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Ecological Usefulness of Urban Farming in Nkubu, Meru County, Kenya

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Abstract

Agriculture has long been considered a rural activity. However, rapid urbanization and rural–urban migration have reduced agricultural land and increased urban food demand. Consequently, urban farming has grown, attracting significant research interest. This study sought to analyze the ecological usefulness of urban farming in line with the greening of Nkubu town and waste management. A sample of 95 households practising urban farming was selected using Nassiuma's (2000) sample size calculation formula. Questionnaires, interviews, and remote sensing were used to collect data. The study found that urban farming played a key role in reducing urban waste through recycling and increasing the aesthetic value of the town. The study also revealed that despite the urban residents adopting urban farming at high magnitudes in the town, the urban green spaces have been reducing since 2010. It was evident that the green spaces are losing out to build–up areas in Nkubu town. The study recommends that urban farming be recognized in the county development plan and that urban residents adopt the new urban farming technologies.

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Abstrak

Pertanian telah lama dianggap sebagai kegiatan pedesaan. Namun, urbanisasi yang pesat dan migrasi desa-kota telah mengurangi lahan pertanian dan meningkatkan permintaan pangan perkotaan. Akibatnya, pertanian perkotaan telah berkembang pesat, menarik minat penelitian yang signifikan. Studi ini bertujuan untuk menganalisis manfaat ekologis pertanian perkotaan sejalan dengan penghijauan kota Nkubu dan pengelolaan sampah. Sampel sebanyak 95 rumah tangga yang mempraktikkan pertanian perkotaan dipilih menggunakan persamaan dari Nassiuma (2000). Kuesioner, wawancara, dan penginderaan jauh digunakan untuk mengumpulkan data. Studi ini menemukan bahwa pertanian perkotaan memainkan peran kunci dalam mengurangi sampah perkotaan melalui daur ulang dan meningkatkan nilai estetika kota. Studi ini juga mengungkapkan bahwa meskipun penduduk perkotaan mengadopsi pertanian perkotaan dalam skala besar di kota, ruang hijau perkotaan telah berkurang sejak tahun 2010. Terlihat jelas bahwa ruang hijau semakin tergerus oleh area pembangunan di kota Nkubu. Studi ini merekomendasikan agar pertanian perkotaan dimasukkan dalam rencana pembangunan kabupaten dan penduduk perkotaan mengadopsi teknologi pertanian perkotaan yang baru.

INTRODUCTION

Urban agriculture originated in European cities like London, Paris, and Stockholm. It started in the 1880s when the urban poor were given gardens in public spaces of the city to produce their food. This was a survival strategy, one for reducing food insecurity among the urban poor population. It was also a way through which the working class produced fresh food. According to Kiribou et al. (2024), people still practice urban farming to date at higher magnitudes as a way to ensure food security among the urban population.

This historical background illustrates that urban agriculture has long been a response to food insecurity and urban challenges. During World War I and World War II, Western governments such as the United States, the United Kingdom, Canada, Australia, and Germany supported the urban agriculture concept because it averted food deficiency when there was reduced transportation of materials because of the war. Similarly, Ackerman et al. (2014) and McClintock (2010) confirmed that when agriculture is practiced in the urban or the peri-urban spaces, there is a high reduction of energy use as the distance between the urban consumers and the producers is reduced. Western governments also introduced the slogan 'digging for power', which people embraced, and they also coined the term' victory gardens' to refer to the farms and backyards where urban farming was practiced (Jean & Lloyd, 1942).

The victory gardens provided the residents with fresh fruits and vegetables. After the war, many people had moved from the cities, and urban agriculture had declined. However, interest in urban farming re-emerged decades later. During the 1990s, the United States cities revived urban farms and gardens as a way to curb food insecurity. This was seen as a great renaissance for urban agriculture, which has since experienced great support. To date, most Western cities' families still have the garden allotments, a concept that is nowadays world-wide.

This global perspective sets the stage for understanding why urban agriculture remains relevant today. According to the Food and Agriculture Organization of the United Nations (2018), the world's demand for food by 2050 is projected to be 70% higher. The rural areas' production alone cannot meet this high demand for food, which therefore calls on urban areas to supplement production. According to FAO's report of 2018, households determined to practice urban farming may grow crops around their compound, keep animals, or even practice aquaculture within the vicinity of their house. The most common crops are the perishable leafy vegetables like kale, spinach, onions, and carrots. Animals kept in the compounds include poultry, dairy cattle, rabbits, and goats. Most studies have revealed that urban and peri-urban agriculture contributes greatly to the social and economic livelihoods of the people (Njenga et al., 2010; Ackmern et al., 2014; FAO, 2018).

