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An Assessment of Land use Change in Itu LGA, Nigeria: The Application of Relative Shannon Entropy.

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ABSTRACT

Land use change is brought about by many environmental, social, economic, and political factors. It occurs at different scales and has substantial effects on the environment, biodiversity, and wellbeing of people. This study set out to determine how much the land usage of Itu Local Government Area (LGA), Nigeria, has changed. The Relative Shannon Entropy (RSE) measure was used to calculate the variation in the area's land use pattern over the previous three decades using Landsat satellite images from 1992 and 2022.The RSE was determined to be 0.6114, confirming that there was a considerable change in the study area's land use pattern between 1992 and 2022. The findings of this study revealed notable trends in land use change, including a decline in water bodies and wetlands, an increased in the built-up areas and cultivated lands, and a reduction in fallowed land. It was concluded that the unguided pattern of land use change being experienced in the area was unsustainable as it has serious implications on the environment. To this end, recommendations such as adoption of smart growth, promotion of green infrastructure, development of land use zoning and regulations, and re-afforestation were made in order to ensure the sustainable physical development of Itu LGA, Nigeria.

Keywords: Land use change, Remote Sensing, Relative Shannon Entropy, Sustainable Land Use Planning

1. INTRODUCTION

Land use change refers to the conversion, modification, or transformation of land from one land use type to another. It is a complex and dynamic process influenced by a wide range of factors, including environmental, social, economic, and political drivers (Etim, 2023). Land use change occurs at various scales, from local to regional and global levels, and has significant implications for the environment, biodiversity, and human well-being. Land use involves both the manner in which the biophysical attributes of land are being manipulated and the intent underlying such manipulations. The magnitude of land use change varies with time, the geographical area, the nature of land cover and the anthropogenic activities going on. The land use pattern of a region is an outcome of natural and socio – economic factors and the utilization of natural resources by man in time and space (Etuk, 2021). The aim of the research is to assess the extent of land use change in Itu LGA over the past three decades. It also discusses the potential impacts of these changes on the environment, biodiversity, and human communities. This study contributes to the growing body of knowledge on land use change in Nigeria and serves as a foundation for evidence-based decision-making and policy formulation in Itu LGA. Understanding the implications of land use change is essential for achieving a sustainable and harmonious coexistence between humans and nature, safeguarding biodiversity, and ensuring the resilience of ecosystems in the face of rapid urbanization and environmental challenges.

2.1 Trend of Land Use Change

The trend of land use change refers to the pattern or direction in which land use categories have evolved over a specific period. It involves analyzing the changes in the distribution and extent of different land use classes, such as agricultural lands, forests, water bodies, urban areas, and other types of land cover, over time (Etim, 2021). Understanding the trend of land use change is essential because it provides valuable insights into the dynamics of human activities, natural processes, and policy decisions that shape the landscape. It helps identify shifts in land use patterns and can reveal the impact of various drivers, such as urbanization, population growth, agricultural expansion, industrialization, and environmental changes. Numerous studies have been conducted to analyze the trend of land use change in various regions, providing valuable insights into the dynamic nature of human activities and their impact on the environment. This paper presents a review of some of these studies, highlighting key findings and implications for land use planning and management.

Munthali *et al.* (2019) focused on Denza District, Central Malawi, and analyzed the land use change between 1991 and 2015. The study revealed a reduction in water bodies, wetland areas, forests, and agricultural land use, while barren land and built-up areas increased. These changes indicate potential challenges to water resources, biodiversity, and food security. This emphasizes the need for sustainable land management practices and urban planning to address these issues. Atser *et al.* (2014) studied land use changes in Ibiono Ibom and observed a decline in fallowed bush, an increase in secondary forest and forested areas, and a decrease in water bodies. The study attributed the forest rejuvenation to rural-urban migration. This highlights the importance of understanding the drivers of land use change and their implications for ecosystem restoration and management.

