

Integrating Cadastral Map for Smart Village Initiatives (Udaipur, India) with GIS: A Novel Approach for Rural Maps Reconstruction

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Abstract: In this paper, four Gram Panchayats were selected from the Udaipur district in India as study areas (Bambora, Bori, Sulawas, and Sihad Gram Panchayat). The research aims to reconstruct rural maps using a novel approach that combines traditional cadastral data with advanced geospatial techniques and socio-economic datasets. By leveraging GIS, the project seeks to enhance land management, improve resource allocation, and support sustainable development in rural areas. The methodology involves digitizing and georeferencing existing cadastral maps, integrating them with spatial and non-spatial data, and creating thematic maps for various resources such as soil, water, and land use. The LULC classification achieved an overall accuracy of 94.33%, revealing that over 59% of the area remains fallow, with dense forest and crop land comprising 10.88% and 2.88%, respectively. This paper discusses the critical importance of maps for spatial analysis and demonstrates the practical benefits of resource mapping within the Smart Village initiative. The resulting integrated GIS-based system provides a scalable and replicable framework for village-level planning, decentralized governance, and participatory development. It ultimately contributes to the empowerment and economic growth of rural communities, aligning with India's Digital India and Smart Village programs.

Keywords: Rural Geography, Smart Village, Geospatial Mapping, Rural Map Reconstruction.

1. Introduction

India is the land of villages, as about 70% of the people live in villages. In accordance with the 2011 census, there are 6, 40, 867 villages in India. A former leader, an outstanding revolutionary of India, said that "India lives in its villages". The agricultural areas are the areas outside the cities, commonly referred to as 'villages' in India. Agriculture is the main source of livelihood in these areas along with fishing, cottage industries, pottery, etc. [Bhattacharyya & Ponnusamy, 2016; Gogoi, 2024]

Therefore, data technology, which has proven its potential for the event, is additionally being used for rural development through the "smart village" idea. The Smart Village concept is designed to support local conditions, infrastructure, and rural resources. By leveraging technology and innovation, smart village infrastructure has the potential to increase access to basic services, promote economic growth and environmental sustainability, and improve the overall quality of life in rural communities (Praveen et al., 2023). The Smart Village corrects social failure by providing housing for sustainable family relationships without disrupting the lifestyles of different generations. The vision of a smart village is that access to modern energy can act as a catalyst for development in education, health, productive entrepreneurship, clean water, sanitation, environmental sustainability, and participatory

democracy, contributing to further improvements in energy access. Originally, the concept of village development came from Mahatma Gandhi, i.e., Swaraj and Suraj Village. We all know that India is a developing country and with the help of Smart Village, we will make India a SS nation. Nowadays, our government is also putting a strong focus on smart villages. The government is implementing a large number of smart village programs, envisioning a holistic transformation of rural life by empowering villages with technology. [Somwanshi, R., et. al; 2016; Choudhary, 2024]

To minimize current rural problems, villages need well-organized micro- and macro-level regional planning for land use and convergence of government programs to ensure that land is held, owned, cultivated, and irrigated in environmentally friendly ways to use it as effectively as possible and maximize returns. Rural banking services need to be popularized and credit should be available for basic services such as "Kisan Rinn".

The current rural development framework of India mainly focuses on poverty alleviation, livelihood improvement, provision of basic amenities and infrastructure services through innovative wage employment and self-employment programs. The proposed area has both tribal and non-tribal population, high out-migration and low per capita income of farmers and girls. "Participatory GIS enables communities to actively participate in mapping, decision-making, and issue resolution, improving our

understanding and interaction with the environment” (Das Malakar & Roy, 2024). Nowadays, the agricultural youth who migrate to the cities are not familiar with the way of life in the cities, which affects their culture, work and psyche. This leads to a huge socio-economic imbalance.

In 2015, the United Nations set 17 Sustainable Development Goals (SDGs) to collectively address the most pressing issues facing our world. The SDGs address broad social, economic, and environmental challenges and provide a framework for collective action. “The NITI-Aayog has a 3-phase plan for the localization of SDGs and follows this up with annual monitoring and evaluation, including state rankings by Goal” (Sakhamuri & Sanagani, 2024). For each of the seventeen SDGs, there is a set of targets and indicators to help countries achieve the goal. To achieve the SDGs, governments and people must understand each challenge and monitor progress toward alleviating the problems. [Kapucu & Beaudet, 2020]

Several of the United Nations Sustainable Development Goals (SDGs) have direct or indirect environmental concerns. These SDGs naturally require greater citizen involvement in achieving their goals. Data visualizations in general, and map visualizations in particular, can play an important role in helping people better understand the environmental challenges facing the world and consequently change their behaviour toward a more sustainable future. [Rist, T., Masoodian, M., 2022]

Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It involves two key concepts: the concept of needs, especially the basic needs of the world's poor, which should be given top priority, and the concept of the limits imposed by the state of technology and social organization on the ability of the environment to meet present and future needs. [Pezzey, 1992]. Sustainable development is the maintenance of a delicate balance between people's need to improve their lifestyles and well-being and the preservation of the natural resources and ecosystems on which we and future generations depend. The success of sustainable development in a region depends on what is known about resource management and problems in the area. [Sunderlin et al., 2005]

In recent decades, the tools and techniques of Remote Sensing (RS) and GIS have been used for a variety of purposes and on a variety of time scales. RS is used to obtain spatial information in several areas of Earth system science. Because RS is capable of monitoring

Earth systems at multiple spatial and temporal scales, it is suitable for addressing global ecological, environmental, and socioeconomic challenges [Joshi et al., 2004; Abdelrahman et al., 2023]. Since the information can be accessed directly through RS, this is the main surveying technology for data collection in inaccessible and remote locations. On the other hand, GIS organizes geographic data so that a person reading a map can select the data needed for a particular project or task. GIS can be an important tool for helping people design plans to successfully implement management strategies that are sustainable at both local and global scales. [Petropoulos et al., 2015]. The role of GIS becomes even more important in rural land tenure systems, as land is not just a physical asset. As noted, “Land tenure recognizes that land is not just a physical resource but also a social and cultural asset, and it consists of the socially constructed rules that govern people’s relations to land (Eshetie et al., 2024).

Maps are very important to geographic research because they put demographic information into context. Through the use of physical maps and geographic information systems, geographers can provide spatial foundations and evidence. Maps such as resource maps, which show natural resources and secondary yields, are extremely useful in geography, and political maps, which specialize in borders and boundaries, are also useful for policymakers and anyone interested in mediation. Maps also allow geographers to support claims with visual evidence that can be processed in presentation techniques such as choropleth maps [Muehrcke, 1981].

Perhaps the most obvious explanation for why maps are so important to researchers and geographers is their use in contextualizing information, particularly in locating demographic data such as age structures and employment status. The key component of a map that is so important for this may be scale, because by mapping a study area to scale, demographic information is localized and expressed in terms of distance relationships [Map, 2023]. An example of this is the mapping of census data, where data are grouped by location and these groups are represented with maps to show proximity. Administrative unit-style maps are best for this purpose because they also show services and infrastructure that regularly complement the demographic data being studied. [Explain the Importance of Maps in Human Geography - 1DEA.me., 2016]

Another explanation for the importance of mapping is that maps can easily and concretely show changes over time. By looking at maps of the same area over many different time periods, human geographers can easily examine changes in infrastructure, economy, and settlement, all of which are important aspects of population change and development. These changes are often correlated with known time periods, such as economic revolutions, or linked to phases of the demographic transition model to explain typical and atypical changes in a region. Finally, mapping is a way of collecting and representing data that is completely universal. It's not constrained by different cultures or language barriers and can, in and of itself, explore and visualize any area of the world and make international or local comparisons with equal ease [Muehrcke, 1981].

In this paper, we'll look at the importance of maps in this context and how maps are important in showing changes in demography or landscape over time. Thematic maps offer perhaps the greatest scope for specialization, as a map is tailored to present specific information in a very particular style to advance a particular theme. There are four gram panchayat was selected as a case study. Raj Singh, B. V., Meena, V. S., & Mishra, R. (2023). The cadastre that was previously in place, which included land registries and paper maps, is now insufficient. Its flaws drive advancements that result in its betterment. By classifying characteristics into thematic layers, digital cadastral maps enable efficient administration of land parcels, infrastructure, and utilities in rural areas—a critical component of well-informed development project decision-making (Cichocinski, P., 1999).

The maintenance of relevant records is essential to the timely making of decisions that improve any society's quality of life. The manual nature of the current land management system causes numerous social issues in the form of land conflicts and is a significant obstacle to the nation's economic development (Shakir, M., Ali, Z., & Arko-Adjei, A., 2022). The vector database aids in the calculation of the land's extent as well as solving of boundary and individual property issues. One can examine the surrounding areas of each cadastral and village by superimposing the satellite image (Maryada, 2019). By integrating digitized cadastral maps, it facilitates **geo-enabled e-governance, location-based information dissemination, decision-making for planning, and electronic delivery of services**, and enabling sustainable rural development under the Digital India initiative (Azad, D. K., 2021).

