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Land Use Land Cover Classification for Africa – A Case of The Republic of Ghana Using Systematic Review and Meta-Analysis

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Abstract
Examining the interaction between global climatic systems, biodiversity, and socioeconomic development depends on understanding Land Use and Land Cover (LULC) changes. Notwithstanding major Earth observation and remote sensing developments, Sub-Saharan Africa, including Ghana, remains underrepresented in LULC studies. Following PRISMA principles, this study fills this need by methodically examining LULC investigations carried out in Ghana between 2000 and 2024. This study examined spatiotemporal trends, environmental determinants, and methodological frameworks in LULC research as well as peer-reviewed literature closely. Particularly from MODIS and Landsat, remote sensing data became clear as indispensable instruments for tracking LULC changes, exposing inter-zonal fluctuations affected by urbanization, climatic variability, mining activity, and socioeconomic pressures, including poverty and population increase. Important issues found are land degradation, deforestation, soil erosion, and loss of biodiversity, combined with unsustainable farming methods and illicit mining. The results show the important part geospatial technology plays in monitoring LULC changes and guiding adaptive land management plans. Refining LULC models and supporting sustainable development initiatives through satellite data integration with local ground-based observations is advised. Achieving Ghana's Sustainable Development Goals (SDGs), especially in poverty reduction, sustainable cities, climate action, and biodiversity preservation, depend on addressing LULC problems. This study emphasizes the need for LULC research in directing policy formation and supporting sustainable resource management, therefore providing actionable insights for combining environmental preservation with socioeconomic development.

Keywords: Land Use and Land Cover Changes, Deforestation and Forest Degradation, Sustainable Land Management, Urbanization and Urban Sprawl, Biodiversity and Ecosystem Impacts, Remote Sensing and GIS Applications

1. Introduction

Changes in LULC are a significant worldwide environmental concern. This dilemma is especially pronounced in developing places such as Africa, where climate change exacerbates these alterations and impacts ecological systems (Barnieh et al., 2022). LULC changes are significant drivers of greenhouse gas emissions in Africa, underscoring the necessity for dependable monitoring and evaluation techniques (Namugize et al., 2018). In sub-Saharan Africa, agricultural expansion, propelled by population increase and economic development, constitutes the principal source of LULC changes (Mucova et al., 2018; Asare et al., 2021; Gbedzi et al., 2022). The conversion of natural vegetation to agriculture alters ecological balances, affecting biogeochemical cycles, biodiversity, soil stability, water quality, and ecosystem services (Houessou et al., 2013).

Ghana represents the overarching LULC trends observed across Africa. The nation has seen substantial alterations in its landscape, evidenced by a 3.7% reduction in the surface area of Lake Bosumtwi from 1986 to 2018, alongside extensive deforestation for agricultural, urban, and barren

land use (Asare et al., 2021). These alterations have significant ramifications across several industries. Environmental management encounters difficulties due to land degradation and deforestation, which exacerbate greenhouse gas emissions and water pollution (Ekumah et al., 2020; Al-Hamdan et al., 2017). Accelerated urbanization results in urban sprawl and the depletion of agricultural land, requiring strategic planning to mitigate habitat fragmentation (Asare et al., 2021; Gbedzi et al., 2022). Agriculture, the principal economic activity in Ghana, both influences and reacts to LULC changes, as farmland development supplants natural vegetation, while illicit mining compels agricultural practices into forested areas (Obodai et al., 2019; Basommi et al., 2015). Conservation initiatives encounter increasing challenges as agricultural and urban expansion lead to habitat fragmentation and degradation, jeopardizing biodiversity and ecosystem services (Gbedzi et al., 2022; Obahoundje et al., 2017).

Notwithstanding the crucial significance of precise LULC categorization for environmental monitoring, resource management, and sustainable development planning, Ghana encounters substantial obstacles in attaining dependable land cover mapping. Technical constraints are the primary significant impediment. Ongoing cloud cover, especially in the southern region and Eastern Guinean Forests, obstructs clear satellite data acquisition and diminishes categorization precision (Torbick et al., 2006; Obodai et al., 2019). Seasonal bush burning in the West Sudanian Savannah modifies vegetation attributes, resulting in temporal fluctuations in LULC mapping (Asare et al., 2021; Kumi et al., 2021). Intricate cocoa cultivation ecosystems that integrate agricultural lands, woodlands, and habitations provide distinct categorization difficulties (Donkor et al., 2022; Biney and Boakye, 2021).

Methodological limitations exacerbate these technological challenges. The spectral similarities among land cover categories, including built-up regions and bare soil, result in misclassification (Aniah et al., 2023; Gbedzi et al., 2022). The restricted availability of high-resolution imagery and ground truth data, especially in rural regions, diminishes classification accuracy. The dependence on irregular intervals for image acquisition, frequently due to cloud cover, undermines the reliability of LULC assessments (Kullo et al., 2021; Aniah et al., 2023). Moreover, fast urbanization, agricultural proliferation, and mining activities generate dynamic landscapes that complicate precise monitoring of LULC developments (Antwi et al., 2014; Boakye et al., 2019; Basommi et al., 2015).

A recent LULC study in Ghana identifies substantial deficiencies that hinder efficient land management and policy execution. Many studies concentrate on regional or national scales, neglecting local dynamics, particularly in sensitive regions such as the savannah ecological zone, which confront distinct environmental concerns necessitating tailored solutions (Obodai et al., 2019; Kumi et al., 2021). Mining impact evaluations are insufficiently incorporated into LULC studies, although their significant environmental repercussions (Asare et al., 2021). The restricted utilization of high-resolution imaging and inconsistent assessment of improved classification algorithms impede the detection of fine-scale modifications and obstruct methodological advancements (Boakye et al., 2019; Basommi et al., 2015).

The classification issues significantly impact Ghana's developmental trajectory. Inaccurate LULC data undermine land management plans and resource allocation choices (Abass et al., 2018; Ekumah et al., 2020). Misclassification conceals deforestation trends and patterns of biodiversity loss, obstructing climate change mitigation efforts and ecosystem conservation activities (Braimoh and Vlek, 2005; Coulter et al., 2016). In the absence of dependable LULC statistics, policymakers are deprived of the essential evidence required for successful sustainable development planning and environmental protection initiatives.

Confronting these problems necessitates a thorough study strategy that enhances both the comprehension and implementation of LULC categorization in Ghana. This study seeks to address significant knowledge deficiencies through five interrelated objectives. This study will evaluate the efficacy of traditional and sophisticated LULC categorization methods utilized in Ghana, analysing their advantages, drawbacks, and precision across various ecological regions. The project will examine spatiotemporal patterns of LULC changes, assessing transformation rates across ecological zones and the natural and anthropogenic factors influencing Ghana's landscapes. Third, it will integrate quantitative and qualitative data using meta-analysis to discern error patterns, optimal practices, and the efficacy of various data sources and methodologies. The project will assess the efficacy of land-use policies in incorporating LULC findings and analyses the congruence between research results and actual land management practices. Ultimately, it will provide a framework to enhance LULC research in Ghana by pinpointing priority study domains, suggesting methodological enhancements, and advocating for standardized strategies for policy integration. This study will establish a solid basis for enhancing LULC categorization techniques, guiding evidence-based policies, and promoting sustainable land management practices in Ghana. The study's thorough methodology tackles the pressing demand for precise, context-relevant LULC data that may inform successful environmental conservation and sustainable development efforts in Ghana and other African settings.

2. Data and Methods

2.1. Study Area

Ghana (Fig. 1), located along the Gulf of Guinea in West Africa, borders Togo, Côte d'Ivoire, and Burkina Faso. Covering over 23.85 million hectares between latitudes 6°00'N and 10°30'N, and longitudes 4°00'W and 2°00'E, it has approximately 57% arable land, highlighting its agricultural importance in the area (Botwe et al., 2012). The nation's strategic geographic position significantly influences environmental and economic trends throughout West Africa. Ghana is situated on the stable West African Craton and is categorized into four principal physiographic zones: the Volta Basin, Northern Plains, Ashanti-Kwahu Region, and Coastal Plains (Lemenkova, 2012). These regions facilitate a variety of economic endeavours, including agriculture,

mining, oil and gas exploration, and energy production. Ghana has tropical equatorial climate characteristics, with bimodal rainfall patterns in the south and unimodal patterns in the north, with average temperatures of 30°C (Botwe et al., 2012). Seasonal Harmattan winds and tropical marine air masses affect local weather, while climatic unpredictability increasingly poses problems to agricultural and water resource management (Asare-Nuamah et al., 2019; Isshaku et al., 2016; Asante and Amuakwa-Nuamah, 2015). Environmental issues, including land degradation, deforestation, pollution, and recurrent floods and droughts, are exacerbated by urban expansion and climate change (Cobbinah et al., 2017; UNDP, 2022). These dynamics underscore the necessity for cohesive solutions via sustainable urban design and climate-resilient agriculture (Ampadu, 2021; Asante and Amuakwa-Mensah, 2015).

The diverse physical and biological attributes of Ghana offer significant prospects for LULC research, facilitating the application of technology such as remote sensing to enhance policy-making that harmonizes economic development with environmental conservation.

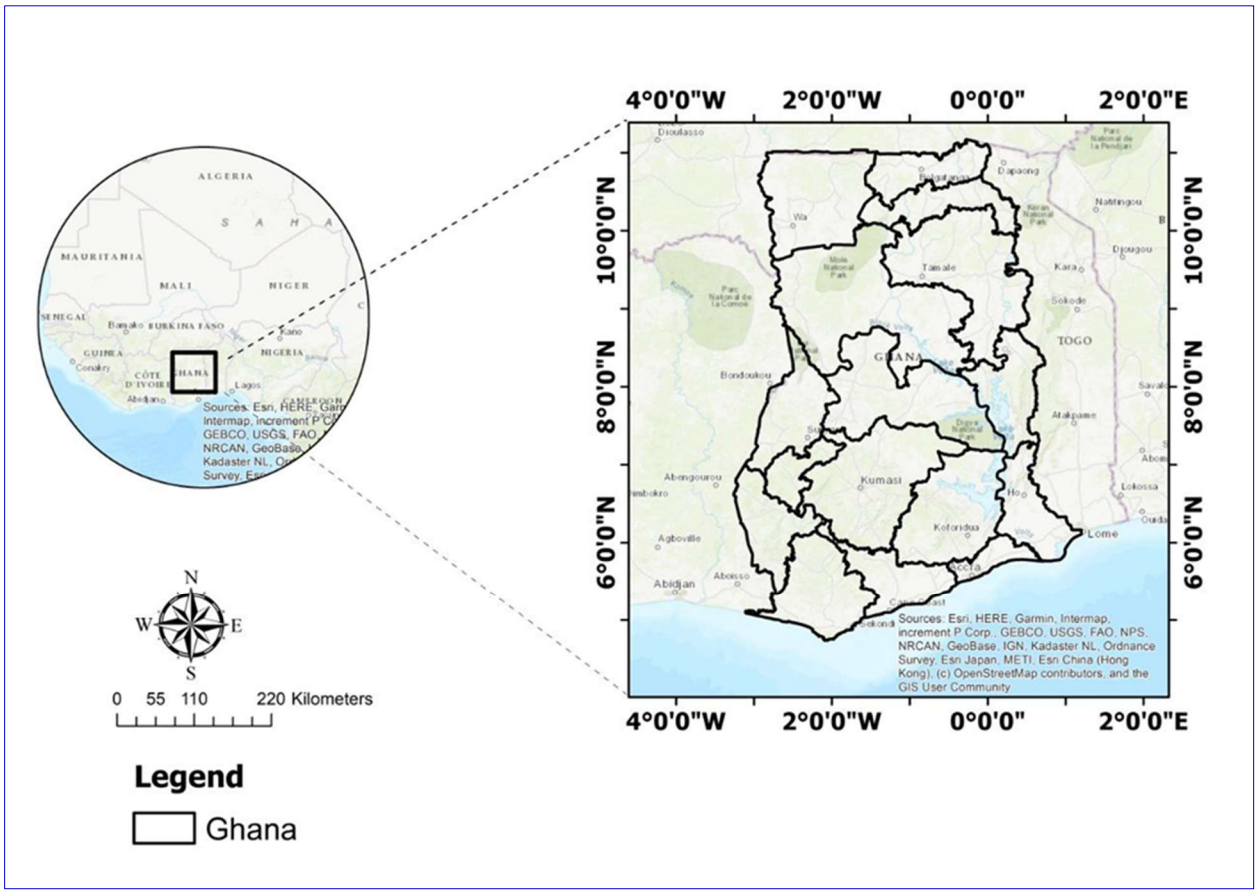

Fig.1. Map of the Ghana Republic

2.3. Literature Review

2.3.1. LULC in Ghana

Effective natural resource management policies depend on LULC studies; this is particularly true in areas experiencing notable socioeconomic and environmental change. Using satellite images and Geographic Information Systems (GIS), significant variations in LULC patterns have been found in Ghana, showing intricate linkages between human activities and environmental changes.

2.3.1.1. Trends in LULC

Primary forests have seen considerable degradation, often evolving into secondary forests. The Barekese watershed had a 43% reduction in closed forest cover from 1973 to 2000 (Biney and Boakye, 2021), whereas the Bosomtwe district lost 4,040 hectares of dense forest from 2002 to 2010 (Asare et al., 2021). The decrease in open forests has occurred, but at a more gradual pace. The Barekese watershed saw a 32% decline in open forest cover from 1973 to 2000 (Biney and Boakye, 2021), whereas the Tano Basin experienced a loss of open forest at a rate of 173.9 km² year from 1986 to 2020 (Aniah et al., 2023).

Agricultural land use has significantly increased, with Ghana's total agricultural area rising from 13% to 28% between 1975 and 2000 (Antwi et al., 2014). In the Bosomtwe area, agricultural land expanded by 380% from 1986 to 2002 (Asare et al., 2021). Urbanization has resulted in an increase in developed land, shown by the Tano Basin, where built-up areas grew by 1.5 km² per year from 1986 to 2020 (Aniah et al., 2023). Likewise, developed land in the Ashanti Region increased from 4.8% in 1990 to 24.8% in 2020 (Boakye et al., 2019; Abass et al., 2018; Asibey et al., 2020). Moreover, mining operations have significantly transformed land

utilization, especially in the Ankobra Basin, where mining proliferated substantially from 2008 to 2016 (Basommi et al., 2015; Basommi et al., 2016).

2.3.1.2. Drivers of LULC Changes

Multiple primary factors are affecting LULC alterations in Ghana. Accelerated population growth and urban migration heighten the demand for land for infrastructure, housing, and agriculture (Biney and Boakye, 2021; Kullo et al., 2021). Government programs like the Ghana Poverty Reduction Strategy (GPRS), although aimed at fostering economic growth, have inadvertently expedited land-use alterations (Kumi et al., 2021; Ekumah et al., 2020). The extraction of gold and other mineral resources has propelled mining growth, sometimes to the detriment of wooded areas (Yeboah et al., 2017; Braimoh and Vlek, 2005). Moreover, agricultural transitions, specifically the substitution of conventional crops like cocoa with high-yield alternatives like oil palm, have altered forested regions to satisfy food requirements (Coulter et al., 2016; Biney and Boakye, 2021). These elements jointly influence the dynamic and continuous alterations in Ghana's land use patterns.

