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Trends Of Geospatial Expansion Of Bauchi Urban Area And Its Associated Environmental Planning Issues

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Abstract:
The dynamics the nature of urban environment calls for the urgent need of integrating an intensive spatial analysis technique into environmental planning and management, as the traditional approaches and techniques in operation presently in most of the Nigerian urban areas proved to be inadequate. This study of the trends of geospatial expansion of Bauchi urban area and its associated environmental planning issues was conceived using quantitative and geospatial techniques. The method used to assess the spatiotemporal changes from 2003 to 2023 were using the Landsat satellite imagery system of Enhanced Thematic Mapper (ETM+) and Operational Land Imager (OLI/TIRs) downloaded from USGS. The imageries were preprocessed in the QGIS environment for the Landsat 7 image, to remove the scene line using gab mask data and exported as TIFF format. The spectral bands were layered stacked in TerrSet 19 (Idrisi) to create a color infrared composite of Band 4, Band 3, and Band 2 for Landsat 7 and Band 5, Band 4, and Band 3 for Landsat 8 at 30m spatial resolution and performed image classification and post classification was done in ArcMap 10.8 and Ms. Excel 2016 for statistical analysis. For the assessment of the environmental planning issues, the research design adopted was cross-sectional survey opinion of professionals form eight chosen field of the built environment. The results therefore show a significant change in land use pattern with built-up areas increasing from 7478sq.km to 30313sq.km.

Keywords: *Geospatial, Environment, Planning, Landsat, Imagery*

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I. Introduction

Urban expansion is a global phenomenon that is caused by humans' action and inactions with current reduction of agricultural land (Lopez, et al. 2011), deforestation (Alphan, 2013), that reduces the growth of plants. Also, a wide range of environmental planning issues, such as decline in housing quality, biodiversity destruction, and pollution were brought on by rapid urbanization and deforestation (Barman et al., 2023; Ahmed and Deb, 2012). As a result of population growth, the expansion and conversion of rural lands and other forested areas to agricultural lands and urban built-up areas particularly in the developing countries of the world is an issue to deliberates on (UN-Habitat, 2013). Nigeria is among the developing countries with rapid population growth as well as urban expansion; and some cities like Kano, Kaduna and Bauchi in the North are experiencing these expansions rapidly.

Urbanization as a concept and phenomena is the spatial concentration of people and economic activity (Roberts & Kanaley, 2016). It can also be seen as the transformation of rural society into an urban society as a result of socio-economic and political growth leading to formation and expansion of urban areas and city centers along with changing land use patterns (Roberts & Kanaley, 2016). The main causes of local, regional, and global environmental changes are the change in land use and land cover that may be attributed to human activity (Barman et al., 2023; Alawamy et al., 2020). As cities are growing, the demand for resources such as water, land etc. grows proportionately to the growth of the population. This causes cities to be experiencing increasing signs of environmental stress, notably in the form of poor air quality, solid waste, excessive noise, traffic congestion, crime, deforestation, slum development etc. (Ruangrit & Sokhi, 2014).

Additionally, the growth in urban populations leads to various population pressures, climatic variability, and fragmentation of tenure and traditional systems. This contributes to the degradation of soil and vegetation, diminishing yields and worsening food insecurity in both urban and rural areas mostly at the fringes of the rapidly growing urban settlements (UN-Habitat, 2017). Such problems in the less developed countries may become acute from its current state of being chronic. It is therefore essential that studies should be undertaken on the trends of

geospatial expansion to keep a tab on the process so as to minimize its adverse environmental planning consequences. It is imperative to also note that with only 2% of the world population urbanized in 1800, the global urban population reached a 15% mark in 1900 and as at 2011, almost 180,000 people were added to the world's urban population each day (Pitale, 2016), therefore urban expansion and urbanization is inevitable and a serious challenge to resources as well as environmental planning and management.

In the same vein, increase in population, destructions of environmental resources, environmental pollution, introduction of various forms of land use are various issues threatening the environment (Ruangrit & Sokhi, 2014). Over the years, man's interaction with his environment has been recognized as a major force shaping the biosphere, mostly its landscape and the atmosphere. Human actions and inactions rather than natural phenomena are the sources of most contemporary changes in the state and flow of the biosphere (Pitale, 2016).

