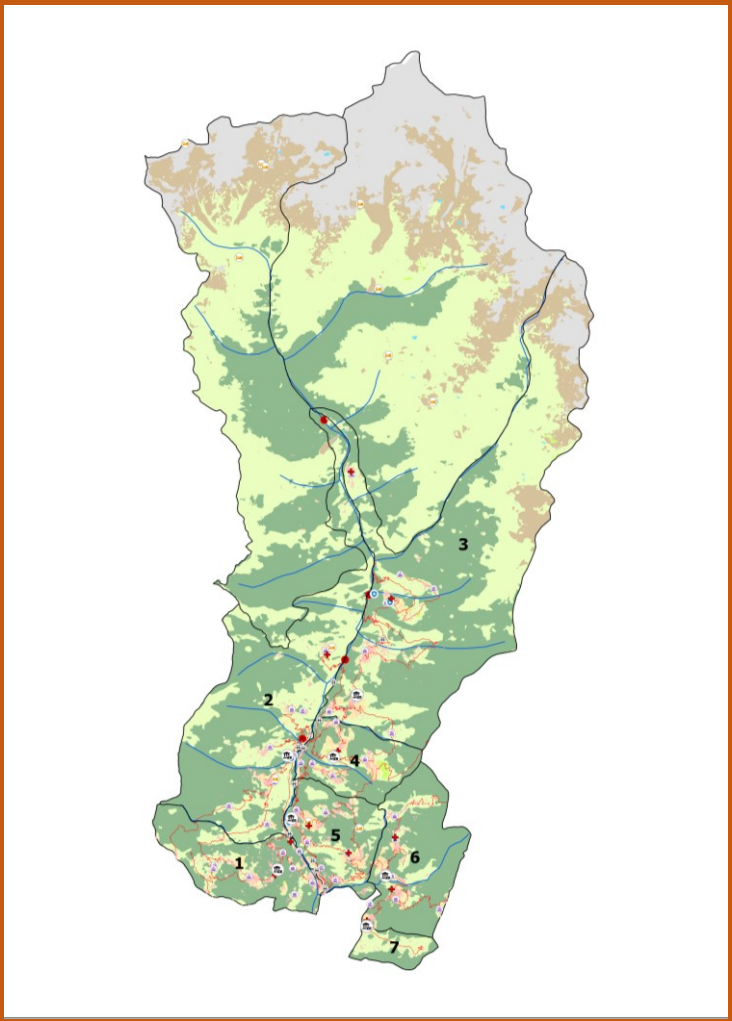
Jugal Rural Municipality

Office of the Municipal Executive

Baramchi, Sindhupalchok,

Bagmati Province



Final Report on

GIS Mapping of

Jugal Rural Municipality, Sindhupalchok

Submitted by:
Ripple Training and Consulting Services,
Pvt. Ltd,
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CHAPTER 1: INTRODUCTION

1.1 Background

Jugal Rural Municipality, situated in the northern mountainous region of Sindhupalchok District, is characterized by its rugged terrain, high-altitude river systems, and ecologically fragile landscapes. While much of the region maintains its rural and traditional character, the municipality faces significant challenges due to its high vulnerability to natural hazards, including landslides, floods, and riverbank erosion. Human settlements in the area are often scattered and established in locations that are susceptible to these environmental risks. Currently, the absence of a comprehensive and updated GIS-based spatial database has hindered the municipality's ability to engage in effective planning and infrastructure development, land use management, and disaster risk reduction. Without a modern, data-driven approach to planning, development remains fragmented, potentially exacerbating the risks posed to the inhabitants and their livelihoods.

In alignment with Nepal's federal structure and the mandate for local-level governance, rural municipalities now hold the primary responsibility for sustainable development and evidence-based decision-making. Effective management of mountain resources and the prioritization of vital infrastructure; such as roads, irrigation, and hydropower, require accurate, geo-referenced information that can withstand the complexities of mountainous geography. Geographic Information Systems (GIS) have emerged as an essential tool for such environments, providing the capability to integrate diverse thematic layers and conduct sophisticated spatial analysis. This initiative establishes a digital spatial database for Jugal Rural Municipality to bridge the gap between traditional planning and modern, resilient governance.

For effective municipal planning, high-resolution data is required to address micro-level challenges within the wards and settlements. This assignment utilizes a multidisciplinary methodology combining high-resolution satellite imagery, Digital Elevation Models (DEM), and secondary data from national agencies like the Survey Department. To ensure ground-level accuracy, primary data is collected through field surveys using GPS and mobile-based GIS applications to map schools, health posts, and cultural heritage sites like Gumbas. A participatory approach is adopted through close consultations with municipal officials and ward representatives, coupled with capacity-building training for staff. Ultimately, the establishment

of this GIS database and the accompanying thematic maps will serve as the foundational spatial data infrastructure for the long-term sustainable development of Jugal Rural Municipality

1.2 Objective

1.2.1 General Objective

The overall objective of this assignment is to develop a comprehensive GIS-based spatial database and thematic maps for Jugal Rural Municipality to support municipal governance, development planning, infrastructure management, and disaster risk management.

1.2.2 Specific Objectives

The specific objectives of the assignment include:

- Preparation of geo-referenced base maps of the Rural Municipality
- Mapping of major government offices, schools, and health facilities
- Mapping of major infrastructure including roads, bridges, irrigation, water supply, and hydropower
- Identification and mapping of disaster-prone areas
- Preparation of land cover and built-up area maps
- Mapping of Gumbas, cultural heritage sites, and other important areas
- Establishment of a GIS database system and capacity building of municipal staff

1.3 Scope of Work

The project encompassed all necessary activities to develop a comprehensive GIS database and a series of thematic maps for Jugal Rural Municipality. The scope involved multi-level consultations with municipal officials and ward representatives, a thorough review of existing documentation, and the integration of primary and secondary data. Furthermore, the work included spatial data processing, complex spatial analysis, the establishment of a municipal GIS system, and targeted capacity-building initiatives.

The specific mapping domains completed during this assignment are detailed below:

Administrative Mapping

- Delineation of the official Rural Municipality and Ward boundaries.
- Spatial identification and naming of major settlements and toles within the municipality.

Government Facilities Mapping

- Digitization of the Rural Municipality Office and all respective Ward Offices.
- Mapping of educational institutions, including both Basic and Secondary schools.
- Location mapping of Health Posts, Community Health Units, and other essential public service centers.

Infrastructure Mapping

- Documentation of the road network.
- Mapping of physical infrastructure such as bridges, trails, and irrigation systems.
- Identification of existing and proposed hydropower projects and available transmission line data.

Disaster Risk Mapping

- Identification and spatial analysis of landslide-prone areas and flood-prone zones.
- Mapping of riverbank erosion areas.
- Cataloging the spatial locations of historical disaster events.

Land Cover and Built-Up Area Mapping

- Detailed classification of forest areas, agricultural land, grassland, and water bodies.
- Mapping of barren land and areas of snow cover where applicable.
- Precise delineation of settlement and built-up clusters.

