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Coffee production and land cover change in kyarumba sub-county, Kasese district

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Abstract

This study examined coffee production and land cover change in Kyarumba Sub-County, Kasese District, Uganda. Using survey data from 165 respondents and GIS analysis, the study found that about 1,800 hectares of land are under coffee cultivation making as the main land use activity in the sub county. It was established that between 2000 and 2020, forest cover declined by 36%, while agricultural land increased by 90%, largely due to coffee expansion. Although initiatives like Rainforest Alliance, organic farming and fair trade exist, their impact remains limited. This is because of low farmer awareness and weak institutional support. The study concludes that coffee farming sustains livelihoods but encourages deforestation. It therefore calls for stronger policies and farmer training to promote sustainable coffee production and compliance with the European Union Deforestation Regulation (EUDR).

Keywords: EUDR, deforestation, land cover, compliance, stakeholders, kyarumba, uganda, sustainability

1. Introduction

1.1 Background

Globally, agricultural production and international trade have increasingly been linked to environmental degradation, especially deforestation and land cover change. Achieving Sustainable Development Goal (SDG) 12, which promotes responsible consumption and production, requires balancing economic growth with environmental conservation. Many governments and private organizations have introduced sustainability standards to reduce the negative effects of global commodity chains (Oluwatosin Yetunde Abdul-Azeez *et al.*, 2024). However, gaps still exist in enforcing these measures effectively, especially in developing countries (Fernandes Martins *et al.*, 2022; Macdonald, 2020; Negi *et al.*, 2020) [23, 31, 36].

To curb deforestation associated with trade in agricultural and forestry products, the European Union (EU) introduced the EU Timber Regulation, which was later replaced by the EU Deforestation Regulation (EUDR) in 2023 (Berning & Sotirov, 2024) [11]. The EUDR seeks to ensure that agricultural commodities imported into the EU, such as coffee, cocoa, palm oil, and soybeans, are not linked to deforestation. This regulation, which will take effect in December 2025, uses satellite imagery and remote sensing technologies to trace the origins of these commodities (Escobar *et al.*, 2020) [20].

Coffee, being the second most traded commodity globally after oil (Ole, 2024) [39] is one of the key agricultural products affected by the EUDR. Major coffee-producing countries, including Uganda, now face the challenge of aligning coffee production with sustainable land use practices. Uganda exports about 65% of its coffee to the EU market (UCDA, 2023a), making compliance with environmental standards crucial for the country's economy. The coffee sector supports over 1.7 million households, mainly smallholders located in the central, eastern, and western parts of Uganda (Poncet *et al.*, 2024) [43]. In the Rwenzori region, including Kyarumba Sub-County in Kasese District, Arabica coffee is the main crop grown on the hilly slopes.

Over the years, coffee production in Kyarumba has expanded as more land is cleared for cultivation. While this has increased household income, it has also contributed to land cover change and environmental degradation.

Yet, the actual extent of land under coffee production, the pattern of land cover change over time and the existing initiatives promoting environmental protection in Kyarumba Sub-County remain unclear. Understanding these dynamics is essential for promoting sustainable coffee production that supports both livelihoods and environmental conservation.

1.2 Problem Statement

Coffee is a vital cash crop in Uganda and a major source of income for households in Kyarumba Sub-County, Kasese District. However, the expansion of coffee farms has increasingly been associated with deforestation and loss of vegetation cover. As global attention shifts toward sustainable production, regulations such as the EU Deforestation Regulation (EUDR) require coffee exported to the EU to be traceable and free from deforestation risk (Berning & Sotirov, 2024) ^[11]. This presents both opportunities and challenges for smallholder coffee farmers in Uganda, who depend heavily on natural forests and steep slopes for cultivation.

In Kyarumba Sub-County, anecdotal evidence suggests that land under coffee cultivation has increased over the past two decades, often replacing natural vegetation and other land uses. Yet, there is limited documentation on how much land is currently under coffee production and how this expansion has influenced land cover change between 2000 and 2020. Additionally, while several environmental protection initiatives exist at national and district levels, it is unclear how these are being implemented or integrated within local coffee farming practices in Kyarumba.