2.3.1.3. Technologies and Classification Systems

Ghana has adopted advanced technology and categorization techniques to enhance LULC research. Satellite imagery, comprising data from Landsat and Sentinel-2, underpins LULC analysis, while GIS software facilitates processing and interpretation (Kumi et al., 2021; Abass et al., 2018). Advanced machine learning methods, including Random Forest (RF) and Support Vector Machines (SVM), are progressively employed to attain superior classification accuracy (Aniah et al., 2023; Yeboah et al., 2017). Standardized classification frameworks, such as the USGS Anderson Classification System, alongside tailored schemes suited to Ghana's distinct landscapes, are extensively utilized to guarantee consistency and relevance in LULC mapping (Kumi et al., 2021; Obodai et al., 2019). The technical and methodological developments are enhancing the accuracy and dependability of land use studies in Ghana.

2.3.1.4. Policy Recommendations and Implications

The documented changes in LULC in Ghana indicate a precarious equilibrium between environmental deterioration and social advancement. To alleviate adverse effects, several strategic measures are advised. Integrating sustainable practices into urban development, forestry, and agriculture can improve long-term environmental resilience (Appiah et al., 2017). Secondly, enhancing data collection and monitoring systems through the utilization of high-resolution satellite imagery and sophisticated classification algorithms can markedly improve the precision of LULC assessments (Aniah et al., 2023; Gbedzi et al., 2022). Third, promoting community engagement in land-use decision-making guarantees that policies correspond with local requirements and priorities (Amproche et al., 2020). Ultimately, aligning environmental and socioeconomic policies might mitigate unexpected repercussions and foster equitable growth (Ekumah et al., 2020).

LULC studies in Ghana highlight the intricate relationship between anthropogenic activity and environmental change. By utilizing new technology and tackling the fundamental causes of land-use change, Ghana may attain a sustainable balance between growth and conservation, ensuring that policy frameworks are consistent with long-term ecological and socioeconomic objectives.

2.3.2. Systematic Review and Meta-Analysis in Environmental Research

Especially in studies on LULC, systematic reviews and meta-analyses are crucial for integrating large amounts of knowledge. These methods provide thorough, open systems for assessing data, spotting trends, and filling in knowledge gaps, thereby improving understanding and directing policy decisions (Akopti et al., 2019; Slayi et al., 2024).

2.3.2.1. Role of Systematic Reviews in LULC Research

Methodical reviews function as systematic frameworks for discovering, assessing, and synthesizing information on certain study subjects. In Ghana's LULC research, these systematic reviews tackle essential priorities. Initially, by analysing previous research, scholars can pinpoint knowledge deficiencies such as insufficiently examined catalysts of change or particular land-use transformations that necessitate more inquiry (Akopti et al., 2019; Slayi et al., 2024). Secondly, these studies evaluate the efficacy of several techniques in alleviating land degradation, deforestation, and other detrimental effects, therefore promoting sustainable land management practices (Slayi et al., 2024). Ultimately, by integrating data from many research studies, systematic reviews produce evidence-based recommendations for tackling drivers of LULC change and enhancing land-use planning frameworks (Akopti et al., 2019). This meticulous methodology fortifies the basis for informed decision-making and policy formulation in Ghana's dynamic environment.

2.3.2.2. Contributions of Meta-Analyses to LULC Research

Meta-analyses augment systematic reviews by statistically consolidating data from several studies, yielding accurate insights into the magnitude and variability of LULC alterations. Meta-analyses, by aggregating data on processes like urban growth and deforestation, elucidate overarching tendencies that surpass individual case studies (Yeboah et al., 2017; Koranteng et al., 2020). Moreover, these studies reveal localized discrepancies in LULC causes and effects, enhancing comprehension of regional dynamics and context-specific issues (Biney and Boakye, 2021; Akopti et al., 2019). This quantitative synthesis enhances the empirical foundation for policymaking and targeted actions in Ghana's dynamic environment.

2.3.2.3. Applications in Global Environmental and Land Use Research

Systematic reviews and meta-analyses have greatly enhanced our comprehension of the correlation between land use and environmental dynamics. Ferraguti et al. (2023) synthesized 654 studies illustrating how land use intensity, especially in altered landscapes, directly affects disease prevalence, significantly impacting both human and avian malaria transmission. Dias et al. (2022) emphasized the dual effects of urbanization, demonstrating its contribution to economic

advancement while concurrently intensifying environmental issues such as urban heat islands and desertification. Akbari et al. (2018) provide additional insights, revealing that economic considerations (e.g., agricultural land values), demographic pressures (e.g., urban population increase), and meteorological variables are significant interrelated drivers of land use change. These extensive studies highlight the intricate relationship between human activities and natural systems, offering essential evidence for sustainable land management practices.

2.3.2.4. Addressing Land Degradation and Agricultural Suitability

Numerous recent studies have offered significant insights into sustainable land management strategies and evaluation approaches. Slayi et al. (2024) highlighted principal factors contributing to rangeland degradation in Sub-Saharan Africa, including deforestation, soil erosion, and socioeconomic pressures, while endorsing rotational grazing and soil conservation as efficacious mitigation techniques. Their findings underscore the necessity of employing these pragmatic strategies to mitigate environmental deterioration. Akpoti et al. (2019) conducted a critical analysis of land suitability studies, emphasizing notable deficiencies in the incorporation of socioeconomic elements and climate change considerations. Their research presents a hybrid evaluation methodology that integrates many assessment factors to improve the sustainability and precision of land suitability studies. Collectively, these studies enhance the knowledge of land management difficulties and provide pragmatic answers for attaining environmental sustainability.

2.3.2.5. Challenges and Limitations

Although systematic reviews and meta-analyses provide strong evidence, they have problems like selection bias, data heterogeneity, and quality variance (Ferraguti et al., 2023; Dias et al., 2022). Dealing with them calls for both thorough approaches and open reporting.

2.3.2.6. Advancing LULC Research in Ghana

Systematic reviews and meta-analyses have demonstrated their significance in tackling Ghana's LULC issues. These extensive research methodologies provide a profound comprehension of land-use dynamics by integrating various data sources, uncovering essential patterns, and determining effective strategies for sustainable land management (Asare-Nuamah et al., 2019; Obodai et al., 2019). By incorporating environmental and socioeconomic variables into policy frameworks, these techniques facilitate more comprehensive and evidence-based decision-making.

The utilization of systematic reviews and meta-analyses in Ghana's LULC study markedly amplifies the breadth and significance of investigations. These methodologies integrate data from many sources, elucidate emerging patterns, and offer actionable insights for sustainable development planning (Koranteng et al., 2020; Yeboah et al., 2017). Consequently, they enhance Ghana's capacity to reconcile ecological preservation with socioeconomic progress, guaranteeing that land-use plans are both scientifically substantiated and pragmatically viable for enduring environmental and economic resilience.

2.3.3. Knowledge Gaps and Challenges

Though data sources, approaches, and scales prevent the comparability and synthesis of results, LULC research in Ghana has evolved dramatically. These difficulties call into doubt the accuracy of research and its applicability for sustainable land management and policy development.

2.3.3.1. Inconsistencies in Data Sources

The methodological techniques in Ghana's LULC studies demonstrate significant variances that affect study findings. A primary challenge arises from discrepancies in satellite data sources, where variations in sensor types (e.g., Landsat TM, ETM+, and Sentinel-2) and spatial resolutions impact classification accuracy and the comparability of results, posing significant issues for longitudinal studies (Obodai et al., 2019; Koranteng et al., 2020; Asare et al., 2021; Basommi et al., 2015). Although Landsat imagery is extensively employed, these technological discrepancies provide challenges for integrating findings across many research initiatives.

Moreover, there is considerable heterogeneity in the integration of supplementary datasets, since research utilizes diverse combinations of topographic maps, transportation networks, and administrative borders to enhance their analyses (Kumi et al., 2021; Biney and Boakye, 2021). The discrepancy in supplemental data utilization adversely affects the geographical representation of results and complicates the standardization of LULC classification procedures, hence hindering cross-study comparisons. The methodological discrepancies underscore the necessity for more consistency in data sources and processing methods to improve the credibility and comparability of LULC research in Ghana.

2.3.3.2. Variability in Methods

The study on LULC in Ghana encounters considerable methodological discrepancies that impede comparison. Although the USGS Anderson categorization System provides a standardized framework, other research utilizes tailored or Ghana-specific categorization methodologies (Asare et al., 2021; Biney and Boakye, 2021). The disparity in classification methods poses significant obstacles to integrating data across various research and restricts the capacity for thorough national-level evaluations.

The subject exhibits a lack of consensus about analytical methodologies, as researchers employ several techniques such as Maximum Likelihood Classification (MLC), Random Forest (RF), Support Vector Machine (SVM), and Artificial Neural Networks (ANN) (Obodai et al., 2019; Yeboah et al., 2017). This methodological diversity creates ambiguity in categorization precision and hinders attempts to amalgamate or authenticate findings across research. The lack of established procedures for categorization systems and analytical methodologies highlights the necessity for improved methodological cooperation across Ghana's LULC research community to augment the reliability and comparability of results.

2.3.3.3. Challenges in Spatial and Temporal Scales

The regional and temporal heterogeneity in Ghana's LULC studies poses considerable hurdles for achieving a thorough

understanding. Research varies significantly in geographic breadth, from regional studies of mining effects to comprehensive national evaluations of deforestation patterns (Asare-Nuamah et al., 2019; Koranteng et al., 2020). This multi-scale methodology offers essential context-specific insights; yet, the absence of methodological consistency across spatial scales constrains researchers' capacity to generalize findings or identify cohesive national trends.

Temporal discrepancies exacerbate LULC analysis, since research utilizes significantly varied timeframes, ranging from single-year snapshots to decadal comparisons (Asare et al., 2021; Nedd et al., 2021). This temporal variability conceals long-term land change trajectories and complicates the differentiation between short-term variations and enduring transformation patterns. The interplay of these geographical and temporal disparities generates significant obstacles to the synthesis of information within Ghana's LULC research domain, underscoring the necessity for more coordinated study designs that enable cross-scale comparisons while preserving local relevance.

2.3.3.4. Recommendations for Standardization

To enhance LULC research in Ghana and rectify current discrepancies, the following measures are suggested. Initially, establishing a consistent categorization method that integrates local land use attributes while conforming to international standards will markedly enhance comparability among research (Kumi et al., 2021; Nedd et al., 2021). This hybrid methodology would preserve local significance while facilitating regional and global comparisons. Secondly, researchers have to utilize uniform satellite data sources, such as Landsat or Sentinel-2, with explicitly stated geographical and temporal criteria (Obodai et al., 2019; Basommi et al., 2015). The integration of primary data sources would improve classification precision and enable longitudinal analysis. Third, formulating best practice recommendations for algorithm selection tailored to individual study aims and data attributes will enhance methodological consistency (Yeboah et al., 2017; Coutler et al., 2016). These recommendations should specify the appropriate circumstances for employing Maximum Likelihood Classification, Random Forest, or alternative machine learning methodologies. Fourth, standardizing geographical resolutions and temporal research periods will provide improved result aggregation and more dependable detection of long-term trends (Asare-Nuamah et al., 2019). This entails defining minimum mapping units and uniform periods for change detection. Ultimately, establishing communal archives for data and procedures will diminish redundant efforts while enhancing research quality through collaborative openness (Kumi et al., 2021; Nedd et al., 2021). These platforms may encompass benchmark datasets, validation methodologies, and defined reporting formats. Rectifying existing discrepancies in data sources, techniques, and scales is essential for the progression of LULC research in Ghana. Executing these proposals would produce more dependable outcomes, facilitate comprehensive evaluations of land use patterns, and guide evidence-based decisions. These initiatives are crucial for attaining sustainable land management and advancing Ghana's overarching environmental and socioeconomic development objectives. The implementation of these standards and collaboration platforms will not only improve individual studies but also foster a more integrated research ecosystem capable of tackling Ghana's intricate land use concerns.

2.4. Study Design

2.4.1. Systematic Review Approach

Based on recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), the methodical review carried out in this study followed Slayi et al. (2024). The approach for choosing studies was carefully described using the PRISMA framework, therefore guaranteeing a systematic and open review process. Furthermore, used to improve the rigor and clarity of the review was a completed PRISMA checklist. The study was not recorded in a publicly available database; hence, we aimed to uphold the best standards of systematic review technique, even if, as past studies (Slayi et al., 2024) demonstrate, using the PRISMA framework improves the clarity, precision, and repeatability of the research process. Two main steps comprised the review process: the methodical identification and selection of pertinent literature, and the thorough management and analysis of data taken from the included research. This rigorous methodology guaranteed a thorough review of the data and created a strong basis for future studies to copy and build upon the conclusions. Fig. 2 shows a flowchart illustrating the research technique, including identification, screening, eligibility, and study inclusion, thereby delineating the phases of the review process.

2.4.2. Relevance and Current State of the Investigated Topic

Finding and evaluating studies consistent with the Population, Exposure, and Outcomes (PEO) paradigm as described by Bettany-Saltikov (2010) was the main goal of this effort. Examining the relevance of the topic and catching the modern state of research in this field depends on this basic step. Careful development of eligibility criteria guarantees the inclusion of highly relevant papers for the research emphasis.

The study concentrated especially on studies on LULC categorization on the African continent. Understanding the consequences of LULC changes in areas where human populations, ecosystems, and cattle are key parts of local economies, and food security depends on this spatial scale. Emphasizing important causes of LULC changes like urbanization and infrastructure, mining operations, agricultural output, climatic circumstances, and issues of land tenure, the exposure criterion stresses that selected studies needed to report on results directly addressing the effects of LULC dynamics on land production. This covered effects on grazing capacity, animal health, and the way of life of societies depending on these ecosystems. Studies that fell short of these standards were eliminated to preserve the review's relevance and emphasis. For instance, studies outside of the African setting or focused just on crop cultivation were excluded. This careful selection approach guaranteed that the assessment focused on important concerns in the Sub-Saharan African setting, an area most impacted by the drivers and effects of LULC changes.

Following these standards improves the relevance and accuracy of the review. It also offers insightful analysis of the present level of knowledge on the drivers and effects of LULC changes in Sub-Saharan Africa, therefore benefiting legislators, scholars, and practitioners of sustainable land management.

