Paving over the source: Land use change and the everyday struggle for water in Mbale town, Kenya (2014-2025)

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ABSTRACT

Secondary cities are where Africa's urban future is being decided, yet they remain academically invisible. While Nairobi, Mombasa and Kisumu are extensively studied, towns like Mbale-Vihiga County's administrative capital absorb over 60% of Kenya's urban growth with no commensurate infrastructure. This study seeks to find out what happens when a town urbanizes over its own catchment. The study is anchored on the Malthusian theory which posits that population growth exerts pressure on finite resources leading to resource degradation. The study quantified land use and land cover (LULC) dynamics in Mbale Town between January 2014 and January 2025 using Landsat 8 OLI and Sentinel-2 MSI imagery, respectively. Maximum Likelihood Classification in QGIS 3.34 SCP was used to map seven LULC classes for Mbale Town. Accuracy assessment based on 105 and 136 ground control points yielded overall accuracies of 77% (2014) and 85% (2025). The transformation is stark. Land use analysis showed that, built-up area surged from 131 to 192 HA, shrubland from 107 to 192 HA, open ground from 64 to 88 HA. On the other hand, forested areas declined from 501-488HA, grassland from 366 to 264 HA, mixed farming from 661 to 515 HA and wetlands collapsed from 33 to 24. This pattern reflects two simultaneous processes: the sub-division of peri-urban farmland and direct encroachment on riparian zones in Mbale Town choking recharge and reducing water availability. The study findings expose that Mbale is not just growing; it is unmaking its water future. This reveals a governance deficit where riparian protection policies exist on paper but fail on the ground. Without urgent enforcement of catchment protection, secondary towns will pave over the very sources they depend on.

Keywords: LULC; Remote Sensing &GIS; Secondary Towns, Urban Sprawl, Wetland Depletion; Water Security

I. INTRODUCTION

Every morning at 4:30 am, women in Lunyerere queue at a spring that is now a trickle surrounded by new bedsitters built where a wetland once recharged it. That queue is Mbale Town's urbanization in one image. Globally urban land will double by 2030 and its epicenter is no longer the megacity (Seto et al., 2011). In Sub-Saharan Africa the real transition is happening in secondary towns – settlements of 10,000 t0 100,000 people that absorb 59% of urban growth (United Nations Department of Economic and Social Affairs, UN-DESA, 2018). Yet they remain *"the invisible cities"*, Kenya's scholarly work reflects this blindness: There are detailed LULC models for Nairobi (Mundia & Aniya, 2006) and Mombasa (Onywere et al., 2012) but silence reigns on secondary cities that carry devolution. Mbale 0° 03'24''N, 34043'30''E, exemplifies this. Rising from a market center to a district headquarters in 1988, and then to a county headquarters in 2013 with a population of 17400 in 2019 (Kenya National Bureau of Statistics, KNBS, 2019), and a growth rate of 4% per year. This is mainly driven by county jobs, educational institutions and the Kisumu-Kakamega economic corridor. VIWASCO supply, however, has remained frozen at 1200m^3/day against a demand of 2800m^3/day and a 45% loss through NRW. This deficit is lived and not statistical: the household survey (n=377, 2025) showed that 41.0% depended on informal and vended water and 58.3% had to stitch together several water sources which were mostly unsafe.

Globally, (Vorosmarty et al., 2010) proved that sprawl, not climate, is the primary destroyer of catchment integrity. In western Kenya, (Kanda et al., 2018) found small WSP's lose 42-50% of water as NRW, but no one has linked that loss to the concrete itself. In Bungoma, (Wafula et al., 2020) documented how conversion of peri-urban farmland reduces infiltration by 30%. Mbale is next. The study's reconnaissance found active construction within 10meters of Edzava wetland in direct violation of the 30-meter riparian buffer mandated by the Water Act 2016 and Vihiga County Spatial Plan (2021-2030). This study therefore closes an empirical and a hydrological gap. Empirically it provides the first LULC change matrix for Mbale 2014-2025. Hydrologically, it links that change to water depletion.

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We specifically quantify LULC conversion using Landsat 8 OLI and Sentinel-2 MSI for 2014 and 2025 respectively, measured the built-up encroachment on wetlands and articulate policies implications for secondary towns water security. The study hypothesizes that Mbale's 46.56% built-up was achieved by depleting 27.27% of its water bodies. Ideally, Mbale is not just expanding. It is erasing the source it drinks from.