Cultural and Religious Sites Mapping

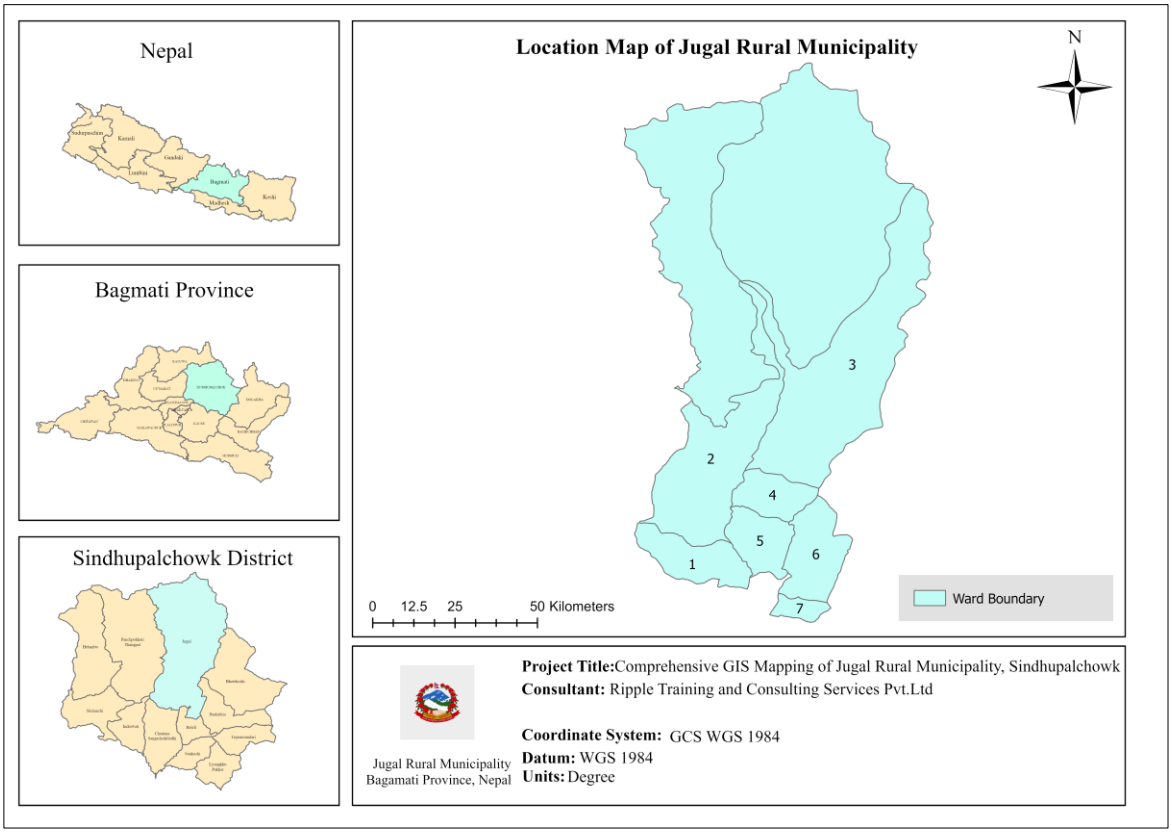
- Comprehensive mapping of Gumbas, temples, and monasteries.
- Identification and spatial recording of heritage sites and areas of significant cultural importance.

CHAPTER 2: STUDY AREA PROFILE

2.1 Physical Characteristics

2.1.1 Location

Jugal Rural Municipality falls under the Sindhupalchok district within Bagmati Province. The total area of this rural municipality is 592 sq. km. This rural municipality is located approximately 90 km northeast of the capital city, Kathmandu. Bordered by Bhotekoshi Rural Municipality and Bahrabise Municipality in the east, Panchpokhari Rural Municipality in the west, Chautara Sangachokgadhi Municipality and Balefi Rural Municipality in the south, and the border of China in the north, this is the largest rural municipality in the Sindhupalchok district. This rural municipality is situated at the headwaters of the continuously flowing Brahmayani River. There are 7 wards in this rural municipality (including the former Selang, Golche, Gumba, Pangtang, Baramchi, and Hagum VDCs).



2.1.2 Topography and Natural Features

Jugal Rural Municipality exhibits a highly varied topography characteristic of the central Himalayan region, with elevations ranging from approximately 300 meters in riverine lowlands

to 7,080 meters at its highest peaks. Covering 592 square kilometers in Sindhupalchok District, the municipality's terrain transitions from steep mid-hill slopes to rugged high-altitude plateaus and glacial zones, dominated by the Jugal Himal range that defines its northern boundary and namesake. This range includes peaks exceeding 6,000 meters, such as Jugal Peak at 6,500 meters on the Nepal-China border, fostering a landscape of deep valleys, glacial moraines, and alpine ridges prone to erosion and mass wasting due to fragile metamorphic geology and tectonic activity.

Key natural features encompass extensive forest cover spanning 197.8 square kilometers, or about 33% of the total area, including 21 community forests and 104 religious forests integrated into protected zones like the Gauri Shankar Conservation Area and Langtang National Park. These forests, featuring rhododendron thickets at lower elevations and coniferous stands ascending to timberlines, support diverse biodiversity amid the transition to barren high-alpine tundra. The Bhotekoshi River and its tributaries carve through the municipality, forming vital hydrological corridors that power over 10 small- and large-scale hydropower projects while contributing to sediment-laden flows that exacerbate landslide risks in monsoon-prone steep gradients exceeding 45 degrees in many areas.

2.1.3 Climate and Environmental Conditions

Jugal Rural Municipality, situated in the northern Himalayan foothills of Sindhupalchok District, spans elevations from approximately 300 meters to over 6,500 meters, resulting in a predominantly alpine and nival climate with significant microclimatic variations due to topography. The area features cold, dry winters with minimum temperatures averaging around 5°C district-wide, though higher altitudes in Jugal experience sub-zero conditions and snowfall, while summers bring milder temperatures with district maximums up to 32.5°C in lower valleys, moderated by elevation in the municipality's core.

Precipitation is dominated by the monsoon season from June to September, with the district receiving an average annual rainfall of 1,615 mm, though northern areas like Jugal see higher intensities exceeding 4,000 mm in some zones due to orographic effects, leading to over 20 wet days per month and peaks above 150 mm per day in July and August. Outside monsoon periods, the region is relatively dry, influenced by Tibetan high-pressure systems, which contribute to seasonal aridity and increased wildfire risks during dry spells.

Environmental conditions are marked by high vulnerability to geo-hazards stemming from steep slopes (over 80% exceeding 20 degrees), young and fragile geology, and seismic activity near major thrusts like the Main Central Thrust. Landslides dominate risks, with Jugal classified as having 11.61% very high and 44.83% high susceptibility, triggered by heavy monsoon rains and events like the 2015 Gorkha earthquake, which induced thousands of slides; notable incidents include the 2020 Lidi landslide and 2021 events causing 73 deaths across northern municipalities including Jugal. Floods from glacial lake outburst floods (GLOFs) and river swelling pose additional threats, with 6.94% very high and 64.66% high flood susceptibility in Jugal, compounded by deforestation and road construction. Climate change exacerbates these through glacier retreat and erratic rainfall, heightening cascading disaster potential in this seismically active zone (Zone V).

2.2 Demographics

2.2.1 Population Trends and Census Data

According to Nepal's National Population and Housing Census conducted on June 22, 2011, Jugal Rural Municipality, comprising its predecessor Village Development Committees, had a total population of 19,231, with 9,581 males and 9,650 females.