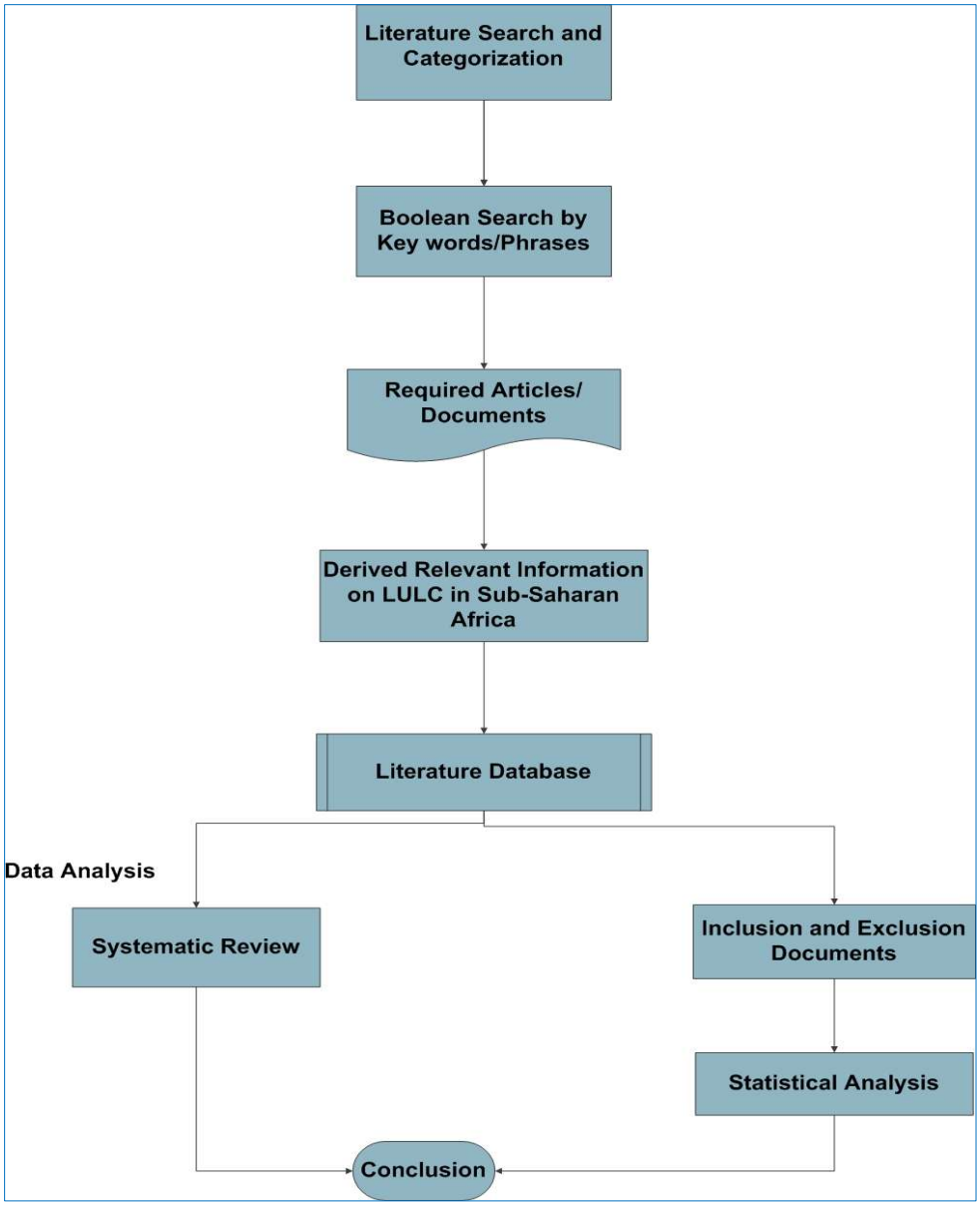

Fig. 2. Literature review building, article categorization, and data analysis were adopted in this study

2.4.3. Historical Literature Search

Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria, a historical literature review was undertaken, guaranteeing a methodical and open approach. 87 out of 745 studies from interdisciplinary academic databases and websites, including Scopus, Web of Science, ScienceDirect, African Journals Online (AJOL), Academia.edu, Google Scholar, and ResearchGate, were included in the review. These sites helped to identify academic publications on the factors influencing LULC changes in Sub-Saharan Africa.

2.4.3.1. Search Strategy and Framework

The search approach was directed by the Population, Exposure, and Outcomes (PEO) paradigm. Important search terms were "LULC classification"; "LULC classification in Africa"; " LULC classification in the Republic of Ghana."; Search criteria limited results to peer-reviewed journal articles, conference publications, book chapters, and English-published review papers dated 2000 to 2024. Among pertinent fields were environmental science, social sciences, and agricultural and biological sciences.

2.4.3.2. Screening and Inclusion Process

Mendeley reference management software (v1.19.8) helped to arrange and screen results. The procedure consisted of first screening titles and abstracts against preset inclusion and exclusion criteria. Full-text evaluation for relevance, with an eye on research on how LULC changes affect ecosystem biodiversity in Ghana and Sub-Saharan Africa.

2.4.3.3. Data Extraction and Quality Assessment

Important anthropogenic and climatic factors of LULC variations were found: Gbedzi et al. (2022); Obodai et al. (2019); Basommi et al. (2015, 2016); Awotwi et al. (2018); Obahoundje et al. (2017); Torbick et al. (2006); Akpoti et al. (2016). Ouedraogo et al. (2010); Lefulebe et al. (2022); Biney and Boakye (2021); Kullo et al. (2021); Abass et al. (2018); Adjei et al. (2014); Adjei et al. (2019). Practices such as shifting farming, overgrazing, and unsustainable pesticide use (Fritz et al., 2010; Kiptala et al., 2013; Kouassi et al., 2021) overexploited Vegetation and Soil Degradation.

2.4.3.4. Mitigation Strategies

Strengthening land tenure rights; promoting alternative livelihoods and poverty eradication; implementing nature-based solutions and smart agricultural practices (Barnieh et al., 2022; Al-Hamdan et al., 2017).

2.4.3.5. Visualization of Trends

Reflecting the growing scholarly interest in LULC alterations and mitigating techniques in recent years, a line graph in Fig. 3 shows trends in peer-reviewed publications on LULC in Ghana, Sub-Saharan Africa, and other African nations. This historical study provides an insightful analysis of important causes, effects, and mitigating methods for LULC changes in Sub-Saharan Africa, therefore guiding sustainable land management and policy development.

2.4.4. Inclusion and Exclusion Criteria

Table 1 delineates the stringent inclusion and exclusion criteria established to guarantee the pertinence and quality of the chosen research. The screening method included numerous essential factors: The review was limited to articles in the English language, reflecting the study team's linguistic capabilities. The geographic scope was intentionally concentrated on LULC categorization studies undertaken in Ghana, Sub-Saharan Africa (SSA), and other African settings. This geographical uniqueness was preserved by deliberately rejecting studies from non-African sites, so guaranteeing the conclusions are immediately relevant to the African setting under examination. The methodological selections aimed to provide a cohesive, contextually pertinent evidence base while adhering to the practical constraints of the research team's capacities.

2.4.4.1. Accessibility and Limitations

The present study's dependence on entirely available literature imposed many constraints on the investigation. Access constraints significantly precluded the inclusion of several pertinent studies, despite their potential contributions to the conclusions. Although the review of existing abstracts and keywords using academic databases yielded limited insights into these inaccessible publications, this method could not substitute for the absence of full-text analysis.

This constraint notably hindered the study's capacity to integrate many methodological techniques and thematic viewpoints (Slayi et al., 2024).

Future research endeavours will greatly benefit from enhanced worldwide access to academic publications, facilitating more thorough literature assessments and improving the representativeness of findings. These accessibility enhancements should alleviate existing limitations in synthesizing the whole array of knowledge about LULC categorization in African contexts.

2.4.4.2. Scope of Review

The review concentrated on research looking at the causes and effects of LULC variations in different countries of SSA. Studies just addressing agriculture, climatic conditions, mining, or urban development without clear LULC involvement were omitted to preserve this emphasis. Since LULC interacts with social, environmental, and financial aspects, it has become very important.

2.4.4.3. Sources and Literature Types

Peer-reviewed journal papers, conference proceedings, book chapters, and review papers took front stage in the review. Gray literature, that is, reports, theses, was eliminated unless it provided significant empirical evidence to guarantee methodological rigor.

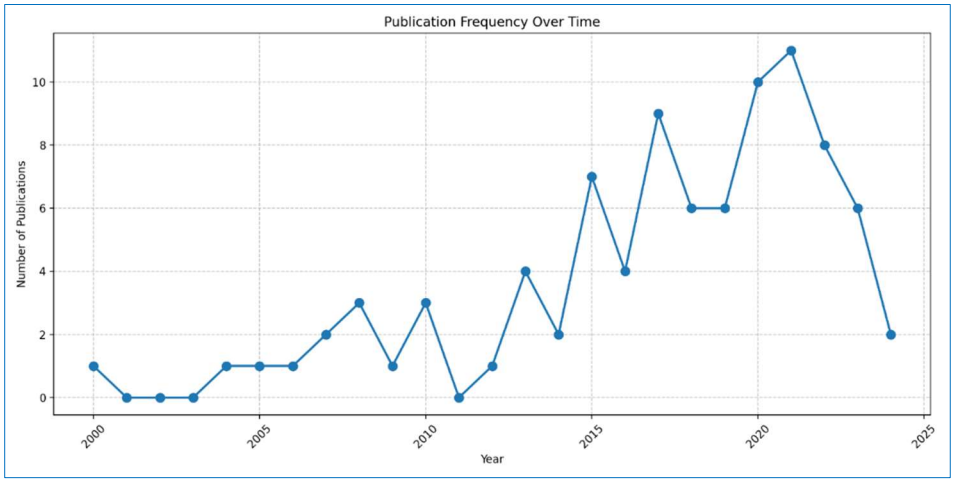

Fig. 3. The Chart displays the frequency distribution of articles over a specific period. The line represents the number of articles published in each year, making it easy to identify trends and peak publication years

Table 1. Inclusion and Exclusion Criteria for the Review Articles in the Order of Selection

Criteria	Included	Excluded	Justification
Language use	English	All other languages	To improve clarity, and by the author's choice
Country or location of study	Ghana, Sub-Saharan Africa, and pertinent African studies	Studies not about Africa	To align with the study's goal
Article availability	Comprehensively accessible publications utilizing the Web of Science, Scopus, Science Direct, African Journals Online, Google Scholar, Academia.edu, and ResearchGate platforms	Article unavailable	To accurately reference the authors
Date of publication	Articles published between the years (2000-2024)	1999 and below	To have the current contemporary perspective on LULC classification in Africa
Research focus	Studies that included LULC classification	Studies focusing solely on agriculture, mining, urban sprawl, and climate change	To be in line with the focus of the study
Type of article	Peer-reviewed research journal articles, conference papers, book chapters, and review papers	Gray literature, including reports and theses, unless they provide substantial information about the subject matter	To increase the validity of the research investigations

2.4.4.4. Emphasis on methodological approaches

Studies using Geographic Information Systems (GIS) methods and remote sensing data received great emphasis. These approaches are crucial for precisely evaluating LULC changes, supplying spatially explicit, high-quality data for analysis of LULC dynamics in SSA. This targeted strategy guarantees the evaluation stays strong, methodologically sound, and relevant to the knowledge of LULC causes and impacts in the African setting.

2.4.5. Data Analysis

The study utilized a theme analysis method to systematically discover and analyses recurring patterns in the evaluated material. This methodological framework facilitated a thorough assessment of three principal dimensions: (1) the primary determinants affecting LULC alterations, encompassing socioeconomic, environmental, and policy-related elements; (2) the resultant effects of LULC modifications on land productivity and ecosystem services; and (3) the relative efficacy of diverse mitigation strategies employed to tackle LULC-related issues. The organized analytical method enabled the research to combine varied data and derive significant conclusions on the intricate dynamics of land use change in the examined contexts.

2.4.5.1. Co-occurrence network and link analysis

Link analysis and co-occurrence network construction were used to investigate the interactions across knowledge areas even more. Using language taken from the abstracts of the chosen publications, this method as described by Slayi et al. (2024) Important features of this study included: the connections between terms in the network show linkages between knowledge areas; the size of labels and circles representing terms in the network reflects their relative relevance depending on their frequency throughout the studies. Terms found near one another in the network indicated stronger relationships.

2.4.5.2. Types of data and analytical techniques

The study included a diverse range of data sources, such as land cover classifications, spatial resolution measurements, and classification accuracy evaluations. The study utilized and critically assessed various advanced methodologies for LULC classification: (1) conventional unsupervised and supervised classification methods, (2) modern machine learning algorithms, and (3) state-of-the-art deep learning and hybrid models. Each methodological technique was subjected to thorough evaluation to ascertain its efficacy in tackling specific LULC difficulties, hence assuring the validity and relevance of the findings to wider LULC research contexts. This systematic evaluation approach enabled a detailed comprehension of the intricate interactions among driving forces, environmental repercussions, and analytical methods employed in the LULC dynamics study. The multi-method approach enabled a comparative investigation of the strengths and limits of multiple methodologies across diverse land cover scenarios, providing new insights into the area of geospatial analysis.

3. Results and Discussion

3.1. Overview of Selected Studies

With an eye toward Sub-Saharan Africa specifically, the methodical study of LULCC dynamics in Africa reveals a complex interaction of elements. Population increases, human activity, poor government systems, wars, limited resources, and climatic variability are among the main forces.

These components interact in diverse biophysical and socioeconomic settings, therefore posing different difficulties and opportunities in different areas. This review draws on extensive research spanning multiple countries and regions, covering Africa (Fritz et al., 2010; Midekisa et al., 2017; Mayaux et al., 2004; Vancutsem et al., 2013), East Africa (Berakhi et al., 2015), Sub-Saharan Africa (Cecchi et al., 2008; Yangouliba et al., 2023; Barnieh et al., 2020), and specific nations such as Burkina Faso (Ouedraogo et al., 2010; Zoungrana et al., 2015), Kenya (Munga et al., 2009), South Africa (Fairbanks et al., 2000; Musetsho et al., 2021; Cloete et al., 2024; Lefulebe et al., 2022), Côte d'Ivoire (Kouassi et al., 2021), Benin (Padonou et al., 2017; Houessou et al., 2013), Ethiopia (Kindu et al., 2013), Central Africa (Basnet and Vodacek, 2015), Togo (Akodewou et al., 2020), and Ghana (Hou et al., 2020; Appiah et al., 2015; Kusimi, 2008; Awotwi et al., 2018; Boakye et al., 2008; Hackman et

al., 2017; Stow et al., 2007; Pabi, 2007; Toure et al., 2020; Asibey et al., 2020; Larbi, 2023; Baidoo et al., 2023; Shih et al., 2015; Ampim et al., 2021; Addae et al., 2021). Particularly, Ghana is the focus of this study; a thorough study of the research scene compiled in Fig. 4 offers a general picture of LULC investigations throughout Africa.

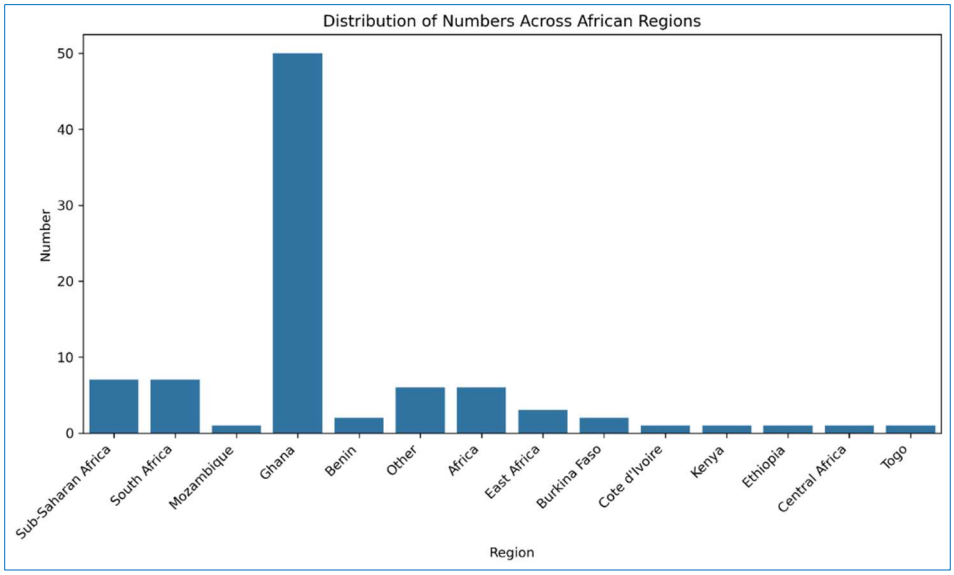

Fig. 4. The Chart above shows the distribution of numbers across the African regions

3.1.1. Research Landscape on LULCC in Ghana (2000–2024)

3.1.1.1. Spatial distribution of studies

Research on LULCC in Ghana has been undertaken at many geographical scales, illustrating the nation's varied ecological and socioeconomic environments. Nationally, extensive research has examined LULC change trends throughout Ghana (Barnieh et al., 2020; Barnieh et al., 2022; Ampim et al., 2021; Pabi, 2007; Huo et al., 2020).

