INTERNATIONAL DEVELOPMENT PLANNING REVIEW
ISSN:1474-6743 | E-ISSN:1478-3401

APPLICATION OF GEOSPATIAL TOOLS TO STUDY LAND USE/ LAND COVER CHANGE ANALYSIS IN FOOTHILL ZONE OF BHUNGA BLOCK HOSHIARPUR DISTRICT

Nadiya Ganaie[1], Rajesh Jolly[2] & Sumit Kumar[1]

[1]Research Scholar
[2]Assistant Professor
Department of Geography, Lovely Professional University, Phagwara, Punjab, India

Abstract

Remote sensing and GIS (Geographic Information Systems) are increasingly integral parts of modern spatial planning solving the issues quickly based on data collected, analysed and displayed in a meaningful way. This research examines the usage of remote sensing and GIS in micro-level planning along the foothill section of Bhunga area in Hoshiarpur District, India. The study intends to evaluate whether these technologies are well-suited for improving planning and effectiveness of decision making at the local level. This research takes satellite imagery, spatial analysis and field surveys as a whole, and identifies land pattern use, natural resources distribution and social and economic features of the study area. This study in particular will aid in deepening the knowledge of remote sensing and GIS utilization in promoting sustainable development and resource governance in similar contexts of geography.

Keywords: Remote Sensing, Geographic Information Systems (GIS), Micro-level Planning, Foothill Zone, Bhunga Block, Spatial Analysis, Satellite Imagery

Introduction:

Foothill zone of Bhunga Block, which belongs to Hoshiarpur District, appears as a multifaceted ecosystem, where the land use diversity is accompanied by natural resources, as well as by social and economic activities. A sound planning and management of this area involve a deep comprehension of the region's (its) spatial dynamics that are related to the use of land, distribution of resources and demographic trends. The ways how we are collecting and processing data keeping the usual difficulty to understand about the complexity and scale of the spatial occurrences. High precision and reliability remain the challenges of ground surveys but, the remote sensing and GIS produce powerful tools for systematic data acquisition, processing and visualization in the process. Ground-based remote sensing uses the sensing from satellite or aerial sensors to gather spatial data at various distances and Imagery of the Earth surface. Such imagery delivers information on types of land cover and its use; vegetation distribution and surface topography. GIS provides remote sensing operations with a platform that is capable of storing, analysing, and visualizing data that is spatially distributed. Through combining remote sensing images with GIS technology, scientists can carry out the analysis of spatial patterns, find the effect of changes on time, and work out projected scenarios with a high degree of accuracy.

At the micro-level stage of planning inside the Bhunga Block extension, the application of the remote sensing and GIS techniques encompasses several prospects. First of all, it helps quickly to develop map of land covers, where places of agriculture, forestry, residential areas, and other types of land use are indicated. It goes without saying that this information is needed for mapping natural resources in space, and at the same time it assists in recognition of areas where conservation and development initiatives are required. Along with that, satellite data can be used for detecting the land cover variation throughout the time and it provides knowledge about the water clumps such as deforestation, urbanization and soil erosion. Next, GIS assists in spatial analysis procedures, such as suitability modelling and spatial interpolation, which can guide decision-making methods relating to land use planning, infrastructure development and disaster management activities. This research would aim at understanding the factors influencing man-induced changes in this region, through the effective use of remote sensing & GIS technologies, and contribute towards designing effective micro-level planning strategies for the foothill area of Bhunga block. Spatial analysis using satellite imagery, field made surveys as well as spatial modelling are among the main techniques employed in this research with the ultimate aim of providing timely and relevant information for the policymakers, planners, and local communities. Underlyingly, that means finding the best compromise between preserving environmental protection and the continuous developmental benefits in this environmentally sensitive area in the long run.

Study Area

The study area includes the mountain slope of the Bhunga Block spread in Hoshiarpur District, Punjab, India. This area is situated in the northwestern part of the country, towards its north lies the lower Himalayan range, while the Siwalik range is to the east of it. The foothill zone is flat to undulating, covering an area of 250 square kilometres and a series of ridges and valleys with an elevation that ranges from mean sea level to 800-meter above mean sea level.

