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ANALYSIS OF LAND USE AND LAND COVER CHANGES IN ARPA RIVER BASIN USING GIS

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Abstract:
The Arpa River Basin in Bilaspur, Chhattisgarh, is vital to the region's ecological and socio-economic systems. In recent decades, the basin has undergone major land use and land cover (LULC) changes, mainly driven by urbanization, agricultural expansion, infrastructure growth, and rising population pressure. This study utilizes Geographic Information System (GIS) and remote sensing techniques to examine the spatial and temporal LULC changes in the basin from 2005 to 2015. The study's objectives include mapping historical and current LULC patterns, identifying and quantifying changes in categories like forests, agriculture, built-up areas, water bodies, and wastelands, and analyzing the ecological impacts and causes of these changes. Satellite imagery from Landsat and Sentinel, along with Digital Elevation Models (DEMs), were analyzed using GIS software such as ArcGIS, QGIS, and ERDAS Imagine. Results indicate a significant decline in forest cover (by 18%) and agricultural land (by 10%), while built-up areas surged by over 250%, particularly around Bilaspur and other urban centers. Water bodies also shrank slightly due to sedimentation and pollution. The analysis shows habitat fragmentation, biodiversity loss, increased surface runoff, and elevated flood risks. These transformations are exacerbated by weak land management policies, ineffective conservation measures, and a lack of sustainable planning. The study emphasizes the need for integrated watershed management, reforestation initiatives, and strict zoning to manage unregulated urban sprawl. Periodic LULC monitoring using GIS tools is crucial to inform policy decisions.

Keywords: Arpa River Basin, Land Use, Land Cover, GIS, Remote Sensing, Change Detection, Environmental Planning

Introduction:

The Arpa River Basin, located in the Bilaspur district of Chhattisgarh, India, holds immense ecological, environmental, and socio-economic significance. Originating from the Maikal Hills, the Arpa River is a vital tributary of the Seonath River and serves as a lifeline for the people and ecosystems in this central Indian region. Over the past few decades, the basin has undergone significant land use and land cover (LULC) transformations due to rapid urbanization, agricultural intensification, infrastructural development, and increasing human population. These changes have had profound impacts on the hydrological regime, biodiversity, soil quality, and overall ecological balance of the region.

Land use and land cover are dynamic parameters that reflect the interaction between natural processes and human activities. While land use refers to how humans utilize the land (e.g., agriculture, settlements), land cover describes the physical characteristics of the Earth's surface (e.g., forests, water bodies, barren land). Monitoring and analyzing LULC changes are crucial for understanding environmental degradation, planning sustainable development, and implementing resource conservation strategies.

In this context, Geographic Information System (GIS) and remote sensing technologies have emerged as powerful tools for analyzing spatial and temporal changes in land use and land cover. These technologies allow for the acquisition, processing, visualization, and interpretation of satellite imagery and spatial data over multiple time periods. With the help of GIS tools and satellite data, researchers can generate land cover maps, detect changes, quantify the extent of transformations, and assess the impacts on the ecosystem.

2. Study Area

The Arpa River Basin lies entirely within the Bilaspur district of the central Indian state of Chhattisgarh, forming a crucial hydrological and ecological region in this part of the country. The Arpa River, which gives the basin its name, originates from the lush and biodiverse Maikal Hills part of the Satpura range located in the northern regions of Chhattisgarh. The river flows predominantly in a south-easterly direction and eventually merges with the Seonath River, a major tributary of the Mahanadi River system. The catchment area of the Arpa River Basin encompasses both rural and urban landscapes and includes several prominent settlements, including Bilaspur city, one of the fastest-growing urban centers in Chhattisgarh.

The geographical extent of the basin is defined by latitudes 21°30'N to 22°30'N and longitudes 82°00'E to 83°00'E, covering an approximate area of 2,994 square kilometers. This diverse region is characterized by a mixture of physiographic features, including gently sloping plains, low-lying hills, dissected uplands, and shallow river valleys. The elevation in the basin ranges from around 260 meters to 650 meters above mean sea level, with the highest elevations occurring in the northern and northwestern sections, where the Maikal Hills dominate the landscape.