Regional investigations have concentrated on significant areas, including the Ashanti Region, specifically Kumasi and its vicinity (Abass et al., 2018; Asibey et al., 2020; Kullo et al., 2021); the Western Region (Biney and Boakye, 2021; Kusimi, 2008; Obodai et al., 2019); and Northern Ghana (Aniah et al., 2023; Braimoh and Vlek, 2005), with the Upper West Region represented by Basommi et al. (2016) research. Additional regions, such as Greater Accra, Eastern, and Central, have also been analyzed (Addae and Oppelt, 2019; Coutler et al., 2016; Ekumah et al., 2020; Shih et al., 2015; Stow et al., 2007).

Localized studies have focused on specific districts such as Bosumtwi (Adjei et al., 2014; Asare et al., 2021), Asutifi North (Gbedzi et al., 2022), and Kintampo (Koranteng et al., 2020), whereas metropolitan analyses have examined major urban centers including Accra and Kumasi (Abass et al., 2019; Addae and Oppelt, 2019; Toure et al., 2020). Hydrological research has investigated significant river basins, including the Odaw (Ackom et al., 2020), Tano (Larbi, 2023), and Pra River basins (Awotwi et al., 2018; Boakye et al., 2019). A supplementary targeted study has examined ecologically vital regions, such as the Juaboso-Bia cocoa landscape (Donkor et al., 2020) and the Barekese catchment (Boakye et al., 2008). This multi-scale study portfolio offers extensive analysis of Ghana's diverse landscapes, highlighting the spatial variability of land use changes throughout the nation.

3.1.1.2. LULCC classification methods

The classification of LULC in Ghana has utilized several remote sensing and GIS techniques, demonstrating technical progress in the discipline. The Maximum Likelihood Classifier (MLC) is the leading supervised classification method, extensively used for its dependability (Asare et al., 2021; Kumi et al., 2021). Spectral angle mapping has often been employed, especially in research examining certain land cover attributes (Awotwi et al., 2018; Boakye et al., 2008). In recent years, there has been an increasing acceptance of object-based categorization methods, which provide benefits in processing high-resolution images (Ampim et al., 2021; Shih et al., 2015; Tahiru et al., 2020).

In addition to these fundamental techniques, researchers have employed several specialized methods, including: (1) visual image interpretation for ground truth validation (Boakye et al., 2008), (2) change detection algorithms to quantify land cover transitions (Amproche et al., 2020; Donkor et al., 2022), (3) Markov Cellular Automaton modelling for predictive analysis (Aniah et al., 2023), and (4) intensity analysis for thorough examination of change patterns (Ekumah et al., 2020). This methodological variation illustrates the field's adaptability to technical advancements and the intricate demands of LULC analysis in Ghana's diverse geographies.

3.1.1.3. General characteristics and key findings

Research on LULCC in Ghana has predominantly utilized multi-temporal Landsat images, employing diverse sensor technologies and geographic resolutions to examine temporal landscape transitions. The study uncovers several interrelated variables contributing to these changes, with population

increase and urbanization being prominent influences. With the expansion of metropolitan areas, agricultural and forest lands are progressively transformed into developed settings, especially in peri-urban regions where urban sprawl encroaches on adjacent natural landscapes (Obodai et al., 2019; Kumi et al., 2021).

Agricultural growth is the primary source of deforestation, with commercial food crop production significantly contributing to forest degradation nationwide. The shift from conventional farming techniques to more intensive agricultural operations has expedited this alteration in land cover (Coutler et al., 2016; Basommi et al., 2015). Mining operations, both legitimate and illicit, have significantly transformed Ghana's landscapes, with surface mining methods resulting in extensive soil degradation and pervasive water contamination. The environmental consequences of these extractive practices have been more apparent in recent years.

Socioeconomic variables significantly influence land use decisions, as economic incentives, land tenure systems, and government policies jointly affect land conversion patterns (Awotwi et al., 2018). Human-induced alterations have resulted in considerable environmental repercussions, encompassing biodiversity decline due to deforestation, habitat fragmentation, and heightened soil erosion. Water supplies are being threatened by pollution from several sources, such as urban runoff, mining activities, and agricultural practices. Moreover, land degradation significantly contributes to greenhouse gas emissions, intensifying the effects of climate change.

The aggregated results from this research underscore the intricate relationship between human activities and environmental systems in Ghana. They emphasize the pressing necessity for comprehensive land use regulations that tackle both the socioeconomic catalysts of change and their environmental repercussions. Effective plans must reconcile development objectives with sustainable land management approaches to address these complex difficulties and guarantee long-term environmental sustainability.

3.2. Methodological approaches

3.2.1. Remote Sensing Data Acquisition and Pre-processing

The efficacy of LULCC analysis in Ghana is significantly contingent upon the selection of suitable data and the use of stringent preparation techniques. Landsat imagery is the most prevalent data source owing to its distinctive advantages: extensive temporal coverage (since 1972), moderate spatial resolution (30 m), and economic efficiency. Researchers frequently employ various Landsat sensor generations, namely Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+), and Operational Land Imager (OLI), chosen according to particular study objectives and temporal needs (Asare et al., 2021; Kumi et al., 2021; Obodai et al., 2019).

In regions characterized by intricate land cover patterns or necessitating greater information, high-resolution commercial satellite imagery, such as QuickBird, has demonstrated its use, although at elevated prices (Aniah et al., 2023; Stow et al., 2007). These datasets are especially valuable for urban studies or diverse landscapes where Landsat's resolution may be inadequate.

The preprocessing pipeline is vital for maintaining data quality and comprises several key steps: radiometric correction for sensor calibration and atmospheric influences, geometric correction to eliminate distortions, and accurate georeferencing for precise spatial analysis (Antwi et al., 2014; Gbedzi et al., 2022; Kullo et al., 2021). These standardized preprocessing protocols mitigate mistakes that may spread through later analytical phases while maintaining comparability across various investigations and temporal contexts. The selection of particular preprocessing techniques frequently hinges on research aims, with advanced atmospheric correction methods utilized for the analysis of vegetation indicators or time-series studies.

This solid framework of data selection and preprocessing allows Ghanaian researchers to do dependable LULCC evaluations throughout the nation's varied ecosystems, ranging from the deep southern forests to the northern savannahs. The integration of medium-resolution time-series data with focused high-resolution analysis offers extensive geographic coverage and precise local insights, facilitating evidence-based land management choices across several scales. Future innovations in data accessibility and processing methods are expected to significantly improve the quality and efficiency of LULCC monitoring in Ghana.

3.2.2. LULC Classification and Change Detection

The LULC study in Ghana utilizes a variety of categorization and change detection methodologies, each offering unique benefits for certain purposes. Supervised classification techniques, especially Maximum Likelihood Classification (MLC), continue to be prevalent owing to their proven dependability. This methodology categorizes pixels utilizing training data and presumes a Gaussian distribution of spectral values, rendering it efficient for broad land cover mapping (Boakye et al., 2019; Obodai et al., 2019). Spectral Angle Mapping conducts spectral-specific analysis by comparing pixel signatures to reference libraries, effectively differentiating identical land cover types with minor spectral variations (Biney and Boakye, 2021).

Object-Based Image Analysis (OBIA) has arisen as a formidable alternative to conventional pixel-based techniques, particularly in diverse environments. OBIA can more correctly depict real-world features and limits by segmenting pictures into significant items based on spectral, spatial, and textural attributes (Stow et al., 2007). The post-classification comparison method is essential for change detection, as it examines independently classified photos from several periods to discern transitions across land cover categories (Abass et al., 2018; Adjei et al., 2014; Ekumah et al., 2020).

Advanced analytical frameworks such as intensity analysis offer profound insights into LULC dynamics by scrutinizing

the intensity and frequency of transitions within categories. This methodology facilitates the identification of prevailing change patterns and fundamental causes, providing essential insights for land use planning and policy development (Ekumah et al., 2020). The choice of suitable methodologies is contingent upon several criteria, such as landscape complexity, data availability, and research aims, with researchers frequently integrating numerous techniques to tackle particular inquiries throughout Ghana's distinct ecological zones. These analytical techniques combined provide thorough monitoring of land cover alterations, hence underpinning evidence-based decision-making for sustainable land management in Ghana.

3.2.3. Additional Methodological Considerations

Recent research on LULCC in Ghana has employed progressively advanced methodological techniques to enhance the comprehension of landscape dynamics. Multiple studies have utilized multi-site sample methodologies, examining various places across diverse geographies to assess the spatial diversity of land use alterations (Appiah et al., 2017; Amproche et al., 2020; Donkor et al., 2022). This comparative method offers significant insights into regional trends and local discrepancies in LULC change processes.

Comprehensive studies amalgamate geospatial technology with socioeconomic data, integrating remote sensing and GIS with demographic statistics, agricultural records, and economic indicators (Appiah et al., 2015; Kusimi et al., 2008; Obodai et al., 2019). This multidisciplinary approach allows researchers to analyse the intricate relationship between biophysical changes and human activities, providing a comprehensive knowledge of the factors and effects of land use transitions. Integrated techniques are especially beneficial for discerning context-specific linkages between socioeconomic issues and environmental changes throughout Ghana's many ecological zones. The integration of spatial analysis with socioeconomic data facilitates the connection between technical land cover evaluations and practical land management requirements, hence enhancing informed decision-making for sustainable development.

3.2.4. Modelling and Prediction

Researchers are increasingly utilizing predictive models to forecast future scenarios of LULCC to facilitate evidence-based land management and policy development. Markov Chain Analysis is a fundamental statistical tool that utilizes historical transition probabilities to predict the probability of future land cover changes (Aniah et al., 2023). Although proficient in identifying temporal trends, Markov models are deficient in geographical specificity.

To overcome this issue, Cellular Automaton (CA)-Markov hybrid models include spatial dynamics into forecasts. The CA component models local interactions and transition rules across land cover categories, whereas Markov chains maintain probabilistic alignment with historical patterns (Aniah et al., 2023). This integrated methodology produces spatially explicit, visually comprehensible predictions of LULCC, rendering it essential for evaluating possible deforestation hotspots, urban development pathways, or agricultural encroachment threats.

These prediction instruments allow policymakers to assess the long-term effects of existing land use choices, examine alternative management strategies, and prioritize conservation efforts. Nonetheless, their precision relies on superior input data, thorough calibration, and the incorporation of both biophysical limitations and socioeconomic factors. Future enhancements may integrate machine learning methodologies and local participatory knowledge to improve model authenticity, especially in swiftly evolving environments such as Ghana's agricultural frontiers and urban outskirts.

By forecasting LULCC trajectories, such models facilitate the alignment of developmental and environmental objectives, ensuring that growth methods are congruent with climate resilience and ecosystem conservation goals. Their conclusions are progressively utilized to inform zoning regulations, protected area allocations, and sustainable investment strategies throughout Ghana's varied ecological zones.

3.2.5. Factors Influencing Methodological Choices

The methodological techniques employed in LULCC studies in Ghana are influenced by several interconnected aspects that researchers must meticulously evaluate. The precise study aims are crucial in selecting suitable procedures, as varying goals like land cover mapping, change detection, or future scenario prediction necessitate various analytical methodologies. The availability of data is a crucial factor, since the quality, resolution, and temporal coverage of remote sensing images and other socioeconomic variables directly affect the feasibility of various methodologies. The geographical attributes of the research region, encompassing its geographic scope and landscape intricacy, further inform the choice of appropriate imaging and analytical methodologies.

Technical competence is a crucial practical factor, since researchers' proficiency in many analytical techniques and the accessibility of computer resources frequently limit methodological options. Advanced methodologies such as machine learning or object-based image analysis need specific expertise and processing capabilities that may not be readily available. Comprehensive and informative LULCC studies often amalgamate many methodologies, integrating geospatial technology such as remote sensing and GIS with socioeconomic data analysis and predictive modelling to deliver a holistic comprehension of land change processes.

These methodological choices necessitate a careful equilibrium between scientific rigor and practical limitations to guarantee that study results are both precise and relevant to real-world land management issues. The variety of Ghana's ecological zones, from coastal wetlands to northern savannas, requires customized strategies that include regional differences in landscape features and factors of change. Future methodological advancements should include improving data accessibility via open platforms, creating standardized procedures to enhance comparability among research, and integrating participatory approaches that utilize local knowledge. By carefully evaluating these many aspects and their interrelations, researchers may

choose and use analytical methods that yield significant insights to aid sustainable land governance and policy development in Ghana's evolving landscapes.

3.3. Data Sources

3.3.1. Landsat Satellite Imagery

Landsat satellite imagery has been the predominant data source for LULCC studies in Ghana, providing numerous significant advantages that enhance its value for researchers. The primary advantage of Landsat is its unmatched historical record, enabling the examination of land cover patterns since the 1970s and offering essential insights into long-term environmental changes. Landsat, with its 30-meter spatial resolution, achieves an ideal equilibrium between detail and coverage, rendering it appropriate for regional-scale studies over Ghana's varied landscapes (Obodai et al., 2019; Asare et al., 2021; Kumi et al., 2021). The cost-effectiveness and accessibility of Landsat data via the USGS EarthExplorer platform have proven crucial for Ghanaian researchers, since the complimentary availability removes financial obstacles that may otherwise restrict remote sensing capabilities.

The multi-generational continuation of the Landsat program enables researchers to choose sensors suited to their particular temporal emphasis. Previous studies predominantly depend on data from the Thematic Mapper (TM) sensor, whereas contemporary research employs the Enhanced Thematic Mapper Plus (ETM+) and Operational Land Imager (OLI) sensors (Obodai et al., 2019; Asare et al., 2021; Kumi et al., 2021). This sensor advancement has preserved spatial resolution constancy while enhancing spectrum capabilities, facilitating more intricate assessments of Ghana's evolving landscapes. The integration of extensive data availability, suitable spatial resolution, and economic viability has positioned Landsat as the cornerstone for the majority of LULCC research in Ghana, facilitating a range of activities from baseline land cover mapping to intricate change detection analyses across the nation's diverse ecological regions.

3.3.2. Additional Data Sources for LULCC Research

Alongside Landsat images, researchers in Ghana employ several supplementary data sources customized for certain research requirements and scales. High-resolution commercial satellite data from platforms such as IKONOS and QuickBird offer improved visual clarity for localized research necessitating detailed spatial analysis; yet, financial constraints sometimes restrict its application to specific small-scale studies (Stow et al., 2007). The freely accessible imagery of Google Earth has emerged as an essential tool for land cover validation, especially in regions where collecting ground truth data is difficult, providing both contemporary and historical high-resolution views (Boakye et al., 2019; Koranteng et al., 2020).

Historical aerial pictures enhance the temporal scope of land cover research by documenting landscape conditions prior to satellite data, hence facilitating the reconstruction of long-term environmental changes (Abass et al., 2019). Conventional topographic maps remain significant in GIS analysis, especially for recognizing and characterizing natural features such as watersheds, elevation contours, and other physiographic aspects (Basommi et al., 2015; Boakye et al., 2019). Land cover maps generated by government agencies function as crucial baseline references and validation sources, offering uniform classifications that enable comparative analysis across research (Abass et al., 2019; Appiah et al., 2017).