1.1 Statement of the Problem

Mbale Town, the headquarters of Vihiga County, exemplifies Kenya's secondary towns urbanization crisis. The crisis in Mbale as a time and place: 4:30 am in Lunyerere, where women queue at a spring that is now a trickle, encircled by bedsitters built on the wetland that once recharged it. That single queue captures a town consuming its own water. Since devolution in 2013 Mbale's population has grown to 17400 persons with a growth rate of 4% per year. The growth is driven by devolution, county jobs and the Kisumu-Kakamega economic corridor. But growth has not been met by service. Of the 4516 customers registered with the utility, only 1060 customers are active. Meaning 76.5% are registered but inactive. The rest of the 16,000 persons in Mbale Town are forced to look for alternative sources of water. . Despite secondary towns driving Kenya's urban transition, there is a distinct scarcity of empirical research on secondary rapidly urbanizing towns like Mbale which exhibit unique socio-economic dynamics, informal settlements patterns and reliance on hybrid water sources. The hydrological cost of their sprawl remains unquantified since most research remains metrocentric. This study provides the first (2014-2025) LULC matrix for Mbale to prove its core thesis that it is erasing the source it drinks from.

1.2 Research Objective

The objective of this study was to determine the extent of built-up expansion into waterbodies/wetlands in Mbale Town.

II. LITERATURE REVIEW

2.1 Theoretical Review

2.1.1 The Malthusian theory of population

The study was anchored on the Malthusian and Neo-Malthusian Theories of Population. Proposed by Thomas Robert Malthus (1798), the theory states that population grows at a geometric rate, while resource production grows at an arithmetic rate, inevitably leading to resource scarcity. Malthus believed that a balance between population growth and food supply can be established through preventive and positive checks. According to this theory, adversities such as wars, calamities and famine will set in as positive checks. However preventive checks can also be embraced to balance the population growth and food supply. The Neo-Malthusian extension advocates for proactive human intervention, such as conscious resource management, to prevent catastrophic resource exhaustion. According to this theory the natural resources remained constant and therefore only the population could be controlled effectively through use of contraceptives by the populace. This theory relevant to the Study in Mbale Town; it provides a robust lens for understanding how rapid demographic expansion is outpacing the static capacity of local water resources. As the population grows, the strain necessitates the adoption of preventive checks which are in this case, household level Water Demand Management (WDM) practices.

2.2 Empirical Review

Globally the world is not urbanizing where we think. For decades we stared at megacities while the real explosion was quiet. Angel et al., (2016) showed that urban land is pushing outwards at 12, 568km^2 per year mostly in places we don't study. Guneralp et al (2017) proved that the fastest growth is not in New York or Lagos rather in secondary towns like Mbale. The science tells us what that concrete does to water: 10% more tarmac=15-20% less ground water recharge. McDonald et al., (2020) put the global bill: one in three cities will lose over 10% of its water by 2050 to land cover change. The global literature gives us our premise that the new urban frontier is in small towns and building on catchments is suicidal.

In Africa the rate is visible from space. In Bahir Dar, Ethiopia, (Fenta et al., 2017) watched built-up grow to 68% and the consequential casualty was wetlands which shrunk by 41%. The hydrological price was measured in West Africa. In Togo, Ahiablame and Shakya (2016) found that, when you build in the riparian zones, the surface run-off will jump to 40% and the dry season flow will generally collapse by a third. Methodologically, Africa also shows how to measure it. Furthermore, (Korah et al., 2023) in Ghana and (Kim et al., 2020) in Ethiopia expose a bias that remote sensing loves capitals leaving secondary towns unmapped. This leaves a gap in planning and enforcement in secondary towns grow faster than the planners can police.

The World Bank (2020) notes 59% of Kenya's urban population now lives in secondary towns. The very places that are called academically invisible. We have elegant LULC matrices for Nairobi (Mundia et al., (2018), but nothing for the towns that became capitals after 2013. Ideally whereas devolution lit the fuse, research remained in Nairobi. In Kenya devolution is the driver. Mundia et al., (2018) in Murang'a shows what happens to the environs when you gazette

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a small market as a headquarters; a land rush, panic subdivision, bedsitters and ribbon development. Onyango et al., (2021) traces that exact fever along the Kisumu-Kakamega economic corridor that runs through Mbale. The water consequence is well documented though disconnected. On paper Kenya is progressive- the Water Act 2016 and the EMCA 2015 ban on constructions within 30m of a wetland exists, however, on the ground, (Nyabaro et al., 2023), found that fewer than 15% of buildings are approved and NEMA acts on less than 5% of the violations. More so, (Kanda et al., 2018) found that small water companies in western Kenya lose 50% as non-revenue water, yet never asked the deeper question: What happens if the catchment itself is gone?