The Arpa River Basin is known for its diverse land use and land cover (LULC) categories. The northern parts are primarily forested, comprising mixed deciduous and sal (Shorea robusta) forests, which are ecologically significant for biodiversity and carbon sequestration. Moving southward, the land gradually transitions into intensively cultivated agricultural zones that rely heavily on seasonal monsoons and, to a lesser extent, canal and groundwater irrigation. Crops such as rice, wheat, maize, and pulses are commonly cultivated. Scattered patches of wetlands and small reservoirs are also found throughout the basin, serving as critical habitats for migratory birds and local fauna, and acting as buffers during flood events.

Urbanization within the basin, particularly around Bilaspur city and its peripheral towns like Takhatpur and Ratanpur, has grown rapidly in recent decades. This growth is fueled by a combination of industrial development, infrastructural expansion, population growth, and enhanced connectivity via road and rail networks. Consequently, built-up land has expanded at the cost of agricultural lands and open spaces, leading to significant changes in the natural hydrological behavior of the basin. Issues such as increased runoff, waterlogging, urban flooding, and decline in groundwater recharge have become prevalent due to unchecked urban sprawl.

The climate of the Arpa River Basin is classified as tropical monsoon, characterized by three distinct seasons: summer (March to June), monsoon (July to September), and winter (October to February). The average annual rainfall ranges between 1,100 mm to 1,300 mm, with over 80% of the precipitation occurring during the monsoon months. This seasonal variation in rainfall greatly influences the flow regime of the Arpa River and its tributaries. While the river swells during the monsoon, it experiences reduced flow during the dry months, sometimes leading to stagnant or discontinuous stretches, especially in urbanized segments.

Soils in the basin are predominantly alluvial and lateritic in nature, with varying degrees of fertility. The alluvial plains in the central and southern parts of the basin are conducive to intensive agriculture, while the upland areas with lateritic soils are more suited for forest cover or less intensive cultivation. Soil erosion and sedimentation are ongoing issues, particularly in deforested and hilly regions, which eventually impact water quality and reservoir capacities downstream.

Hydrologically, the Arpa River is a seasonal river, exhibiting pronounced fluctuations in flow and water levels throughout the year. Several small tributaries and nallahs feed into the Arpa, contributing to its seasonal discharge. Surface water in the basin is used for multiple purposes including domestic consumption, agriculture, and industrial activities. However, the unregulated exploitation of groundwater, coupled with inadequate wastewater management, has begun to threaten the long-term water sustainability of the region.

Environmental concerns in the basin are mounting due to deforestation, habitat fragmentation, overextraction of water, and pollution from both point and non-point sources. Riverbank encroachments and indiscriminate sand mining have altered river morphology and reduced the capacity of the river to support aquatic life. Biodiversity loss, particularly of endemic and migratory species, is becoming increasingly evident. Moreover, the combination of natural and anthropogenic pressures has made the basin more susceptible to climate change impacts, including erratic rainfall patterns, heatwaves, and prolonged droughts.

In terms of governance, multiple local bodies, municipal corporations, and state-level departments oversee the planning and resource management within the basin. However, a lack of coordination, fragmented data systems, and poor enforcement of environmental regulations have hindered the development of integrated and sustainable management strategies. Recent initiatives, such as river rejuvenation programs and smart city planning for Bilaspur, offer hope for more structured interventions but require robust data and community participation to be effective.

The Arpa River Basin is a region of high environmental, economic, and social significance. Its dynamic landscape and evolving land use patterns make it an ideal case study for understanding the complex interactions between natural resources and human development. With GIS and remote sensing technologies, it is possible to monitor, assess, and forecast changes in land use and land cover within this basin knowledge that is crucial for devising strategies for sustainable development, environmental conservation, and disaster resilience.

3. Data and Methodology

Methodology

The methodology adopted in this study is a structured combination of geospatial techniques, satellite image processing, and statistical analysis to monitor and interpret the land use and land cover (LULC) changes within the Arpa River Basin over a 10-year period. The comprehensive approach involves the acquisition and processing of multi-temporal satellite imagery, utilization of ancillary data, and application of sophisticated GIS and remote sensing software tools. The following subsections detail each component of the methodology.

3.1. Satellite Data Acquisition:

This study evaluates decades of land use and land cover change between 2005 and 2015.

The dataset used in the study is NRSC AWiFS data with a resolution of 54 meters.

Data collection.

- GIS, IRS satellite sensor >ArcGIS
  >LULC data.
- Existing and revised data from the reports of Govt. of Chhattisgarh and Dept. of Forest and Climate change .