The importance of monitoring land use and land cover changes in decision-making cannot be overstated. The emergence of geospatial techniques has ushered in a new era, providing a platform for the comprehensive assessment, mapping, monitoring, and modeling of urban expansion. This technological advancement has proven particularly advantageous for urban planners, environmentalists, and geographers, enabling more accurate predictions of urban sprawl compared to traditional methods (Okabe, 2016). The combined use of remote sensing and Geographic Information Systems (GIS) has gained widespread recognition as a potent and efficient tool for identifying changes in urban land use and land cover (Martin et al., 2012).

In Musa, et al. (2017), the land cover features of Bauchi metropolis were reclassified into forest and non-forest for cross-tabulation analysis and the result of the analysis indicates a change of 14965.97Ha (39.68%) from forest to non-forest (deforestation) and that of 467.69Ha (1.24%) form non-forest to forest (afforestation) between 1986 and 2016. This shows a rapid increase in built-up area (urban expansion) and rapid decrease in forest (deforestation), which may be attributed to lack of proper environmental planning and protection strategy in the metropolis. This reveals that the rate of urban expansion is very high in the metropolis and portends danger to lives and properties as it was seen in the June, 2018 rainstorm. Kafi et al., (2019) stated that the rainstorm has caused a lot of damages to Bauchi metropolis with the residential land use majorly affected among the various land uses. A total of 47.6% structures were identified as having damaged roofs, whereas 39.2% were identified with fallen walls, while the remaining 13.2% are cases of both damage roofs and fallen walls incidents (Kafi et al., 2019).

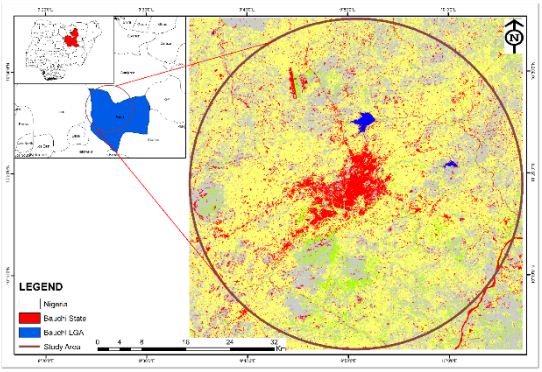
Urban expansion and urban land cover dynamics is shrinking the amount of cultivated land through the development of infrastructures and various development projects. This without doubt has consequences on the environment such as conversion of forest land for agricultural use, climate change, windstorm, rainstorm, desertification among other natural and manmade disasters. Bauchi urban area is a diverse urban landscape with a population of over 493,730. However, insecurity in the neighboring states has made Bauchi a safe haven for displaced persons resulting in the proliferation of low-quality housing (Kafi et al., 2021, Muhammad, 2015). Like most typical small and medium-sized cities in developing countries, Bauchi is witnessing rapid population growth and transformation as well as expansion of its landscapes. For instance, between 2003 and 2013, over 45% of hitherto agricultural lands around Bauchi metropolis were converted into built-up areas (Kafi et al, 2021., Kafi et al., 2014). This development significantly reduced the size of cultivated/vegetated areas, especially trees which serve as microclimate regulators as well as windbreakers capable of mitigating the adverse effects of strong winds such as the one of June 2018 which caused wreckage in the city (Kafi, 2021).

It is in the light of the above that a study of the trends of geospatial expansion of Bauchi urban area and its associated environmental planning issues was conceived using quantitative and geospatial techniques. The results will therefore help environmental experts and city planners as well as policy makers attain a sustainable decision for future urban development.

II. The Study Area

The study area is located in Bauchi, the capital of Bauchi State and is located between latitudes 10.3060^0 N and longitude 9.8404^0 E as shown in fig. 1.

Fig. 1: Maps of the study area.



III. Research Methodology

The method used to assess the spatiotemporal changes of Bauchi urban area from 2003 to 2023 were using the Landsat satellite imagery system of Enhanced Thematic Mapper (ETM+) and Operational Land Imager (OLI/TIRs) downloaded from USGS. The imageries were preprocessed in the QGIS environment for the Landsat 7 image, to remove the scene line using gab mask data and exported as GeoTIFF format. The spectral bands were layered stacked in TerrSet 19 (Idrisi) to create a color infrared composite of Band 4, Band 3, and Band 2 for Landsat 7 and Band 5, Band 4, and Band 3 for Landsat 8 at 30m spatial resolution.