Therefore, this study seeks to assess the amount of land under coffee production, examine land cover change between 2000, 2010, and 2020, and identify existing environmental protection initiatives in Kyarumba Sub-County, Kasese District. The findings will contribute to understanding the relationship between coffee production and land use dynamics, supporting sustainable agricultural and environmental management efforts in the region.

1.3 Objectives

- i) To assess the amount of land under coffee production in Kyarumba Sub-County.
- ii) To examine the land cover change in Kyarumba Sub-County from the years 2000, 2010 and 2020.
- iii) To examine the existing initiatives for environmental protection in Kyarumba Sub-County.

1.4 Significance of the Study

This study provides critical insights into the relationship between coffee production and land cover change in Kyarumba Sub-County, Kasese District. It offers evidence on how the expansion of coffee farming has influenced environmental conditions and supports the formulation of sustainable land management strategies. The study findings will guide local authorities, policymakers and the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) in balancing agricultural productivity with environmental conservation. Additionally, the study contributes to academic knowledge on sustainable coffee production and raises community awareness about integrating environmental protection into farming practices.

3. Materials and Methods

3.1. Description of the study area

Geographically the study was conducted in Kyarumba Sub-County in Kasese district, southwestern Uganda. This was because Kyarumba Sub-County is one of the main coffee producing hubs in Uganda but also known for rampant destruction of trees. The neighboring areas of Kyarumba were also of great importance.

3.2. Research Design

This study applied a cross-sectional survey design, incorporating both quantitative and qualitative approaches. A qualitative approach was used due to its ability to study phenomena in detail. Meanwhile, a quantitative approach was employed to capture measurable data. The cross-sectional research design enabled the researcher to analyze land cover change by examining the phenomena as they existed within the recorded time, drawing on existing occurrences.

3.3. Target population

The study involved coffee producers in Kyarumba Sub-County who are directly affected by coffee-related regulations. It also engaged policymakers from government departments such as UCDA, NFA, NEMA and GIZ to gain insight into their reception of the coffee production and land cover change in Uganda.

3.4. Sampling procedure and sample size determination

3.4.1. Sampling procedure

Simple random sampling was used to select participants from the coffee producers/farmers. The researcher randomly chose participants, ensuring that everyone in the study population had an equal likelihood of being selected. Additionally, purposive sampling was employed to select key informants. This non-probability sampling method involved deliberately choosing participants based on specific qualities. Coffee producers were selected through purposive sampling since they were clearly identified and known to be relevant to the study.

3.4.2. Sample size determination

The sample size was determined from a population of 290. Using the Krejcie and Morgan table, 165 respondents participated and were interviewed. This method was chosen because the selected sample accurately reflects the characteristics of the target population that is coffee producers and buyers in Kyarumba Sub County.

3.5. Data collection methods

Being a qualitative study, the research involved interviews, questionnaires and documentary reviews to collect data from participants.

3.5.1. Questionnaire method

A structured questionnaire was used to collect data from producers. This helped the researcher to collect quantifiable data which was used to provide triangulation and validation of the qualitative findings from key informants (Rathi & Ronald, 2022) ^[44].

3.5.2. Interviews

Interviews helped the researcher to engage deeper with the participant and thus a deeper understanding of the

phenomenon of the study. Data from key stakeholders were collected using Key informant interviews.

3.5.3. Document review

This involved systematic collection, documentation, analysis and interpretation to collect data from secondary sources. Relevant publications such as institutional reports, research publications, textbooks, newspapers and others were visited by the researcher to collect relevant information about coffee production and sustainable regulations. During the discussion, primary data was validated using information from these secondary.