Ogar *et al.* (2016) conducted research on the Stubb Creek forest in Akwa Ibom state and found a significant decrease in dense forest cover over the years, with corresponding increases in sparse forest and degraded land. The study emphasized the need for conservation efforts and sustainable land use practices to protect dense vegetation cover and biodiversity. Alfred *et al.* (2016) monitored land use changes in Suleja LGA, Niger State, and identified a significant increase in built-up areas over the years. This indicates rapid urban expansion, which requires effective urban planning to ensure infrastructure development and environmental conservation are balanced. Uhwache *et al.* (2015) studied land use dynamics in Zaria between 1973 and 2009 and reported substantial expansion of built-up areas, leading to the loss of scrubland, farmlands, and flood plains. This underscores the importance of managing urban growth to preserve valuable agricultural land and natural habitats. Ukor *et al.* (2016) found a decrease in vegetated lands and an increase in built-up areas in Ikeja. This highlights the need for sustainable land use planning and management to address the challenges of urban expansion and deforestation.

Eke (2016) assessed the impact of urban development on land use types in Akure from 1972 to 2009. The study revealed rapid expansion in built-up areas over the years, emphasizing the importance of sustainable urban planning to manage urban growth and preserve natural resources. Ekpenyong (2015) observed a high rate of deforestation in Akwa Ibom state, with a decrease in swamp and secondary forest areas and an increase in built-up areas. The study advocated for effective land use monitoring and development control measures. Fred (2019) investigated the effects of land use changes on agriculture in Abak LGA, Akwa Ibom State, and reported a decrease in forested land cover and farmlands, and an increase in built-up areas. This highlights the need for sustainable agricultural practices and land use planning to mitigate the impact of land use change on agriculture.

Etuk (2021) analyzed the land use changing pattern in Nsit Ibom Local Government Area, Akwa Ibom State, and found a reduction in forested land cover and an expansion in bush fallow and built-up areas. This emphasizes the importance of preserving forested areas and implementing sustainable land use practices. Etim (2021) noted that over the course of four decades, Ikot Ekpene Local Government Area, Akwa Ibom State has undergone significant land use changes. The thick forest land use class, composed of high forest relics and fragmented secondary forests, experienced a declining trend, reducing from 58.611 km² in 1980 to 30.158 km² in 2020. This represents about 39.99% of the total land use change. Cultivated farmland also decreased from 39.084 km² to 33.231 km² during the same period, accounting for approximately 8.18% of the total change. In contrast, the built-up area witnessed substantial expansion, increasing by 35.591 km² over the four decades. This represented 35.591% of the total land use changes.

The reviewed studies illustrate the dynamic nature of land use change and its far-reaching implications for ecosystems, biodiversity, agriculture, and urban development. These findings highlight the need for sustainable land use planning, conservation efforts, and effective urban management to address the challenges posed by land use change in order to ensure the balanced and sustainable development of our environment and communities. Effective policies and practices that promote responsible land use and preserve natural resources are crucial to safeguarding the well-being of current and future generations

2.2 Relative Shannon Entropy (RSE) Index.

The Relative Shannon Entropy (RSE) index is a statistical measure used to compare the similarity or dissimilarity between two probability distributions. The RSE index is derived from the Shannon Entropy, which is a measure of uncertainty or randomness in a probability distribution. It takes into account the probabilities of different categories within the distribution. Relative Entropy, also called Shannon equitability index, has great importance in measurement of diversity and similarity for spatial related issue in the field of biology, geography and urban studies (Rastogi and Jain, 2018). It has practical applications in fields where understanding the divergence or similarity between different data distributions is important for making informed decisions or optimizing algorithms. The relative entropy value starts from zero to one. In the assessment of patterns of urban growth, a zero value denotes a compact distribution of urban areas (infill), whereas values near one indicate the dispersed distribution of urban areas. Thus, higher entropy values indicate higher sprawl occurrences (Alsharif *et al.*, 2015). In land use change studies such as this, the RSE index helps to quantify the changes in the spatial distribution of different land use categories over time. A higher RSE value indicates greater dissimilarity or variation in land use patterns between the two periods, while a lower value suggests more similarity or consistency. It can also be used to measure the degree of spatial concentration and dispersion of a variable in a given area (Igbokwe and Ezeomedo, 2013).

Given two probability distributions P(X) and Q(X) for a random variable X, the relative entropy (KL divergence) from P to Q is calculated as:

$$D(P \parallel Q) = \Sigma [P(x) * \log_2(P(x) / Q(x))], \qquad (1)$$

where the summation is performed over all possible values of x in X.