The supervised image classification techniques were adopted using the maximum likelihood algorithm (MLA). The images were classified into five classes; Built-up, Vegetation, Bare land, Waterbody, and Rock. As proposed by Anderson's classification scheme of land use (Muhammad et al., 2021 and Anderson et al. 1976), as shown in Table 1.

Table 1. Land use classes

Level I	Level II	Explanation
Key land use	Sub-land use	
Urban	Built-up land	Residential, industrial, transportation, commercial and services, communications and utilities, and mixed-use land
Non-Urban	Vacant Land	Open space, fallow land, construction sites, excavation sites, bare soils, and exposed areas.
	Vegetation/ Agriculture	Trees, natural vegetation, forest, grassland, gardens, parks and play areas, agricultural land, and crop fields.
	Rock	
Water Body	Water	Rivers, streams and canals, open water, ponds, lakes, and reservoirs.

The vector layer of Bauchi urban area, with a radius of 30m from the city center as defined by the Bauchi state government, involved the sub-setting of each image to clip the study area from the complete scene in ArcGIS 10.8. for post-classification and statistical analysis.

For the assessment of the environmental planning issues, the research design adopted was cross-sectional survey of professionals form eight chosen field of built environment. The areas town planning, environmental management, estate surveying and valuation, architecture, building technology, surveying and geoinformatics, quantity survey, and Industrial design in Bauchi urban area. The choice of cross-sectional survey was based on the nature of the research objectives and the benefits this offered in the generation of data from geographically dispersed population within a shortest period of time at relatively lower cost. In addition to this fact authors such as Dipeolu et al. 2021; Chiesura, 2004; Shan, 2014; Mansor et al., 2015; Craik et al., 2015 adopted same research design.

Because of non-record the exact research population, the sample size (n) for the survey was estimated using the formula presented by Turner (2003) as shown in Eq. (1).

$$n = \frac{(Z\alpha)^2 r(1 - r)fk}{} \quad (1)$$

phe^2

Where: n = the sample size, Zα = 1.96, is the critical value of the normal distribution obtained from the Table of Standard Normal Distribution at 95% confidence level, r = 60% represents an estimate of the proportion of the respondents in the survey, $f = 1$ is the design effect, while k = 25% represents non-response rate, p = 0.03 × 8 = 0.24, which is the proportion of the total population accounted for by the target population and upon which the parameter, r, is based. According to Turner (2003), as a rule of thumb, 0.03 is used for each year of age represented by the target population and $h = 8$ is the average least size of the professionals in the built environment in the area and $e = 0.05$ is the margin of error. Therefore,

$$n = \frac{(1.96^2 \times 0.6 \times 0.4 \times 1 \times 0.25)}{[0.24 \times 8\ (0.05 \times 0.5)^2]} = 192.08 \approx 192.$$

The instrument for data collection used was a structured questionnaire. The questionnaires were subjected to validity test by experts and observations were corrected before administration. It is important to note that the reliability test conducted on the returned questionnaire has Cronbach's alpha value of 0.78 which is acceptable. Furthermore, a simple random sampling was adopted for the questionnaires administration.

A total of 192 questionnaire were self-administered by the researchers, but 178 were returned which represent 92.7%. Data collected were subjected to descriptive statistical analyses. The analyses helped in revealing the frequency and percentage distributions of the respondents according to the environmental planning issues raised.

IV. Results

Table 2: Landsat satellite imagery metadata.

Date of Acquisition	Spacecraft	Sensor	Spectral Band	Spatial Resolution	Path/Row
2003-12-19	LANDSAT_7	ETM+	1-8	30m	187/053
			Gap-mask 1-8		
2013-12-14	LANDSAT_7	ETM+	1-8	30m	187/053
			Gap-mask 1-8		
2023-12-18	LANDSAT_8	OLI-TIRS	1-8	30m	187/53
			Pan (9)	15m	

Table 3: Land use change 2003 to 2023

Year		Land-use Type					Total Area
		Built-up Area	Bare-land	Vegetation	Water Bodies	Rock	(in sq. km)
2003	Area sq. km	7478	89505	29580	735	235403	362701
	Percentage	2.06	24.68	8.16	0.20	64.90	100
2013	Area sq. km	8844	153835	5481	797	193744	362701
	Percentage	2.44	42.41	1.51	0.22	53.42	100
2023	Area sq. km	30313	194763	21927	852	114846	362701
	Percentage	8.36	53.70	6.05	0.23	31.66	100