The 2021 census, enumerated on November 25, recorded a decline to 18,303 residents, including 9,194 males (50.2% of the total) and 9,109 females (49.8%).

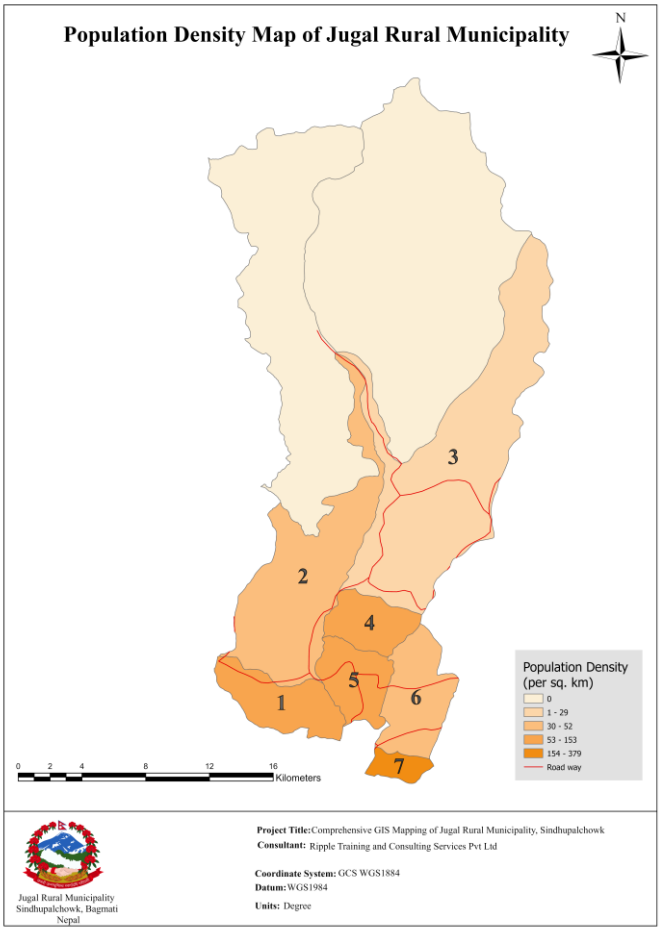


Table 1: Number of households, population by sex, average household size and sex ratio, NPHC 2021

	Number of Household	Population (2021)			Average Household size	Sex Ratio
		Total	Male	Female		
All Wards	4528	18303	9194	9109	4.04	100.93
1	721	2940	1479	1461	4.08	101.23
2	804	3614	1829	1785	4.5	102.46
3	756	3291	1671	1620	4.35	103.15
4	619	2399	1234	1165	3.88	105.92
5	755	2814	1409	1405	3.73	100.28
6	301	1108	537	571	3.68	94.05
7	572	2137	1035	1102	3.74	93.92

This represents an average annual population growth rate of -0.47% over the decade, attributable to factors such as rural out-migration to urban centers and abroad.

The following table summarizes key census figures:

Table 2: Population Growth Rate

Census Year	Total Population	Males	Females	Annual Growth Rate
2011	19231	9581	9650	N/A
2021	18303	9194	9109	-0.47

Population density in 2021 stood at 30.68 persons per square kilometer across the municipality's 596.5 km² area, underscoring its sparse rural character.

2.2.2 Ethnic and Linguistic Composition

The ethnic composition of Jugal Rural Municipality is characterized by a strong predominance of the Tamang group, reflecting the municipality's location in the mountainous regions of

Sindhupalchok District where Tibeto-Burman communities historically settled. According to the National Population and Housing Census 2021, Tamang individuals comprise the largest share, aligned with linguistic patterns where Tamang ethnicity correlates closely with mother tongue usage. Smaller proportions include Chhetri (approximately 11% or 2,077 persons based on census breakdowns) and Hill Brahmin, with marginal presence of Sherpa, Hyolmo, and Dalit castes such as Kami.

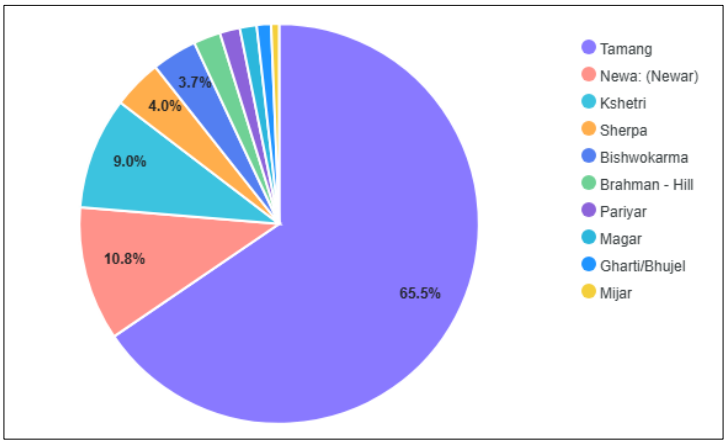


Figure 1: Population percentage based on caste

Linguistically, Tamang is the primary mother tongue, indicative of ethnic continuity in this rural, high-altitude setting. Nepali, the national language, is the second most common, used by roughly 30-40% as a first language among non-Tamang groups and widely as a second language for administration, education, and inter-community interaction, consistent with district-level trends in Sindhupalchok where Tibeto-Burman languages (including Tamang) account for over 50% of mother tongues. Other languages like Nepal Bhasa or Sherpa appear sporadically, tied to minor ethnic enclaves, but do not exceed 5% collectively. This composition supports cultural practices rooted in Tamang traditions, including Buddhist influences and agrarian lifestyles, though Nepali dominance in formal sectors promotes bilingualism.

2.3 Infrastructure and Development

2.3.1 Education and Human Capital

Jugal Rural Municipality operates a basic education system comprising 32 pre-primary schools, 39 basic schools, 10 secondary schools, and 2 higher secondary (plus-two) institutions, predominantly public with one religious school. A 2025 baseline survey identified 45 schools

overall, though coverage focused on 12 institutions in wards 3, 5, and 7, serving early childhood development through grade 8.

Literacy stands at 60.6% among the population aged 5 and above (totaling 16,736 individuals), with males at 66.3% and females at 54.7%, per Nepal's 2078 BS census data (corresponding to 2021 CE). Enrollment in the surveyed schools totals 2,045 students from ECD to grade 8, achieving a gender parity index of 0.99, though pre-primary enrollment remains low municipality-wide due to factors like distance and economic pressures. Student-teacher ratios average approximately 14:1 across these schools, supported by 145 educators, 40.7% of whom have received formal training.

Human capital development is constrained by these educational gaps, yielding a workforce with limited advanced skills; teacher qualifications include 40.7% bachelor's degrees and 20% master's degree, but broader adult literacy deficits hinder vocational adaptability in agriculture-dominant economy. Community initiatives like child clubs in 83% of surveyed schools foster basic leadership and awareness, yet low household incomes, primarily from farming (34.4% of women's earnings), restrict further investment in skills training or higher education, perpetuating reliance on remittances over local capacity building.

2.3.2 Health Services and Accessibility

Jugal Rural Municipality operates basic health facilities primarily through ward-level health posts that deliver essential services such as maternal care, vaccinations, and primary treatment. These posts, present in nearly every one of the municipality's seven wards, handle routine health needs including outpatient consultations and minor procedures, with staffing often limited to nurses and auxiliary health workers. Specialized units like the Hagam Birthing Center in a remote area support midwife-led deliveries and ultrasound diagnostics, addressing maternal health in geographically isolated zones.