Beyond food security, urban agriculture plays an important role in environmental sustainability. Urban agriculture has promoted organic waste recycling. Njenga et al. (2010) established that domestic waste can be used as food for the reared animals in the backyards. Urban agriculture also contributes to the town's aesthetic by enhancing the number of green spaces that strengthen resilience towards climate change. It is very beneficial to the environment as it reduces the carbon footprint in the town, increases biodiversity, and also brings forth very cool and serene towns (Lin et al., 2015). It also accounts for climate regulation when the farms bring about a cooler microclimate and improved air quality, mitigating against the urban heat island effect (Qiu & Zhao, 2023).

The situation in Nkubu town reflects these global dynamics at a local scale. The town has continued to witness a great expansion because of urbanization. The urban population has also been increasing over the years at a rate of 0.39% annually, hence raising the food demand in the town (KNBS, 2019). The rising population and the rising demand for food pose a challenge to food security in the town. This has triggered the urban residents to make use of any available spaces in the town for agriculture. Being a medium-sized town, it still has some open spaces available for crop and livestock keeping, which is evident as one walks across the town.

Understanding these changes requires a reliable method to assess vegetation cover associated with urban farming. Urban farming is seasonal, but it impact on the vegetation cover in the town, which influences the local environment. Remote sensing data from satellite missions is an effective method used to detect and quantify vegetation cover in small and large areas. The Landsat satellite provides time series imagery of a place that can be used to track changes and assess utility. The analysis of the Landsat images done in this study was the Normalized Difference Vegetation Index (NDVI). The NDVI is the difference between near-infrared (NIR) light (strongly reflected by healthy plants) and Red light (absorbed during photosynthesis). It is a strong indicator of how well urban crops or green areas are photosynthesizing, as well as how they support carbon sequestration, oxygen production, and microclimate regulation. In this study, it is used because it gives a measurable, recurrent, and spatially detailed measure of vegetation health and coverage, making it ideal for assessing how urban farming contributes to ecological functions like climate regulation, biodiversity support, and air quality improvement.

According to Buchhorn et al. (2016), NDVI is used to empirically show the changes in vegetation cover/health in a specified area over time. Using NDVI, one is able to calculate the area of vegetated areas and the non-vegetated areas, hence giving more insights into the green areas, even in an urban area that has many land uses. Many researchers seeking to understand land use changes have adopted this remote sensing method because it provides real-time data (Ghodieh, 2023).

Despite growing literature on urban farming, a critical gap remains. While there is a growing literature on urban farming, there is limited knowledge on the ecological usefulness of urban farming and its contribution to greening the environment. On the other hand, most studies have been done in big towns, which have few open spaces, hence necessitating a study in a small growing town with available open spaces for farming. In this regard, this study investigated the ecological benefits of urban farming in line with urban greening and waste management.

METHOD

Study Area

The research was conducted in Nkubu town in Meru County. The town is located on the Eastern slopes of Mt. Kenya, and it lies between the longitude 0°4'9"S and latitude 37°39'58"E, as shown in the map below (Figure 1). Nkubu is the largest town in South Imenti Constituency in Meru County. The town has experienced rapid urbanization in terms of population and social amenities. The town has a population of 7,675 people with approximately 2,000 households according to the 2019 Census data. In the town outskirts, there are four estates, namely, Taita, Kiigene, Kigumo, and Kirwiro. This population is expected to continue rising as per the current trends.