2.3 Concept of Sustainable Land Use Planning and Management

Sustainable land use planning and management refer to approaches and practices that aim to achieve a balance between meeting human needs and maintaining the health and integrity of natural ecosystems (Akanmu *et al.*, 2019). It involves the thoughtful and responsible utilization of land resources to support economic development, social well-being, and environmental conservation. Sustainable land use planning and management play a crucial role in addressing the challenges posed by land use changes and promoting long-term environmental sustainability and resilience. At the core of sustainable land use planning and management are several key principles and components:

i) The Ecosystem-Based Approach: This approach considers the interconnectedness of different ecosystems and the services they provide. It recognizes the dependencies of human activities on these services and seeks to maintain the ecological processes and functions of the land.

ii) Preservation of Natural Areas: Protecting and preserving natural areas such as forests, wetlands, and wildlife habitats is crucial for conserving biodiversity, mitigating climate change, and maintaining ecosystem services.

iii) Promoting Agro-ecology**:** Sustainable land use planning encourages environmentally friendly and sustainable agricultural practices, such as organic farming and agro-forestry, that prioritize ecological balance and reduce environmental impacts.

iv) Urban Green Spaces: Incorporating green spaces within urban areas improves air quality, reduces the urban heat island effect, and enhances the overall livability of cities.

v) Mixed Land Use: Integrating mixed land use in urban planning fosters vibrant and inclusive communities, reduces transportation needs, and supports walkability and public transit use.

vi) Smart Growth and Compact Development: Smart growth strategies limit urban sprawl and encourage compact development, making efficient use of existing infrastructure and reducing land conversion.

vii) Community Engagement and Participation: Engaging local communities and stakeholders in land use planning processes ensures that diverse perspectives and needs are considered, building support for sustainable practices.

viii) Land Use Zoning and Regulations: Effective land use zoning and regulations guide development in alignment with sustainability goals, protecting sensitive areas and promoting sustainable practices.

ix) Climate Change Adaptation: Sustainable land use planning considers the potential impacts of climate change and incorporates climate-resilient strategies to ensure long-term viability.

x) Monitoring and Evaluation: Regular monitoring and evaluation of land use patterns and impacts allow for adaptive management, refining and improving sustainable strategies over time.

Sustainable land use planning and management aim to steer land use change in a direction that is environmentally responsible, socially equitable, and economically viable. By promoting conservation, sustainable agriculture, climate resilience, community engagement, and informed decision-making, these practices help mitigate the negative impacts of land use change while supporting a more sustainable and resilient future

3. STUDY AREA

Geographically, Itu LGA is situated in the coastal plains region of Nigeria and covers an area of approximately 606.10 square kilometres (Bassey *et al*, 2022). It shares borders with Uyo LGA to the east, Ikono LGA to the north, and Ibiono Ibom LGA to the northwest. The LGA's southern boundary is defined by the Cross River, which separates it from Akwa Ibom's neighbouring state, Cross River State. Itu LGA is home to a vibrant and diverse population comprising various ethnic groups, with the Ibibio being the dominant ethnic group. The Ibibio language is widely spoken in the area, although English is also commonly used for official and administrative purposes. The Population of Itu Local Government Area as at the last National Census in the year 2006 was 127,856 persons (NPC, 2006). Two seasons exist in the area; the rainy and dry season. The rainy season extends from April to October while the dry season extends from December to March. There is a variable extension of both seasons into the months of November and March.

Economically, Itu LGA is primarily agrarian, with agriculture serving as the mainstay of the local economy. The fertile soil and favourable climatic conditions in the region support the cultivation of crops such as cassava, yam, palm produce, plantains, and other cash crops. Fishing is also a significant economic activity due to the presence of water bodies, including the Cross River and numerous streams and creeks. Infrastructure development in Itu LGA has been progressing steadily, with improvements in road networks, electricity supply, and other essential amenities. The rapid increase in population and urbanization in Itu LGA has serious implications on landuse patterns. As the population grows, there is a higher demand for housing, infrastructure, and commercial spaces, leading to the conversion of agricultural or natural land into built-up areas.