3.5.4. Satellite Imagery

To investigate land cover change and degradation in Kyarumba Sub-county between 2000 and 2020, the researcher employed remote sensing techniques using Landsat satellite imagery. The process was structured to ensure that data collected would be both accurate and relevant to the local landscape. The researcher acquired Landsat 8 satellite images for the years 2000, 2010, and 2020, representing three critical periods over a span of 20 years. These images were selected to provide a comparative view of land cover dynamics over time. Since raw satellite images are often affected by cloud cover, cloud removal techniques were applied using cloud computing algorithms. Specifically, raster-based cloud filtering was used to eliminate clouded areas, resulting in clear and usable imagery suitable for classification and analysis. The study utilized Google Earth Engine (GEE) for preprocessing Landsat imagery, leveraging its extensive satellite imagery archive and advanced geospatial analysis capabilities to detect and quantify earth surface changes.

3.6. Data management and analysis

3.6.1. Descriptive statistics

Quantitative survey data was analyzed using SPSS version 27, and the descriptive statistics are presented as frequencies and percentages in the tables and charts.

3.6.2. Thematic analysis

Qualitative data was thematically analyzed through categorization into similar groups which groups were then presented and explained as narratives, experiences, proverbs and quotations to make the data meaningful (Braun & Clarke, 2019) [13]. The fields were systematically arranged in order of occurrence to make them more meaningful and the events in these themes were chronologically analyzed.

3.6.3. GIS Analysis

Geographic Information System (Arc GIS) tools were used to analyze historical and current satellite imagery. Image processing was conducted in ArcGIS Pro 3.02 using the maximum likelihood classification algorithm. For each of the three study periods, we will classify images using 40 training areas (10 per LULC class) based on signature files. All imagery will maintain 30m resolution with UTM-WGS 1984 Zone 36 projection. Preprocessing steps included band ratio calculations, radiometric correction (haze reduction), Tasseled Cap transformation, and post-classification comparisons to ensure accurate reflectance characterization. After preprocessing, the researcher carried out both unsupervised and supervised classification. Unsupervised classification helped in identifying general land cover

categories based on spectral similarities. This step provided a basis for selecting training samples for more refined classification. For supervised classification, the researcher used different spectral band combinations to enhance feature differentiation. One of the most effective was the 432 RGB band combination (Red, Green, Blue), which was particularly useful in distinguishing agricultural areas, especially coffee plantations. Each land cover type was identified based on its unique spectral signature.

The classified land cover types included: Agriculture (mainly coffee farms); Bareland (exposed or degraded soil); Forest land; Grassland; and Settlements (villages and towns). We analyzed two decades of Landsat 8 data (2000-2020) through cross-tabulation matrices and overlaid functions in ArcGIS to quantify temporal changes. Change matrix analysis and calculation of gross gains/losses were performed in Excel.

Accuracy assessment evaluated how well classified images represent ground conditions. We conducted ground verification to identify misclassified areas, then generate an error matrix and calculate overall accuracy using Kappa statistics (Gunathilaka & Fernando, 2022) [26]. Overall accuracy was determined by dividing correctly classified pixels by total pixels, with $\geq 70\%$ considered acceptable. The figure below presents the statistical analysis workflow.

3.7. Data quality control

3.7.1. Validity

Validity is the extent to which the research instrument measures what it is meant to measure (Sudaryono *et al.*, 2019). The study objectives were clearly operationalized and well defined and questions were well developed in line with the objectives by the researcher. The Content Validity Index was calculated using Amin (2005) formula;

$$CVI = \frac{\text{Total number of items rated relevant by experts}}{\text{Total number of items}}$$

The CVI value of 0.78 was obtained, and since it is greater than 0.7 as recommended by Avinç & Doğan, (2024), the instrument was considered valid for data collection.

3.7.2. Reliability

This looked at data collection instruments' capability to produce similar results when used to measure something severally (Salmia, 2023) [48]. Before going to the field, I conducted a pilot study and peer review of the tools to identify any omissions and eliminate possibilities of error. The reliability of the research was calculated from the formula;

$$\alpha = \frac{N * \bar{c}}{\bar{v} + (N - 1) * \bar{c}}$$

Where N is equal to the number of items, $\bar{c}$ is the average inter-item covariance among the items and $\bar{v}$ equals the average variance. A value 0.80 was obtained, and hence the instrument was considered reliable for use in data collection.