Accessibility remains severely constrained by the municipality's mountainous terrain and inadequate road infrastructure, particularly in wards such as 3 (Tembathan), where residents must trek hours or days to reach facilities due to absent motorable roads. Villages including Dipu, Tega, and Tembathan lack reliable connectivity, exacerbating delays in emergency care and routine access, with patients often relying on porters or helicopters for transport to district-level hospitals in Chautara.

2.3.3 Transportation and Connectivity

Jugal Rural Municipality's transportation system centers on road networks, with the Araniko Highway (National Highway 34) providing the primary link to Kathmandu, approximately 100 kilometers south, and extending northward to the Nepal-China border at Kodari. This highway traverses southern wards of the municipality, facilitating trade, passenger buses, and freight transport toward Tibet, though it remains a two-lane blacktop road prone to seasonal closures.

Local connectivity depends on district and rural roads branching from the highway, including paths to ward centers like Baramchi, the administrative headquarters. These secondary roads, often gravel or earthen, total limited lengths suitable for all-weather access, with upgrades pursued through national initiatives such as the Strengthening the National Rural Transport Program, which aims to enhance rural road maintenance and poverty reduction via improved links. However, progress in Jugal is hampered by the Himalayan terrain, with frequent landslides disrupting the Araniko Highway and isolating communities during monsoons.

No domestic airports or rail lines serve the municipality; the nearest aviation hub is Tribhuvan International Airport in Kathmandu, accessible primarily by road. Public transport includes microbuses and jeeps for intra-municipality travel, supplemented by footpaths in remote high-altitude wards near Jugal Himal, underscoring persistent challenges in equitable connectivity despite ongoing government tenders for road construction and bridges.

CHAPTER 3: METHODOLOGY

The methodology for developing the GIS-based spatial database and thematic maps for Jugal Rural Municipality was structured into sequential phases to ensure systematic data acquisition, processing, validation, and database development. The approach integrated geospatial technologies, field-based verification, and stakeholder participation to produce reliable and planning-oriented outputs.

3.1 Inception Phase

The inception phase established the foundation for the entire assignment by aligning technical activities with municipal needs and available resources.

A kickoff meeting was conducted with municipal officials, ward representatives, and relevant stakeholders to formally initiate the project. During this meeting, the scope of work, expected outputs, timelines, and responsibilities were clearly discussed and agreed upon. Special emphasis was placed on understanding local priorities related to infrastructure development, disaster risk management, and service delivery.

A comprehensive review of existing documents was undertaken, including previous reports, Detailed Project Reports (DPRs), land use plans, and sectoral data. This review helped assess data availability, quality, scale, and usability.

Based on this assessment, data gaps were identified, particularly in areas such as high-resolution spatial data, infrastructure mapping, and hazard information. A detailed work plan was then prepared, outlining the methodology, timeline, resource allocation, and survey strategy. This plan guided subsequent phases and ensured efficient project execution.

3.2 Data Collection Methodology

Data collection combined secondary data acquisition, remote sensing techniques, and primary field surveys to ensure a comprehensive and accurate spatial database.

3.2.1 Secondary Data Collection

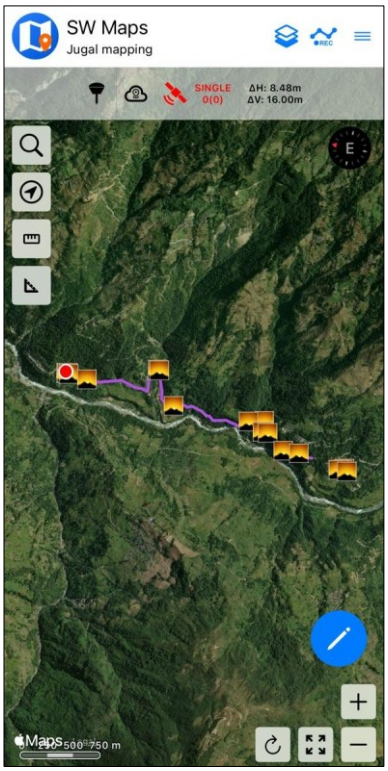
Secondary data formed the baseline for the study and included administrative boundaries, Digital Elevation Models (DEM), high-resolution satellite imagery, topographic maps, and

hydrological and disaster-related datasets. These datasets provided the initial spatial framework necessary for mapping and analysis.

3.2.2 Remote Sensing and Image Processing

Remote sensing techniques were applied to process and analyze satellite imagery using ArcGIS Pro. The imagery underwent preprocessing steps, including geometric and radiometric corrections, to ensure positional accuracy and consistency. Subsequently, image classification techniques, were employed to derive land cover information. The study area was categorized into land cover classes such as forest, agricultural land, grassland, water bodies, barren land, and built-up areas, with the classification scheme refined in consultation with municipal stakeholders. Accuracy assessment was performed using ground truth data, allowing for validation and refinement of classification outputs. Built-up areas and settlement clusters were also delineated from the processed imagery to support infrastructure and service planning.

3.2.3 Field Survey and Ground Truthing



Field surveys were conducted to collect primary data using tools such as SW maps and validate spatial datasets. Field surveys played a crucial role in validating and enriching the spatial database. Given the rugged terrain and dispersed settlement pattern of the municipality, extensive ground verification was undertaken using GPS devices and mobile-based GIS tools.

Key features such as schools, health posts, and government offices were geo-referenced, while infrastructure elements including roads, bridges, irrigation canals, and water supply systems were mapped in detail. Hydropower sites and culturally significant locations such as Gumbas and temples were also documented.

In addition, field observations were used to identify and verify landslide-prone areas, flood-prone zones, and riverbank erosion sites. Ground truthing was particularly important for improving the accuracy of land cover classification and ensuring that mapped features accurately reflected on-the-ground conditions.

3.3 GIS Database Development

A comprehensive and structured GIS database was developed to organize and manage all spatial and non-spatial data collected during the project.

All collected and processed data were systematically organized into a structured GIS database. The development of this database involved the creation of multiple thematic layers representing administrative boundaries, infrastructure, land use and land cover, hydrology, disaster risk, and cultural sites among other layers. Spatial features were digitized from satellite imagery, and field data, ensuring a high level of positional accuracy.

Attribute information describing each feature, such as name, type, condition, and functional characteristics, was integrated into the database to enhance its analytical value. In addition, standardized metadata were prepared for each dataset, documenting key details such as data sources, scale, projection system, and date of creation. All spatial data were harmonized using an appropriate coordinate reference system, WGS 84/ UTM Zone 45N, to maintain consistency across datasets.

The final GIS database was developed in widely used and compatible formats, including Shapefile, GeoPackage, and File Geodatabase, ensuring ease of use, interoperability, and long-term sustainability. This structured database now serves as a foundational spatial data infrastructure for the municipality, supporting evidence-based planning, resource management, and future data updates.

CHAPTER 4: RESULTS AND OUTPUTS

4.1 Cartographic Outputs

A number of general and thematic maps, including administrative, social, infrastructure, land use, and cultural sites maps, were prepared to provide a comprehensive spatial foundation for this report. These maps transition from broad jurisdictional overviews to specialized thematic analyses, utilizing a combination of existing topographic maps, satellite imagery, Digital Elevation Models (DEMs), and field-verified data.