While studies that have been conducted offer insight into urban sprawl. In Mbale Town, no study has quantified how many square kilometers have been traded for concrete even as new foundations sit 10m from the wetlands against the 30m law. Global research proves that secondary towns are the new urban. African research proves built-up eats wetlands. Kenyan research proves devolution accelerated it and laws on paper cannot stop it. Ideally, what is missing is not proof that towns grow or whether wetland suffer, rather a case where both town growth and wetland depletion should be measured together and tied to what people actually drink. No study has placed Mbale's LULC matrix i.e., the rise in built up areas alongside the decline in water bodies. This paper does.

III. METHODOLOGY

3.1 The Study area and context

Mbale lies at $0^{o}\,03'24''N, 34^{0}43'30''E$, at 1,520 m above sea level. The town lies along the Kisumu-Kakamega corridor and serves as the administrative capital of Vihiga County. It covers approximately12.6km^2 and was purposively selected because it typifies the post-2013 devolution boom. Mbale is a former district headquarters turned county capital with a 2019 census population of 17,400 growing at >4% annually against static water supply of 1200m^3/day (KNBS, 2019).

3.2 Research design and sampling strategies

A mixed research design was employed. Spatial changes were examined using GIS and Remote Sensing in the period between 2014 and 2025 while household surveys were used to collect data on key selection drivers for primary sources of water. The research area is shown in Appendix 1. The target population included household residents of Mbale Town. The sampling strategy, used was purposive to get the study settlements and stratified random sampling to get the household respondents with the total number of respondents 377 obtained based on the table of sampling by Krejci and Morgan (1970).

3.3 Methods of data collection

Primary data collection instruments were structured questionnaires and peer-reviewed literature. Quantitative data analysis methods were used to analyze the data comprehensively while quantitative data from household survey were analyzed using descriptive and inferential statistics including Pearson's correlation and Chi-square test.

3.3.1 Household surveys

Krejci and Morgan table of sampling was used to get a sample of 377 respondents. Expected data was on primary water sources and the key selection drivers.

3.3.2 Remote Sensing Images

Land use changes that have affected water access and provision in the study period of 2014-2025 was collected using a set of remotely sensed data. The extend of built-up expansion into wetlands was assessed from the LULC changes. Two land sat images from the USGS website were sought for 2014 and 2025.Landsat data was chosen because it is freely accessible. Table 1 lists the data from land satellite images that were utilized for the research.

Table 1

showing Landsat images used in the study

Data	Year	Band/Sensor	Spatial resolution	Source	Path/Row & Cloud cover
Landsat 8	January 2014	Operational Land Imager (OLI)	30m	USGS Earth explorer	Path 170/Row 60, <5% cloud
Sentinel-2	January 2025	Multi-Spectral Instrument (MSI)	10-20m	ESA Copernicus Open Access Hub	Tile 36NYN <5% cloud

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3.4 Landsat data acquisition and processing

3.4.1 Image classification

Data processing was done to make the raw satellite images usable for mapping the 1863 HA study area for Mbale Town. Two cloud free images were acquired as shown in Table 1. Landsat 8 OLI for January 2014, 30m from USGS Earth Explorer-Path170/Row 160 and Sentinel -2 MSI for January 2025, 10-20m from ESA Copernicus Hub (Tile 36 NYN). January was selected because it is a dry month in Vihiga with cloud cover less than 5% which reduces confusion between farmland and grassland. This makes it easier to separate built-up areas from open ground which is critical for this study. In QGIS 3.34 bands were stacked i.e., band 2-7 for Landsat 8 and bands 2,3,4,8,11,12 for Sentinel 2, atmospheric correction was then done using the Semi-Automatic Classification Plugin to remove haze. The corrected images were then clipped to the Mbale Town boundary shapefile obtained from the county government of Vihiga. It was then reprojected to UTM Zone 36N, WGS84 for accurate area calculation. Supervised classification using Maximum Likelihood Classifier (MLC) where 105 and 136 training samples for 2014 and 2025 rom false color composites supported by field GPS with spectral separability verified by J-M distance (>1.8) giving rise to seven classes; forests, shrubland, grassland, open ground, mixed farming, built-up areas and wetlands. Post classification majority filtering was applied to produce final maps showing built-up increase from 131-192HA and mixed farming decline from 661 to 515HA. This is because MLC is best suited for smallholder landscapes like Mbale Town.