2. Study Area

The study area is located in Kurabad (Earlier in Girwa) Tehsil of Udaipur District. Kurabad is a tehsil/block (CD) in Udaipur district of Rajasthan. (Fig. 1). The project envisages the development of a village cluster of Bombora, Bori, Sulawas, Sihad Gram Panchayat of Udaipur district (Fig. 2). It is an integrated and holistic approach to improve traditional cadastral maps and geo spatial mapping of the natural resources in the selected villages of Udaipur district. It also aims to contribute in policy making and good governance for sustainable local development with cluster growth programmes.

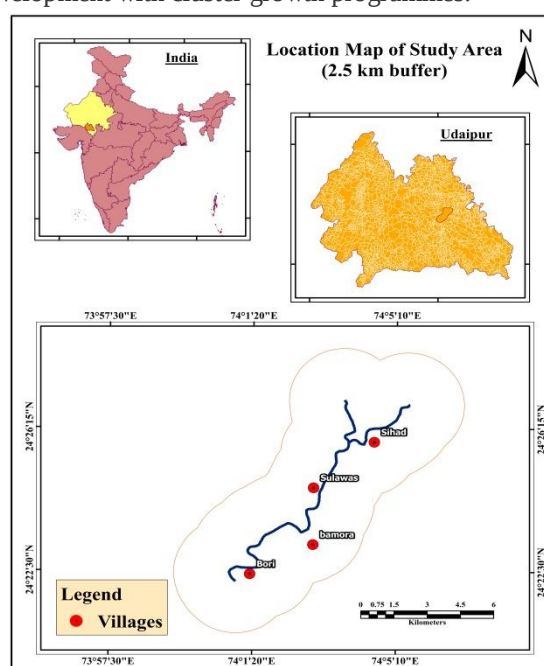


Fig. 1. Location Map with Study Area

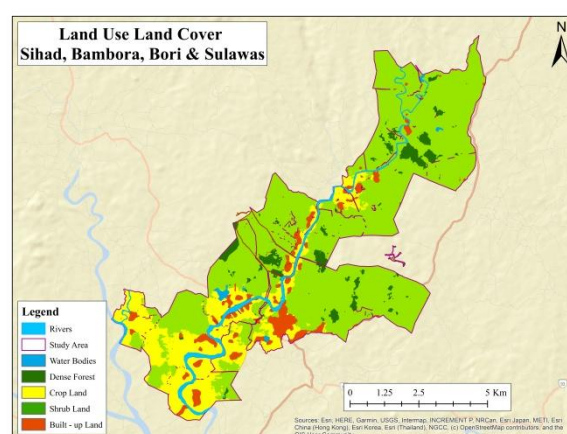


Fig. 2 Study Area

2.1. Bambora

Bambora Village is located in Kurabad tehsil in the Udaipur District of Rajasthan State, India. It is known for

its rich cultural heritage and natural beauty. The climate in Bambora is mild, with warm summers and cool winters.

The economy of this village is primarily based on agriculture activities with main crops being wheat, barley and mustard. Bambora Local Language is Hindi. Bambora Village total population is 3964 and number of houses are 821. (Census of India, 2011)

But nowadays its faces several challenges including environmental challenges, lack of infrastructure and limited access to basic amenities, which threaten the local ecosystem.