4.1.1 Base Map

A base map is a fundamental geospatial layer that provides essential background reference information, including administrative boundaries, hydrological networks, and primary infrastructure, upon which specialized thematic data is overlaid for spatial context.

The Base Map of Jugal Rural Municipality serves as the primary spatial reference for this comprehensive GIS mapping project, integrating various critical data layers into a single consolidated view. The map delineates the seven administrative ward boundaries and identifies the spatial distribution of key social and physical infrastructure. Essential public services are georeferenced, including schools, health service centers, and all seven ward offices. Connectivity and natural features are represented through a detailed road network, bridges, and the Brahmayani River system. Additionally, the map highlights the locations of hydropower projects, police stations, and tourist destinations across the municipality's varied terrain. Produced at a scale of 1:150,000 using the GCS WGS 1984 coordinate system, this base map provides the necessary geographic framework for effective municipal governance and infrastructure planning.

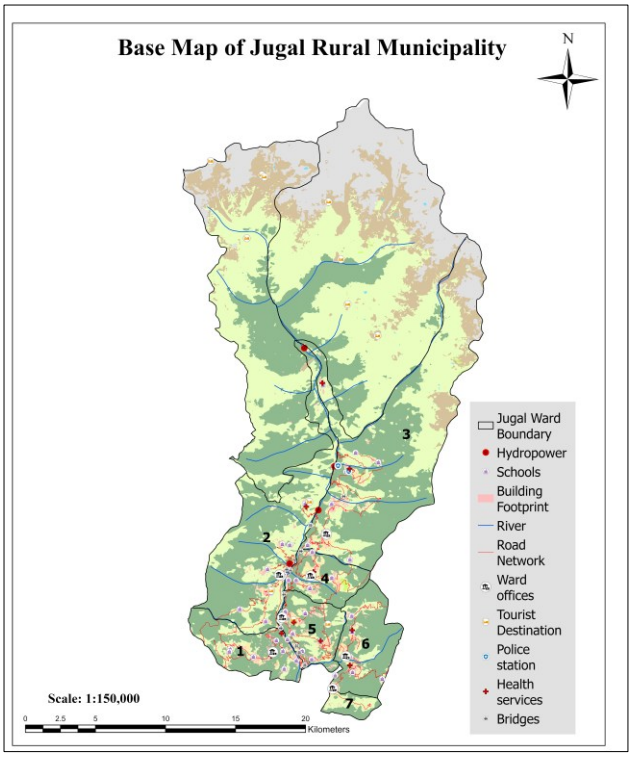


Figure 2: Chamkuna Waterfall

Figure 3: Tilman pass

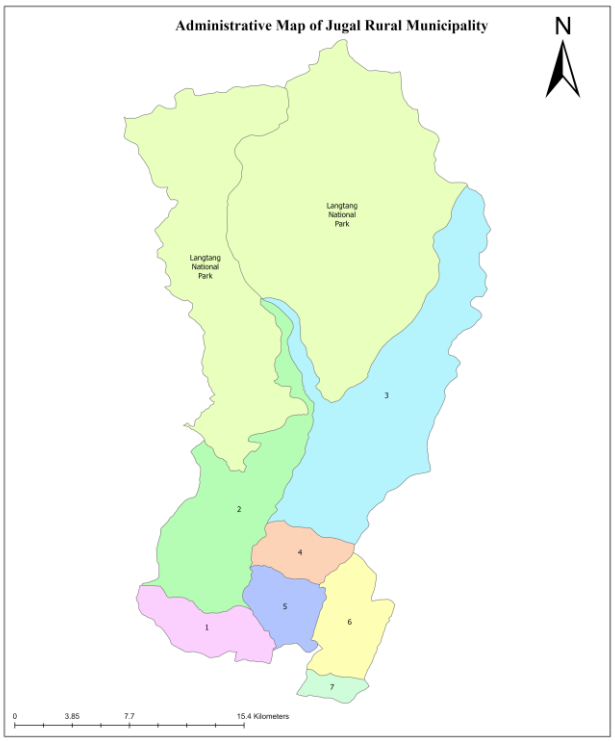
Figure 4: Police Station

Figure 5: School

Figure 6: Hydrpower

Figure 7: Balephi Hydropower Plant

4.1.2 Administrative Map



An administrative map is a specialized cartographic representation that delineates jurisdictional boundaries, governmental divisions, and the locations of official administrative centers within a specific geographic region.

Figure 8: Municipal Office of Jugal Rural Municipality

Figure 9: Ward office of ward no.2

The administrative map of Jugal Rural Municipality provides a comprehensive spatial overview of the region's jurisdictional layout. It delineates the boundaries of the seven constituent wards and highlights the significant intersection with the Langtang National Park boundary to the north. Key administrative landmarks are identified, including the primary municipal office and the individual ward offices for each division. This map serves as a foundational reference for understanding the spatial distribution of local governance and protected areas within the municipality.

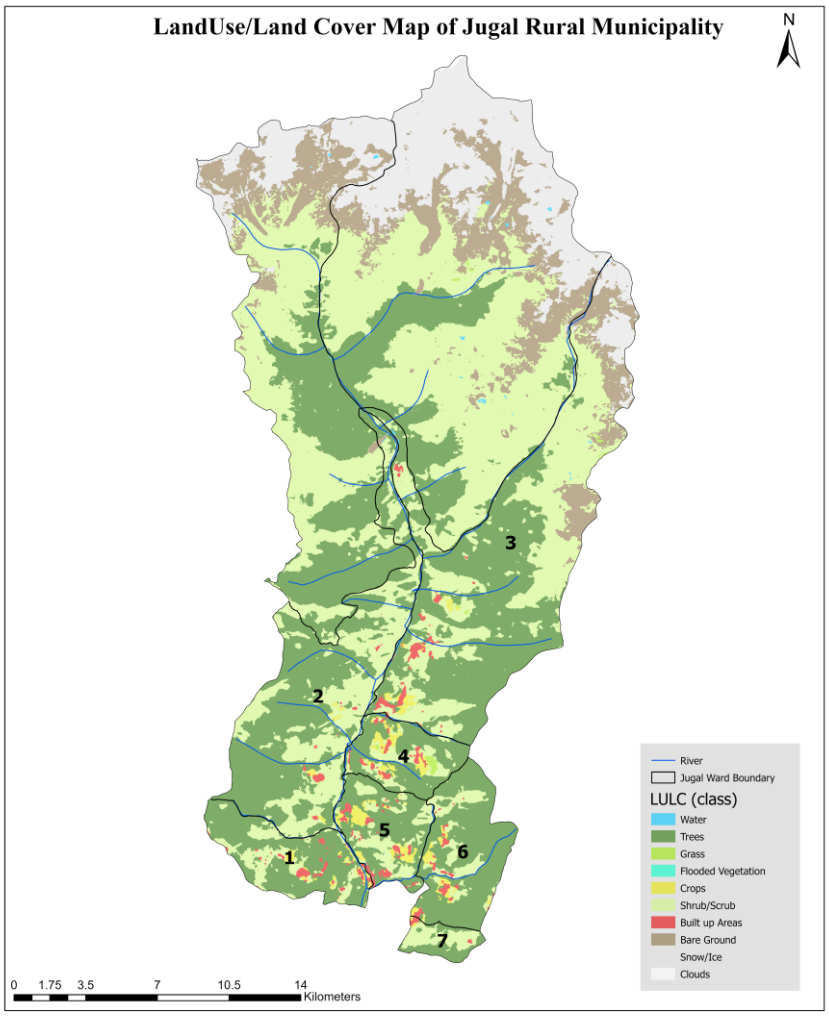
4.1.3 Land Cover Map

A Land Use Land Cover map is a thematic representation that classifies the physical material on the earth's surface and the human-driven activities taking place upon it to provide a comprehensive inventory of a region's landscape.