The climate of the study area is characterized as subtropical, with three distinct seasons: a very hot and dry season (April to June) which is usually followed by a sticky monsoon (July to September) and a fair winter (November to February). Typically the annual rainfall is 1000 mm on average and during monsoons the rainfall is maximum. There are extremes where the weather can vary from the highest temperature of 40°C in the summer to the lowest of 5°C in the winter. The area is characterized by a number of seasonal streams and rivulets that are ultimately participants of the river system of the Beas River which is the principal river of Punjab. A dendritic drainage pattern is seen which helps to reflect the geological substrata and topography of the area being discussed. The study area has several kinds of soils, with the valleys having the sandy loams, while the ridges have the clay loams. The soil fertility ranges from very low to very high due to the fact that the factors such as slope, drainage, and vegetation cover can change it significantly. Soil erosion is one of the most critical issues in the region where the land is undulated and receives the most rainfall usually in the monsoon season. Throughout the tilling area in Bhunga, where agriculture is the major activity, the cultivation of crops like wheat, maize, rice, and vegetables is the common practice. We have extensive woodlands too in this region that are composed of a mixture of coniferous and deciduous tree species.

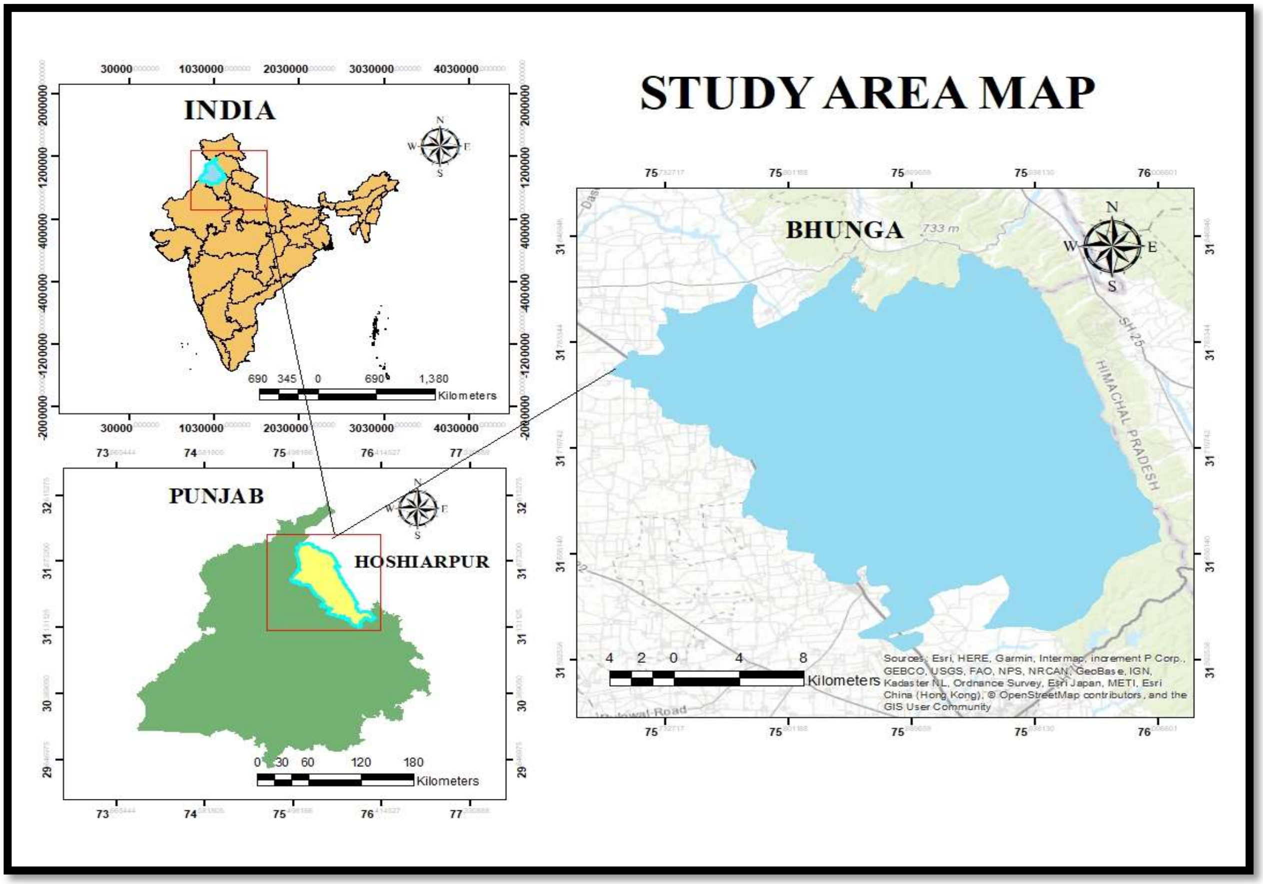


Figure 1. Study area map Bhunga

Methodological Tools

Data Acquisition and Preprocessing: Satellite data from the Landsat-8 Operational Land Imager (OLI) sensor and base maps at a scale of 1:50,000 were used to cover the area of interest with appropriate details. The satellite images, through geometric and radiometric corrections, gained spatial accuracy and radiometric consistency. Atmospheric adjustments were executed using the FLAASH (Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes) module to account for the effects of the atmosphere and improve the quality of the data before further processing.