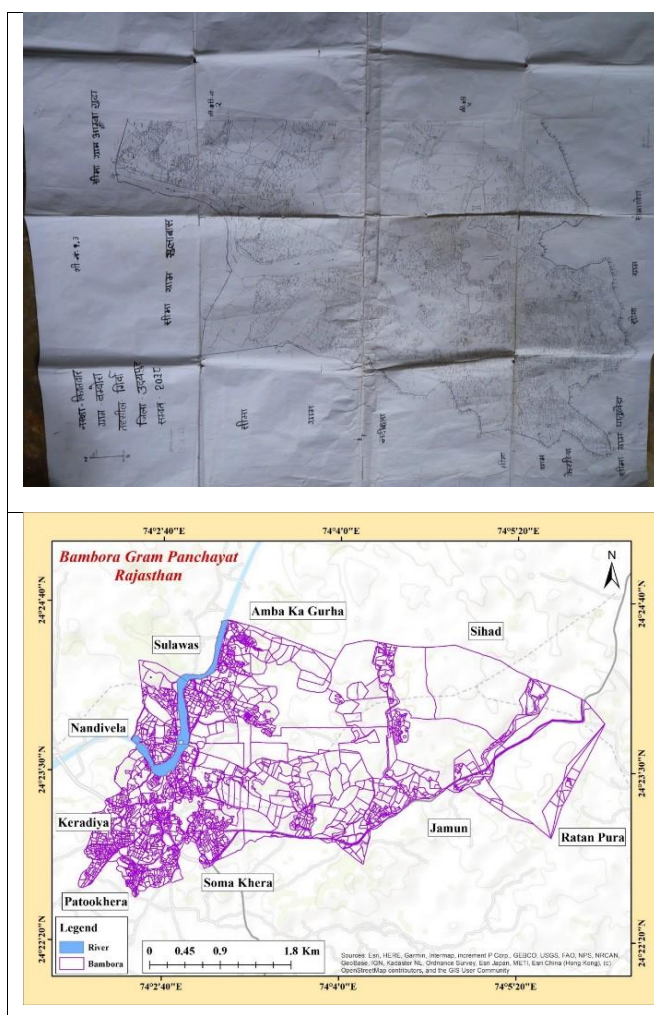


Fig. 3. Bambora Gram Panchayat, Cadastral Level Map

2.2. Bori

Bori village is a located near Bambora village of the Udaipur District of Rajasthan. As of 2011 India census, Bori village have a population of 903, with 440 males and 463 females. (Census of India, 2011)

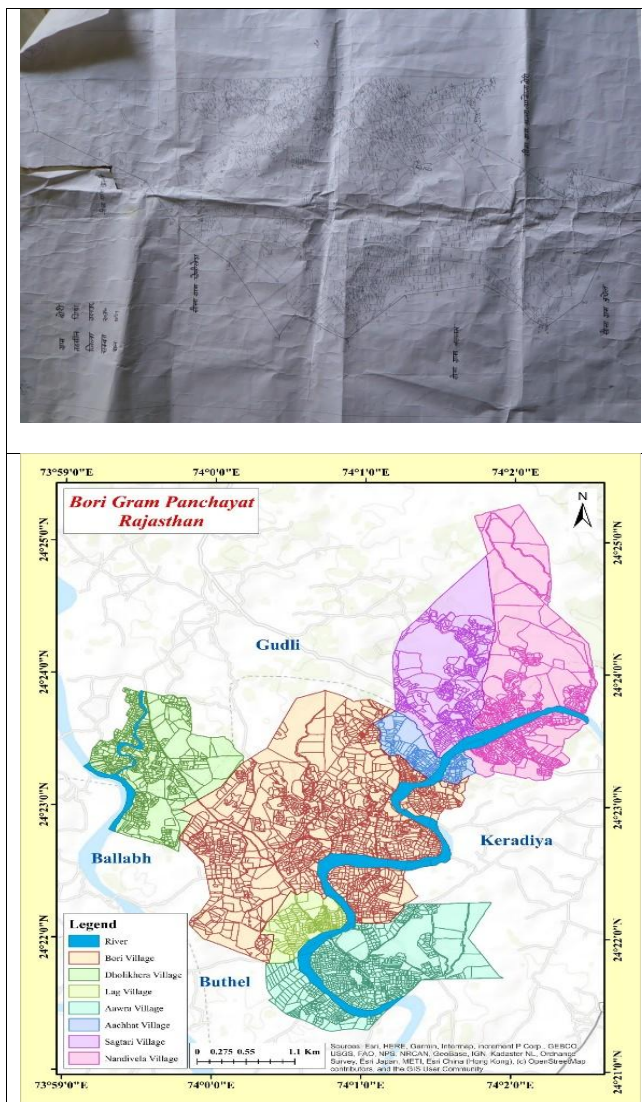


Fig. 4. Bori Gram Panchayat, Cadastral Level Map

2.3. Sulawas

Sulawas village located North side of the the Bambora, Udaipur District of Rajasthan State, India. It has a total population of 206 peoples. There are about 59 houses in Sulawas village. (Census of India, 2011)



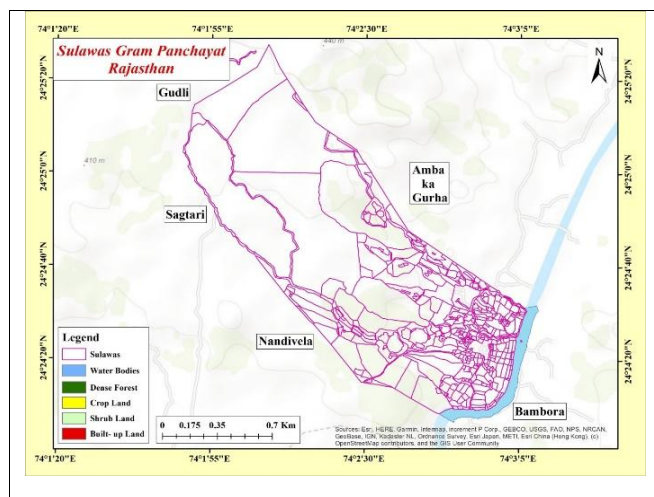


Fig. 5. Sulawas Gram Panchayat, Cadastral Level Map

2.4. Sihad

Sihad village is located North side of Bambora village Udaipur District of Rajasthan State, India. In the village, most of population is based on the primary activities such as agriculture and animal husbandry activities.