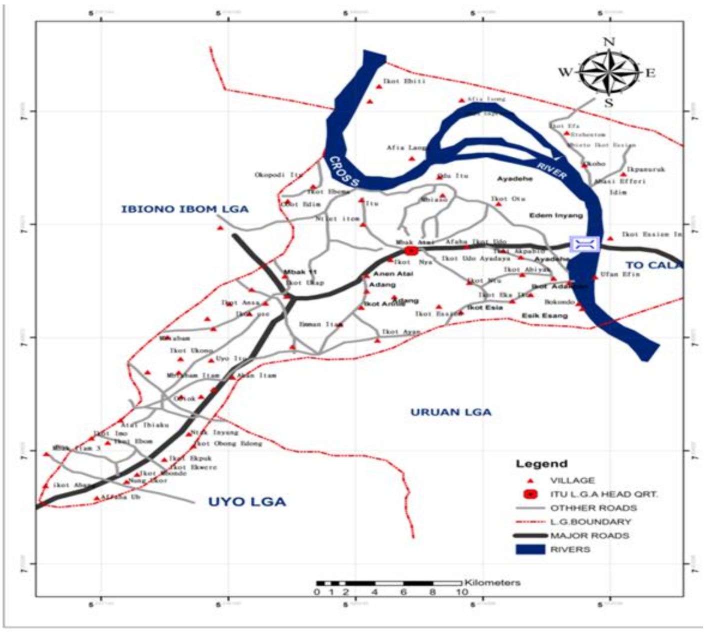

Fig. 1. Map of Itu Local Government Area.

4. RESEARCH METHODS

Landsat satellite imageries for the two epochs 1992 and 2022 were acquired from United States Geological Survey website. These data were used in determining the status and magnitude of each land use class. Pixels were chosen throughout the study area (image) after which ground truthing was done and compared with the classified map, which matched. Enough random pixels were checked and the percentage of accurate pixel gave a fairly good estimate of accuracy of the whole map. Other secondary data were sourced from journal articles and government gazettes. The study proposed a hypothesis related to land use pattern variation. To test this hypothesis, the Relative Shannon entropy or Kullback-Leibler divergence, was used to compare the land use patterns in 1992 and 2022 and determine if there was a significant difference between the two distributions.

5. Findings and Discussion of Findings.

The Land use/cover of the region was characterized into five classes; water bodies, wetlands, fallowed lands, cultivated lands and built up areas. The results of the analysis of land use change in Itu LGA over the period between 1992 and 2022 are discussed in this section.