Table 3: Land Cover classes and the coverage percentage

Land Cover Class	**Area(hectare)**	**Percentage**
Water	97.976	0.16
Trees	21990.000	36.92
Grass	79.215	0.13
Crops	635.053	1.07
Scrubland	22543.900	37.85
Built up Areas	597.876	1.00

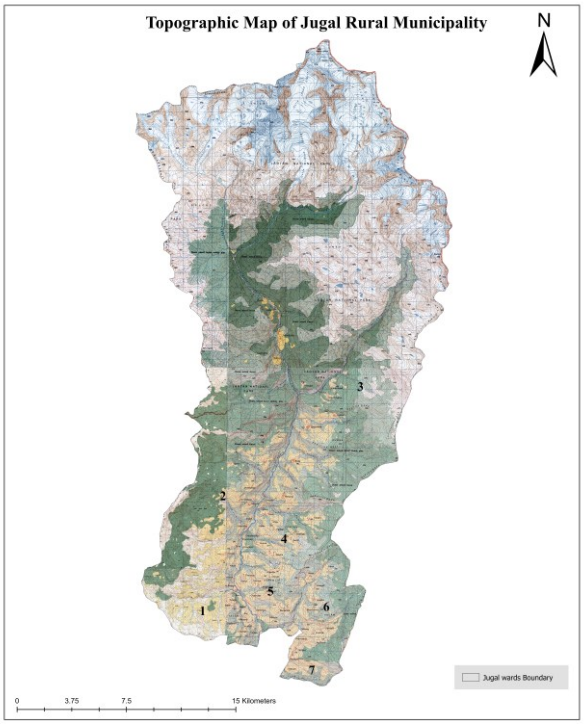
Bare Ground	6305.420	10.59
Snow/Ice	7313.390	12.28



The Land Use Land Cover (LULC) map of Jugal Rural Municipality provides a detailed spatial inventory of the diverse environmental and anthropogenic features across the study area. The map identifies several primary categories, including forest cover, agricultural land, barren rocky terrain, shrubland, and built-up areas, as well as the snowy zones within the northern reaches of Langtang National Park. Preliminary analysis indicates that Scrubland occupies the largest portion of the municipality, covering approximately 37.85% of the total area, while agricultural activities are primarily concentrated in the lower elevations of the southern wards.

4.1.4 Topographic Map

A topographic map is a high-precision general-purpose map series produced by a national mapping agency that portrays both natural and man-made features, using contour lines to represent the detailed relief and shape of the earth's surface.



The Topographic Map of Jugal Rural Municipality utilized for this project is part of the standard national map series produced by the Government of Nepal, Survey Department. This map is based on the Modified Universal Transverse Mercator (MUTM) projection and the Everest 1830 Spheroid, serving as the authoritative spatial reference for the region. Unlike thematic layers generated specifically for this study, this map provides a standardized, multi-layered view of the terrain at a scale of 1:50,000 (typical for high-mountain regions) or 1:25,000 (for lower elevations).

4.1.5 Road Network Map

A road network map is a spatial representation of the interconnected system of transport routes, classifying them by type, surface material, and accessibility to visualize the connectivity and physical mobility within a region.

The Road Network Map of Jugal Rural Municipality provides a detailed inventory of the transportation arteries that facilitate movement and commerce across its seven wards. The network is anchored by the Araniko Highway, which traverses the southern portion of the municipality, providing a vital link to Kathmandu and the Nepal-China border. Local connectivity is maintained through a series of district and rural roads that branch from the highway toward ward centers like Baramchi.

While the southern and central clusters are served by gravel or earthen roads, large portions of the high-altitude northern territory remain inaccessible to motor vehicles, relying instead on footpaths and trails. The map specifically identifies critical nodes such as bridges that allow for river crossings over the Brahmayani River and its tributaries.

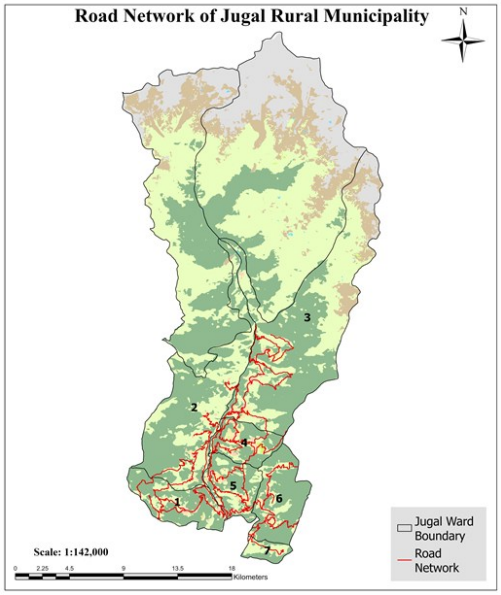


Figure 10 Roads of Jugal Rural Municipality

4.1.6 River Network Map

A river network map is a hydrological geospatial dataset that delineates the spatial distribution of flowing water bodies, including perennial rivers, seasonal streams, and tributaries, to visualize the drainage patterns and water resources of a region.

The River Network Map of Jugal Rural Municipality illustrates the intricate hydrological system that defines the region's topography and drainage. The municipality is primarily drained by the Brahmayani River (also known as the Balephi Khola), which flows southwards and acts as a major geographical spine for the area. The network is characterized by a high-density dendritic drainage pattern, featuring numerous primary and secondary tributaries, such as the Gyalzen Khola, Phurbi Ghyachu Khola, and Larke Khola, which originate from the high Himalayan glaciers of the Jugal Himal range.