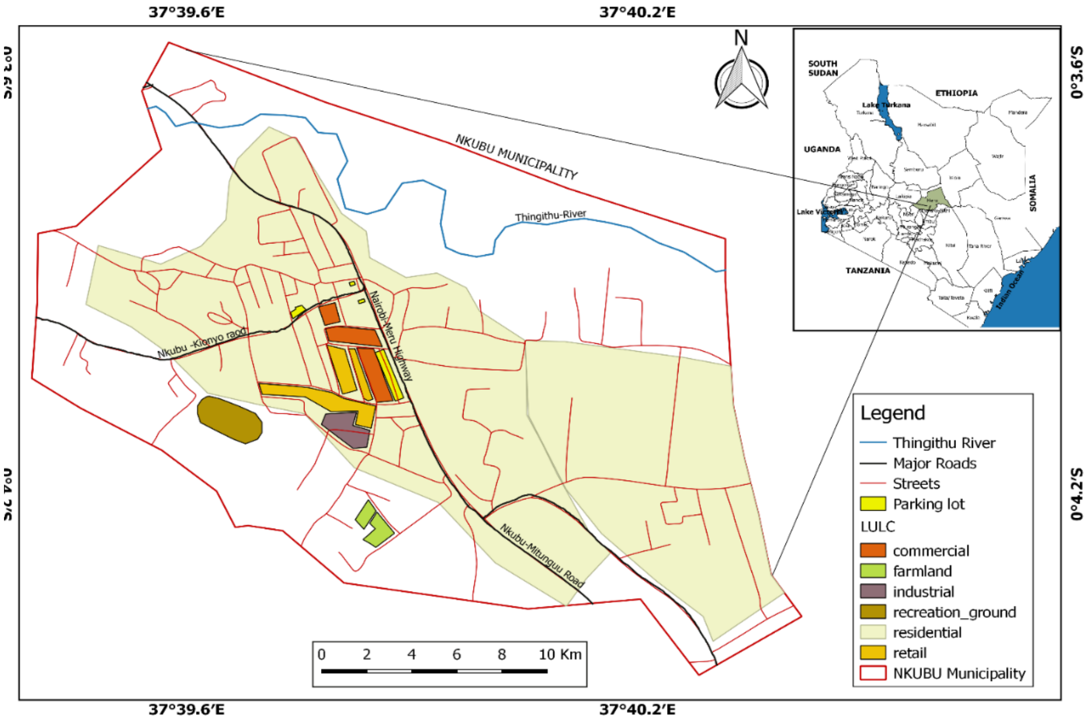

Figure 1. The Map of Nkubu Town Showing Land Use and Land Cover

Study Design

The objective of the study was to examine the ecological usefulness of urban farming in Nkubu town with emphasis on the greening of the town and waste management. To achieve this objective, the study adopted a concurrent mixed methods approach, which merges the collection of qualitative and quantitative data and analyzes them integratively. The concurrent mixed method enhances triangulation of findings that bring about a deeper understanding of urban greenness and perceptions on waste management in Nkubu town. Regarding sampling, for the households, a sample of 95 respondents was selected from 2,000 using the Nassiuma (2000) sample size calculation formula. Because it is recommended for a finite population, which is the case of the household population in Nkubu town, that has census data. The study used cluster sampling to select the respondents from the four estates of the town.

Data collection involved multiple instruments to ensure comprehensive coverage. Questionnaires, observations, interviews, and remote sensing were used to collect data from the town. The questionnaires were used to collect quantitative data on households' perceptions in regards to urban waste management. Through an observation checklist, the researcher was able to verify and ascertain data collected using other research instruments to check greenness levels and waste management conditions in the town. To complement household data, key informants' interviews were used to collect data from the physical planning officer, the extension officers in South Imenti, and the area managers. This data provided insights regarding policy implementations and challenges facing urban farming and how they affect greenness and waste management in town.

The GPS Waypoints Finder captured locations for ground truthing what was revealed from satellite imagery analysis. The Landsat 8 OLI/TIRS images of Nkubu town were retrieved from the United States Geological Survey (USGS) and used to depict the vegetation cover change dynamics for the study period of 2010-2020, measured using NDVI. Overall, the combination of these methods ensured that sufficient data were collected to comprehensively answer the study questions.

Image Processing

Raw satellite images were geometrically and radiometrically corrected before the analysis to ensure accurate geometry in the images, allowing data pixels to be properly aligned for time-series analysis. The images were also rectified to enhance clarity and the precise depiction of different features. After preprocessing, the images were classified to categorize all image pixels to obtain a given set of land cover themes.

The supervised classification method was used to categorize pixels into specified land cover types in the town. According to Ghodieh (2023) supervised classification method is an image processing technique that organizes pixels in a satellite image into land cover themes. To maintain image quality, the study set the image cloud cover at 30 %. The NDVI values representing land cover themes were classified as shown below based on prior studies (Table 1).