Figure 2: Land use map of Bauchi Metropolis from 2003 to 2013

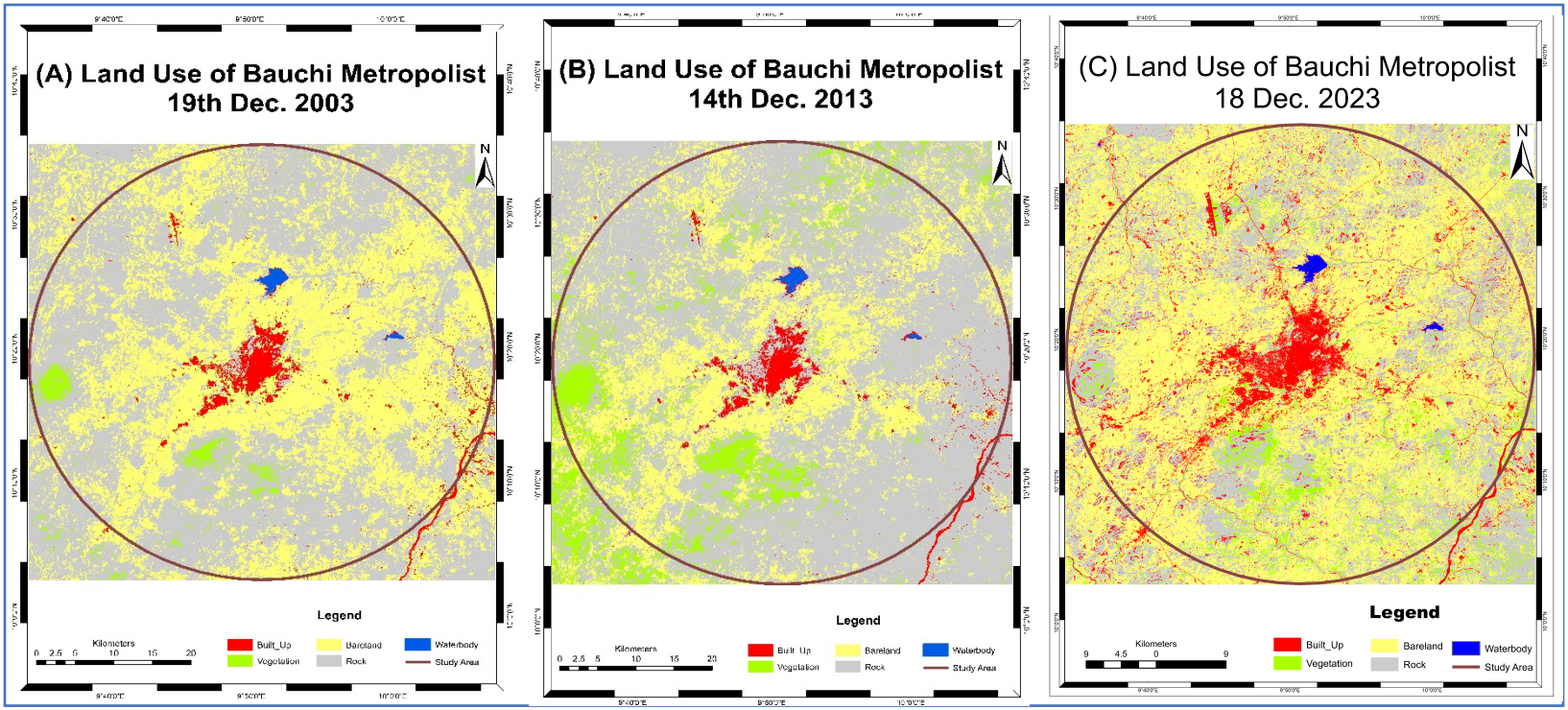


Table 4: Opinion of the professional in the built environment on environmental issues associated to geospatial expansion