3.4.2 Accuracy assessment

Accuracy assessment is important to confirm that what we see on the map is actually what is on the ground. I n this study, confusion matrices were generated using 136 and 105 ground truth points for 2025 and 2014 respectively. The overall accuracy for 2025 was 85.29% with a kappa coefficient of 0.83, indicating very strong agreement, while 2014 achieved 77.14% with a kappa coefficient of 0.73, indicating good agreement. Both accuracies exceed the minimum threshold of 75% recommended for credible LULC change studies. The higher accuracy in 2025 is attributed to the use of a larger number of ground truth points and Sentinel-2 imagery with 10-20m resolution compared to Landsat 8 at 30m 2014. In 2025, built-up areas had the highest accuracy with both user and producer accuracy at 95% (19 out of 20) and wetland achieved 100% producer accuracy meaning all real wetlands were captured. For this study, this is important because it confirms that the increase in built-up area from 131-192HA (+46.56%) and the decline in wetland from 33 HA-24 HA (-27.27%), are real land transformations and not classification errors. Forested areas also had a high accuracy at 90% user and 94.7% producer. The lowest accuracy was in mixed farming at 75% user, where 5 points mapped as farmland were actually grassland (2) and open ground (3), which is common in Vihiga where farms after harvest resemble bare land. Confusion was mainly among spectrally similar classes such as grassland, shrubland and mixed farming.

IV. FINDINGS & DISCUSSION

4.1 Findings

Data was derived from supervised classification of Landsat 8 OLI (2014) and Sentinel-2 MSI (2025) imagery using Maximum Likelihood Classification, a method validated by Forkuo and Frimpong (2019) in Kumasi Ghana. With 89% accuracy and a household survey (n=377, valid n=351for water source analysis) in Mbale CBD, Mukuli and Mutsulyu.

4.1.1 Extent of built-up expansion in Mbale Town 2014-2025

LULC analysis across 1863 HA shows a town in rapid transition (Table 2).

Table 2

LULC Change Matrix for Mbale Town 2014-2025

Class Type	2014(Area HA)	% of Total 2014	2025(Area HA)	% of Total 2025	Change in Hectares	Percentage change
Forest area	501	26.89%	488	26.19%	-13	-2.59%
Shrubland	107	5.74%	292	16.67%	+185	+172.90%
Grassland	366	19.64%	264	14.17%	-102	-27.87%
Open ground	64	3.44%	88	4.72%	+24	+37.05%
Farmland	661	35.48%	515	27.64%	-146	-22.09%
Built-up area	131	7.03%	192	10.31%	+61	+46.56%
Wetland	33	1.77%	24	1.29%	-9	-27.27
TOTAL	**1863**	**100%**	**1863**	**100%**	**0**	**0**

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Built-up area increased by 61 HA (+46.56%) concentrated in Mbale CBD with spillover into Mukuli and Mutsulyu. 24 HA of open ground (+37.05%) indicative of cleared land and awaiting constructions. The 185 HA explosion in shrubland (+172.9%) is not regreening. Field walks in Mutsulyu confirmed that there were abandoned farms because they had lost fertility. The households had shifted livelihood to casual labor and doing boda rider business in the CBD.

4.1.2 Effect of Built-up Expansion on Wetlands and Productive Cover

Every hectare of concrete has a receipt. In Mbale, the receipt is water. Table 2 shows the direct ecological cost of the 46.56% growth in built-up expansion. The expansion was purchased with a direct loss of ecological infrastructure Table 3.

Table 3

Productive and Ecological Cover Loss as Hydrological Cost of Built-up area

Class Type	2014 HA	2025 HA	Change in HA	% Change	Functional role in the water cycle
Farmland	661	515	-146	-22.09	Informal recharge, food buffer
Grassland	366	264	-102	-27.87	Infiltration zone grazing
Forest area	501	488	-13	-2.59	Canopy interception deep recharge
Wetland	33	24	-9	-27.27	Sponge dry season base flow
Combined recharge loss	1027	779	-248	-24.15	Total productive cover converted

IV>DV1: A 46.56 expansion in built-up area resulted in a 27.27% erasure of wetland and a combined 48 HA loss of farmland and grassland that functioned as recharge zones. While forest loss is marginal in absolute terms its location on upper slopes of Mutsulyu is critical for anchoring recharge.