Table 1. Classification of Land Uses According to NDVI Values

NDVI values	Land use class
-1 - 0.0	Water bodies, clouds
0.0 - to 0.2	Built-up area
- 0.2 - 0.3	Bareland
0.3 - 0.4	Moderate vegetation
> 0.5	Healthy vegetation

Source: Aryal et al., 2022.

Data Analysis

A spatial analyst tool using map algebra was deployed to compute the total area under green spaces within Nkubu town. This process was complemented by NDVI-based classification, which identified vegetation cover. The amalgamated geospatial approach enabled both the quantification of green space extent and the evaluation of vegetation utility. Through this integration, the study connected urban farming activities with their ecological benefits, including carbon sequestration, air quality improvement, biodiversity support, and urban microclimate regulation.

The total area of each land cover class was computed using raster data analysis, where the classified NDVI raster was reclassified and converted into zonal statistics for area calculation using Equation 1 below.

$$A_c = \frac{N_c \times r^2}{1{,}000{,}000} \quad (1)$$

where A_c represents the total area of vegetation class in km^2, N_c number of pixels classified as vegetation, r denotes the spatial resolution of the sensor in meters (for Landsat, r=30 m) , and 1,000,000 is the conversion factor from square meters to square kilometres (Jensen, 2015; Ghodieh, 2023).

The study also computed the NDVI. The NDVI compares the amount of the absorbed red light and the Near-infrared light reflected. The green colouring matter in a plant absorbs a lot of the visible red light, whereas the cell structure of the plant reflects much of the infrared light. The green and dense vegetation has low red-light reflectance and very high reflectance of infrared, hence high levels of NDVI. The index varies from place to place. Lewis et al. (1998) state that there is a close relationship between the NDVI and the plant cover in a place. The use of satellite images of Nkubu town in this research helped to map NDVI as an indicator of some ecological benefits of urban farming. The formula for calculating NDVI is shown by the following Equation 2.

$$NDVI = \frac{NIR - Red}{NIR + Red} \quad (2)$$

where $NDVI$ are Normalized Difference Vegetation Index (unitless, range: -1 to +1), NIR are surface reflectance values in the Near-Infrared band (Band 5), and Red are surface reflectance values in the Red band (Band 4).

The quantitative data were captured using a questionnaire that largely had Likert scale questions on residents' perceptions of waste management. The data was analyzed using frequencies and percentages to measure the proportion of views on different waste management issues. To strengthen the analysis, these findings were triangulated with qualitative data from interviews and observation checklists.

Thematic analysis was conducted following the structured approach recommended by Braun & Clarke (2006). First, all interviews that had been voice-recorded were transcribed verbatim into Microsoft Word documents. The researcher read through the data repeatedly, capturing initial impressions such as references to cool environments, biodiversity preservation, and waste reduction. Using open coding, segmentation, and labelling of descriptive codes were performed. These codes included: carbon storage, urban heat regulation, biodiversity habitat, stormwater speed regulation, air cleaning, and aesthetic value. The codes were then grouped into the following categories of ecological utility: climate regulation, ecosystem support, and soil and water management.

Emerging patterns and relationships were synthesized into preliminary themes. These included urban farming as a weather regulator, biodiversity enhancement and green spaces enhancement, and public health and well-being benefits. Each theme was reviewed and refined to ensure clarity and appropriate naming. Finally, the findings were presented in analytical narratives, supported by participant quotations and linked to relevant ecological theory and empirical studies (Creswell & Poth, 2018).

RESULT AND DISCUSSION

The NDVI measures greenness of a place with values ranging from -1 to 1. The NDVI values of the town region in 2010, 2015, and 2020 are shown in the maps below.

The NDVI analysis revealed that in 2010, values ranged from 0.0399 to 0.7031, in 2015 from 0.0341 to 0.5799, and in 2020 from 0.0504 to 0.5598. This indicates a gradual decline in vegetation health and density over time.

The data further shows variations in the extent of green spaces across the years. In 2010, dense vegetation covered 7.386 km^2, but this slightly decreased to 6.7326 km^2 in 2015. By 2020, the green space had reduced significantly to 5.5188 km^2. This decline can largely be attributed to urban development activities, which necessitated vegetation clearance and consequently reduced reflectance in the near-infrared spectrum.