This multi-source methodology enables researchers to integrate the advantages of many data types, utilizing Landsat's temporal coverage for change detection, commercial imagery's precision for local validation, historical photographs for longitudinal context, and official maps for uniformity. The amalgamation of these heterogeneous datasets facilitates more thorough and precise LULCC evaluations throughout Ghana's numerous terrains, while simultaneously resolving particular study limitations, including cost, resolution, and temporal scope. This methodological versatility is crucial due to Ghana's different ecosystems and the differing scales of land use changes, ranging from small mining effects to regional agricultural growth trends.

3.3.3. Integration of Socio-Economic Data

The amalgamation of remote sensing data with socioeconomic information establishes a comprehensive framework for elucidating the intricate factors influencing LULCC in Ghana. Population statistics are essential for researchers to evaluate the effects of urbanization and population expansion on landscape changes (Amproche et al., 2020; Donkor et al., 2022).

Agricultural data, encompassing records of farming techniques and crop production trends, provide critical insights into the ways agricultural development and intensification lead to alterations in land cover (Hou et al., 2020). Economic variables, including commodity pricing, market trends, and development strategies, profoundly impact land-use decisions, establishing critical connections between economic conditions and environmental alterations (Appiah et al., 2017).

Institutional and policy frameworks significantly influence LULC change dynamics. Examinations of land tenure systems, mining laws, and forestry management techniques elucidate the governance frameworks that either restrict or facilitate alterations in land use (Hou et al., 2020). Socioeconomic data are often gathered using mixed-method techniques, comprising household surveys, key informant interviews, focus group discussions, and analyses of existing literature and government databases. This integration of quantitative and qualitative methodologies guarantees a comprehensive knowledge of the human factors influencing observed land cover alterations.

By integrating geospatial analysis with socioeconomic statistics, researchers may transcend basic change detection to elucidate the fundamental drivers of LULCC. This comprehensive approach is especially significant in Ghana, where fast urbanization, agricultural growth, and extractive industries intersect with local livelihoods and legislative frameworks to catalyse landscape changes. The insights

obtained allow comprehensive land management methods that consider both environmental sustainability and human developmental requirements. Subsequent studies may fortify these connections by establishing standardized techniques for the gathering of socioeconomic data and its integration with remote sensing products, therefore improving comparability between studies and geographies.

3.3.4. Factors Influencing Data Source Selection

The methodological framework for LULCC research in Ghana is primarily influenced by numerous critical factors. The primary focus is on the specific study objectives, which dictate the choice of suitable data sources and analytical methods. The study's objective, whether to map present land cover patterns, identify historical changes, or project future scenarios directly impacts the selection of remote sensing platforms, categorization techniques, and modelling strategies.

Temporal requirements represent a crucial element, since the study's time frame determines the necessary historical depth of picture capture and supplementary information. Investigations extending over several decades must be judiciously chosen from existing historical materials, whereas modern analysis can utilize more recent, high-resolution photography. The geographic extent and necessary detail impose further limitations, since national-scale evaluations often use medium-resolution data such as Landsat, while localized investigations may utilize commercial high-resolution imaging or UAV datasets where appropriate and warranted.

The availability of financial and technological resources, especially in research contexts with limited resources, frequently imposes practical constraints on data collecting and processing capabilities. The substantial expenses linked to commercial satellite images or sophisticated analysis tools may limit methodological choices, requiring cautious compromises between scientific integrity and practical viability. The interconnected factors of study objectives, temporal demands, spatial necessities, and resource limitations jointly inform researchers in formulating effective and feasible procedures suited to Ghana's varied landscapes and research environments.

3.3.5. Combined Use of Data Sources

A thorough comprehension of LULCC in Ghana necessitates the amalgamation of several data sources, each offering distinct perspectives for the study. Satellite photography, especially from the Landsat program, is the primary dataset owing to its broad geographical and temporal coverage, delivering reliable observations across vast geographic regions over several decades. High-resolution photography, such as Google Earth, enhances wider datasets for verification and comprehensive local-scale research by facilitating precise analysis and ground truth validation.

In addition to remote sensing data, socioeconomic information is essential for contextualizing LULCC trends by elucidating the human and economic factors that drive the observed alterations. This includes elements such as demographic expansion, agricultural development, and policy impacts that influence land-use choices. Landsat serves as the foundation of LULCC research in Ghana due to its accessibility, historical breadth, and versatility; however, additional resources such as historical maps, aerial images, and field surveys enhance the analysis of land-use changes.

The meticulous selection and integration of these varied data sources augment the reliability of LULCC evaluations, guaranteeing that studies reflect both the physical changes and the social factors influencing them. Researchers may enhance their understanding of land-use changes by integrating geographical, historical, and socioeconomic datasets, therefore facilitating informed decision-making for sustainable land management in Ghana.

3.4. Land use Changes and Patterns

Human activities and natural elements interact to affect LULC changes in Ghana, thereby generating dynamic and multifarious effects on the environment, economy, and society (Obodai et al., 2019; Asare et al., 2021; Kumi et al., 2021). Key trends, motivating factors, and effects of these developments are summarized below.

3.4.1. Deforestation and Forest Degradation

The forest ecosystems of Ghana have seen considerable alterations as a result of various human-induced stressors. Closed forest cover has significantly diminished due to agricultural expansion, wood extraction, mining operations, and urban development (Aniah et al., 2023; Antwi et al., 2014; Ekumah et al., 2020; Gbedzi et al., 2022; Yeboah et al., 2017). The trend of deforestation encompasses open forest regions, which are progressively being transformed into agricultural land (Braimoh and Vlek, 2005; Coutler et al., 2016). The geographical pattern of forest loss demonstrates considerable regional diversity, with some places seeing more pronounced deforestation rates than others (Gbedzi et al., 2022; Kullo et al., 2021).

Reforestation programs are currently restricted in scale and mostly focused on rainforest areas (Appiah et al., 2015), underscoring the necessity for broader and more varied restoration projects throughout Ghana's diverse biological regions. The alterations in forest exhibit clear geographical patterns, with certain areas displaying increased resilience while others see rapid shifts. The aggregate effect of these alterations transcends mere deforestation, influencing biodiversity, carbon sequestration potential, and regional ecological services. The geographical variability of deforestation highlights the necessity for focused, location-specific conservation policies that include regional differences in both the causes and effects of forest cover change.

3.4.2. Expansion of Agriculture

The extension of agricultural land is a major catalyst for landscape modification in Ghana, significantly impacting forest ecosystems and biodiversity. The increasing need for food production has resulted in significant transformation of forests and grasslands into agricultural land (Braimoh and

Vlek, 2005; Ekumah et al., 2020; Yeboah et al., 2017). The agricultural frontier persistently advances into wooded regions, especially by removing indigenous vegetation for the establishment of new farmland (Appiah et al., 2015; Donkor et al., 2022; Hou et al., 2020). Conventional agricultural methods, such as slash-and-burn techniques, intensify these effects by causing both rapid deforestation and prolonged land degradation (Aniah et al., 2023; Antwi et al., 2014; Boakye et al., 2019).

The dynamics of agricultural land use exhibit intricate geographical and temporal patterns throughout Ghana's landscapes. In certain instances, the neglect of agricultural fields or the adoption of fallow times has resulted in partial vegetation restoration, producing a mosaic of active production and regenerating zones (Awotwi et al., 2018; Boakye et al., 2008; Kusimi, 2008). Nonetheless, even limited occurrences of recovery frequently do not offset the overarching deforestation patterns induced by agricultural development. The cumulative impacts of these land use alterations transcend mere forest cover diminishment, affecting soil quality, water resources, and regional climatic patterns.

These agricultural transitions exhibit notable regional disparities, with certain regions undergoing more intense conversion than others, indicative of inequalities in soil fertility, market accessibility, and population pressures. The resultant landscape patterns illustrate the conflict between food security requirements and environmental preservation, emphasizing the necessity of formulating sustainable agricultural intensification plans that fulfill production goals while reducing ecological consequences. The geographical variability of these changes necessitates customized land use strategies that include regional differences in agricultural systems and environmental susceptibility.

3.4.3. Urbanization and Settlement Growth

Ghana is seeing fast urban growth, especially in peri-urban regions where developed land is progressively invading previous agricultural and woodland areas (Ekumah et al., 2020; Yeboah et al., 2017; Braimoh and Vlek, 2005). The urban expansion is chiefly propelled by two interconnected factors: natural population growth and considerable rural-to-urban migration, which together generate enormous demand for residential and commercial properties (Ekumah et al., 2020; Yeboah et al., 2017; Braimoh and Vlek, 2005). The conversion process alters profitable agricultural fields and ecologically significant woods into residential and commercial developments, resulting in a unique land cover transition pattern surrounding metropolitan centers.

This urban growth displays several distinctive spatial patterns. Development generally emanates from urban centers along principal transportation routes, resulting in a dendritic development pattern. Peri-urban areas exhibit notably rapid transformations as they evolve from rural to urban characteristics, frequently featuring fragmented remnants of agricultural or natural land amidst new developments. The pace and nature of urbanization differ by area, with significant growth seen in key economic centers such as Accra, Kumasi, and Tamale. Urban transitions profoundly impact food security (due to the loss of agricultural land), ecosystem services (due to the decline of green areas), and infrastructure design, hence requiring meticulous land use control to facilitate sustainable urban development.

3.4.4. Mining Activities

The mining sector in Ghana has seen considerable growth in recent years, especially between 2022 and 2023, with both large-scale industrial operations and artisanal small-scale mining expanding in mineral-rich areas (Antwi et al., 2014; Boakye et al., 2019). This expansion has resulted in significant environmental repercussions, including extensive soil degradation, deforestation, and the poisoning of aquatic bodies due to chemical contamination and sedimentation. The environmental consequences are especially grave in regions impacted by illicit small-scale mining activities, referred to locally as "Galamsey" (Ekumah et al., 2020; Yeboah et al., 2017). These illicit operations not only intensify ecological harm but also pose considerable obstacles to effective land management and restoration initiatives.

The geographical distribution of mining effects exhibits diverse patterns throughout Ghana's terrain. Mining operations, concentrated mostly in the Western, Ashanti, and Eastern regions, have converted extensive sections of formerly wooded and agricultural terrain into dug pits and tailings. The resultant land cover alterations encompass total plant clearance, soil compaction, and modifications to hydrological processes. Illicit mining activities often transpire along riverbanks and within forest reserves, resulting in significant destruction of riparian ecosystems and watersheds. These activities exhibit a clustering pattern around established mineral resources, with the magnitude of environmental consequences related to both mining activity and the efficacy of regulatory enforcement across various locales. The cumulative impacts transcend direct mining locations, affecting regional water quality, biodiversity, and agricultural output in adjacent regions.

3.4.5. Water Bodies

Ghana's aquatic ecosystems are experiencing substantial alterations owing to fluctuating land use practices and mining operations. The alterations demonstrate divergent spatial patterns across various regions. Some areas face diminishing water levels due to modified hydrology from deforestation and land conversion, while others witness water accumulation in abandoned mining pits that have evolved into artificial ponds (Donkor et al., 2022; Ekumah et al., 2020; Yeboah et al., 2017). This duality generates a complicated array of hydrological effects across the nation's basins.

The ramifications of land cover changes encompass not only variations in water quantity but also significant transformations in water quality and hydrological systems. Deforestation and ensuing soil erosion have markedly impaired water quality and altered streamflow patterns (Biney and Boakye, 2021; Kullo et al., 2021; Kumi et al., 2021). The consequences exhibit clear regional patterns, with the most pronounced effects concentrating on highly mined streams and regions undergoing fast agricultural growth. The cumulative impacts encompass heightened sedimentation,

modified seasonal flow patterns, and pollution from agricultural and mining runoff, which cumulatively jeopardize aquatic ecosystems and the availability of water resources. The hydrological alterations differ geographically according to underlying geology, land use intensity, and conservation strategies, resulting in a mosaic of susceptibility throughout Ghana's principal river basins.

3.4.6. Other Land Cover Changes

The landscapes of Ghana demonstrate dynamic shifts between barren land and vegetated regions, influenced by the opposing forces of land degradation and restoration initiatives. The spatial extent of bare land varies considerably, with certain areas seeing growth owing to soil erosion, overgrazing, and mining, while others exhibit a decrease through natural regeneration or deliberate forestry initiatives (Donkor et al., 2022; Hou et al., 2020). These alterations provide an intricate mosaic of land cover conditions throughout many ecological zones.

Grassland ecosystems exhibit notable susceptibility to climate fluctuations and agricultural influences. These transitional landscapes experience ongoing alterations due to seasonal climatic variations, the intensity of animal grazing, and the conversion to agricultural areas (Appiah et al., 2015; Donkor et al., 2022; Hou et al., 2020). The spatial distribution of grassland alterations demonstrates distinct regional patterns; northern savanna grasslands encounter different pressures from climate variability and pastoral activities than coastal savanna ecosystems, which are more influenced by agricultural expansion and urban encroachment. The divergent consequences result in diverse trajectories of grassland change nationwide, with certain regions undergoing degradation while others exhibit relative stability or even expansion due to forest retreat amid shifting climatic circumstances. The interaction between natural and human-induced elements creates a constantly changing environment that needs vigilant oversight for sustainable land management.

3.4.7. Temporal Patterns

In Ghana, LULCC has markedly escalated in recent decades, predominantly due to human activities (Pabi, 2007; Stow et al., 2007; Toure et al., 2020). The rate and nature of these transitions varied significantly across various locations, shaped by a complex interaction of climatic circumstances and socioeconomic variables (Ekumah et al., 2020; Yeboah et al., 2017). Certain landscape alterations exhibit a degree of reversibility; given suitable environmental conditions and effective management interventions, several regions have indicated potential for vegetation recovery and ecological restoration (Abass et al., 2018; Koranteng et al., 2020).

These processes exhibit unique geographical and temporal patterns throughout Ghana's varied ecosystems. Some places undergo rapid, frequently permanent transformation of natural landscapes into urban or agricultural zones, while others exhibit more cyclical patterns of change, especially in transitional areas where fallowing techniques or conservation initiatives provide partial regeneration. The rate of change is most evident in peri-urban and resource-rich areas, where development pressures are intense, whereas protected and less accessible places often exhibit higher stability. This variety highlights the necessity of localized, context-specific land management strategies that include both the factors of change and the ecological capacity for recovery in various regions of the country.

3.4.8. Sub-Regional Variations

The patterns of LULCC in Ghana exhibit intricate spatial differences influenced by a combination of local influences. At the regional level, unique patterns of landscape modification arise from the interaction of socioeconomic situations, cultural practices, and biophysical factors (Aniah et al., 2023; Gbedzi et al., 2022; Kullo et al., 2021). These localized dynamics provide a patchwork of changing patterns nationwide, with certain regions undergoing fast deforestation while others exhibit more stable land cover.

Analyses at the sub-basin level have been particularly effective in pinpointing areas of significant environmental change, with some watersheds exhibiting increased susceptibility to degradation and deforestation (Ekumah et al., 2020). These micro-scale studies demonstrate how terrain, hydrology, and resource distribution intensify land use pressures in certain areas. The geographic aggregation of alterations frequently exhibits a high correlation with fundamental geological characteristics and ecological productivity.