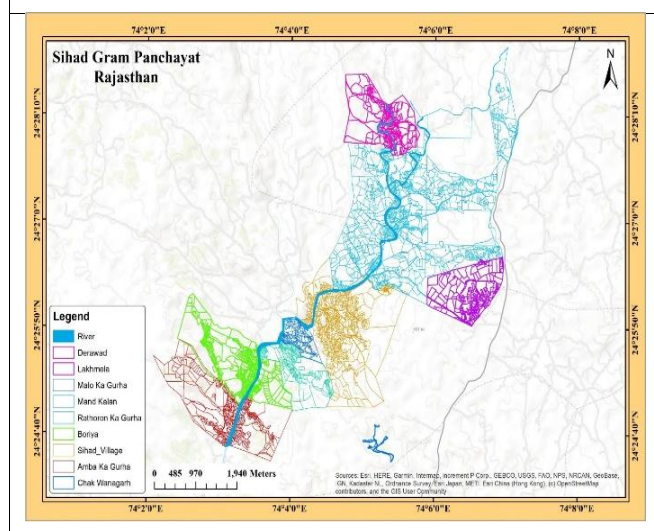
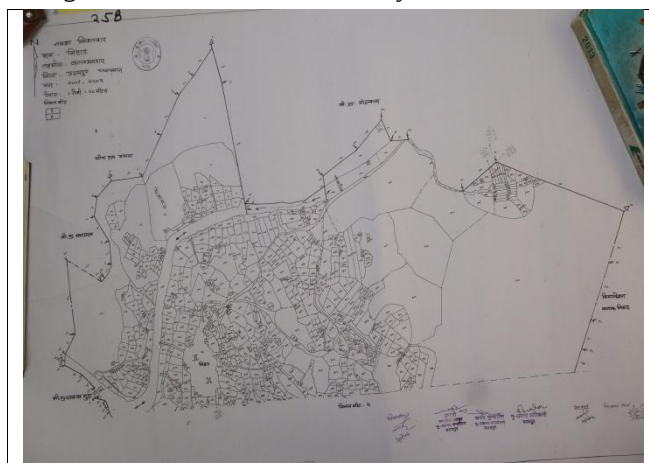


Fig. 6. Sihad Gram Panchayat, Cadastral Level Map

3. Data Mapping of Research Area

3.1 Physical Mapping

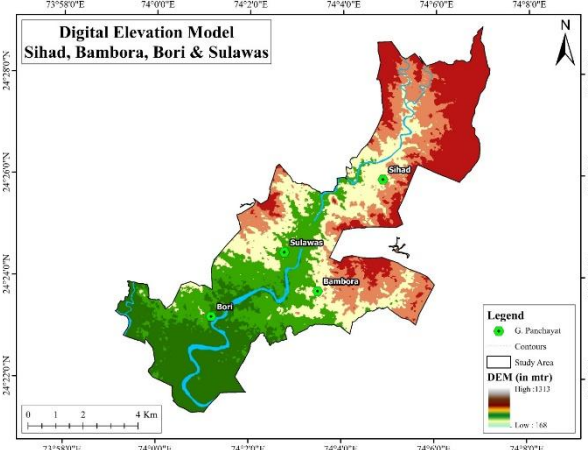


Fig. 7a) DEM maps of Bambora, Bori, Sulawas & Sihad Gram Panchayat;

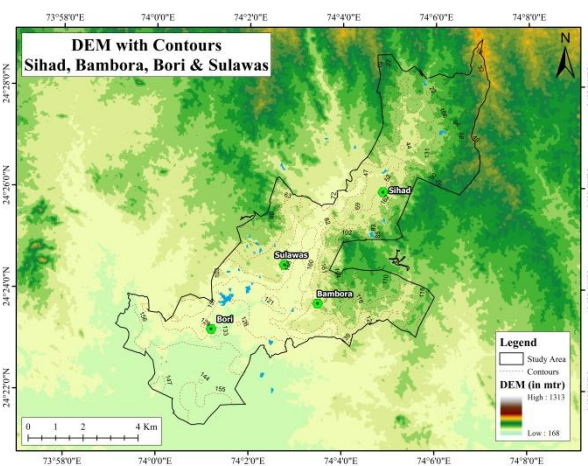


Fig. 7b.) Elevation maps of Bambora, Bori, Sulawas & Sihad Gram Panchayat;