Conversely, built-up and non-vegetated areas steadily increased during the same period. In 2010, non-vegetated land occupied 1.0323 km^2, which rose to 1.5688 km^2 in 2015, and further expanded to 2.7882 km^2 by 2020, as summarized in Table 2.

A detailed analysis of the estates indicates

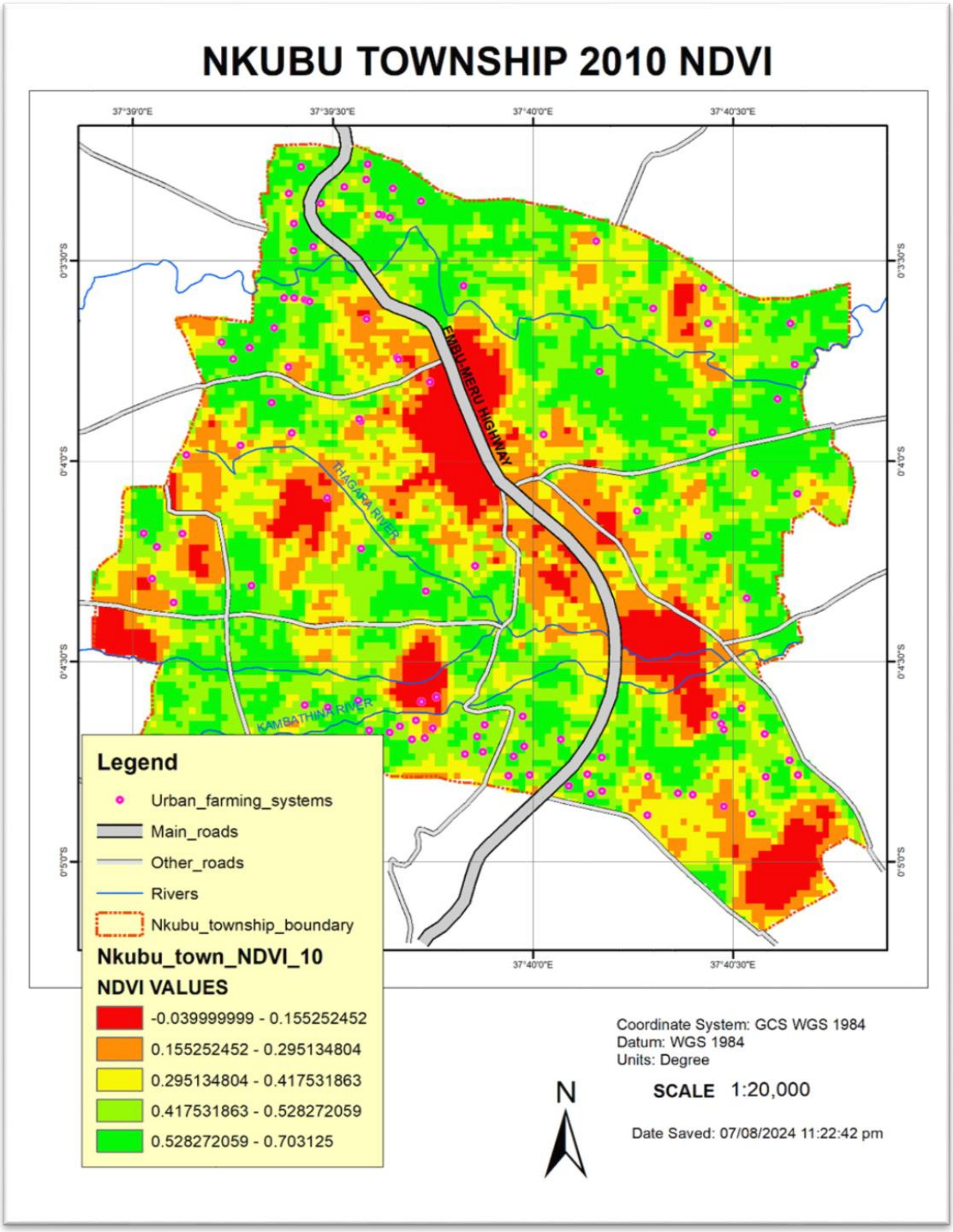

Figure 2. NDVI Values in 2010

that Kiigene, being the most densely populated estate in Nkubu, has experienced a marked decline in vegetated land accompanied by an increase in non-vegetated surfaces. This trend is primarily associated with the growing demand for residential apartments within the estate. Furthermore, its relatively flat terrain facilitates construction, thereby accelerating the expansion of built-up areas. Over time, this has resulted in the proliferation of residential homes, hotels, and road networks within the estate.