3.8. Ethical Considerations

Ethical principles as guided in scientific research were observed closely by the researcher. First, informed consent

was sought from all participants and for in-school adolescents being mainly minors; it was sought first from the responsible authorities at the local government and line MDAs. Objectivity from the level of sampling were observed through the simple random sampling technique. Furthermore, anonymity was highly observed that respondent's identity won't be attached to their responses but responses will be treated as general findings (Mozersky *et al.*, 2020) [33]. Confidentiality was observed and individual data will not be exposed to third parties but their contributions were treated as general data. The study also kept academic that no material rewards were given to respondents in exchange for data.

4. Results and Discussions

This chapter presents and analyzes the demographic information of respondents, study's findings on land under coffee production, land cover change and existing Initiatives for Environmental Protection in Kyarumba Sub-County. The chapter also compares local trends with global practices, offering insights into the balance between agricultural growth and environmental conservation.

4.1. Socio-demographic characteristics of respondents

Table 1: Frequency distribution of respondents' socio-demographic characteristics

Variable	Frequency (n = 165)	Proportion (%)	X ²	p-value
Gender				
Male	95	57.6	3.79	0.052
Female	70	42.4		
Age group				
18-28	40	24.2	20.00	<0.001
29-38	50	30.3		
39-48	35	21.2		
49-58	25	15.2		
59 and above	15	9.1		
Engagement in coffee production				
Yes	120	72.7	33.55	<0.001
No	45	27.3		
Years in coffee production				
1-5 years	63	52.5	25.68	<0.001
6-10 years	38	31.7		
Over 10 years	19	15.8		
Awareness of the EUDR				
Yes	27	16.4	75.44	<0.001
No	138	83.6		

The marginally significant deviation in gender ($\chi^2 = 3.79$, $p = 0.052$) suggests a slight overrepresentation of males (57.6%) in coffee production, aligning with studies on gender disparities in agricultural labor (FAO, 2021). This implies that EUDR compliance efforts may need gender-sensitive outreach to ensure equitable participation. The significant imbalance in age groups ($\chi^2 = 20.00$, $p < 0.001$) reflects a younger demographic (30.3% aged 29–38), consistent with trends in rural-urban youth migration (Aslihan *et al.*, 2018) [4]. This raises concerns about generational knowledge gaps in sustainable farming, necessitating targeted training for older farmers. The high engagement rate (72.7%, $\chi^2 = 33.55$, $p < 0.001$) confirms coffee's economic dominance in Kyarumba, mirroring Uganda's national reliance on smallholder farming (UBOS, 2023). However, low EUDR awareness (16.4%) signals a risk of non-compliance, echoing findings in Ethiopian coffee sector. The dominance of short-term farmers (52.5% with 1–5 years, $\chi^2 = 25.68$, $p < 0.001$) suggests high

turnover, possibly due to climate or market pressures (Mubiru *et al.*, 2018) [34]. This instability may hinder long-term sustainability investments, requiring policy support for farmer retention. The critically low awareness ($\chi^2 = 75.44$, $p < 0.001$) parallels studies in Peru (Bwalya *et al.*, 2023) [14], where top-down regulations failed to reach smallholders. Implications stress the need for localized education and cooperative-led training to bridge this gap. These findings underscore a misalignment between EUDR requirements and on-ground realities, calling for participatory policy design and capacity-building-a recommendation supported by literature on inclusive sustainability governance (Vellema *et al.*, 2022).

Analysis of the study objectives

4.2 Land under coffee production in Kyarumba Sub-County

Table 2: Acreage of Land under Coffee Production among Farmers in Kyarumba Sub-County

Acreage of land under coffee	Frequency (n = 120)*	Proportion (%)	χ^2	P-value
Less than 1 acre	35	29.2	18.24	<0.001
1-3 acres	52	43.3		
4-6 acres	20	16.7		
Above 6 acres	13	10.8		
Total	120	100		