4.1.3 Primary Water Source Category and Selection Drivers (n=351)

The household water source choices reflect adaptation to the DV1 loss. While production capacity has remained largely unchanged, (VIWASCO 2025), the spatial growth of the town has not. Built-up area has expanded by 46.56% from 131 to 192HA, with open ground awaiting construction increasing by 37.05%. This implies longer distribution networks and higher non-revenue water Table 4 presents data on primary sources of water for Mbale Town residents and the key selection drivers.

Table 4

Classification of Primary Water Sources and Key Selection Drivers

Primary Water Source Category	Affordability (n)	Availability (n)	Proximity (n)	Reliability (n)	Total (n)	Percentage (%)
Informal & Vended Supply	55	41	41	7	144	41.0
Formal Piped & Networked Supply	24	39	46	4	113	32.2
Surface Water & Rainwater Harvesting	4	16	35	8	63	17.9
Groundwater & Self-Supply	7	13	11	0	31	8.8
Total	**90**	**109**	**133**	**19**	**351**	**100.0**

There are three emerging patterns from the data in table 3. There is a reliability collapse. Only 5.4% (n=19) of the households cited reliability as a selection driver. Zero households cited reliability for groundwater, indicating shallow well drying. Another striking revelation was that proximity replaced reliability: proximity (n=133) outweighs reliability (n=19) by 7:1. Households tend to choose the closest water available that day. The third realization is monetization of access: 41% depended on informal vended supply, driven by affordability (n=55). Households purchase 20L jerricans at KES 30 because daily affordability outweighs monthly bill economics.

4.2 Discussion

4.2.1 Devolution as the Driver of Secondary town expansion

The 46.56% built-up growth confirms the global shift described by (*Angel et al.*, 2016) and (Guneralp et al., 2017): urban land expansion is fastest in secondary towns that are academically invisible (World Bank 2020). Mbale did not sprawl randomly rather making it a county capital contributed to its growth. The study's findings validate this trajectory. The 146HA loss of farmland is not a market anomaly but the spatial signature of devolution. Unlike high-income contexts where GDP drives expansion (Seto et al., 2011), Mbale growth is institutionally and population driven. More so, this study addresses the bias noted by (Kim et al., 2020) and (Korah et al., 2023) by providing the first LULC change matrix on built-up expansion using accessible Land sat and Sentinel-2 data.

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4.2.2 The Hydrological cost: Urbanizing over the sponge

The wetland loss of 27.27%, though 9 HA in absolute terms is hydrologically disproportionate. Wetlands in this catchment act as sponges, sustaining dry-season base-flow. Fenta et al., (2017) in Bahir Dar recorded 68% built-up growth purchased with 41% wetland loss. The hydrological price is quantified by (Ahiablame and Shakya 2016): building in riparian zones increases runoff by 40% and collapses dry-season flow by a third. In Mbale, farmland and grassland are fenced into private open ground (+37.05%), simultaneously losing infiltration and communal access to springs. Women in Mukuli reported footpaths to communal springs that had served many generations, are now blocked by plot boundaries, this is documented by (Obando et al., 2017) in Mau. Crucially unlike Nairobi, (Mundia *et al*., 2018), Mbale has no alternative bulk supply, so wetland shrinkage is felt directly in household queues at 4:30am.

4.2.3 From catchment loss to vended water: Adaptive water insecurity

This study closes a gap identified in Kenyan literature. Kanda *et al*. (2018) found small water providers in Western Kenya lose averagely 50% in non-revenue water but did not link it to catchment loss. The data from this study links IV>DV1>DV2 (Built-up expansion and associated LULC change->Extent of wetlands and productive ecological cover->Household water security (source choice and reliability logic)

Proximity (37.9%) now dominates choice logic over reliability (5.4%). As one respondent in Mukuli stated, "*Maji ya bomba huja mara moja kwa wiki, tunaenda pale maji iko karibu*"-piped water comes once a week, we go where water is close. Kiamba *et al*. (2023) demonstrated using SWAT and WEAP models that catchment degradation undermines formal systems reliability; in Mbale this is measured as 41% dependence on informal and vended supply. This is monetization of access as World Bank (2017) described for secondary towns: when free springs are enclosed, water becomes a product sold by boda riders.