Local land use decisions further influence these patterns through culturally ingrained habits. Conventional land tenure systems, traditional agricultural practices, and community resource management strategies generate unique geographical indicators of transformation (Regional context). The human elements combine with environmental gradients to generate the observed regional differences in LULC change trajectories across Ghana's varied biological zones, ranging from the coastal savannahs to the northern guinea savannah. The resultant geography of change embodies both the physical terrain and the social dynamics of decision-making.

3.4.9. Driving Forces of Land Use Changes

The alterations in LULC in Ghana are influenced by a multifaceted interaction of social, political, and institutional elements. Population increases acts as a primary catalyst, propelling urban development, agricultural expansion, and deforestation as communities and food production systems enlarge to satisfy increasing needs (Aniah et al., 2023; Antwi et al., 2014). Economic elements significantly influence these alterations, since market forces and commodity needs expedite the conversion of natural landscapes for agricultural and extractive purposes (Donkor et al., 2022).

Government policies and governance frameworks significantly influence land use trends, although in an occasionally unforeseen manner. Regulations about mining operations, agricultural expansion, and forest stewardship can have cascading impacts across ecosystems, perhaps resulting in unanticipated outcomes that intensify environmental deterioration (Pabi, 2007). Land tenure regimes exacerbate these trends by affecting access, ownership, and land-use decisions. Conventional and formal tenure systems generate specific geographical incentives,

promoting either sustainable management or, in certain instances, quick exploitation (Local context).

These forces interact in geographically unique manners, resulting in a varied pattern of land use change throughout Ghana. Coastal areas may encounter increased urban and commercial agricultural pressures, whereas northern regions confront varying mixtures of subsistence agriculture and climate-related adaptations. Mining hotspots, such the Ashanti and Western regions, illustrate the capacity of extractive industries to dictate local land use patterns. The resultant alterations in the environment are indicative of these many influences, necessitating cohesive policies that concurrently tackle population pressures, economic incentives, governance deficiencies, and tenure security to facilitate sustainable transitions.

3.4.10. Impacts of Land Use Changes

The alteration of Ghana's landscapes via LULCC has precipitated considerable environmental and social repercussions. These alterations have resulted in extensive habitat fragmentation and a decline in biodiversity due to the disruption of natural ecosystems. Simultaneously, increasing soil erosion and land degradation are reducing agricultural production and ecological resilience. Hydrological systems experience significant stress, characterized by modified water cycles that result in degraded water quality and heightened surface runoff, hence increasing flood risks, a trend extensively recorded in susceptible watersheds (Biney and Boakye, 2021; Kumi et al., 2021).

The climate aspect indicates localized microclimatic changes, encompassing temperature variations and altered precipitation patterns, as alterations in land cover disturb energy balances and moisture recycling. These environmental alterations impact human systems, as the transformation of agricultural land jeopardizes food security (Obodai et al., 2019), while ecosystem degradation compromises livelihoods reliant on forestry and agriculture. The intricate interaction of these effects illustrates how LULCC operates as a systemic risk amplifier, concurrently influencing ecological stability, economic security, and community welfare.

Confronting these difficulties requires cohesive strategies that connect scientific comprehension with policy implementation. Primary objectives encompass formulating climate-resilient land management methods, executing biodiversity-sensitive spatial planning, and establishing livelihood transition programs for impacted people. Effective mitigation relies on collaborative frameworks that integrate scientific monitoring, policy innovation, and community involvement, ensuring land use decisions reconcile developmental requirements with long-term sustainability. The geographical variety of these effects throughout Ghana's ecological zones requires customized solutions that include regional disparities in vulnerability and adaptation capability.

3.5. Change Detection Analysis

The landscapes of Ghana are experiencing substantial changes due to the intricate interplay between natural elements and human activity. The alterations in LULC demonstrate unique geographical and temporal patterns throughout the nation's many biological zones, significantly impacting ecosystems, water resources, and socioeconomic development (Asare et al., 2021; Kumi et al., 2021; Obodai et al., 2019).

A significant trend is deforestation and forest degradation, mostly driven by agricultural expansion, urbanization, and mining activities (Aniah et al., 2023; Antwi et al., 2014; Gbedzi et al., 2022). Significant deforestation occurred in critical ecological zones such as the Pra River Basin and Lake Bosumtwi Watershed from 1986 to 2018 (Asare et al., 2021; Boakye et al., 2019). Despite the existence of reforestation projects, they are spatially constrained and unable to mitigate overarching deforestation trends.

Agricultural land development has increasingly intruded onto forests and savannas, especially in Lake Bosumtwi Watershed and Tano River Basin (Asare et al., 2021; Larbi, 2023). Conventional methods like slash-and-burn agriculture have intensified land degradation, diminishing soil fertility and ecological resilience (Tahiru et al., 2020). This increase signifies both demographic pressures and the advancement of commercial agriculture.

Urbanization and settlement expansion have significantly transformed peri-urban environments, propelled by population increase and economic development (Aniah et al., 2023). Significant urban centers such as Accra and environmentally vulnerable regions like the Lake Bosumtwi Watershed have seen the conversion of agricultural and wooded land into developed areas (Ackom et al., 2020; Asare et al., 2021). This urban expansion has generated novel environmental issues while altering rural-urban interactions. Mining activities both lawful and unlawful have resulted in significant environmental degradation, including deforestation, soil deterioration, and water contamination (Basommi et al., 2015; Obodai et al., 2019). Areas like the Black Volta Basin have seen significant landscape transformations as a result of increased mining operations (Amproche et al., 2020). The ecological repercussions of these extractive operations reach much beyond the actual mining locations.

The principal factors influencing LULC change include fast population increase, which has catalyzed urbanization, agricultural expansion, and deforestation (Aniah et al., 2023; Basommi et al., 2015). Economic incentives, including market demand for minerals and agricultural commodities, have expedited land conversion rates (Donkor et al., 2022). Furthermore, diverse land tenure systems affect land-use choices across different locations (Ekumah et al., 2020), whereas governmental initiatives regarding mining, agriculture, and urban planning can have unanticipated outcomes (Pabi, 2007).

The environmental and economic ramifications of these alterations are intricate and extensive. Environmental issues include habitat fragmentation, biodiversity depletion, soil

erosion, and modified hydrological cycles (Kumi et al., 2021). The quality of water has declined in several mining and deforested regions, jeopardizing aquatic ecosystems and human health (Biney and Boakye, 2021; Kumi et al., 2021). Augmented surface runoff has intensified flood hazards, while alterations in microclimates are influencing local meteorological patterns (Obodai et al., 2019). These shifts have exacerbated food insecurity, disturbed traditional livelihoods, and stressed urban infrastructure (Asare et al., 2021; Obodai et al., 2019). These effects collectively demonstrate how LULC changes function as systemic risk amplifiers, compromising ecological stability, economic resilience, and community well-being throughout Ghana's regions.

To tackle these difficulties, pathways for sustainable land management must include policies that harmonize development with environmental sustainability. Priorities encompass climate-resilient land management, biodiversity-conscious spatial design, and livelihood transition initiatives for affected populations. These initiatives must function within collaborative frameworks that include scientific monitoring, policy innovation, and community involvement. Due to the geographical variety of consequences, customized solutions that account for regional disparities in susceptibility and adaptive capability are necessary.

Enhancing land governance, augmenting regulatory enforcement, and fostering participatory land-use planning are essential for sustainable landscape management. These techniques must be anchored in ongoing research to track changes, evaluate intervention results, and inform evidence-based decisions. By employing comprehensive strategies, Ghana may more effectively manage the trade-offs between developmental priorities and environmental preservation in its changing landscapes.

3.6. Accuracy Assessment

The dependability of classified pictures obtained from remote sensing data is fundamentally contingent upon the accuracy assessment. It guarantees that evaluations of LULC changes rely on high-quality maps that can precisely detect and evaluate LULC dynamics (Obodai et al., 2019; Asare et al., 2021). Accuracy is generally evaluated by many methodologies and metrics, including the error matrix and the Kappa coefficient (Gbedzi et al., 2022).

The accuracy assessment is fundamentally based on the error matrix, or confusion matrix, which juxtaposes classified data with reference data to derive critical metrics. User's Accuracy denotes the likelihood that a pixel designated as a certain land cover type accurately corresponds to that category in reality (Aniah et al., 2023). Producer's Accuracy assesses the probability that a ground-truth land cover type is accurately categorized (Aniah et al., 2023). Overall Accuracy determines the ratio of accurately recognized pixels to the entire number evaluated (Aniah et al., 2023).

The Kappa coefficient, adjusted for chance agreement, quantifies the concordance between categorized outputs and reference data (Gbedzi et al., 2022). The values span from 0 to +1, with elevated numbers signifying greater agreement. Kappa values under 0.4 indicate poor agreement, values from 0.4 to 0.8 signify moderate agreement, while values over 0.8 denote good agreement (Amproche et al., 2020; Aniah et al., 2023).

Data utilized for accuracy assessment often derives from field surveys, high-resolution satellite images (Kumi et al., 2021), topographic maps, and indigenous knowledge (Basommi et al., 2015; Biney and Boakye, 2021). The selection of sample procedures profoundly influences assessment results. Stratified random sampling guarantees representation of all LULC classes, even infrequent ones (Abass et al., 2018). Simple random sampling use uniform intervals in the selection of reference sites (Asibey et al., 2020), whereas visual interpretation-based sampling depends on the manual assessment of randomly selected samples (Larbi, 2023).

Accuracy evaluation encompasses post-classification comparisons of independently classified pictures across time to identify "from-to" transitions between LULC categories (Ackom et al., 2020). Furthermore, validation juxtaposes projected LULC maps with empirical data to ascertain model efficacy (Shih et al., 2015).

Various unique factors affect the efficacy of accuracy assessment. The U.S. Geological Survey (USGS) advocates for a minimum categorization accuracy of 85% for LULC maps. Increased spatial resolution often improves classification accuracy (Abass et al., 2018). Nonetheless, elements like as cloud cover, seasonal variations (Kumi et al., 2021), and varied terrain (Biney and Boakye, 2021) might confound accuracy evaluations. Frequently utilized software applications for assessment comprise QGIS, ERDAS Imagine, and ArcGIS (Obodai et al., 2019). The Kappa statistic, although prevalent, has faced criticism for its susceptibility to class imbalance and interpretative intricacies, leading to a growing interest in alternative measures such as quantity and allocation dispute (Abass et al., 2018).

Research indicates that overall accuracy of 80% are typically deemed appropriate for LULC change studies (Boakye et al., 2019). With well curated training data and high-resolution images, accuracy may surpass 90% (Asibey et al., 2020). Classification accuracy differs by category; built-up and water classes often exhibit better accuracy, whereas forest and agricultural regions are more susceptible to misclassification (Appiah et al., 2017).

The significance of accuracy evaluation is in its function of evaluating the trustworthiness of LULC maps. Precise evaluations facilitate improved decision-making and endorse sustainable land-use policies. Effective assessments need high-quality reference data, suitable sampling techniques, and careful metric selection to guarantee that LULC monitoring is both dependable and beneficial for environmental and socioeconomic planning.

3.7. Key Findings

Research on LULC in Ghana indicates notable geographical and temporal patterns influenced by a confluence of socioeconomic and environmental factors. These dynamics

highlight the imperative of sustainable land management to alleviate adverse effects on natural resources and ecosystems. Deforestation and the loss of forest cover have been ongoing in several locations, mostly due to land conversion. Both closed and open forests have had a consistent reduction (Obodai et al., 2019; Asare et al., 2021; Kumi et al., 2021). Extensive and illicit mining activities have notably expedited deforestation, with the Lake Bosumtwi watershed suffering the most significant degradation from 2007 to 2018 (Basommi et al., 2015; Obodai et al., 2019; Asare et al., 2021).

Agricultural growth is a significant driver of LULC changes, frequently supplanting forest and savanna ecosystems. In the Lake Bosumtwi watershed, agricultural land increased markedly from 1986 to 2018, whereas in the Asutifi North District, the amount of farmland doubled from 2000 to 2020 (Aniah et al., 2023; Asare et al., 2021; Gbedzi et al., 2022). Northern Ghana has seen significant agricultural development, whilst southern regions, particularly the Ashanti Region, emphasize export crop production driven by market dynamics and policy (Braimoh and Vlek, 2005; Tahiru et al., 2020; Kullo et al., 2021; Abass et al., 2018).

Urbanization and settlement expansion are altering peri-urban environments, especially next to main thoroughfares and metropolitan areas. The Greater Accra and Greater Kumasi Metropolitan Areas have had significant expansions in built-up regions, with Kumasi's urban development exceeding that of Accra from 2000 to 2010 (Appiah et al., 2017; Stow et al., 2007; Abass et al., 2018). By 2025, GAMA is anticipated to include 70% of its territory, with urban growth predominantly taking place along the urban-rural interface (Appiah et al., 2015; Hou et al., 2020).

The effects of mining on land use are seen in deforestation and extensive land degradation, especially in regions characterized by illicit and small-scale activities. Small-scale mining accounts for around 80% of the increase in bare land in the Black Volta Basin (Basommi et al., 2015; Amproche et al., 2020), and in the Asutifi North District, it continues to be a primary catalyst for land cover alteration (Gbedzi et al., 2022).

Alterations in water bodies also indicate alterations in LULC. Lake Bosumtwi saw a reduction of 3.7% in its surface area from 1986 to 2018 (Asare et al., 2021). Urban growth and mining have resulted in the loss of wetlands and modifications to hydrological systems, with water-filled mining pits considerably impacting water supply (Ekumah et al., 2020; Kumi et al., 2021). Mining, agriculture, and deforestation have heightened turbidity in surface waterways, compromising water quality (Gbedzi et al., 2022). Temporal patterns demonstrate that LULC changes have intensified after 2000. The Lake Bosumtwi basin saw significant deforestation from 2007 to 2018. Notable LULC modifications occurred from 2000 to 2014 in contrast to prior periods (Asare et al., 2021; Awotwi et al., 2018).

Regional disparities have a distinct geographical dispersion. Urbanization and the extension of built-up areas have predominated in southern Ghana, whereas agricultural growth is more significant in the northern regions (Yeboah et al., 2017). Sub-basins within identical biological zones, such as those in the Pra River Basin, demonstrate diverse patterns of land cover alteration (Boakye et al., 2019).

The primary drivers of LULC change are anthropogenic, encompassing population increase, urban development, and economic activity (Obodai et al., 2019; Gbedzi et al., 2022). Moreover, neoliberal policies and resource exploitation are exacerbating changes in land use (Aniah et al., 2023).

Overall trends indicate a systematic progression in which thick forests are initially diminished to open woodlands, then evolving into agricultural and urban landscapes (Gbedzi et al., 2022). This fast change endangers biodiversity and highlights the imperative for sustainable land-use practices (Ackom et al., 2020).

Deforestation, agricultural expansion, urbanization, and mining are the primary agents of change, with the studies together emphasizing the intricate connections between human activities and environmental factors. These shifts significantly impact biodiversity, water security, and land sustainability. Addressing them necessitates cohesive land management methods that align development goals with environmental preservation.

3.8. Technical Challenges

Using remote sensing and GIS approaches, the study of LULC confronts several technological difficulties at several phases: data collecting, processing, categorization, change detection, validation, and general methodological restrictions. These difficulties affect the dependability and correctness of LULC, change findings and the need for careful thought.