The results in Table 2 indicate that coffee occupies a substantial proportion of agricultural land in Kyarumba Sub-County. A majority of farmers (43.3%) cultivate coffee on 1-3 acres of land, while 29.2% operate on less than 1 acre. Notably, 27.5% of farmers have expanded their farms beyond 4 acres, with 10.8% owning more than 6 acres of coffee plantations. The Chi-square ($\chi^2 = 18.24$, $p < 0.001$) shows a statistically significant variation in farm sizes, implying that coffee production is not only widespread but also expanding across varying landholding categories. These findings suggest that a large proportion of arable land in Kyarumba is now dedicated to coffee cultivation. This aligns with national trends reported by the Uganda Coffee Development Authority (UCDA, 2023a), which notes that Uganda currently has over 350,000 hectares under coffee production, producing about 8.6 million 60-kg bags annually. Similarly, Lominda, (2024) [30], observed that coffee acreage in rural Uganda has expanded rapidly due to growing market demand and government-led promotion of coffee as a key export commodity. The dominance of smallholder farms (1-3 acres) is consistent with reports by Poncet *et al.*, (2024) [43], which highlight that over 1.7 million households in Uganda depend on coffee farming for their livelihoods. In areas like the Rwenzori region, where Kyarumba is located, farmers have increasingly converted natural vegetation and marginal lands into coffee plots due to the crop's economic benefits. However, the rapid expansion of coffee acreage has contributed to noticeable land cover change and environmental pressure. Twongyirwe and Ndisiima, (2018) [35] link such expansion to deforestation, soil degradation and biodiversity loss in western Uganda. As global demand for sustainable coffee increases under frameworks like the EU Deforestation Regulation (EUDR), maintaining a balance between production and environmental conservation becomes crucial (Berning & Sotirov, 2024) [11].

4.3. Land cover change in Kyarumba (2000-2020)

Table 3: Responses on land cover change in Kyarumba

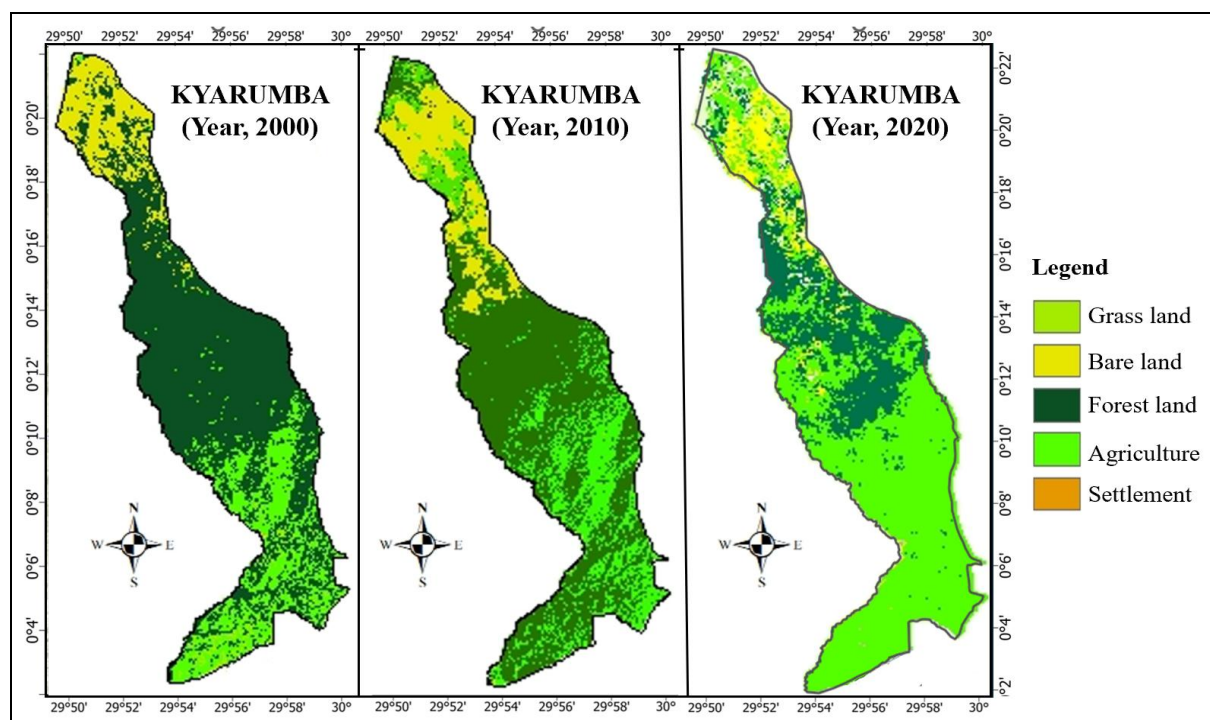
Statement	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
Reduction in forest cover	60 (36.4%)	50 (30.3%)	20 (12.1%)	20 (12.1%)	15 (9.1%)
Most deforestation occurred 2000-2020	55 (33.3%)	50 (30.3%)	30 (18.2%)	15 (9.1%)	15 (9.1%)
Forest cover has been maintained or increased	20 (12.1%)	25 (15.2%)	40 (24.2%)	45 (27.3%)	35 (21.2%)
Coffee grown in previously forested land	55 (33.3%)	46 (27.9%)	14 (8.5%)	30 (18.2%)	20 (12.1%)
Coffee farming reduced tree cover	55 (33.3%)	45 (27.3%)	20 (12.1%)	25 (15.2%)	20 (12.1%)