4.2.4 Theoretical and policy contribution

Kenya has progressive legislation – Water Act 2016 and EMCA 2015 which prohibit construction within 30m of wetlands. However, (Nyabaro et al., 2023) found <15% of buildings approved and NEMA acts on <5% of violations, a condition (Omollo *et al*., 2021) terms as paper policy syndrome whereas secondary towns grow three times faster than the enforcement capacity can catch up with them. This study provides empirical evidence in a county capital. Foundations sit 10m against the wetlands in relation to a 30m legal buffer as shown in the LULC map in appendix III, and no prior LULC matrix existed to quantify it.

The contribution of this study: The global literature proves secondary towns are the new focus of growth Angel et al., (2016). African literature proves built-up growth eats wetlands (Fenta et al., 2017). Kenyan literature proves devolution accelerates it and enforcement cannot keep up (Mwaniki& Kivuva, 2022). What was missing is the complete chain in one town measured and tied to what people drink. This study provides that chain.: IV (Built-up +46.56%)->DV1(Wetland-27.27% +248 HA recharge lost)->DV2 (Shift from free, reliable springs to paid, proximal vended water at 41%)

V. CONCLUSION & RECOMMENDATIONS

5.1. Conclusion

Mbale town answers the research question. When a town urbanizes over its source, it does not just lose its land cover. It urbanizes over its sponge. This study found that between 2014 and 2025, Mbale Town changed significantly. The loss of 146HA of farmland, 102HA of grassland, 13 HA of forest to 61 HA of new built-up area and 28 HA of open ground has sealed the surfaces that once allowed water to infiltrate. This is felt in Mbale through the seasonal drying of springs in Mukuli and Mutsulyu and the strain on VIWASCO. The current supply therefore cannot keep pace with the town's growth. Securing water for Mbale will require protecting the remaining forests and grasslands to restore recharge, reducing unaccounted-for water as an immediate intervention and aligning land use planning with water supply expansion. In conclusion, Mbale is transitioning from a compact market center to an expansive administrative town. If current trends continue, water may be functionally unavailable in future.

5.2 Recommendations

The study recommends that enforcement of the law on 30-meter riparian reserve as per the Water Act 2016, to ensure recharge zones are kept safe. This study also recommends that the county government controls unplanned sprawl through regulated building approvals and include a requirement for permeable surfaces. The study also recommends that the County government of Vihiga integrates biennial LULC monitoring into the Vihiga County Spatial Plan to track the changes affecting riparian zones. This study measured extent, not the rate of infiltration loss. Future research should apply SWAT and WEAP hydrological models to Mbale Town specifically to quantify how the observed loss of farmland, grassland and forest translates into spring yield decline. Also, the IV->DV1->DV2 framework can be

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replicated in other designated county capitals in Kenya to test whether Mbale is an outlier or the norm for secondary towns.