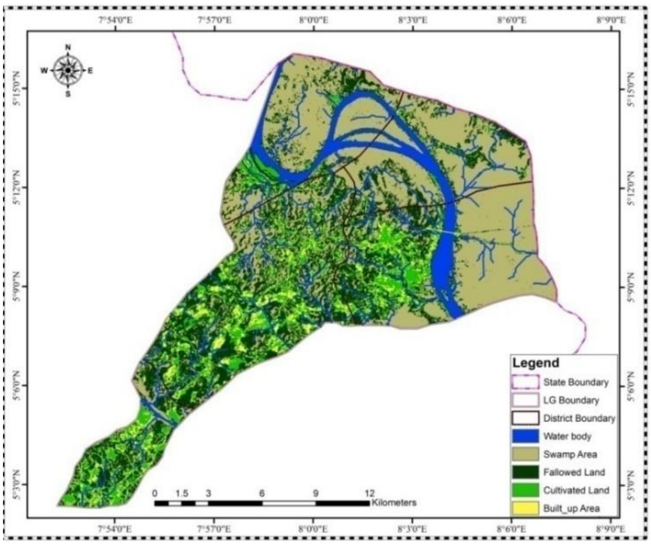

Fig. 2. Land use/Land Cover Classified Imagery of the Study Area in 1992

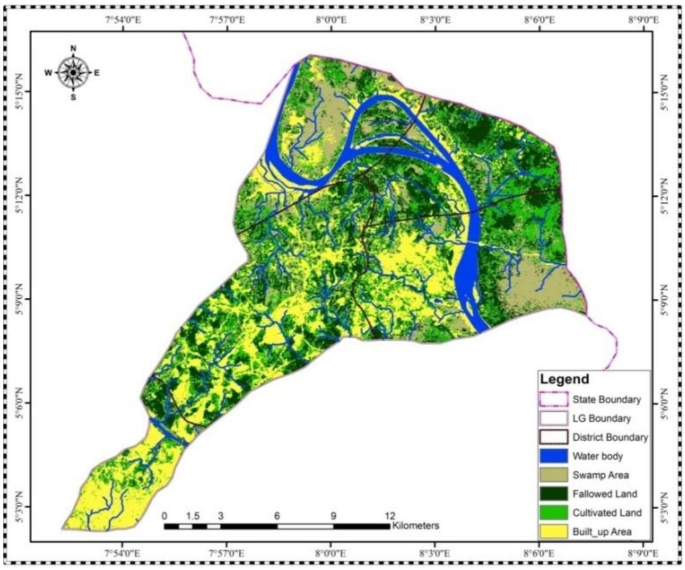

Fig. 3. Land use/Land Cover Classified Images of the Study Area in 2022

Table 1. Trend of Land Use Change in the Study Area, 1992 -2022

S/N	Land use Class	1992 (Km^2)	2022 (Km^2)	Magnitude of Change (in Km^2)	Rate of Change
1.	Water bodies	37.882	35.275	-2.607	-6.9%
2.	Wetlands	255.895	106.613	-149.282	-58.4%
3.	Fallowed Land	186.133	152.313	-33.820	-18.2%
4	Cultivated Land	83.763	151.707	67.944	81.1%
5.	Built-Up Area	42.427	160.132	117.705	277.2%

Source: Extracted from LandSat Imageries 1992 and 2022 of Itu Local Government Area.

The table above presents the magnitude and rate of change for each land use class between the years 1992 and 2022. The data provides valuable insights into the changes that have occurred in the land use distribution over the 30-year period.

a. Water Bodies

The data shows a small decline in water body area over the 30-year period, with a magnitude of change of -2.607 km². The rate of change of -6.9% indicates a slight reduction in water bodies, which might have occurred due to factors such as urbanization, land use conversion, or changes in water resources. The reduction in water body area may lead to habitat loss for aquatic species, affecting biodiversity and ecosystem health. Many water bodies serve as essential breeding grounds for various aquatic organisms, and their decline can disrupt the natural balance of the ecosystem. Additionally, a decrease in water bodies can affect water quality and the availability of freshwater resources, leading to potential water scarcity and increased vulnerability to pollution. Water bodies play a vital role in regulating local climates and microenvironments. Their decline can contribute to altered weather patterns, including temperature changes and reduced humidity levels.

b. Wetlands (Swamps)

The wetlands have experienced a significant decline in area over the 30 years, with a magnitude of change of -149.282 km². The rate of change of -58.4% indicates a substantial reduction in wetland area, likely due to factors such as land conversion, urban expansion, and agricultural development. Wetlands play a crucial role in maintaining ecological balance and providing valuable ecosystem services. Their decline can result in the loss of essential functions, such as water filtration, flood regulation, and carbon sequestration. The reduction of wetlands may also lead to increased vulnerability to flooding and other extreme weather events, as these areas act as natural buffers against such occurrences. Wetlands are effective carbon sinks, capturing and storing large amounts of carbon dioxide from the atmosphere. The loss of wetland area can result in increased greenhouse gas emissions, contributing to climate change.

c. Fallowed Land: Magnitude of Change:

Fallowed lands have also declined over the 30-year period, with a magnitude of change of -33.820 km². The rate of change of -18.2% suggests a decrease in fallowed land area, possibly due to increased cultivation or changes in agricultural practices. The decrease in fallowed land suggests increased cultivation or changes in agricultural practices. Farmers might be intensifying their agricultural activities to meet the growing demands for food and other agricultural products. While agricultural intensification can lead to higher yields and increased production, it may also put pressure on natural resources, such as soil and water, if not managed sustainably. Fallowed lands are beneficial for soil erosion control as they provide cover and reduce the risk of surface runoff during heavy rainfall. With fewer fallowed lands, there is an increased risk of soil erosion, leading to sedimentation of water bodies and potential water quality issues.

d. Cultivated Lands.

The data shows a significant increase in cultivated land area, with a magnitude of change of 67.944 km². The rate of change of 81.1% indicates a substantial growth in cultivated land, likely driven by agricultural expansion, intensification, or land use policy changes. The substantial growth in cultivated land area suggests efforts to increase agricultural production to meet the rising demand for food and other agricultural products. This expansion can contribute to improved agricultural productivity, food security, and the ability to support a growing population. Expanding cultivated land can lead to environmental challenges, including soil degradation, water pollution from agricultural runoff, and reduced biodiversity in converted areas. The use of intensive agricultural practices, such as increased fertilizer and pesticide use, may also contribute to water quality issues and ecological disruptions.

e. Built-up Areas.