Land Use/Land Cover Mapping: LULC patterns of the area of study were conducted by means of supervised classification techniques. The training data with different LCS classes, such as, agriculture, forest, water bodies, and built-up areas, were collected via field surveys and visual interpretation of high-resolution imagery. These training samples prepared the algorithm to differentiate between the wide range of features that could be present in the satellite imagery.The Maximum Likelihood Classification (MLC) algorithm is employed to classify the satellite images into preidentified LULC categories. MLC is a method of categorization that is extensively used because of its reliability and simplicity. It takes into account the probability of a pixel belonging to a specific class by considering the spectral features of a pixel and the statistical properties of the training samples.

To validate the results of the classes the ground truth data was obtained from field surveys and high-resolution images. By analysing the ground truth data, we obtain information about the land cover types at the instances of interest within the study area. High-resolution imagery, for instance drone pictures and aerial surveys, supplied detailed visual information that could be contrasted with the classified output to measure accuracy levels.

Further Methodological Considerations: In light of this, the methodological sections came with a few additional concerns that were taken into account to maximize the robustness and reliability of the findings:

1. **Image Enhancement:** At first, through the use of image enhancement methods (improvement of visual quality and interpretability of the satellite images) our dataset was prepared for the type of output we desired to achieve. In this case, the near-infrared comparative analysis, expanded contrast stretching, histogram equalization techniques, and sharpening filters were used to enhance certain features and improve interpretability.
2. **Feature Selection**: The choice of relevant spectral bands, image acquisition, and processing was the key factor determining classification accuracy. Different land emerging types show unique spectral signatures for various bands, so identifying the most significant ones expands the classification procedure. Techniques such as correlation analysis, grouping analysis, and dimensionality reduction (e.g. Principal Component Analysis) were used to choose the most trait with a good quality use for taxonomy.
3. **Accuracy Assessment:** Once the data had been classified, then the industrious analysis of the accuracy assessment followed to establish the fidelity of the classified output. The evaluation comprises of comparing the classified delineation with judgment data [e.g., ground truth points or high-resolution imagery] in order to find the accuracy measure parameters namely overall accuracy, user's accuracy, output's accuracy as well as kappa coefficient.
4. **Post-Classification Processing**: Following that, the post-classification processing methods were used to generalize and enhance the spatial influences of the lands that were classified by the system. The filtering operations with the majority rule to get rid of isolated mislabeling, the clump removal to clean small clusters of misclassified dots and the edge-

matching algorithms to smoothen the transitions between different land cover classes were examples of these methods. Moreover, the recommendation results were placed with supplementary data sources, which are the topographic maps and the existing land use/land cover datasets in order to enhance accuracy in the output.