Similarly, the central part of Nkubu town has recorded a significant increase in non-vegetated areas. This shift can be attributed to intensive urban development projects, including the construction of commercial buildings, markets, paved roads, and related infrastructure. Such developments have progressively encroached upon existing vegetated land, consequently diminishing the overall green cover in the town.

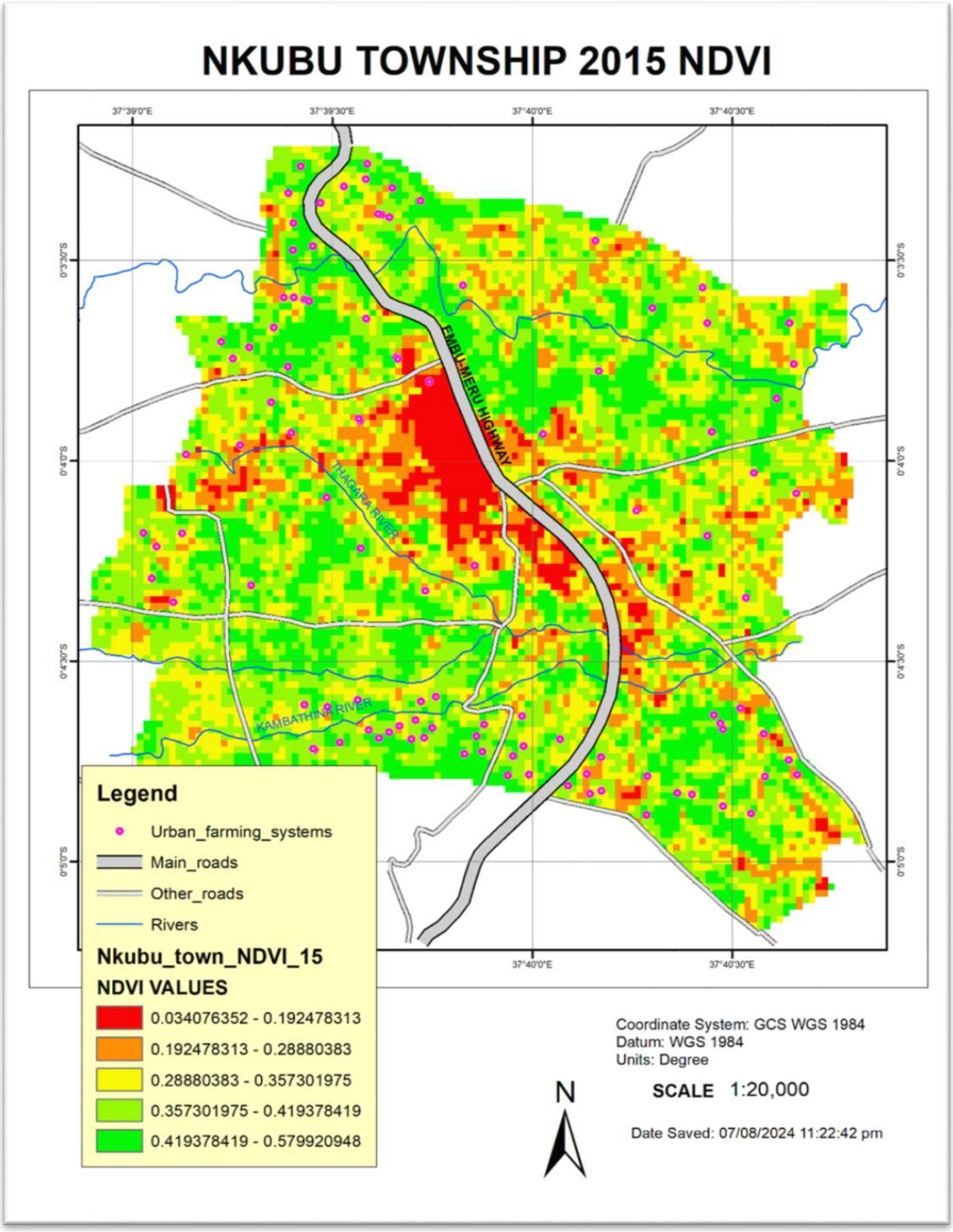

Figure 3. NDVI Values in 2015

In contrast, Kirwiro estate retains considerable green spaces relative to other estates. This condition is largely explained by the uneven terrain, which acts as a natural constraint to settlement and large-scale construction. Additionally, the area is predominantly occupied by native residents who continue to utilize inherited lands for agricultural purposes, thus sustaining vegetation cover. The availability of open spaces further promotes cultivation, while the presence of the Thingithu River creates a more favorable microenvironment for vegetation growth, reinforcing the ecological integrity of this estate.