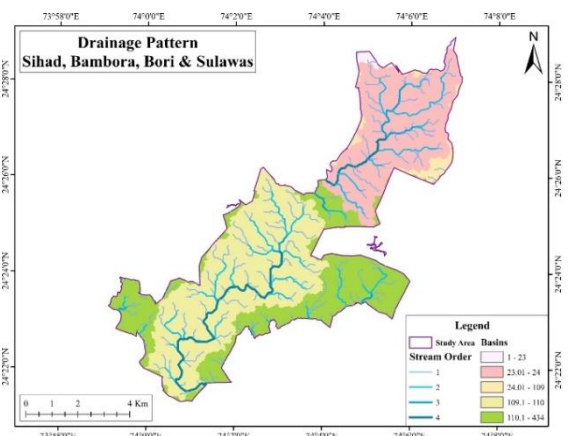


Fig. 7c) Drainage maps of Bambora, Bori, Sulawas & Sihad Gram Panchayat;

A digital elevation model (DEM) is a representation of the bare topographic surface of the Earth without trees,

buildings, and other surface objects. USGS DEMs were derived primarily from topographic maps. A digital elevation model or DEM is a computerised 3D or three-dimensional model used to represent the Earth's surface. Slope, inclination, and relief maps are created using DEM data.

In the elevation map, elevation is represented using terrain elevations, contour lines, and elevation shading. The three-dimensional features of an area can be accurately represented by a topographic elevation map. These maps generally show the man-made and natural aspects of an area. Natural landscapes generally include valleys, hills, plateaus, rivers, lakes, and plants.

A drainage map is a map that shows riparian zones and floodplains in an area. Simply put, a drainage map is a graphic representation of the flow of water in a given area.

3.2 Socio-Economic Mapping according to Census – 2011

This is a study of the socioeconomic status of rural and urban households, which allows households to be classified on the basis of given parameters. The census in rural areas is conducted by the Rural Development Department, while the census in urban areas is the administrative responsibility of the Ministry of Housing and Poverty Alleviation. The caste census is under the administrative control of the Ministry of Home Affairs: The Registrar General of India (RGI) and the Census Commissioner of India.

- The data is entered by the respondents with the countersignature of the enumerator. The data is "disclosed data" from the house to the enumerator. However, the data collected is also approved by the Gram Sabhas and Panchayats.
- The structure of the houses is described in the census as kutchha or pucca based on the information provided by the respondents about the predominant material used for walls and roofs.
- House ownership status is respondent information.
- The main household-related sources of income in rural areas are described as follows: Farming, casual manual labour, part-time or full-time household service, begging, non-agricultural own business, begging/charity/begging, and other. However, the various components of 'other' were not enumerated.