Environmental Planning issues	**Rating by the respondents**				
	Strongly Agree No.& %	**Agree No.& %**	**Neutral No.& %**	**Disagree No.& %**	**Strongly Disagree No.& %**
Geospatial Expansion can lead to deforestation, resulting in the loss of valuable carbon sinks, disruption of ecosystems, and increased greenhouse gas emissions.	92 (51.6%)	56 (31.5%)	23 (12.9%)	4 (2.3%)	3 (1.6%)
As urban area expands for housing, agriculture, or industry, natural habitats are often destroyed or fragmented, leading to a loss of biodiversity and potential endangerment of species.	63 (35.4%)	76 (42.6%)	19 (10.6%)	12 (6.7%)	8 (4.5%)
Increased urbanization can result in runoff of pollutants like pesticides, fertilizers, and heavy metals into water bodies, causing water pollution and harming aquatic ecosystems.	83 (46.6%)	58 (32.5%)	23 (12.9%)	12 (6.7%)	2 (1.1%)
Geospatial expansion can strain water resources, leading to over-extraction, reduced availability, and competition for water.	54 (30.3%)	88 (49.4%)	34 (19.1%)	1 (0.56%)	1 (0.56%)
Geospatial expansion contributes to climate change through carbon emissions from construction and transportation, and altered land cover that affects local climate patterns.	117 (65.7%)	59 (33.1%)	2 (1.1%)	0	0
Expanding cities and transportation networks can disrupt natural drainage systems, leading to increased flooding and stormwater management challenges.	12 (6.7%)	37 (20.7%)	38 (21.3%)	47 (20.4%)	41 (23.0%)
New developments often require energy-intensive infrastructure, contributing to higher energy consumption and emissions.	22 (12.4%)	29 (16.3%)	53 (29.7%)	51 (28.6%)	23 (12.9%)
Geospatial expansion can drive increased resource extraction, leading to ecological damage and resource depletion.	37 (20.7%)	63 (35.4%)	42 (23.5%)	21 (11.7%)	15 (8.4%)
Fragmentation of natural landscapes as a result of expansion can isolate wildlife populations, making it difficult for them to find food, mates, and suitable habitats.	13 (7.3%)	51 (28.6%)	62 (34.8%)	27 (15.2%)	25 (14.0)
Conversion of agricultural land to other uses reduces food production capacity and can lead to food security concerns.	103 (57.8%)	71 (39.8%)	4 (2.2%)	0	0
Geospatial expansion can lead to air pollution through emissions from vehicles and factories, affecting human health and ecosystems.	51 (28.6%)	113 (63.5%)	9 (5.1%)	5 (2.8%)	0
Expansion can result in higher noise levels causing health problems for nearby residents.	63	97	29	14	4

	(35.4%)	(54.5%)	(16.3%)	(7.8%)	(2.2%)
Growing populations and urbanization lead to increased solid waste production, posing challenges for waste management and disposal.	97 (54.5%)	71 (39.8%)	10 (5.6%)	0	0
Urban expansion may threaten cultural heritage sites and historical landmarks, impacting cultural identity and tourism.	54 (30.3%)	83 (46.6%)	41 (23.0%)	0	0
Increased demand for water in expanding urban areas can deplete groundwater reserves and harm aquatic ecosystems.	14 (7.8%)	49 (27.5%)	61 (34.3%)	33 (18.5%)	21 (11.7%)
As cities expand, they may create urban heat islands, where higher temperatures and reduced vegetation can have adverse effects on air quality and public health.	85 (47.7%)	72 (40.4%)	13 (7.3%)	3 (1.7%)	2 (1.1%)

Field survey, 2023

Rating	**Number**	**Mean**	**Standard Deviation**	**Standard Error**
Strongly Agree	16	60	14	3.5
Agree	16	67	6	1.5
Neutral	16	28.3	3.8	0.95
Disagree	16	14.4	0.1	0.025
Strongly Disagree	16	9.1	0.15	0.0375

IV. Discussion

Trends of Land-Use geospatial changes

The built-up area has experienced a notable increase over the years, from 0.26% in 2003 to 8.36% in 2023. This growth indicates significant urban development and infrastructure expansion, potentially driven by population growth, economic activities, or changes in land-use policies. This is in agreement with Modibbo et al., 2019 that the Bauchi Urban area has expanded at various rates.

Bare-land dominates the landscape throughout the three periods, representing half or more of the total area. The decrease from 2013 to 2023 may be attributed to various factors, including urbanization, agricultural expansion, or land-use changes. The vegetation area has significantly decreased over the period of the study, from 8.16% in 2003 to 6.03% in 2023. This indicates potential deforestation, changes in land use for agriculture or urbanization, and raises concerns about biodiversity and ecosystem health.