This study demonstrates that urban green spaces in Nkubu have been declining. This trend poses adverse implications for the urban environment, particularly in terms of reduced carbon sequestration, diminished groundwater infiltration, and increased urban heat levels.

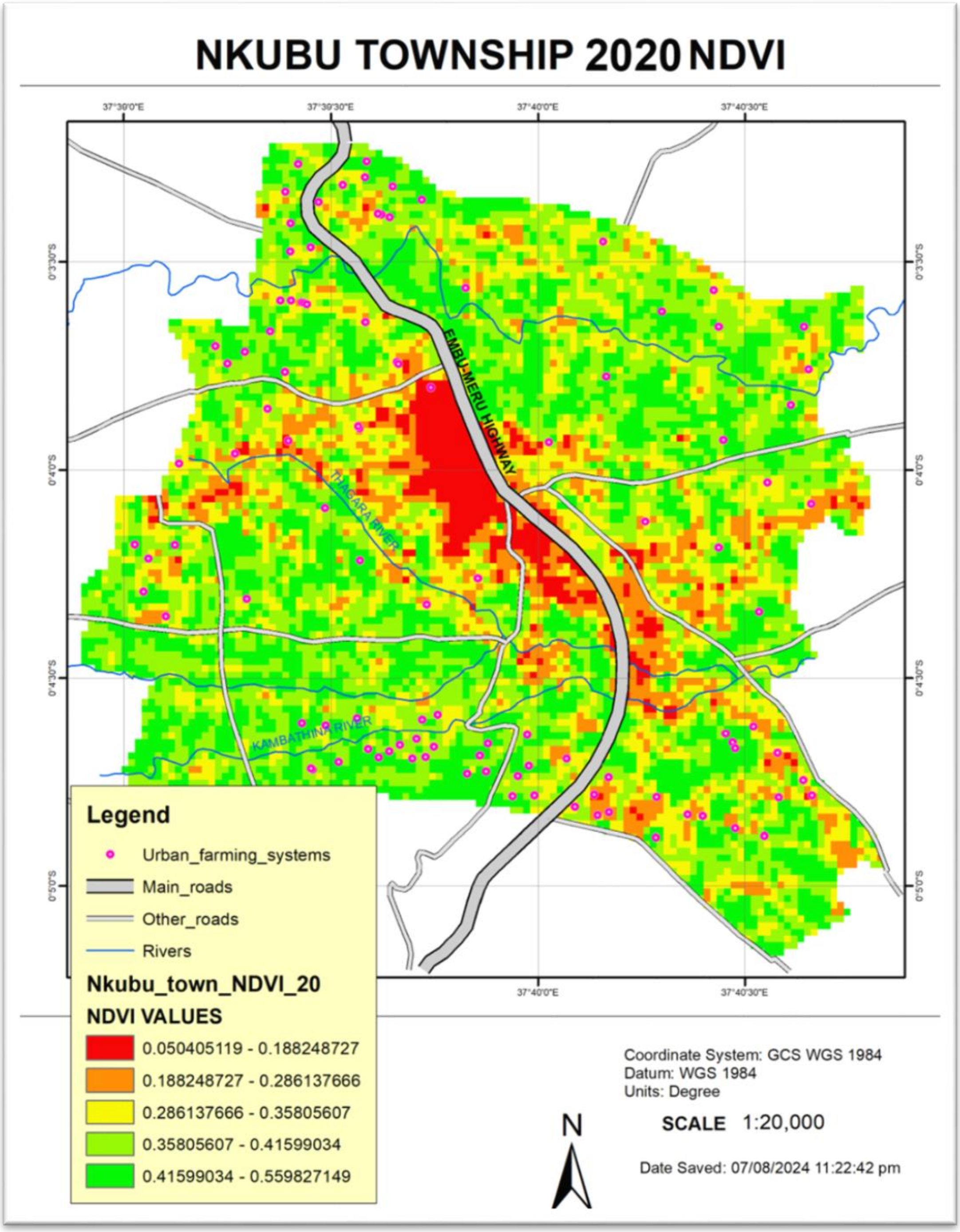

Figure 4. NDVI Values in 2020

Table 2. Changes in Vegetated and Non-Vegetated Area in Nkubu Town

Year	Vegetated area (km^2)	Non-vegetated area (km^2)
2010	7.3860	1.0323
2015	6.7326	1.5688
2020	5.5188	2.7882