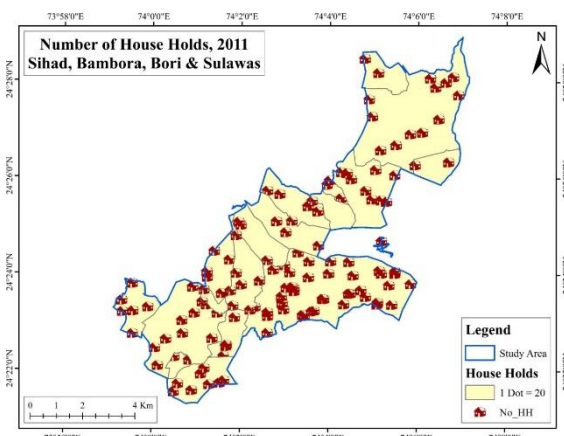


Fig. 8a) Number of Households

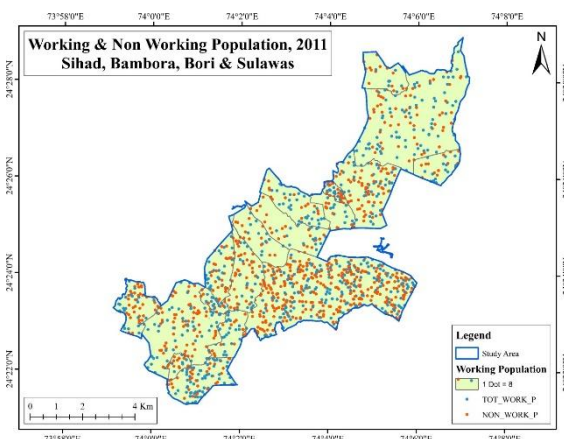


Fig. 8b) Working and Non-working Population

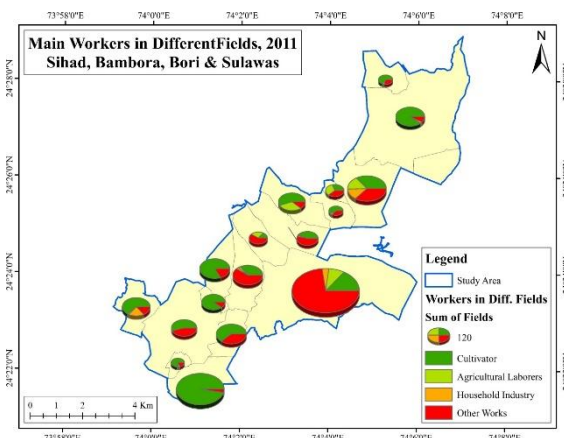


Fig. 8c) Main workers and their fields

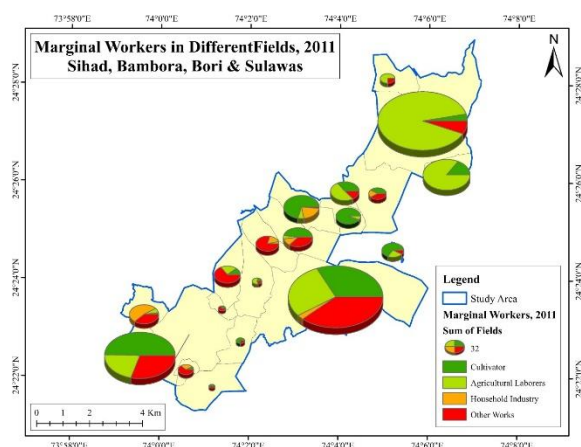


Fig. 8d) Marginal Workers and their fields

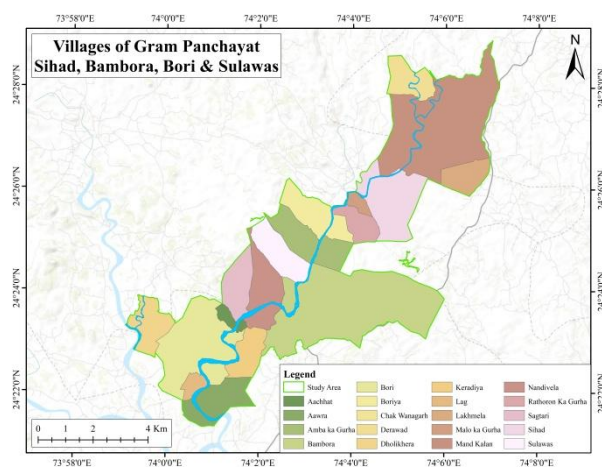


Fig. 8e) List of the Villages

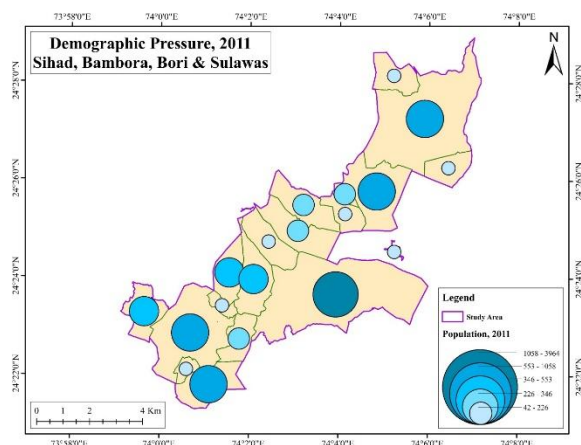


Fig. 8f) Demographic Population (Proportional Symbol Map)

3.3 Land Use and Land Cover

The terms land use and land cover is often used interchangeably, but each term has its own meaning. Land cover refers to the surface cover of the land such as vegetation, urban infrastructure, water, bare soil, etc. Land cover identification provides the basis for activities such as thematic mapping and change detection analysis. Land use refers to the purpose the land serves, such as

recreation, wildlife habitat, or agriculture. [Al-Doski et.al., 2013]