Declaration of Interest

The authors declare that they do not have any known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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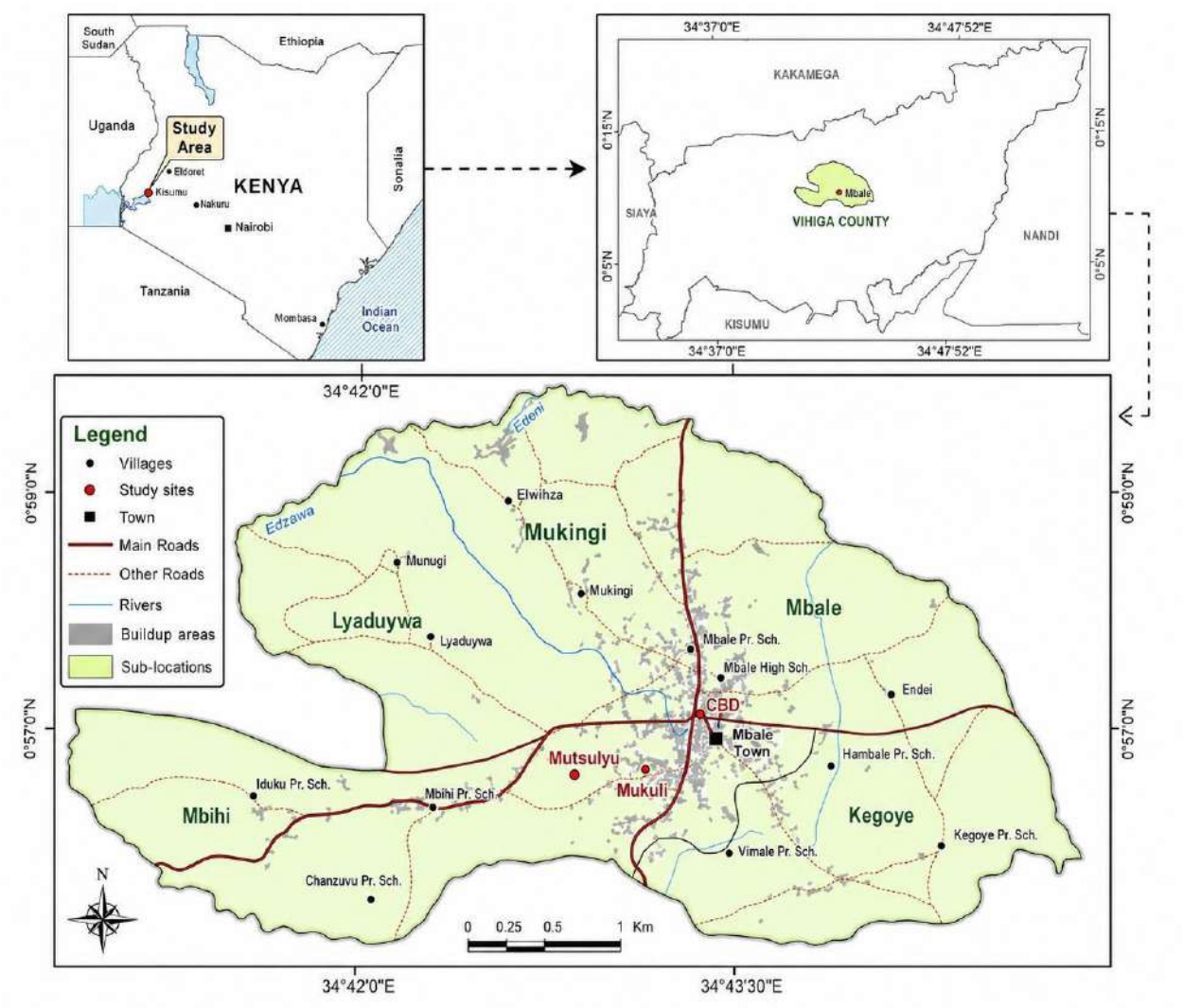
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Appendices