The findings underscore the urgent need for the town to preserve its ecological integrity. Promoting urban farming emerges as a viable strategy to sustain greenery amidst rapid urban development.

The results align with the findings of Kamal et al. (2017), who investigated the greening of urban spaces using geospatial techniques in Bangkok. Their study, which also employed NDVI as an indicator of vegetation cover, revealed a similar pattern of diminishing greenery due to the expansion of built-up areas. This reduction was associated with negative impacts on urban air purification and a consequent rise in urban heat.

Additionally, this study examined the perceptions of urban farmers regarding waste recycling, greening of the area, and the aesthetic value associated with urban farming. These perceptions were captured through a questionnaire employing a likert scale ranging from 1 to 5, providing quantitative insights into the social dimension of urban ecological sustainability (Table 3).

Table 3. Urban Farmers' Responses to the Ecological Importance of Urban Farming

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly agree	Mean response
Household farming encourages the recycling of materials	0	9	21	10	50	4.1
Urban household farming increases the green area coverage in the area	1	2	4	62	21	4.1
Urban household farming brings about better waste management	20	21	19	22	8	2.7
Urban household farming increases the aesthetic value of an area	0	5	18	22	45	4.2
Urban household farming should be embraced in every household	5	12	5	54	14	3.7

The study established that urban farming plays a critical role in recycling household waste. Farmers indicated that kitchen waste and animal waste serve as inputs for urban gardens, while animals are fed with kitchen refuse, thereby reducing the cost of purchasing commercial animal feeds. Recycling minimizes the amount of garbage disposed of in municipal tanks, reducing transportation costs to dumpsites and decreasing reliance on inorganic fertilizers, thus promoting healthy biodiversity within the town and its environs. These findings align with Karanja et al. (2010), who reported that urban farming significantly contributes to household waste management in Nakuru.

The study further observed that urban farming enhances green spaces within the town, contributing to aesthetic appeal and air purification. Respondents noted that green spaces are visually appealing and often serve as recreational spots, where residents relax. Urban farming reduces the urban heat island effect and pollution, thereby improving urban livability. If widely adopted by households, urban farming could transform urban areas into vibrant, sustainable spaces. This is consistent with Swanwick et al. (2003), who argued that urban green spaces create sustainable environments by addressing environmental concerns, improving physical and mental well-being, and supporting economic development.

Despite providing valuable insights into changes in vegetated and non-vegetated areas in Nkubu town, the study acknowledges certain limitations. The use of Landsat 8 imagery, with its moderate spatial resolution, may have underestimated small vegetation patches, and cloud cover may have introduced minor classification errors in NDVI analysis.

Overall, the research revealed a decline in vegetated areas due to rapid urbanization. Urban residents expressed strong support for urban farming as a strategy for waste management, contributing to cleaner urban environments. These findings highlight the social benefits of urban farming, even as physical green spaces diminish. The study underscores the need for county policy planners to integrate urban farming into urban sustainability strategies. If adopted and legalized by local authorities, urban farming could enhance food security, promote environmental sustainability, and mitigate the adverse effects of urbanization, which is urban farming as a sustainability pillar.

CONCLUSION

Urban farming has become an increasingly embraced practice in Nkubu town. Benefiting from abundant water resources, open spaces, and tropical climatic conditions conducive to diverse crop and livestock production, it is evident that this practice will continue to gain popularity among residents. Its role in enhancing recycling and promoting effective waste management further underscores its significance. Urban farming also contributes to the greening of the town; however, as urban development accelerates, green spaces are diminishing, as empirically demonstrated in this study. This trend presents a challenge, as the decline in vegetated areas is likely to persist. Therefore, the study recommends educating farmers on emerging urban farming technologies to ensure that the reduction of available farming spaces does not compromise agricultural productivity.

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