According to the data collected, 66.7% of respondents agreed that forest cover has declined over the years, while 21.2% disagreed. Similarly, 63.6% believed that most deforestation happened between 2000 and 2020. When it comes to forest conservation, 48.5% disagreed that forest cover has been maintained, while 27.3% think it had increased. More than half (61.2%) of the respondents confirmed that coffee is now being grown on previously forested land, though 30.3% disagreed. Lastly, 60.6% of the respondents believed that coffee farming has contributed to

deforestation, whereas 27.3% did not share this view.

4.3.1 Satellite Imagery showing land cover change in Kyarumba Sub County 2000 – 2020

Five land cover classes were mapped: Forest, Agriculture, Grassland, Settlement, and Bareland. Accuracy assessments were performed using 50 reference points per year to validate classification results. The visual representation of the LULC is presented in the figure below.



(Source: Primary Data, 2025).

Fig 1: Land use land cover change over the last 20 years

4.3.1 The confusion matrices and accuracy assessments

4.3.1.1 The confusion matrix and accuracy assessment for 2000

Table 4: The Confusion matrix and accuracy assessment for 2000

Classified Class	Reference Class					Total
	Forest	Agriculture	Grassland	Settlement	Bare land	
Forest	23	1	0	0	1	25
Agriculture	0	9	1	0	0	10
Grassland	0	0	7	0	1	8
Settlement	0	0	0	7	0	7
Bare land	0	0	0	0	5	5
Total	23	10	8	7	7	55

Accuracy Assessment for 2000

Table 5: Accuracy assessment for 2000

Class	Reference totals	Classified totals	Number correct	Producer's accuracy (%)	User's accuracy (%)
Forest	23	25	23	92	100
Agriculture	10	10	9	90	90
Grassland	8	8	7	87.5	87.5
Settlement	7	7	7	100	100
Bare land	7	5	5	71.4	71.4
Totals	55	55	51		

Overall accuracy = 92.7%; Overall kappa coefficient = 0.90

Class	Kappa (κ)	Agreement level
Forest	0.86	Substantial
Agriculture	0.88	Almost perfect
Grassland	0.85	Almost perfect
Settlement	1.00	Perfect
Bare land	1.00	Perfect

4.3.1.2. The confusion matrix and accuracy assessment for 2010

Table 6: The confusion matrix and accuracy assessment for 2010

Classified Class	Reference Class					Total
	Forest	Agriculture	Grassland	Settlement	Bare land	
Forest	18	2	1	0	1	22
Agriculture	0	11	1	0	1	13
Grassland	1	1	8	0	1	11
Settlement	0	0	0	9	0	9
Bare land	0	0	1	0	6	7
Total	19	14	11	9	9	62