3.2. Software Tools:

A combination of commercial and open-source software tools were used throughout the study:

- **ArcGIS 10.x**: For spatial analysis, map creation, and integration of raster and vector data.
- **QGIS 3.x**: As a complementary open-source GIS platform for geoprocessing and visualization.

- **ERDAS Imagine**: For advanced image processing, including classification and change detection.

These tools were essential for handling large datasets and executing a range of spatial and temporal analyses.

3.3. Image Preprocessing:

Before analysis, all satellite images underwent the following preprocessing steps:

- **Geometric Correction and Geo-referencing**: Ensured that all images were correctly aligned to the WGS 84/UTM Zone 44N coordinate system.
- **Radiometric and Atmospheric Correction**: Performed to remove atmospheric distortions and normalize reflectance values using standard correction models such as Dark Object Subtraction (DOS).
- **Image Enhancement**: Techniques such as histogram equalization and contrast stretching were applied to improve the visual interpretation of land features.

3.4. Land Use and Land Cover Classification:

Supervised classification was conducted using the Maximum Likelihood Algorithm (MLA), a widely accepted and robust statistical approach that considers both the spectral signature and variance-covariance of training data.

- **Training Sample Collection**: Based on field visits, high-resolution Google Earth imagery, and topographic maps.
- **LULC Categories**: The classification was carried out for the following categories: Forest, Agriculture, Built-up, Water Bodies, and Barren/Wasteland.
- **Post-classification Editing**: Included filtering and reclassification to remove noise and improve thematic accuracy.

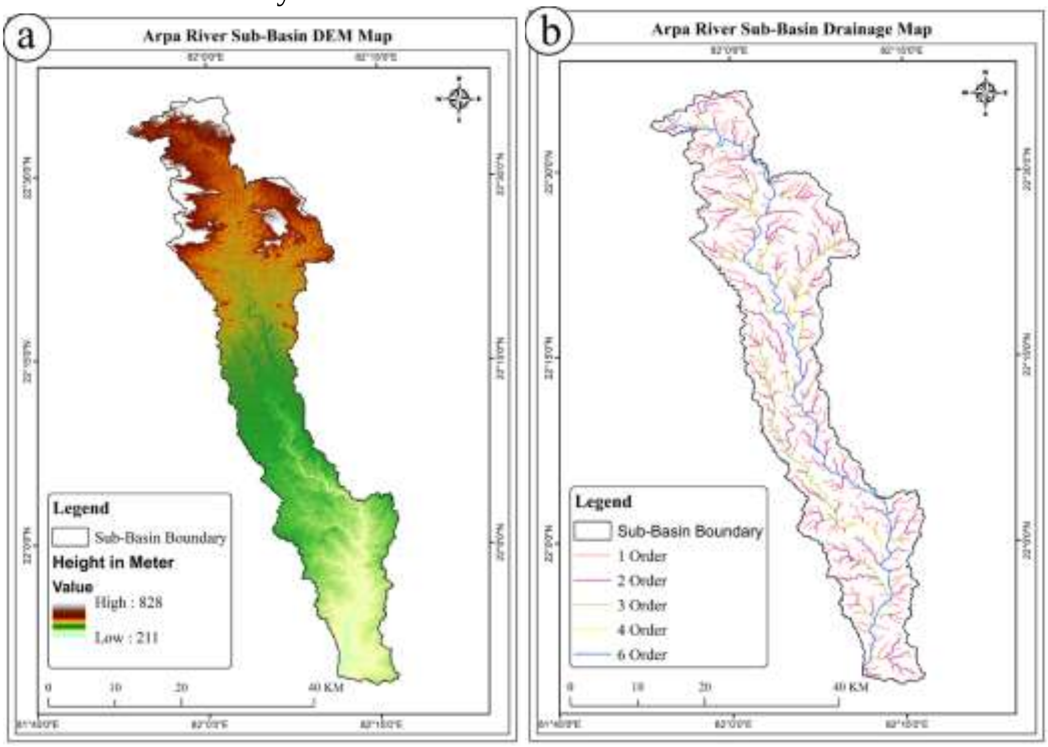

Fig. 3: Digital Elevation Model Map (a) and channel network (b) of Arpa River basin (*Source*: SRTM satellite database, www.usgs.com).