The built-up area has experienced a remarkable expansion over the 30-year period, with a magnitude of change of 117.705 km². The rate of change of 277.7% indicates a significant increase in urban development and built-up areas, possibly due to urbanization, population growth, and economic activities. The substantial increase in built-up areas indicates rapid urbanization and population growth in the region. This urban expansion puts immense pressure on infrastructure, including transportation networks, housing, water supply, sanitation, and waste management systems. The demand for urban services and utilities may outpace the capacity to provide them, leading to infrastructure challenges and potential service gaps. The expansion of built-up areas often involves the conversion of natural landscapes, such as forests, wetlands, or agricultural lands, into impervious surfaces. This leads to reduced natural habitats, increased surface runoff, and decreased water infiltration, contributing to issues like urban heat island effect, water pollution, and decreased biodiversity. While urbanization can create opportunities for economic development and improved living standards, it also poses challenges related to infrastructure, environmental sustainability, social equity, and resource management. Effective urban planning, sustainable development practices, and a holistic approach to managing urban growth are crucial to address the implications of this significant increase in built-up areas and to create livable, resilient, and environmentally friendly environment.

6. Testing of Hypothesis

H_0: there is no significant variation in the Land use pattern of the study area.

The Relative Shannon entropy was used in testing the hypothesis.

To calculate the relative Shannon entropy between the land use distributions in 1992 and 2022, land use areas were converted into probabilities by dividing each area by the total land area for each year. Then, the formula for Shannon entropy was used to compare the two probability distributions.

a) Calculation of Landuse Probabilities for 1992

Total land area in 1992 = Water Body + Wetlands + Fallowed Land + Cultivated Land + Built-up Area Total land area in 1992 = 37.882 + 255.895 + 186.133 + 83.763 + 42.427 = 605.1 km²

i) Landuse Probabilities for 1992:

P(Water Body) = 37.882 / 605.1 ≈ 0.0625

P(Wetlands) = 255.895 / 605.1 ≈ 0.4227

P(Fallowed Land) = 186.133 / 605.1 ≈ 0.3076

P(Cultivated Land) = 83.763 / 605.1 ≈ 0.1384

P(Built-up Area) = 42.427 / 605.1 ≈ 0.0701

b) Calculation of Landuse Probabilities for 2022

Total land area in 2022 = Water Body + Wetlands + Fallowed Land + Cultivated Land + Built-up Area Total land area in 2022 = 35.275 + 106.613 + 152.313 + 151.707 + 160.132 = 605.04 km²

Probabilities for 2022:

P(Water Body) = 35.275 / 605.04 ≈ 0.0583,

P(Wetlands) = 106.613 / 605.04 ≈ 0.1761

P(Fallowed Land) = 152.313 / 605.04 ≈ 0.2517,

P(Cultivated Land) = 151.707 / 605.04 ≈ 0.2506,

P(Built-up Area) = 160.132 / 605.04 ≈ 0.2649

c) Calculation of Relative Shannon Entropy

Using the formula for Shannon entropy:

$H(P) = -\Sigma [P(x) * \log_2(P(x))]$,

where x represents each land use category.

Shannon Entropy for 1992 (H(P_1992)):

$H(P\_1992) = -[0.0625 * \log_2(0.0625)] - [0.4227 * \log_2(0.4227)] - [0.3076 * \log_2(0.3076)] - [0.1384 * \log_2(0.1384)] - [0.0701 * \log_2(0.0701)]$

$H(P\_1992) \approx 2.0758$ bits

Shannon Entropy for 2022 (H(P_2022)):

$H(P\_2022) = -[0.0583 * \log_2(0.0583)] - [0.1761 * \log_2(0.1761)] - [0.2517 * \log_2(0.2517)] - [0.2506 * \log_2(0.2506)] - [0.2649 * \log_2(0.2649)]$

$H(P\_2022) \approx 2.1512$ bits

d) Relative Shannon Entropy (KL Divergence)

Using the formula for relative Shannon entropy (KL divergence):

$D(P\_1992 \| P\_2022) = \Sigma [P\_1992(x) * \log_2(P\_1992(x) / P\_2022(x))]$,

where x represents each land use category.