Water bodies constitute a small percentage of the total area, with minimal changes observed over the years. Fluctuations in water bodies might be influenced by factors such as climate variations, land-use changes, or human activities. The rock area has undergone significant changes, decreasing from 64.90% in 2003 to 53.42% in 2013 and then sharply increasing to 31.66% in 2023 as shown in fig. 2.

Environmental planning issues associated with geospatial expansion

Over half of the respondents (51.6%) strongly agree that geospatial expansion can lead to deforestation, resulting in the loss of valuable carbon sinks. This high level of agreement suggests a widespread concern about the environmental impact of urban development on forests and their crucial role as carbon sinks. A substantial number of respondents (35.4% strongly agree, 42.6% agree) express concerns about urban expansion leading to the destruction or fragmentation of natural habitats, resulting in a loss of biodiversity. This indicates a significant awareness among participants regarding the potential negative consequences of urban growth on the variety and abundance of plant and animal species as shown in table 4.

Nearly half of the respondents (46.6%) strongly agree that increased urbanization can result in the runoff of pollutants into water bodies, causing water pollution and harming aquatic ecosystems. The high level of agreement underscores the perceived risk of urban expansion contributing to water pollution, highlighting the need for sustainable urban planning and stormwater management. On water resource strain the respondents attest, with 30.3% strongly agreeing and 49.4% agreeing that geospatial expansion can strain water resources.

While there is recognition of potential strain on water resources, the division in opinions suggests a need for further exploration of specific concerns related to water availability and competition.

Additionally, majority of respondents (65.7%) strongly agree that geospatial expansion contributes to climate change through carbon emissions and altered land cover. This strong consensus indicates a prevailing awareness of the role of urban development in contributing to climate change, emphasizing the importance of sustainable and low-carbon urban planning. Views on the impact of urban expansion on flooding and stormwater management are mixed, with a relatively small percentage strongly agreeing (6.7%) and a larger percentage expressing neutrality (21.3%). The mixed views suggest a potential need for more education or discussion on the relationship between urban expansion and flooding-related challenges.

A notable portion of respondents (29.7%) expresses neutrality regarding the idea that new developments often require energy-intensive infrastructure. This neutrality suggests a potential gap in understanding or awareness regarding the energy implications of urban expansion, highlighting an area for further exploration or communication. Respondents are concerned about geospatial expansion driving increased resource extraction, with 20.7% strongly agreeing and 35.4% agreeing. This indicates a notable level of awareness regarding the potential ecological consequences of resource extraction linked to urban development.

A significant percentage (34.8%) agrees that the fragmentation of natural landscapes as a result of expansion can isolate wildlife populations. This acknowledgment highlights a concern for the impact of urban growth on wildlife habitats and the need for measures to mitigate fragmentation. Also, a significant majority (57.8%) strongly agrees that converting agricultural land can lead to food security concerns. The strong agreement emphasizes the perceived risk associated with converting agricultural land and the potential consequences for food production and security.

V. Conclusion

In conclusion, the survey results provide a comprehensive view of respondents' opinion towards the environmental implications of geospatial expansion and urban development. The data underscores a shared concern among participants regarding the potential adverse effects on ecosystems, biodiversity, and essential natural resources. The strong agreement on issues such as deforestation, loss of biodiversity, water pollution, and climate change contribution suggests a collective awareness of the environmental challenges associated with urban growth by the professionals. These findings emphasize the importance of integrating sustainable practices and thoughtful environmental planning into future urban development initiatives.

VI. Recommendations

The data suggests a notable trend of urbanization and built-up area expansion over the period, accompanied by changes in the distribution of bare-land, vegetation, water bodies, and rocks. The decrease in vegetation and increase in built-up areas and rocks raise environmental concerns, including habitat loss, biodiversity decline, and potential geological impacts. Ongoing monitoring and detailed studies are crucial to understanding the complex interplay of natural and anthropogenic factors influencing land-use changes.

Sustainable land-use planning is essential to balance urban development with environmental conservation. Conservation measures for vegetation and water bodies should be considered to mitigate the ecological impact of land-use changes. Further research is also needed to understand the drivers behind the observed trends, including economic, social, and policy factors.

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