4. Results and Discussion

The analysis of land use and land cover (LULC) changes in the Arpa River Basin over the 10-year period from 2005 to 2015 reveals substantial environmental transformations that are deeply tied to

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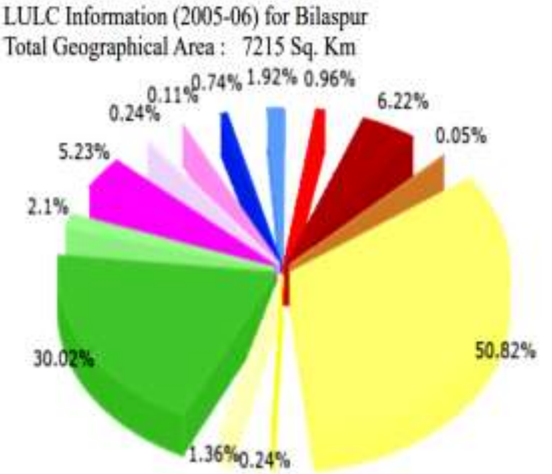
anthropogenic pressures, urban expansion, and ecological stress. These changes are captured through satellite data analysis using supervised classification methods and are discussed below in terms of individual land cover categories and their broader environmental implications.



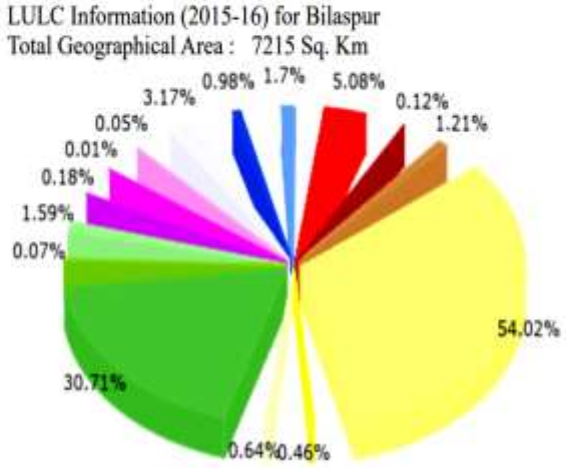


Table : 1 LULC Information (2005-06) for Bilaspur

LULC Class	Area (Sq. Km)
Built-up, Urban	69.15
Built-up, Mining	3.65
Built-up, Rural	448.96
Agriculture, Plantation	17.42
Agriculture, Crop land	3666.63
Agriculture, Fallow	98.12
Forest, Deciduous	2166.18
Forest, Scrub Forest	151.64
Barren/Unculturable/Wastelands, Scrub land	377.22
Barren/Unculturable/Wastelands, Barren rocky	7.67
Barren/Unculturable/Wastelands, Sandy area	17.09
Wetlands/Water Bodies, Reservoir/Lakes/Ponds	138.18
Wetlands/Water Bodies, River/Stream/Canals	53.09

Table : 2 LULC Information (2005-06) for Bilaspur

LULC Class	Area (Sq. Km)
Built-up, Urban	366.61
Built-up, Mining	87.59
Built-up, Rural	8.88
Agriculture, Plantation	33.39
Agriculture, Crop land	3897.68
Agriculture, Fallow	46.31
Forest, Deciduous	2215.68
Forest, Scrub Forest	114.47
Forest, Forest Plantation	4.94
Barren/Unculturable/Wastelands, Scrub land	0.67
Barren/Unculturable/Wastelands, Rann	228.85
Barren/Unculturable/Wastelands, Gullied/Ravine Land	12.73
Barren/Unculturable/Wastelands, Barren rocky	3.79
Wetlands/Water Bodies, Reservoir/Lakes/Ponds	122.81
Wetlands/Water Bodies, River/Stream/Canals	70.59

Table -3 The analysis of land use and land cover (LULC) changes in the Arpa River Basin

Land Use / Land Cover Category	2005 (%)	2015 (%)	Change (%)	Primary Causes	Environmental Impact
Forest Cover	28%	10%	-18%	Logging, encroachment, infrastructure development	Loss of biodiversity, increased soil erosion, ecological imbalance
Agricultural Land	45%	35%	-10%	Soil degradation, urban expansion	Decline in food production, loss of rural livelihoods
Built-up Area	5%	17%	+12%	Urbanization, industrial and residential development	Urban sprawl, pressure on resources, risk of flooding
Water Bodies	Moderate	Slightly Less	- (Slight)	Sedimentation, encroachments	Reduced water storage, degradation of aquatic ecosystems
Wasteland	Low	Marginally High	+ (Slight)	Land degradation, deforestation, unsustainable farming practices	Increased aridity, unproductive land, dust storms

These changes indicate a clear trend towards urbanization and ecological stress, increasing vulnerability to floods and biodiversity loss.