$D(P\_1992 \| P\_2022) = [0.0625 * \log2(0.0625 / 0.0583)] + [0.4227 * \log2(0.4227 / 0.1761)] + [0.3076 * \log_2(0.3076 / 0.2517)] + [0.1384 * \log_2(0.1384 / 0.2506)] + [0.0701 * \log_2(0.0701 / 0.2649)]$

$D(P\_1992 \| P\_2022) \approx 0.6114$ bits

The calculated relative Shannon entropy value ($D(P\_1992 \| P\_2022) \approx 0.6114$ bits) indicates that there is a significant difference or divergence between the land use distributions in 1992 and 2022.

e) Decision

The Shannon entropy value ranges from 0 to $\log_2$ (N), where N is the number of years. In this case; the value of $\log_2(2)$ is exactly 1. Hence the value ranges from 0-1. A value of 0 indicates perfect certainty, meaning there is no variability in the land use pattern of the study area, while a higher value indicates more diversity in the land use distribution.

Since, $D(P\_1992 \| P\_2022) = 0.6114$ which is greater than 0.5,

The null hypothesis (H_0) was rejected and this affirmed that there was a significant variation in the land use pattern of the study area between 1992 and 2022.

This means that the two probability distributions representing land use patterns for these two years are not identical; there have been changes in the composition and spatial distribution of land use categories. The higher relative entropy value (0.6114 bits) affirms that the land use patterns have changed significantly over this period. The change could be attributed to various factors, such as urban expansion, change in agricultural practices, changes in land management practices, or environmental shifts.

7. Conclusion

The use of Shannon Entropy in this study allowed for a more objective and data-driven analysis of land use change, avoiding subjective biases and interpretations. It provided a solid foundation for the discussion of findings and the formulation of informed conclusions about the implications of land use change in Itu LGA. The application of Shannon Entropy as a measure of land use change in Itu Local Government Area (LGA) has proven to be highly apt and effective. The utilization of the Relative Shannon Entropy (RSE) index allowed for a comprehensive analysis of the shifting land use patterns over the three-decade study period.

The analysis of land use change in Itu LGA between the years 1992 and 2022 provides valuable insights into the dynamic nature of urban development and its impact on the environment and society. The data reveals notable shifts in land use patterns, with implications for ecosystems, biodiversity, agricultural productivity, and urbanization challenges. The test of the hypothesis confirmed that there has been a significant change in the land use pattern of the area in the past three decades. The decline in wetlands and water bodies raises concerns about habitat loss, water quality, and flood regulation. The expansion of built-up areas and cultivated lands indicate urbanization and intensification, which can lead to land degradation, habitat fragmentation, and increased resource demand. Additionally, the declines in fallowed lands do have negative impact on agricultural productivity and food security. These findings call for urgent intervention by Town Planners, policy makers and the Local Government Authorities.

8. Recommendations.

In order to halt the ongoing unguided land use changes that is being experienced in Itu Local Government Area, and to put the area on the path of sustainable physical development. The following recommendations have been made;

i) Preservation of Wetlands and Water Bodies: Given the observed decline in water bodies and wetlands, it is imperative to prioritize their conservation. The Establishment of protected areas and buffer zones around these ecosystems will safeguard them from encroachment and pollution.

ii) Adoption of Smart growth Strategies: With an increasing trend in built-up areas, smart urban planning strategies should be adopted to manage urban expansion effectively. Compact and mixed-use development should be encouraged to minimize the loss of agricultural and natural lands. The Promotion of green infrastructure, such as urban parks and green spaces will improve the urban environment and provide recreational opportunities.

iii) Promotion of Sustainable Agricultural Practices: As cultivated lands have expanded, it is crucial to promote sustainable agricultural practices. Farmers should be trained and supported on sustainable farming methods, including agro-forestry, crop rotation, and organic farming. The use of efficient irrigation techniques to conserve water resources should be enforced.

iv) Reforestation and Afforestation: To counter-balance the loss of fallowed lands and enhance the region's green cover, the implementation of reforestation and afforestation projects is advocated. Suitable areas for tree planting should be identified and the local communities should be involved in tree planting initiatives. Trees play a vital role in sequestering carbon, conserving soil, and supporting biodiversity.

v) Enactment of Land Use Zoning and Regulations: Land use zoning and regulations to guide development in a balanced manner should be developed and enforced. The Area Planning Authority should develop action area and local plans to guide the physical development of the Local Government areas. Areas for agriculture, residential, industrial, and conservation land uses should be earmarked. Development projects should be made to adhere to environmental impact assessments and sustainability guidelines.

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