3.8.1. Data Acquisition Challenges

Persistent cloud cover is a substantial impediment to satellite-based land monitoring in Ghana's tropical climate, sometimes obscuring the land surface and resulting in gaps in time-series data (Biney and Boakye, 2021; Kullo et al., 2021; Kumi et al., 2021). This atmospheric interference hinders the acquisition of uninterrupted, cloud-free images vital for reliable change detection and monitoring. The technical constraints of satellite sensors intensify data availability issues, notably the failure of Landsat 7's Scan Line Corrector (SLC) and the absence of Landsat 5 Thematic Mapper (TM) archives for certain regions of West Africa, resulting in historical data voids that impede long-term trend analysis (Obodai et al., 2019).

Financial limitations constitute an additional obstacle to thorough land cover evaluation, as the substantial expenses linked to procuring very high-resolution commercial satellite imagery (e.g., QuickBird, WorldView) restrict their regular application for intricate feature mapping or sophisticated landscape classification (Kullo et al., 2021). This economic reality compels several researchers to depend predominantly on freely accessible medium-resolution data, which may be deficient in the requisite information for certain applications.

The cumulative challenges—atmospheric, technological, and financial establish a multifaceted operational landscape for remote sensing-based land monitoring in Ghana, necessitating novel strategies to optimize data value within these limitations.

3.8.2. Data Processing Challenges

Reliable LULC analysis necessitates advanced preprocessing of satellite images, encompassing atmospheric and geometric adjustments, which pose considerable technological challenges (Gbedzi et al., 2022). These critical processing stages need specialized knowledge and software tools that may not be accessible to all researchers, possibly jeopardizing data quality and analytical precision. The computing requirements for processing extensive multi-temporal imaging data exacerbate these issues, necessitating a powerful hardware infrastructure that may be beyond the capabilities of several research institutes in Ghana (Aniah et al., 2023).

The amalgamation of data from several sensors presents further difficulties owing to discrepancies in spatial, spectral, and temporal resolutions among distinct satellite systems (Obodai et al., 2019). These inconsistencies establish technological impediments to efficient data fusion, constraining the potential advantages of integrating complementary datasets. Multi-temporal analyses encounter distinct problems, since seasonal fluctuations in vegetation and varying land-use patterns across time may lead to inaccuracies or misinterpretations in change detection investigations (Biney and Boakye, 2021).

The amalgamation of these technological challenges—from data preprocessing to multi-sensor integration and temporal analysis—establishes a rigorous operational landscape for LULC researchers in Ghana, necessitating both technical remedies and capacity enhancement to surmount.

The processing constraints are especially pronounced in Ghana's tropical climate, where continuous cloud cover restricts data accessibility. The technological challenges associated with accessible photography exacerbate fundamental data gathering issues, resulting in a complex array of limitations that researchers must traverse to get precise LULC evaluations. Overcoming these problems necessitates investments in technological infrastructure, specialized training programs, and the formulation of standardized processing methods according to Ghana's unique climatic circumstances and research requirements.

3.8.3. Classification Challenges

Numerous enduring problems hinder land cover categorization in remote sensing research. A critical challenge is the development of dependable training datasets, especially when ground truth data is few and landscapes exhibit significant variability in land cover types (Aniah et al., 2023). This problem is exacerbated in diverse situations because mixed pixels, having spectral signatures from many land cover classes, commonly arise, hence confounding the classification process greatly (Antwi et al., 2014). The issue is intensified when several land cover categories have analogous spectral features, a frequent situation that results in misclassification mistakes, particularly with medium-resolution imagery (Obodai et al., 2019).

The quality of training data significantly impacts classification accuracy, since imbalanced representation of land cover classes in training samples can lead to systematic biases in the findings (Antwi et al., 2014). Although advanced machine learning algorithms, including Support Vector Machines (SVM) and Random Forest (RF), are increasingly utilized, their performance benefits over traditional methods such as Maximum Likelihood Classifier (MLC) may be minimal in specific applications, prompting inquiries regarding their cost-effectiveness for certain studies (Obodai et al., 2019). Object-Based Image Analysis (OBIA) poses additional hurdles, since these methodologies need meticulous parameterization of several variables, including size and form measurements, rendering them computationally demanding and possibly challenging to execute consistently (Stow et al., 2007).

These categorization issues underscore the necessity for context-specific methodological approaches that meticulously account for landscape features, data availability, and research aims. Future methodological advancements should concentrate on enhancing approaches for managing mixed pixels, refining training data acquisition, and creating more resilient classification frameworks capable of adapting to varied environmental situations while ensuring operational viability. The use of supplementary data sources and hybrid classification methods may provide effective solutions for overcoming these ongoing issues in land cover mapping.

3.8.4. Change Detection Challenges

Numerous technological constraints impede the efficacy of conventional LULC change detection methodologies. Traditional analytical methods frequently fail to identify nuanced alterations within extensive land cover classifications, thereby overlooking biologically important although visually modest changes (Basommi et al., 2015). The prevalent post-classification comparison approach has more issues, as its efficacy is contingent upon the precision of the foundational classifications. This reliance may result in the neglect of incremental alterations or inadequate assessment of the extent of change (Koranteng et al., 2020).

Moreover, discrete categorization approaches inherently restrict temporal precision, complicating the identification of precise transition timings and potentially concealing gradual, cumulative landscape alterations that transpire slowly over time (Kullo et al., 2021). These methodological limitations underscore the necessity for more nuanced analytical frameworks that can accurately capture both sudden and gradual land changes with enhanced temporal and thematic clarity. Future methodological advancements should prioritize continuous change detection strategies and hybrid algorithms that integrate the advantages of discrete classification with more sophisticated change characterization methods. Such developments will greatly enhance our capacity to see and comprehend the complete range of land cover changes across various temporal and geographical scales.

3.8.5. Validation and Accuracy Assessment Challenges

Numerous methodological issues hinder the accuracy evaluation process in LULC research. Initially, acquiring adequate reference data for validation is resource-demanding, frequently necessitating expensive field surveys or high-resolution imaging (Obodai et al., 2019). This establishes considerable obstacles, especially for extensive or longitudinal research. Secondly, the integrity of reference data may be undermined by interpretative inaccuracies, as both field observations and image analyses are significantly reliant on the interpreter's proficiency, which may introduce biases into validation outcomes (Koranteng et al., 2020).

The issues are exacerbated by the complexity of formulating statistically sound sampling procedures that consider spatial autocorrelation, a prevalent feature of land cover patterns that can skew accuracy estimates if inadequately managed (Abass et al., 2018). Collectively, these constraints underscore the necessity for more effective validation processes that reconcile scientific rigor with practical feasibility, especially in resource-limited research environments. The creation of standardized, economical accuracy assessment procedures is a significant domain for future methodological advancement in LULC investigations.

3.8.6. Other Challenges

Numerous significant obstacles impede the accurate study of LULC changes in Ghana. The lack of established approaches for LULC categorization and change detection presents considerable obstacles in comparing data across various research (Ekumah et al., 2020). This inconsistency restricts the capacity to integrate findings at the regional or national levels. Secondly, resource limitations in several places hinder access to sophisticated software and technical skills essential for effective remote sensing and GIS applications (Ekumah et al., 2020; Yeboah et al., 2017), resulting in discrepancies in research capacities between affluent and underprivileged areas.

A third problem pertains to the amalgamation of indigenous knowledge with quantitative remote sensing data, which is crucial for comprehensively understanding the drivers of change, yet remains methodologically intricate (Braimoh and Vlek, 2005; Yeboah et al., 2017). Fourth, land change modelling persists in encountering challenges in selecting suitable variables and building dependable functional linkages that effectively depict real-world processes (Abass et al., 2019). Modelling constraints impair the prediction efficacy of LULC investigations.

Ultimately, dependence on respondents' recollections for reconstructing long-term land use histories includes possible mistakes and memory biases that may undermine data quality (Abass et al., 2019; Appiah et al., 2017). This constraint is especially difficult for research aimed at documenting multi-decadal alterations in land use.

Collectively, these issues underscore the necessity for enhanced methodological standards, capacity development, and new strategies that integrate technical and participatory methodologies to further LULC research in Ghana. Mitigating these constraints would improve the credibility and usefulness of findings for land management and policy development.

3.8.7. Addressing the Challenges

To augment the study of LULC changes, various methodological enhancements are suggested. Initially, utilizing multi-source data helps rectify current data deficiencies and discrepancies by amalgamating information from diverse, complementary sources. The implementation of modern algorithms and machine learning approaches has considerable potential to enhance analytical precision; nonetheless, it is essential to carefully balance methodological complexity with practical applicability.

Capacity building is a vital domain, especially via specialized training programs that provide researchers in resource-constrained environments with essential tools and technology for conducting comprehensive LULC studies. Furthermore, the amalgamation of qualitative local knowledge with remote sensing data might yield a more holistic comprehension of LULC changes by including both technical metrics and community-derived insights.

Implementing uniform procedures across research will greatly enhance the comparability and synthesis of data. Focusing on these critical areas will significantly enhance LULC change analysis, resulting in more dependable insights to facilitate evidence-based policymaking, sustainable land management, and environmental conservation initiatives (Amproche et al., 2020; Donkor et al., 2022). These enhancements would allow academics and policymakers to more effectively comprehend and address the intricate factors and consequences of land use changes in many situations.

3.9. Future Research Directions

Future studies should concentrate on certain important areas to improve knowledge, prediction, and sustainable management of land resources in Ghana:

3.9.1. Improving Methodologies and Techniques

Subsequent investigations of LULC alterations in Ghana have to employ more integrated methodologies that amalgamate remote sensing data with socio-economic metrics, hydrological data, and indigenous knowledge systems. This multidimensional integration will yield a more thorough comprehension of LULC dynamics by elucidating the intricate interactions among biophysical processes, economic considerations, and social forces (Obodai et al., 2019; Asare et al., 2021; Kumi et al., 2021). To augment predictive capabilities, research should investigate sophisticated computational methodologies, including machine learning algorithms and hybrid modelling techniques like cellular automaton-Markov chain combinations and neural network-Markov chain models, which can enhance the precision of LULC change projections (Aniah et al., 2023; Antwi et al., 2014).

There is an urgent requirement for a systematic assessment of uncertainties in LULC mapping, change detection, and predictive modelling to mitigate restrictions arising from data constraints and model assumptions (Abass et al., 2018; Adjei

et al., 2014). Temporal analysis would be enhanced by employing dense time-series data to discern long-term trends, cyclical patterns, and significant transition phases in land cover alterations. Comparative analyses of continuous index methodologies and discrete classification techniques may provide significant insights into the temporal dynamics of landscape modifications (Yeboah et al., 2017; Braimoh and Vlek, 2005). Methodological innovations must prioritize the development of high-resolution analytical tools that can identify changes overlooked by ordinary image resolutions, thereby enhancing the sensitivity of change detection (Braimoh and Vlek, 2005; Coutler et al., 2016).

Comparative regional research across Ghana's many biological zones and socioeconomic settings are crucial for comprehending spatial differences in land use patterns, their underlying causes, and environmental impacts (Coutler et al., 2016; Abass et al., 2019). Comparative analysis may elucidate how varying government systems, cultural practices, and natural factors influence divergent land use trajectories throughout the country. Collectively, these study avenues will greatly enhance the scientific rigor and practical relevance of LULC studies in Ghana, equipping policymakers with more effective tools for sustainable land management. The amalgamation of sophisticated technological methodologies with contextual socio-economic insights would be especially beneficial for tackling Ghana's intricate land use issues across many scales.

3.9.2. Focusing on Specific LULC Dynamics

Ghana confronts significant land use concerns necessitating focused study to guide sustainable development policies and practices. The dynamics of urbanization necessitate targeted examination, especially regarding the catalysts and consequences of urban sprawl in peri-urban areas, encompassing the expansion of informal settlements and slum formation, along with its ramifications for sustainable urban design (Coutler et al., 2016; Appiah et al., 2019). The agricultural sector necessitates thorough investigations into the impact of expansion on forest cover, biodiversity, and water resources, with a specific focus on identifying and advocating for Sustainable Agricultural Land Management (SALM) practices that reconcile production demands with conservation objectives (Donkor et al., 2022; Hou et al., 2020).

The impacts of mining constitute a critical research priority, requiring investigations into the environmental repercussions of both legal and illegal activities, such as land degradation, water contamination, and biodiversity decline, as well as assessments of effective rehabilitation methods for abandoned mining sites (Kusimi, 2008; Awotwi et al., 2018). Wetland ecosystems in anthropogenically altered landscapes want more study focus to comprehend the impact of land use modifications on their ecological integrity and ability to deliver vital ecosystem services (Awotwi et al., 2018; Ekumah et al., 2020). Furthermore, research should investigate sustainable forest management strategies that tackle degradation factors such as timber extraction, fuelwood collection, and agricultural encroachment, while assessing the efficacy of conservation programs like REDD+ (Ackom et al., 2020; Hackman et al., 2017). The interrelated research goals together furnish the data required to formulate integrated land management plans that reconcile Ghana's developmental objectives with environmental sustainability across its varied ecosystems. The results will be essential for developing strategies that tackle both present difficulties and future demands on land and natural resources.

3.9.3. Addressing Environmental and Socio-Economic Impacts

Future studies must employ a multidisciplinary approach to comprehensively comprehend the intricate effects of land use changes on Ghana's ecosystems. Hydrological studies must examine the effects of urbanization, land degradation, and deforestation on water quality, availability, and hydrological processes, including their influence on both surface water and groundwater systems (Ekumah et al., 2020; Adjei et al., 2014). These studies are especially critical in light of Ghana's escalating water security issues.

Biodiversity protection necessitates targeted study on landscape-scale strategies to alleviate habitat loss and fragmentation resulting from LULC changes (Stow et al., 2007). Concurrent studies must assess the climatic effects of land transformations by evaluating carbon emissions and greenhouse gas fluxes across various land use systems (Tahiru et al., 2020; Akpoti et al., 2019), therefore furnishing essential data for climate change mitigation efforts.

The human aspects of LULC change require equal consideration, especially the socio-political, institutional, and technological elements influencing landscape alterations (Stow et al., 2007; Pabi, 2007). Community-level studies are crucial for comprehending local dynamics and their correlation with overarching land use patterns. Assessments of the impact of LULC changes on livelihoods are equally crucial, particularly for communities reliant on natural resources, to discern paths for climate-resilient development (Yeboah et al., 2017).

These research goals jointly encompass the environmental, climatic, and socioeconomic aspects of land use change, offering the necessary evidence foundation for integrated landscape management in Ghana. The results will be essential for formulating strategies that reconcile conservation objectives with sustainable development requirements throughout the nation's many biological regions. Implementation must prioritize participative methods that integrate local knowledge while utilizing sophisticated GIS and modeling tools to capture both local specifics and broader trends. This extensive research will allow Ghana to more effectively predict and manage the trade-offs among various land uses and their cumulative effects on ecosystems and human well-being.

3.9.4. Emphasizing Geographic-Specific Research

To enhance sustainable land governance in Ghana, research initiatives must employ a spatially focused methodology that tackles region-specific issues. Studies at the sub-basin level warrant significant focus, as they facilitate the identification of high-risk regions and aid in the formulation of localized resource management plans adapted to specific hydrological and biological contexts (Larbi, 2023). The savannah regions necessitate concentrated scientific attention, particularly with

the cumulative effects of agricultural expansion, urban development, and land degradation that jeopardize these delicate ecosystems (Aniah et al., 2023).

Coastal locations represent a vital research frontier, necessitating investigations into the intricate relationships of land cover alterations, pollution pressures, climate change effects, and developmental activities (Shih et al., 2015). Targeted research is essential for ecological and economically vital basins such as the Tano River, Pra River, Lake Bosumtwi, and Black Volta basins, where alterations in land use significantly affect biodiversity and local livelihoods (Asare et al., 2021).