Figure No. 1 Methodological Flow Chart

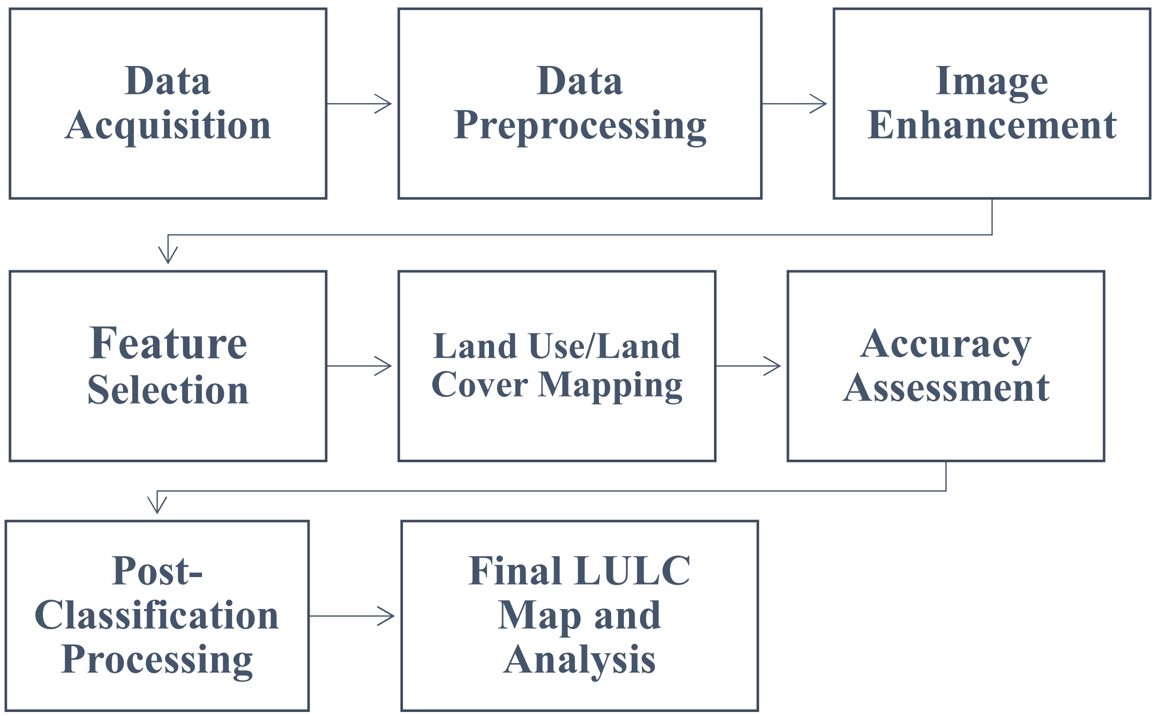


Table No. 1 Satellite Dataset Source and date

Sr. No	Satellite used	Sensor	Recording Date	Resolution (m)	No of Bands	Path	Row
1	**Landsat 8 (OLI)**	OLI	18-OCT-2013	25m	**7**	148	38
2	**Landsat 8 (OLI)**	OLI	06-OCT-2023	25 m	7	148	38