When used in conjunction with the term land use/land cover (LULC), it generally refers to the categorization or classification of human activities and natural elements on the landscape within a given time frame based on established scientific and statistical methods of analysis of appropriate source material. Land use maps play an important and primary role in planning, managing, and monitoring programmes at the local, regional, and national levels. This type of information both provides a better understanding of land use issues and plays an important role in the formulation of policies and programmes necessary for development planning. To ensure sustainable development, the ongoing process of land use/land cover patterns must be monitored over a period of time. In order to achieve sustainable urban development and curb haphazard urban development, it is necessary for agencies involved in urban development to establish such planning models so that every available piece of land can be used in a rational and optimal manner. This requires information about the present and past land use/land cover of the area. LULC maps also help us study the changes that are taking place in our ecosystem and environment. When we have centimetre-level information about the land use/land cover of the study unit, we can take action and establish programmes to protect our environment. [Olaodeet al., 2014]

Figure 9, represents the land use and land cover area of the Study Area of the years 2021. The LULC contains 7 classes namely Water Bodies, Fellow Land, Shrubs Land, Dense Forest, Built-up Area, Barren Land, Crop Land.

In the below figure 9 of Land use land Cover, the area of Water Bodies, Fellow land, Shrub Land, Dense Forest, Built -up Area, Barren Land, and Crop Land are 1.74 km² (2.78 %), 37.05 km² (59.12%), 5.46 km² (8.73%), 6.82 km² (10.88%), 1.86 km² (2.97%), 7.92 km² (12.64%), and 1.81km² (2.88%) respectively. In the analysis of LULCC, we found that the Shrub Land and Dense are very low as comparison to the fellow land at the study area (Table 1).

Sr. No.	LULC Class	2021	Area Percentage
1	Water Bodies	1.74	2.78
2	Fellow Land	37.05	59.12
3	Shrubs Land	5.47	8.73
4	Dense Forest	6.82	10.88

5	Built-up Area	1.86	2.97
6	Barren Land	7.92	12.64
7	Crop Land	1.81	2.88

Table 1: Land Use & Land Cover - 2021.

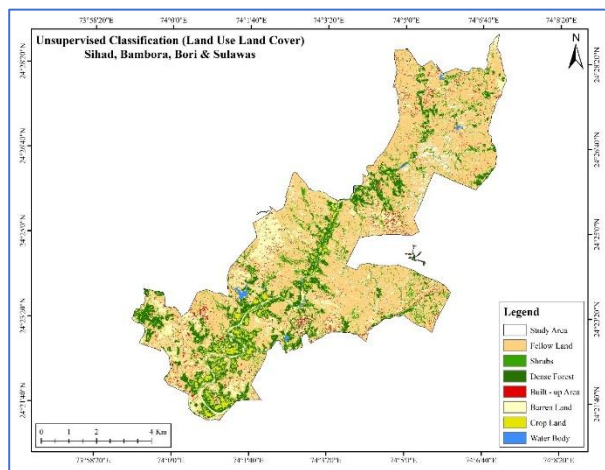


Fig.9) Unsupervised Classification Method with seven LULC classes

3.4 Accuracy Assessment: Accuracy assessments essentially determine the quality of the information derived from remote sensing data. These assessments can be either qualitative or quantitative. Qualitative assessments are usually quick comparisons to determine if the remote sensing data or maps look "right" and match the conditions on the ground. Assessing the accuracy of a classified satellite image provides an indication of the quality of information that can be obtained from remote sensing data. [Mantero et al., 2005]. Accuracy is evaluated using 300 random points generated from LULC remote sensing data and ground information obtained from another source, such as Google Earth. The overall accuracy is about 94.33%, which is very good in the context of the similarity of the ground data.

4. Conclusion

In summary, maps are an extremely important tool for researchers and planners. Research is aided by the contextualization of knowledge provided by maps and the connections to development, population structure, and growth that are made through them.

This study illustrates how high-resolution, thematic spatial data that is essential for micro-level rural development planning can be obtained by combining cadastral maps with GIS and remote sensing methods. Important discoveries, including the study area's large proportion of fallow land (59.12%) and low thick forest cover (10.88%), underscore the pressing need for

resource management. The methodology's dependability is further supported by the 94.33% classification accuracy.

This paper provides a focused overview of how remote sensing and GIS can support sustainable development efforts, particularly under Smart Village initiatives. By linking digitized cadastral data with demographic and economic indicators, the research offers a model for decentralised planning, participatory development, and data-driven governance at the Gram Panchayat level.

Information on the nature, extent, spatial distribution, potential, and limits of natural resources is a prerequisite for sustainable development strategy planning. This research compiled thematic maps of the study region, which can help in setting development policies. Future work could explore participatory GIS and time-series land use analysis to further enhance village-level spatial planning and monitoring.

5. Acknowledgements

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