Geographically focused research programs should utilize integrated approaches that combine remote sensing, field surveys, and community knowledge to capture the biophysical and socioeconomic aspects of land use change. By selecting these critical areas, researchers may produce the localized evidence necessary for tailored policy actions that tackle Ghana's varied landscape concerns while promoting sustainable development objectives. The results of this research will be essential for creating adaptive management frameworks that address local conditions and overarching environmental change trends.

3.9.5. Enhancing Policy and Management Applications

Scientific research should be integral to formulating Ghana's land use policy to attain a harmonious equilibrium between environmental preservation and socioeconomic advancement. Evidence-based policies must guide the development of sustainable land management frameworks, whereas integrated water resources management (IWRM) methods necessitate ongoing revisions to tackle new environmental concerns (Appiah et al., 2015; Kusimi, 2008). Participatory research methodology is crucial, including local people, civil society groups, and policymakers in the collaborative design and execution of land management strategies (Awotwi et al., 2018). This collaborative framework guarantees the integration of scientific knowledge with local viewpoints and practical circumstances.

Research institutions must establish comprehensive monitoring frameworks to assess Ghana's advancement in fulfilling land-related Sustainable Development Goals (SDGs), ensuring data-driven accountability for environmental pledges (Tahiru et al., 2020). Targeted studies are essential to assess and enhance management strategies for high-impact sectors such as mining and agriculture, with the objective of reducing their ecological footprint (Baidoo et al., 2023). This research should evaluate the efficacy of current mitigation strategies and the promise of novel methodologies.

By addressing these research goals, the scientific community can provide policymakers with the necessary tools and information to execute sustainable land governance initiatives. This collaboration between academics and policymakers will be essential for protecting Ghana's natural resources while fostering sustainable economic growth, therefore guaranteeing environmental security for future generations. The efficacy of these projects relies on sustaining robust connections among scientific research, policy development, and practical execution, fostering an ongoing cycle of learning and enhancement in land management methods.

3.10. Policy and Practical Implications

The study of LULC in Ghana emphasizes the requirement of integrated land management and sustainable development by means of which the sources underline the need for policy changes and pragmatic approaches to handle the possibilities and difficulties presented by LULC transition.

3.10.1. Policy Implications

Efficient governance and policy execution are essential for tackling Ghana's land use issues. Prioritization of the rigorous implementation of current environmental regulations in critical sectors—specifically mining, forestry, and urban development—is essential for the preservation of natural landscapes (Obodai et al., 2019; Asare et al., 2021; Kumi et al., 2021; Biney and Boakye, 2021). These regulatory measures must be supplemented by cohesive land use planning frameworks that meticulously reconcile socioeconomic growth with ecological conservation (Biney and Boakye, 2021; Kullo et al., 2021). Effective execution necessitates robust cooperation among governmental entities, local communities, traditional leaders, and civil society groups (Asare et al., 2021; Kumi et al., 2021).

A spatially diversified strategy is crucial, with policies customized to tackle region-specific factors influencing land use change (Boakye et al., 2019; Basommi et al., 2015; Koranteng et al., 2020). Urban planning strategies must advocate for compact city models, vertical growth, and the protection of natural spaces to mitigate urban sprawl (Ekumah et al., 2020; Yeboah et al., 2017; Braimoh and Vlek, 2005). In agricultural regions, strategies should promote sustainable intensification to mitigate encroachment into natural habitats while preserving productivity (Donkor et al., 2022).

Forest conservation needs immediate focus via enhanced protection of reserves, replanting initiatives, and sustainable land management strategies (Obodai et al., 2019; Asare et al., 2021; Kumi et al., 2021). The mining industry requires more stringent rules, especially with land reclamation and ecosystem restoration (Basommi et al., 2015; Obodai et al., 2019). Public education initiatives can enhance understanding of sustainable land use practices and the ramifications of environmental deterioration (Obodai et al., 2019).

Technological integration is essential, as geospatial technologies such as remote sensing and GIS furnish the data required for evidence-based decision-making (Appiah et al., 2017; Amproche et al., 2020). Ensuring policy consistency across sectors such as agriculture, mining, infrastructure, and population management is crucial to prevent competing objectives (Donkor et al., 2022; Hou et al., 2020). Land tenure changes must acknowledge traditional ownership systems while fostering sustainable utilization (Hou et al.,

2020; Appiah et al., 2015). Ultimately, rural development initiatives and decentralization can alleviate urban migration pressures and foster equitable regional growth (Appiah et al., 2015; Kusimi, 2008).

Coordinated implementation of these comprehensive policy initiatives can enable Ghana to attain sustainable land management that fosters ecosystem health and socioeconomic growth. The efficacy of these projects relies on ongoing oversight, flexible management, and robust collaborations among all parties engaged in land governance.

3.10.2 Practical Implications

Establishing early warning systems to detect factors influencing LULC change is essential for safeguarding environmentally vulnerable regions (Obodai et al., 2019). Such technologies would provide preemptive measures prior to the onset of irreparable harm. A comprehensive knowledge of LULC dynamics is crucial for the implementation of sustainable land and water management strategies, as evidenced by studies conducted in diverse Ghanaian environments (Appiah et al., 2015; Kusimi, 2008). These findings are especially beneficial for directing conservation initiatives in areas most impacted by biodiversity decline resulting from LULC changes (Kusimi, 2008; Awotwi et al., 2018).

The establishment of continuous monitoring systems by remote sensing and GIS technology underpins adaptive policymaking (Awotwi et al., 2018; Boakye et al., 2008). These instruments provide real-time monitoring of landscape alterations, especially in regions affected by extractive industries where reclamation and rehabilitation must be prioritized (Obodai et al., 2019; Basommi et al., 2015). Agricultural methods present an additional intervention opportunity, since agroforestry and conservation agriculture exhibit potential to diminish deforestation rates while preserving soil health (Braimoh and Vlek, 2005; Donkor et al., 2022). Complementary methods encompass the promotion of alternative livelihoods to mitigate reliance on natural resource exploitation (Obodai et al., 2019).

Urban planning projects must include green infrastructure development to improve sustainability in rapidly expanding cities (Aniah et al., 2023; Coutler et al., 2016). Advanced planning techniques that combine predictive modeling with geospatial technology can greatly enhance decision-making processes (Pabi, 2007; Toure et al., 2020). All these interventions need significant public engagement to guarantee cultural relevance and community ownership of sustainable land use practices (Antwi et al., 2014; Boakye et al., 2019). This participatory method facilitates the connection between technical solutions and local execution, promoting enduring environmental care throughout Ghana's varied landscapes. The amalgamation of these diverse strategies—incorporating technology innovation, legislative change, and community engagement—presents the most potential avenue for equitable and sustainable land use management in Ghana.

3.10.3 Addressing Challenges

To tackle significant issues in LULC research in Ghana, several methodological enhancements can increase data quality and analytical rigor. Initially, utilizing multi-sensor datasets and temporal compositing methods can substantially alleviate the challenges posed by persistent cloud cover that frequently hinders optical remote sensing in tropical areas (Coutler et al., 2016; Abass et al., 2019). The integration of data from many satellite platforms and sensors enhances observation frequency and spatial coverage, facilitating more dependable change detection.

Secondly, the integration of varied data sources via unique analytical methods facilitates the capturing of the multifaceted characteristics of LULC changes. By integrating remote sensing data with socioeconomic surveys, temperature records, and terrestrial observations, researchers can enhance their comprehension of the intricate linkages between human activities and environmental changes (Appiah et al., 2017; Amproche et al., 2020). This comprehensive technique offers a broader perspective on land-change processes across several temporal and geographical dimensions.

Third, integrating local and indigenous knowledge systems into LULC research guarantees that findings and recommendations are congruent with community practices and cultural settings (Boakye et al., 2019; Basommi et al., 2015). Participatory techniques promote data accuracy via local validation and increase the relevance and uptake of research outputs among stakeholders.

Ultimately, effective LULC management necessitates a comprehensive framework that amalgamates several critical components: (1) enhanced regulatory enforcement to avert unsustainable land conversions, (2) integrated spatial planning that reconciles developmental and conservation imperatives, (3) proactive stakeholder engagement in decision-making processes, (4) evidence-based policymaking underpinned by robust monitoring systems, and (5) advocacy for sustainable land use practices. This comprehensive plan seeks to reduce environmental harm while fostering socioeconomic advancement and enhancing community well-being. By employing these strategies, Ghana may more effectively manage the intricate trade-offs between land use requirements and environmental conservation, promoting sustainable landscape management for present and future generations. The efficacy of such projects relies on ongoing monitoring, flexible management, and robust collaborations among researchers, politicians, and local populations.

3.11. Potential Limitation

LULC categorization in Sub-Saharan Africa is investigated in this systematic review using Ghana as a case study. The study notes important new information while also noting many constraints that could affect the dependability and scope of the results.

3.11.1. Limitations of the Review

The present study's dependence on English-language publications presents a possible linguistic bias, since it may exclude pertinent research undertaken in other languages, especially in areas where substantial academic work is published in local or regional languages. This constraint may

neglect significant viewpoints and discoveries from non-English sources that might provide essential insights into the dynamics of LULC.

Furthermore, the emphasis on peer-reviewed journal papers indicates that gray literature, such as government reports, theses, and institutional publications, was not routinely included in the review. Although peer-reviewed research often upholds rigorous academic standards, gray literature frequently contains practical, empirical facts and localized insights that might enhance the study. The omission of these sources restricts the review's scope and may exclude essential context for comprehending LULC developments.

A further problem emerges from the inconsistency in study designs throughout the literature examined. Variations in procedures, sample sizes, data collection methods, and geographic scope hinder the synthesis of findings and impedes the ability to derive consistent conclusions. This variability may produce ostensibly contradictory outcomes, diminishing the capacity to generalize patterns across many situations.

Publication bias affects the review, since research with statistically significant or remarkable findings are more likely to be published, but those with null or less notable results frequently go unreported. This distorts the comprehensive picture of land degradation effects, perhaps exaggerating severe consequences while inadequately portraying more subtle or less extreme instances.

A time constraint occurs, since several included research may not adequately reflect current changes in land management policy, climate adaptation methods, and socioeconomic developments. Due to the swift environmental and demographic transformations in Sub-Saharan Africa, previous studies may not adequately represent current LULC patterns, hence diminishing its applicability for modern policy and planning choices.

The lack of long-term studies constitutes a substantial deficiency. The majority of existing research emphasizes short-term observations, which may insufficiently evaluate the enduring impacts of LULC changes or the long-term effectiveness of mitigation strategies. Longitudinal data is crucial for comprehending the cumulative effects on ecosystems, agricultural output, and livelihoods across time. Mitigating these constraints in forthcoming research would enhance the evidentiary foundation for sustainable land management and policy development.

3.11.2. Contributions and Future Directions

Notwithstanding these constraints, the current study provides a significant synthesis of existing information on LULC categorization, while pinpointing essential avenues for future research. To further the area, future research should use more inclusive methodologies by integrating gray literature and non-English publications, therefore offering a more thorough comprehension of LULC dynamics. Methodological standardization constitutes a vital area for enhancement, since minimizing discrepancies in research methodologies would markedly increase the reliability and comparability of findings across investigations.

There is an urgent requirement for longitudinal study approaches that can accurately monitor long-term LULC shifts and their cumulative effects, especially for ecosystem services and agricultural output. Future research should aim for enhanced geographic and temporal scope to more accurately reflect the swiftly changing socioeconomic and environmental conditions throughout Sub-Saharan Africa. The region's distinctive developmental problems and climatic vulnerabilities necessitate study paradigms that consider these evolving variables.

By addressing these knowledge deficiencies, forthcoming research can markedly enhance our comprehension of the intricate linkages between LULC transitions and agricultural systems. These developments would enhance land management techniques and policy decisions, hence promoting sustainable development objectives throughout the area. The results would be especially significant for reconciling ecological preservation with agricultural production requirements in this swiftly evolving environment.

These study advancements will not only augment academic comprehension but also furnish practical insights for policymakers and land managers addressing the interrelated concerns of environmental sustainability, food security, and climate change adaptation in Sub-Saharan Africa. The resultant information may facilitate the connection between scientific inquiry and practical land management strategies within the region's varied ecological and agricultural environments.

4. Conclusion and Recommendation

4.1. Conclusion

The results on LULC changes in Ghana expose notable changes motivated by population increase, economic activity, mining, and climate change. Deforestation, urban development, and land degradation, among other changes, have significant effects on the environment and society, including loss of biodiversity and damage to water resources. The consequences differ widely; significant patterns include urban sprawl in large cities, Ashanti Region deforestation, and bare land growth in mining areas. Key causes of these developments are unsustainable resource exploitation, fast urbanization, and poor policy execution. Methodologically, remote sensing and GIS technologies have proved crucial for tracking LULC changes; nonetheless, data shortages and accuracy issues continue to be problems. These technologies offer insightful analysis of the geographical and temporal dynamics of LULC changes, together with sophisticated categorization methods and predictive modelling. Nevertheless, the urgency of sustainable and integrated land management strategies is evident as current interventions are inadequate, and the rapid speed of change jeopardizes long-term environmental and social sustainability.

4.2. Recommendations

To advance sustainable land management in Ghana, it is

essential to establish comprehensive land use plans that meticulously reconcile social, economic, and environmental goals. This necessitates synchronized policymaking across essential sectors such as mining, urban development, agriculture, and forestry to avert clashing agendas and guarantee complementing strategies.

Enhancing environmental governance is essential, notably via the rigorous implementation of rules targeting unregulated urban sprawl, illicit mining operations, and deforestation. Policy measures must require land reclamation for degraded regions and encourage the use of ecologically sustainable mining methods.

Prioritization of forest conservation efforts should encompass several strategies, such as the establishment of protected forest reserves, the support of community-based forestry initiatives, and the integration of agroforestry systems within agricultural landscapes. It is imperative to aggressively promote sustainable agricultural practices to mitigate soil deterioration and alleviate strain on existing wooded regions. Urban planning strategies must integrate spatial planning concepts to regulate growth patterns, safeguard green spaces, and deploy green infrastructure solutions. Urban greening programs can substantially improve ecological resilience in swiftly rising cities and towns.

Technological developments should be utilized through the enhanced application of remote sensing and GIS capabilities for real-time monitoring of land use alterations. Enhancing access to superior, localized, and enduring land use data can mitigate existing information deficiencies and facilitate evidence-based decision-making. Local knowledge systems must be included into planning procedures to guarantee contextually suitable solutions, supplemented by public awareness initiatives about sustainable land use practices and the ramifications of environmental degradation.

Region-specific policies are essential to tackle distinct land use concerns in environmentally vulnerable locations, including the Ashanti Region, Black Volta Basin, and Lake Bosumtwi region. Conservation initiatives must adopt sustainable land management techniques to safeguard essential ecosystems and mitigate habitat fragmentation. Investment in research should prioritize the comprehension of the socioeconomic aspects of land use change, the effects on biodiversity, and measures for climate adaptation, while enhancing predictive modeling skills to refine future land use planning.

Successful implementation necessitates robust collaboration among government entities, non-governmental groups, local communities, and traditional leadership frameworks. These extensive proposals seek to promote equitable development that alleviates the adverse effects of land use alterations while advancing Ghana's sustainable development objectives. Confronting present difficulties and preserving natural resources for future generations will rely on cohesive, science-driven solutions and synchronized efforts across all societal levels.

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Conflict of Interest

Regarding the subject matter of this paper, the writers have no conflicts of interest to disclose.

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