Source: Bhuvan Official Website

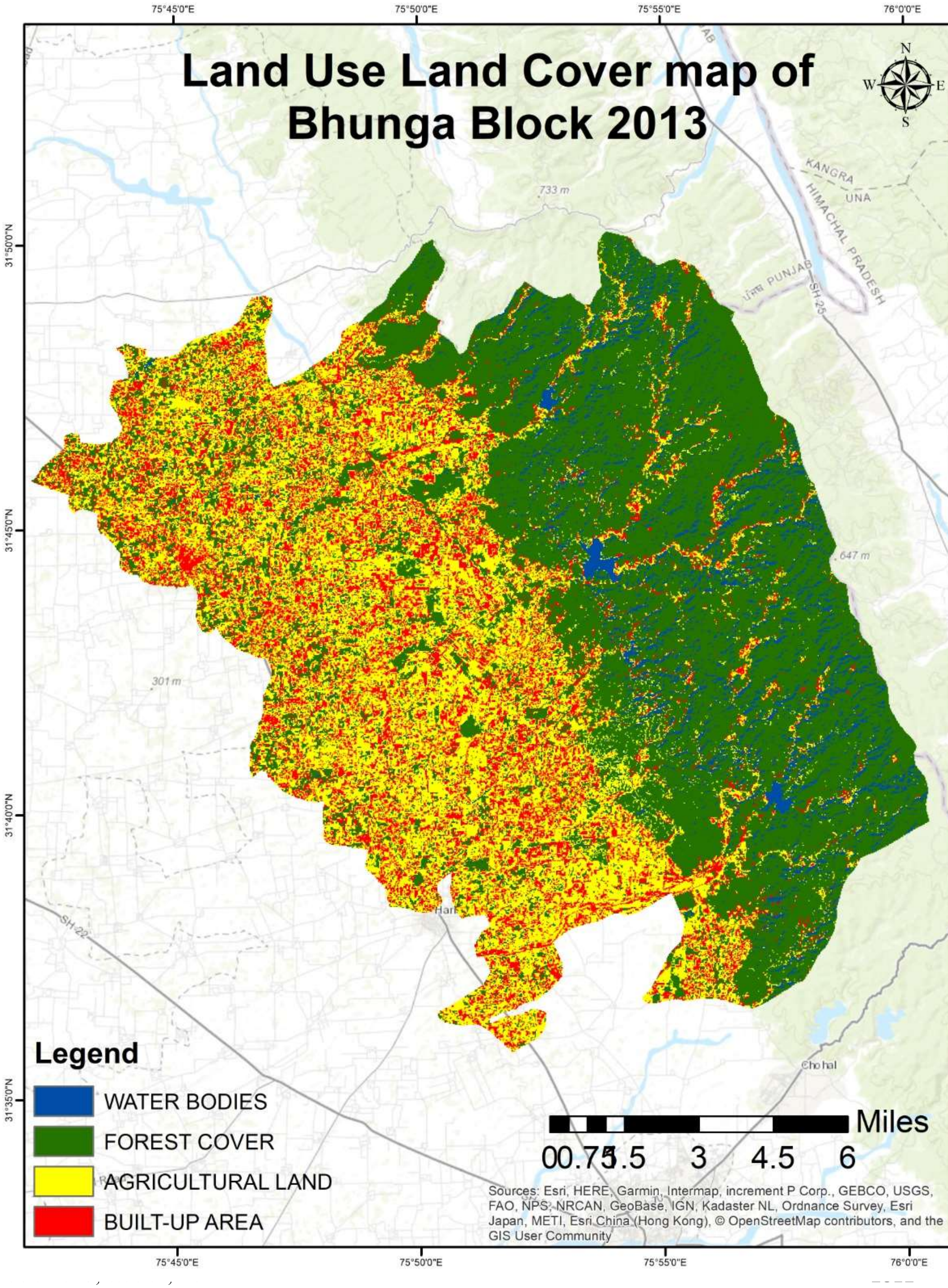
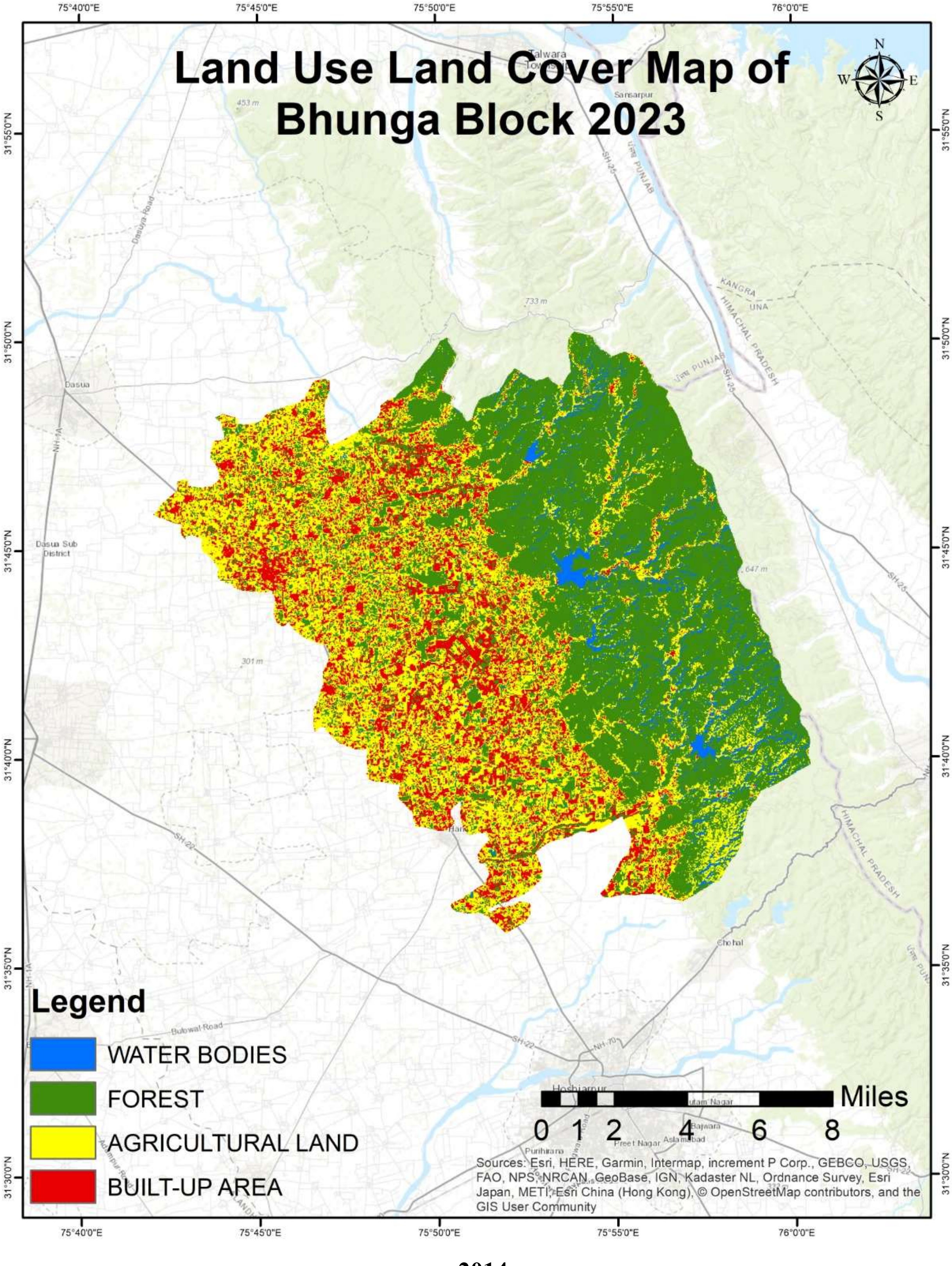