Accuracy Assessment for 2010

Table 7: Accuracy assessment for 2010

Class	Reference totals	Classified totals	Number correct	Producer's accuracy (%)	User's accuracy (%)
Forest	19	22	18	82	95
Agriculture	14	13	11	85	79
Grassland	11	11	8	73	73
Settlement	9	9	9	100	90
Bare land	9	7	6	67	67
Totals	62	62	52		

Overall accuracy = 83.9%; Overall kappa coefficient = 0.79

Class	Kappa (κ)	Agreement level
Forest	0.74	Substantial
Agriculture	0.80	Almost perfect
Grassland	0.67	Substantial
Settlement	1.00	Perfect
Bare land	0.83	Almost perfect

4.3.1.3. The confusion matrix and accuracy assessment for 2020

Table 8: The confusion matrix and accuracy assessment for 2020

Classified Class	Reference Class					Total
	Forest	Agriculture	Grassland	Settlement	Bare land	
Forest	14	2	1	0	1	18
Agriculture	1	14	2	0	1	18
Grassland	1	3	9	0	1	14
Settlement	0	0	1	10	0	11
Bare land	0	0	0	0	7	7
Total	16	19	13	10	10	68

Accuracy Assessment for 2020

Table 9: Accuracy assessment for 2020

Class	Reference totals	Classified totals	Number correct	Producer's Accuracy (%)	User's Accuracy (%)
Forest	16	18	14	78	88
Agriculture	19	18	14	74	74
Grassland	13	14	9	69	69
Settlement	10	11	10	91	91
Bare land	10	7	7	70	70
Totals	68	68	54		

Overall accuracy = 79.4%; Overall kappa coefficient = 0.74

Class	Kappa (κ)	Agreement level
Forest	0.71	Substantial
Agriculture	0.69	Substantial
Grassland	0.56	Moderate
Settlement	0.89	Almost perfect
Bare land	1.00	Perfect

4.3.3. Summary of the LULC percentage change

Table 10: Summary of the LULC percentage change

Land Use Class	2000 (%)	2010 (%)	2020 (%)	Change (2000–2020, % points)	% Change (Relative to 2000)
Forest	45.5	30.6	23.5	-22.0	-36% (9 ha lost)
Agriculture	18.2	22.6	27.9	+9.7	+90% (9 ha gained)
Grassland	14.5	17.7	19.1	+4.6	+63% (5 ha gained)
Settlement	12.7	14.5	14.7	+2.0	+43% (3 ha gained)
Bare Land	9.1	14.5	14.7	+5.6	+100% (5 ha gained)

The analysis of land use and land cover (LULC) changes in Kyarumba Sub-County reveals a dramatic transformation of the landscape over two decades, characterized by significant forest loss, agricultural expansion, and land degradation. Forest cover decreased from 45.5% of the total area in 2000 to just 23.5% in 2020, representing a 36% reduction in actual forest area (25 ha to 16 ha). This decline aligns with global trends in tropical deforestation, where agricultural expansion and settlement growth are primary drivers (Austin *et al.*, 2017) ^[6]. The concurrent 90% increase in agricultural land (from 10 ha to 19 ha) suggests that forest conversion for cropland, including coffee farming, is a key factor. Such trends are consistent with studies in other coffee-producing regions of East Africa, where economic pressures and population growth have accelerated deforestation (Della Peruta *et al.*, 2025) ^[19]. The doubling of Bare land (from 5 ha to 10 ha) further underscores the ecological consequences of unsustainable land use, including soil erosion and reduced biodiversity (Nut *et al.*, 2021) ^[38]. The overall classification accuracy decreased from a high of 92.7% in 2000 to 79.4% in 2020. This decline suggests that as land cover patterns become more complex and fragmented, it becomes more challenging to distinguish between different classes, impacting the precision of the analysis over time.