The analysis of Land Use / Land Cover (LULC) changes over the decade (2005–2015) in the basin reveals significant spatial transformations influenced by both natural processes and anthropogenic activities. The major categories- forest cover, agricultural land, built-up areas, water bodies, and wasteland each show distinct patterns of change with serious environmental implications.

1. Forest Cover

- ❖ Change Observed: A sharp decline from 28% in 2005 to 10% in 2015, reflecting an 18% decrease.
- ❖ Primary Causes: The major drivers behind this loss include large-scale logging, encroachment for agriculture or habitation, and infrastructure development such as roads, settlements, and utilities.
- ❖ Environmental Impact: This drastic reduction has led to the loss of biodiversity, increased soil erosion, and ecological imbalance. Forest loss disrupts wildlife corridors and reduces the region's capacity to act as a carbon sink.

2. Agricultural Land

- ❖ Change Observed: A decrease from 45% to 35%, marking a 10% reduction.
- ❖ Primary Causes: The shrinking of farmland is linked to soil degradation (due to overuse, chemical inputs), urban sprawl, and land conversion for non-agricultural use.
- ❖ Environmental Impact: This decline can result in reduced food production, economic distress among rural communities, and loss of agro-biodiversity. It also makes the local economy more dependent on urban sectors.

3. Built-up Area

- ❖ Change Observed: A rapid increase from 5% in 2005 to 17% in 2015, a 12% rise.
- ❖ Primary Causes: Accelerated urbanization and industrial and residential development are key contributors. Migration from rural to urban areas has led to the expansion of towns and cities.
- ❖ Environmental Impact: The rise in built-up area has caused urban sprawl, exerting pressure on natural resources, increasing the risk of surface runoff and flooding, and reducing green cover in the region.

4. Water Bodies

- ❖ Change Observed: A slight decrease; from "Moderate" in 2005 to "Slightly Less" in 2015.
- ❖ Primary Causes: Sedimentation from upstream activities and encroachments along riverbanks and lakes are major contributors.
- ❖ Environmental Impact: This subtle decline impacts aquatic ecosystems, reduces groundwater recharge, and may affect irrigation and drinking water availability, especially during dry seasons.

5. Wasteland

- ❖ Change Observed: A slight increase, from "Low" to "Marginally High".
- ❖ Primary Causes: Land degradation, deforestation, and unsustainable farming practices (like overgrazing and slash-and-burn agriculture) have led to an expansion of unproductive lands.
- ❖ Environmental Impact: Increasing wastelands lead to desertification, dust storms, and further decline in land fertility, making reclamation efforts more difficult and expensive.

5. Overall Trends and Implications

The observed trends suggest a clear trade-off between ecological sustainability and urban development. While built-up areas are expanding rapidly, it is coming at the cost of forests and agricultural land. The decline in water bodies and the rise in wastelands further exacerbate environmental vulnerability.

This transformation underscores the need for integrated land use planning, reforestation efforts, and urban growth regulation to ensure sustainable development in the basin. Policy measures should focus on reclaiming degraded land, preserving forest ecosystems, and protecting water bodies to maintain ecological balance and support long-term human well-being.

6. Recommendations

- Adoption of Integrated Watershed Management.
- Reforestation and afforestation programs.
- Urban zoning and land use regulations.
- Community participation in land stewardship.
- Periodic LULC monitoring using GIS tools.

7. Conclusion

The Arpa River Basin is undergoing rapid transformation in land use and land cover, significantly impacting its ecology and sustainability. This study demonstrates the efficacy of GIS and remote sensing in tracking these changes and provides a scientific foundation for sustainable regional planning. Long-term monitoring and informed policymaking are essential to restore and preserve the basin's ecological integrity. The spatial and temporal analysis of LULC changes in the Arpa River Basin provides critical insights into the region’s environmental trajectory. The significant decline in forest and agricultural lands, along with the surge in built-up areas, calls for immediate intervention by policymakers, planners, and local communities. Sustainable urban development, combined with ecological conservation, is necessary to mitigate environmental degradation and ensure long-term water and food security in the region. Through continued monitoring using remote sensing and GIS tools, coupled with community participation and scientific land management practices, the Arpa River Basin can move towards a more balanced and resilient future.

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