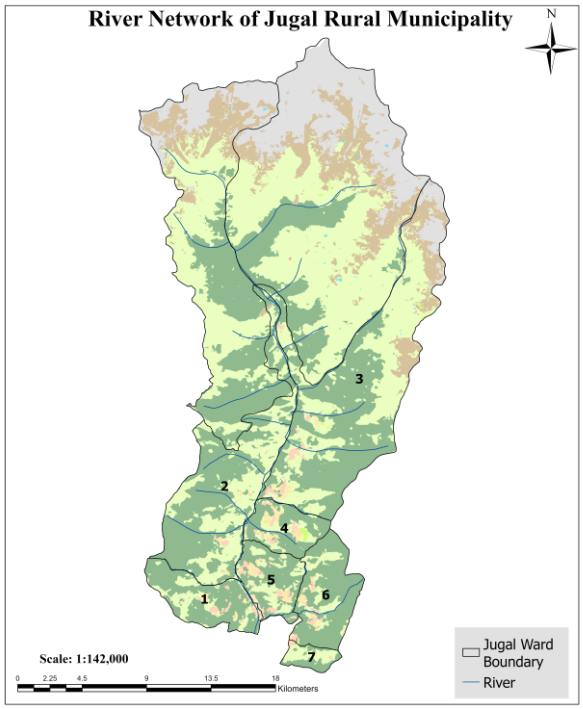
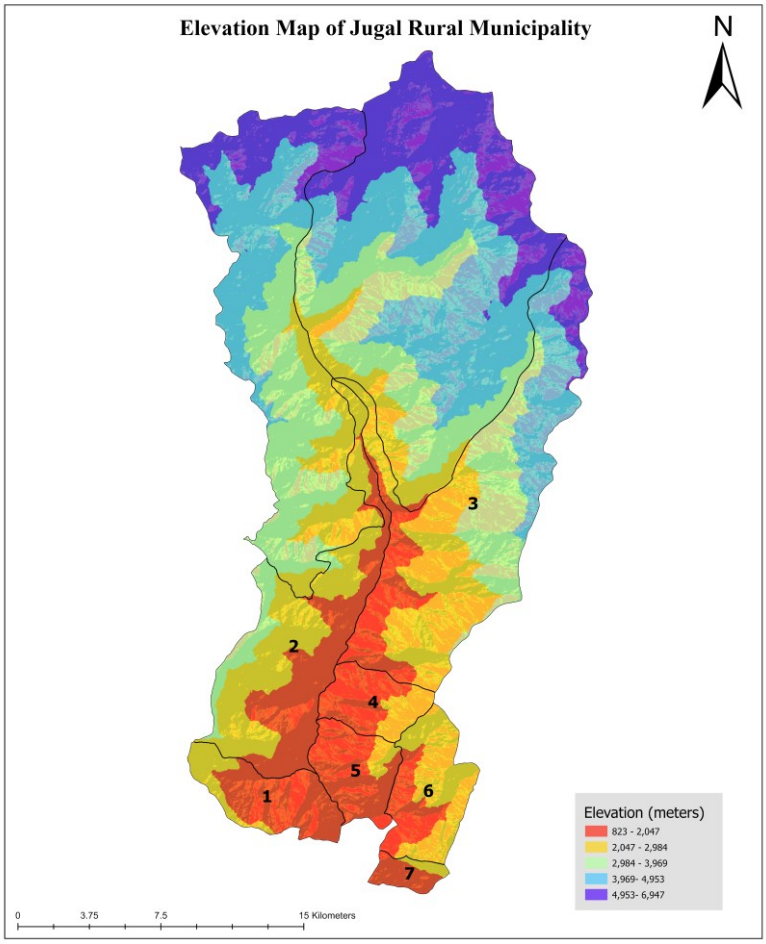


Figure 11: Rivers and river infrastructure of Jugal Rural Municipality

4.1.7 Elevation Map

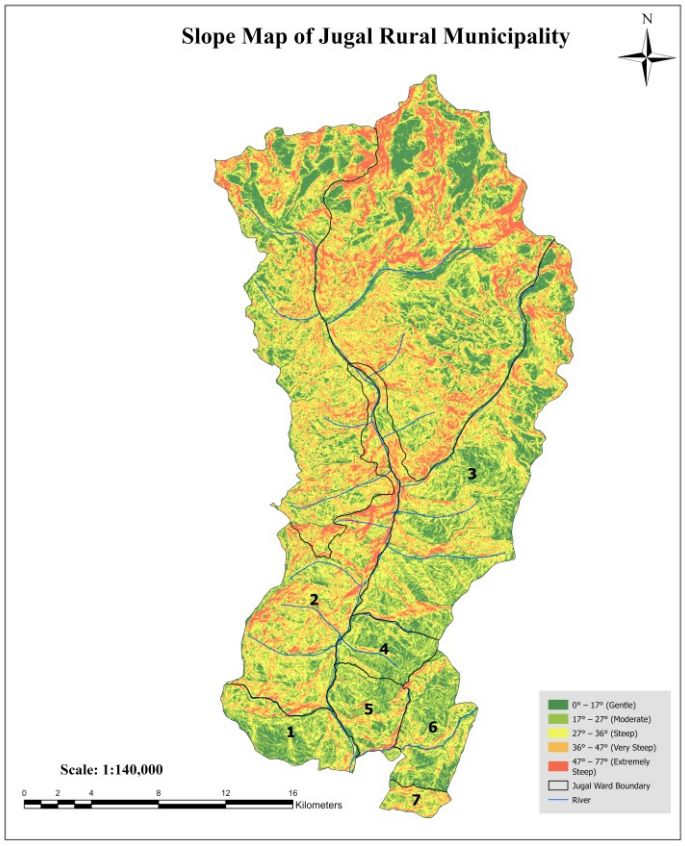
An elevation map is a topographic tool that illustrates the vertical height of the land surface above a reference datum, typically mean sea level, to visualize the relief and physical terrain of a given area.



The elevation map of Jugal Rural Municipality illustrates the significant topographic variation across the region. It depicts a dramatic altitudinal gradient, rising from a minimum elevation of 823 meters in the southern river valleys to a maximum of 6940 meters at the high-altitude peaks of the Jugal Himal range within Langtang National Park. The map utilizes a color-coded relief system to represent these varied elevation zones, providing essential context for understanding the municipality's climate, vegetation patterns, and settlement distribution. This vertical profile, spanning a total range of 6123 meters, is crucial for assessing the physical constraints and opportunities for development within the seven wards.

4.1.8 Slope Map

A slope map is a thematic geospatial representation that calculates and visualizes the steepness or inclination of the terrain surface relative to the horizontal plane, typically expressed in degrees or percentages.