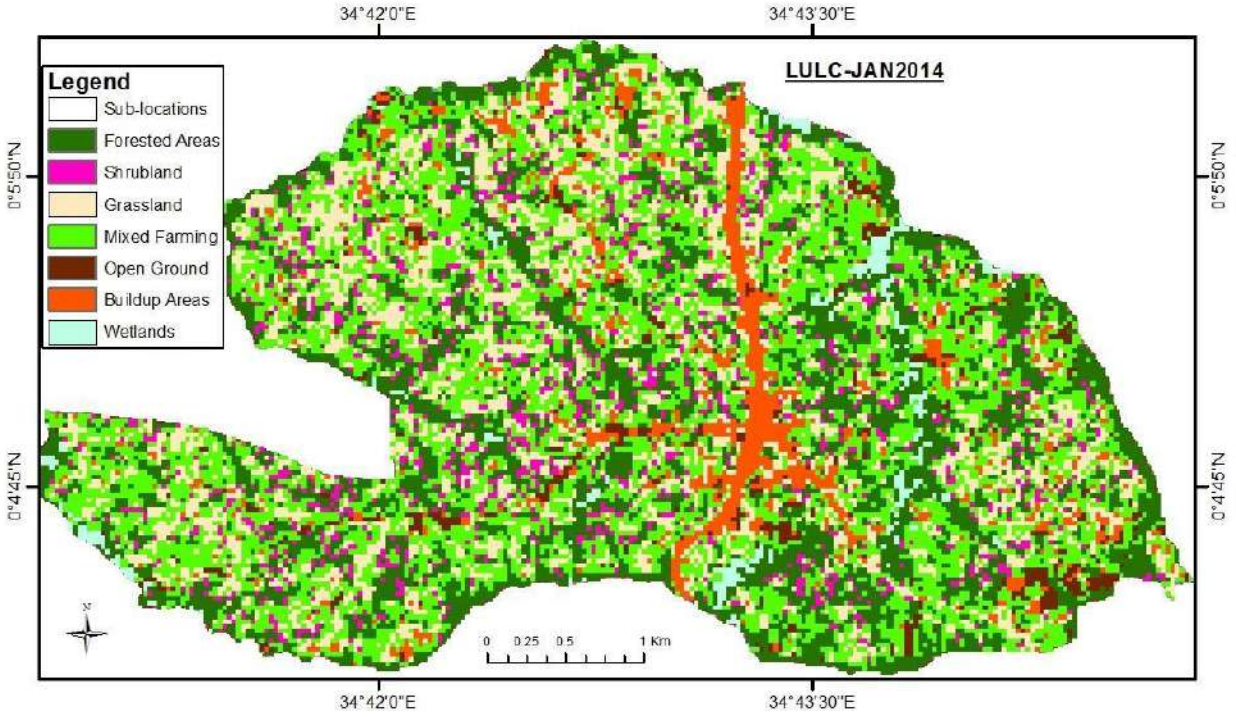
Appendix I : The Map of the Study Area



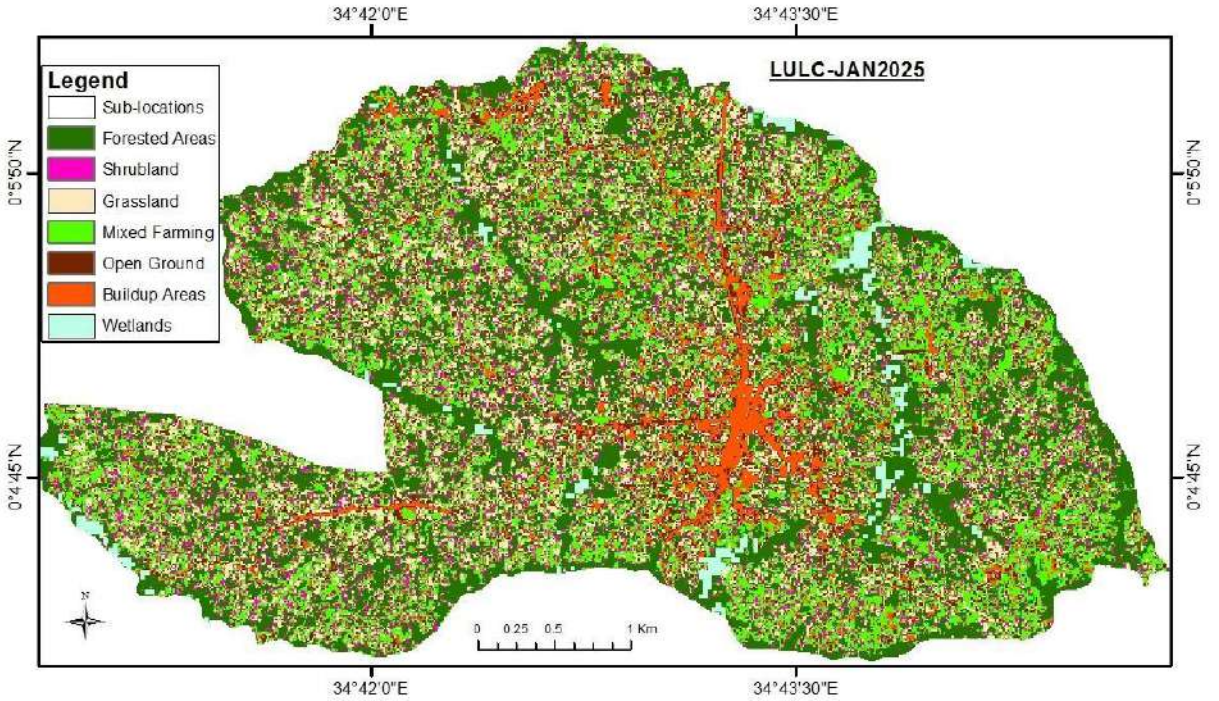
Source: The survey of Kenya

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Appendix II: Landsat Imagery of Mbale Town 2014



Appendix III: Landsat Imagery of Mbale Town in 2025



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