Land Use Land Cover map of Bhunga Block 2013
N
S
E
W
75°45'0"E
75°50'0"E
75°55'0"E
76°0'0"E
31°50'0"N
31°45'0"N
31°40'0"N
31°35'0"N
Legend
WATER BODIES
FOREST COVER
AGRICULTURAL LAND
BUILT-UP AREA
Miles
0 0.75 1.5 3 4.5 6
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), © OpenStreetMap contributors, and the GIS User Community

Figure No. 2 Land use/Land cover Map



, 2014

Figure No. 3 Land use/Land cover Map, 2023

Table no. 2 Land Use/Land Cover (LULC) Category wise distribution, 2023

Land Use/Land Cover	Area (km²)	Percentage
Agricultural Land	101.04	40%
Forest Cover	63.15	25%
Water Bodies	25.26	10%
Built-Up Areas	37.89	15%
Total	**252.6**	**100%**

Source: IRS Resourcesat LISS III March 2023

Table no. 3 Slope Analysis

Slope Range	Area (km²)	Percentage
Gentle (0-5%)	75.78	30%
Moderate (5-15%)	63.15	25%
Steep (>15%)	113.67	45%
Total	**252.6**	**100%**

Table no. 4 Landuse/Landcover Site Suitability

Suitability	Area (km²)	Percentage
Agriculture	88.41	35%
Afforestation	50.52	20%
Construction	37.89	15%
Unsuitable	75.78	30%
Total	**252.6**	**100%**

Results and Discussions

Land Use/Land Cover (LULC) Distribution: Land Use/Land Cover (LULC) Distribution:
It is discovered through the study that agricultural land land covers the largest part of the study area, amounting to 40% of the whole land. These demonstrates agriculture like the key land user.

The forest harbours an area occupying 25% which suggests that this a vast natural vegetation and the numerous wild animals inhabiting that space. The area of water covers 10% of total territory; it is the keystone of hydrological processes and the endurance of water communities. Upon this category falls 15% of the entire land area, where urban and infrastructure developments are the main dimension of human expansion on land and transformation processes.

Slope Analysis

The gradient analysis discloses nothing more than the morphology of the research area. About 30% of the landscape features present cultivation zones 0-5% in gradient that are suitable for farming. The other 25% is made up of moderate inclines (between 5-15% degrees) which are ideal for large-scale afforestation projects. The steeplest slopes that measure to at least 15%, occupy 45% of the plot, and may be too challenging for domestic development and use of the land. The formation of slopes shows the urgent need to touch on the topographic factors when planners and managers are planning for the land utilization activities**.**

Suitability Analysis

The assessment of suitability uses a wide range of factors: land cover, slope, soil characteri stics, and land use objectives, to determine the suitability of various land uses within the study area. Agriculture is considered acceptable for 35% of the land mainly in the form of gentle sloping area which is located near to water resources. Afforestation which is found among 20% of the area would concentrate mainly on the moderate slopes in order to provide the needed forest conservation services and ecosystem functions. Allocation of the 15% of the area for construction purpose is mainly in urban places with flatlands that are preferred for urban development. While 70% of the area is very suitable for this purpose, the rest 30% cannot be used because of steeps slopes, poor drainage, and issues with soils.

Discussion

The outcomes of spatial analysis result in some important insights on the nature of the land use/land cover, terrain, and land use suitability in the study area. The essence of agricultural land is down to the fact that agriculture is the leading source of income meaning that there is need of sustainable agricultural practices and land management strategies to maintain food security and livelihoods of the rural people. The realities of a densely forested area point to the necessity of maintaining ecological niches and their richness. It is of paramount importance to focus on forest conservation, planting trees and sustainable forestry so that we can maintain the provision of ecosystem services, fight climate change and build ecological stability.

Water bodies identification should be followed by such management and conservation measures for water resources. Saving of waterbodies that involve deep rivers, shallow lakes, and small ponds is essential for sustaining freshwater systems, sustaining biodiversity, and meeting the water needs of both people and ecosystems.

Slope analysis provided a basis for studying the terrain characteristics with regards to challenges and possibilities. Low slopes offer opportunities for agriculture, while steeper slopes need concerted efforts from the planning department to prevent soil erosion, landslides, and other hazards from occurring. Sustainable land management methods for instance graded cultivation and intercropping can efficiently fight the problem and save the soil from wastage.