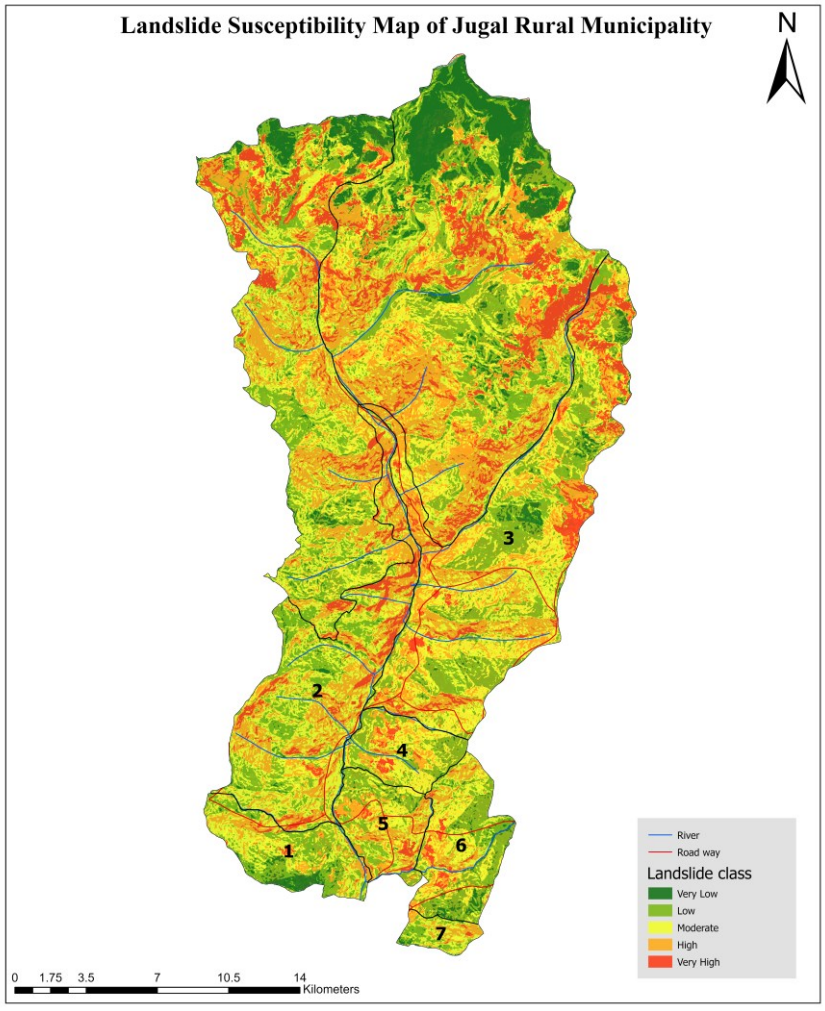


The slope map of Jugal Rural Municipality categorizes the terrain based on its gradient to identify developable land and potential geographic constraints. The analysis reveals a highly rugged landscape, with slope values ranging from minimum on the valley floors to over

maximum slope in the high Himalayan cliff. By classifying these gradients, the gentle slopes suitable for agriculture and settlement, and steep terrain exceeding that may be prone to landslides or require specialized engineering can be distinguished.

4.1.9 Landslide Susceptibility Map

A Landslide Susceptibility Map is a predictive geospatial model that categorizes the landscape into different levels of risk based on the likelihood of slope failure, determined by analyzing factors such as terrain steepness, geology, land cover, and historical landslide data.



The Landslide Susceptibility Map of Jugal Rural Municipality provides a critical assessment of geological hazards across its rugged Himalayan terrain. Given that the municipality is situated in a geologically active zone with extreme relief, the map classifies the territory into zones of Very Low, Low, Moderate, High, and Very High susceptibility. The analysis reveals

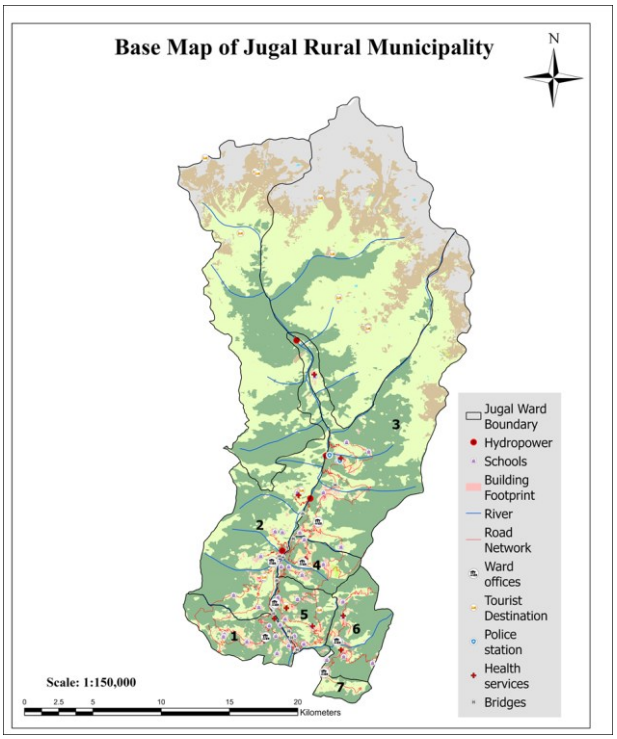
that high-risk zones are predominantly concentrated along steep, south-facing slopes and areas with degraded vegetation or active river undercutting.

4.1.10 Built-up Area and Settlement Map

A Settlement and Built-up Area Map is a thematic geospatial output that identifies the spatial distribution of human habitations, including residential clusters, commercial buildings, and associated man-made infrastructure, to analyze urbanization patterns and population density.

The settlement and built-up area map provides a detailed spatial analysis of human habitation patterns across Jugal Rural Municipality, utilizing a combination of point-based settlement locations and digitized building footprints. The data reveals a significant north-south disparity in settlement density.

The southern wards exhibit the highest concentration of building footprints, with large, interconnected clusters around settlements such as Selang, Baramchi, Pangtang, and Hagam. These areas represent the administrative and economic core of the municipality, where infrastructure connectivity is most developed.



The central region is characterized by smaller, semi-contiguous built-up clusters, including Lidi, Bolde, and Ghumthang, which are situated primarily along mid-hill ridges and terraced agricultural slopes.

In contrast, the northern territory is nearly devoid of built-up area, with habitation restricted to small, isolated high-altitude pockets such as Tembathang, Nagikharka, and Tharpu/Mahathan. These settlements serve as the final inhabited points before the terrain transitions into the protected forest and glaciated zones of the high Himalayas.

This mapping layer highlights that the vast majority of the municipality's 18,303 residents live within the lower one-third of the total land area. By visualizing the exact extent of building

footprints, this map serves as a critical tool for identifying infrastructure gaps and assessing the vulnerability of specific households to localized environmental hazards

4.2 Digital Geospatial Database

Beyond the static cartographic outputs, a comprehensive geospatial database was developed to store all vector and raster datasets generated for Jugal Rural Municipality. This database organizes spatial features into distinct feature classes with standardized attribute schemas. Each entry in the database is populated with relevant non-spatial information, including ward numbers, office names, and coordinate locations. By maintaining a structured geodatabase format, the data ensures long-term interoperability and allows the municipality to perform future spatial queries, updates, and multi-criteria analyses as part of their digital governance and resource management.

CHAPTER 5: CONCLUSION

The comprehensive GIS mapping of Jugal Rural Municipality represents a significant step toward establishing a modern, data-driven foundation for local governance and sustainable development. Through the integration of secondary datasets, remote sensing techniques, and extensive field verification, this project has successfully developed a reliable and structured geospatial database accompanied by a series of thematic maps. These outputs collectively provide a detailed spatial understanding of the municipality's physical environment, infrastructure, settlement patterns, and hazard-prone areas.

The findings highlight the unique challenges and opportunities within the municipality. The rugged topography, high environmental sensitivity, and exposure to natural hazards such as landslides and floods underscore the need for informed planning and risk-sensitive development approaches. At the same time, the availability of mapped infrastructure, land cover, and socio-cultural features creates new opportunities for targeted interventions in sectors such as transportation, agriculture, disaster management, and service delivery.

The GIS database developed under this assignment serves not only as a repository of spatial information but also as a dynamic decision-support tool. It enables municipal authorities to perform spatial analysis, monitor development activities, and update information as needed, thereby enhancing institutional capacity for evidence-based planning. Furthermore, the participatory approach adopted during the project has strengthened local ownership and improved the usability of the outputs.

In conclusion, this project bridges the gap between traditional planning practices and modern geospatial technologies in Jugal Rural Municipality. For long-term sustainability, it is essential that the municipality continues to update and utilize this GIS system, integrate it into routine planning processes, and invest in capacity building of technical staff. By doing so, the municipality will be better equipped to achieve resilient development, optimize resource management, and improve the overall quality of life for its residents.