According to the suitability assessment, it will be of use for planning departments and other officials during decision making and land use procedures. Through the identification of appropriate sites for agriculture, afforestation and construction, decision makers, and planners are able to classify land usage, enact infrastructure projects, and equally allocate the natural resources to achieve the ambitiously set goals of the sustainable development plan

Conclusion

The findings from the undertaken detailed analysis in the research acts as a foundation upon which well-informed policies and future decisions on how to manage natural resources and dispose land can be made in the study area. Through careful inspection, like for instance, of the land cover distribution, slope behaviour and land use suitability to mention a few, stakeholders access helpful data thus making informed decisions. Such perceptions being met, stakeholders come out with strategies covering ecological, social as well as economic aspects of land management. Seeking the understating and ecological relationships of the territory being managed is the most important factor in coming up with sustainable land use practices. This is done by appreciating that these are the forests, animal species, and the essential environmental gains responsible for our well-being and quality of life. Classifying locations that provide higher ecosystem services allows the managers to increase their relative conservation efforts. However, the integration of ecological considerations into land use planning is not only aiming to solve the specific environmental issues like a soil erosion, habitat loss, and water pollution, but also develop landscape resilience. Furthermore, social sensitivity and influence in the community is a crucial requirement as it links the community engagements and equitable social status. Knowing the hopes and desires of local communities empowers one to design the land use plan that will fit in with social values and aspirations. Other than this, the stakeholder approach that entails the process integrates the stakeholders in the decision-making results which lead to the feeling of the ownership as well as empowerment and more socially equitable and sustainable outcomes. Therefore, as well as the economic impact should be taken into consideration to stimulate sustainable growth and prosperity. To analysis whether the alternatives use of the land will be competitive in prospect of different uses different stakeholders for instance can identify chances that will increase productivity, generating employment and promoting economic growth. Furthermore, inclusion of economic parameters in land use policies encourages the qualified use of resources for determining the activities that generate maximum social as well as economic benefits and minimal environmental damages.

REFERENCES

1. Jat, M.K., Choudhary, M., & Saxena, A. (2017). Application of geo-spatial techniques in micro-level planning for sustainable development of hilly areas. Applied Geomatics, 9(4), 225-239. https://doi.org/10.1007/s12518-017-0197-7

2. Weier, J., & Herring, D. (2000). Measuring vegetation (NDVI & EVI). NASA Earth Observatory. Retrieved from https://earthobservatory.nasa.gov/features/MeasuringVegetation

3. Xie, Y., Sha, Z., & Yu, M. (2008). Remote sensing imagery in vegetation mapping: A review. Journal of Plant Ecology, 1(1), 9-23. https://doi.org/10.1093/jpe/rtm005

4. Paudel, B., Gao, J., Baral, H., & Timilsina, Y. P. (2021). Integration of remote sensing and GIS for land use/land cover change analysis and its impact on soil erosion risk in the Phewa Lake catchment, Nepal. Environmental Challenges, 5, 100296. https://doi.org/10.1016/j.envc.2021.100296

5. Lillesand, T.M., Kiefer, R.W., & Chipman, J.W. (2015). Remote sensing and image interpretation (7th ed.). John Wiley & Sons, Inc.

6. Mutanga, O., & Skidmore, A.K. (2004). Hyperspectral band depth analysis for a pixel-wise discrimination of vegetation species. International Journal of Applied Earth Observation and Geoinformation, 5(2), 87-96. https://doi.org/10.1016/j.jag.2004.01.002

7. Kumar, A., & Pandey, A.C. (2019). Land use/land cover mapping and change detection of Garhwal Himalaya using satellite data. Geocarto International, 34(14), 1621-1635. https://doi.org/10.1080/10106049.2018.1494896

8. Muriithi, F.K. (2016). Land use and land cover (LULC) changes in semi-arid sub-catchments of Laikipia and Athi River basins, Kenya. Journal of Geography and Regional Planning, 9(8), 138-145. https://doi.org/10.5897/JGRP2016.0576

9. Singh, S.K., Mustak, S., Srivastava, P.K., Sahoo, S., & Karnatak, H.C. (2017). Geographical Information System (GIS) and remote sensing in mapping of landslide susceptibility using analytical hierarchy process (AHP). Geomatics, Natural Hazards and Risk, 8(2), 1619-1638. https://doi.org/10.1080/19475705.2017.1347251

10. Rawat, J.S., & Kumar, M. (2015). Monitoring land use/cover change using remote sensing and GIS techniques: A case study of Hawalbagh block, district Almora, Uttarakhand, India. The Egyptian Journal of Remote Sensing and Space Sciences, 18(1), 77-84. https://doi.org/10.1016/j.ejrs.2015.02.002

11. Shalaby, A., & Tateishi, R. (2007). Remote sensing and GIS for mapping and monitoring land cover and land-use changes in the Northwestern coastal zone of Egypt. Applied Geography, 27(1), 28-41. https://doi.org/10.1016/j.apgeog.2006.09.004

12. Jia, K., Liang, S., Zhang, N., Yao, Y., Xieg, X., Chen, J., Li, Y., & Chen, X. (2018). A residual convolutional neural network for separating soil and vegetation components from hyperspectral imagery. IEEE Transactions on Geoscience and Remote Sensing, 56(2), 846-862. https://doi.org/10.1109/TGRS.2017.2755003

13. Gupta, R.D., Arora, S., Gupta, V.K., & Pawan, K. (2010). Drainage line identification and updation using remote sensing and GIS techniques. International Journal of Geomatics and Geosciences, 1(2), 119-127.

14. Uddin, K., Sharan, G., Noor, M. A., Ahmed, T., Guis, V., & Saeed, U. (2019). Mapping of spatial multi-hazard foothill region employing geospatial techniques. Geocarto International, 34(14), 1576-1591. https://doi.org/10.1080/10106049.2018.1494895

15. Chakraborty, A., Sahoo, S., Pandey, A.C., & Arvind, C. (2021). Evaluation of land use/land cover change in a Himalayan foothill ecosystem using geospatial techniques. Journal of Earth System Science, 130(3), 1-20. https://doi.org/10.1007/s12040-021-01600-8

16. Joshi, N., Baumann, M., Ehammer, A., Fensholt, R., Grogan, K., Hostert, P., Jepsen, M.R., Kuemmerle, T., Meyfroidt, P., Mitchard, E.T.A., Reiche, J., Ryan, C.M., & Waske, B. (2016). A review of the application of optical and radar remote sensing data fusion to land use mapping and monitoring. Remote Sensing, 8(1), 70. https://doi.org/10.3390/rs8010070

17. Gómez, C., White, J.C., & Wulder, M.A. (2016). Optical remotely sensed time series data for land cover classification: A review. ISPRS Journal of Photogrammetry and Remote Sensing, 116, 55-72. https://doi.org/10.1016/j.isprsjprs.2016.03.008

18. Dey, J., Mitra, A., & Chakravorty, B. (2022). Supervised classification of land cover in foothills of Himalayas using geospatial techniques. International Journal of Remote Sensing, 43(9), 3269-3293. https://doi.org/10.1080/01431161.2022.2038516

19. Zewdie, W., Csaplovics, E., & Inostroza, L. (2017). Monitoring ecosystem dynamics in northwestern Ethiopia using NDVI data for environmental management. Ecology and Evolution, 7(3), 938-953. https://doi.org/10.1002/ece3.2635

20. Mishra, V.N., Rai, P.K., & Prasad, R. (2019). Application of remote sensing and GIS in land use/land cover mapping and monitoring: A review. Journal of the Indian Society of Remote Sensing, 47(9), 1437-1451. https://doi.org/10.1007/s12524-019-01003-8

21. Rajendran, S., Nasir, S., Hussain, M., & Thirunavukkarasu, R. (2021). Integration of remote sensing and GIS techniques for land use/land cover mapping and soil erosion risk assessment in Kotri Governorate, the State of Sindh, Pakistan. Arabian Journal of Geosciences, 14(12), 1-17. https://doi.org/10.1007/s12517-021-07265-7

22. Suliman, A.H.A., & Meresa, E.H. (2020). Land use/land cover change risk mapping using remote sensing and GIS techniques: A case study of Sheikan area in Sudan. Environmental Monitoring and Assessment, 192(9), 1-16. https://doi.org/10.1007/s10661-020-08498-0

23. Abro, J.A., Maran, S., Bhatti, S.S., & Anjum, S.A. (2022). Application of remote sensing and GIS techniques for mapping and monitoring land use land cover changes in the foothill region of Khairpur District, Sindh, Pakistan. Environmental Monitoring and Assessment, 194(5), 1-20. https://doi.org/10.1007/s10661-022-10045-7

24. Patidar, S., Mishra, V.N., & Rai, P.K. (2018). Mapping of land use/land cover and their impacts using remote sensing and GIS techniques in the Gwalior-Chambal region, Madhya Pradesh, India. Remote Sensing Applications: Society and Environment, 11, 142-151. https://doi.org/10.1016/j.rsase.2018.06.003

25. Ghosh, M.K., Kumar, L., & Singh, P.K. (2019). Geospatial strategy for sustainable management of natural resources in the Shiwalik foothill region of India. Journal of Environmental Management, 234, 438-451. https://doi.org/10.1016/j.jenvman.2018.12.112