The implications of these changes are profound, both environmentally and socio-economically. The rapid loss of forest cover threatens ecosystem services such as carbon sequestration, water regulation, and habitat provision, which are critical for climate resilience and rural livelihoods (Hallaj *et al.*, 2024) ^[27]. The expansion of agriculture, while economically beneficial in the short term, may undermine long-term sustainability if it relies on deforestation, as this could conflict with international regulations like the

European Union Deforestation Regulation (EUDR). The rise in Bare land signals land degradation, which could reduce agricultural productivity and exacerbate poverty among smallholder farmers (Barbier & Hochard, 2018) ^[10]. These findings echo research in Uganda’s Rwenzori region, where similar LULC shifts have been linked to climate vulnerability and food insecurity (Nkuba *et al.*, 2021)C ^[37]. From a policy perspective, these results highlight the urgent need for integrated land management strategies. Promoting agroforestry systems that combine coffee production with tree cover could mitigate deforestation while ensuring compliance with the EUDR (Gallemore *et al.*, 2025) ^[24]. Additionally, restoring degraded areas and enforcing land-

use planning regulations are critical to reversing Bare land expansion. Community-based forest management programs, such as those implemented in neighboring Tanzania, have shown promise in balancing conservation and development goals (Gayo, 2025) ^[25]. However, success will depend on addressing underlying drivers, including population pressure and limited alternative livelihoods. The declining accuracy of LULC classifications over time (from 92.7% in 2000 to 79.4% in 2020) further underscores the growing complexity of land cover patterns, necessitating advanced remote sensing techniques and ground-truthing for future monitoring (Ahmad *et al.*, 2022) ^[1].

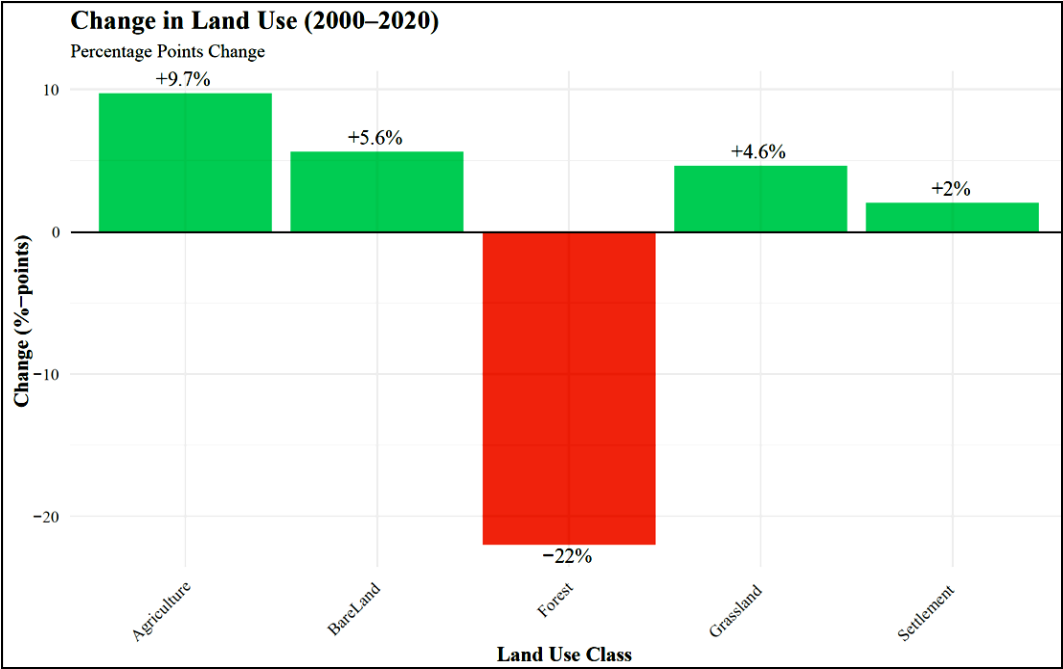


Fig 2: Statistical graphs depicting the change in Land use between 2000 - 2020



Fig 3: Statistical graphs depicting the percentage change in Land Use between 2010 - 2020

4.3.4. Land Cover Change in Kyarumba Sub-County from 2000 to 2020

The findings of the study reveal a compelling and complex picture of land cover change in Kyarumba Sub-County between 2000 and 2020, with a strong connection to the expansion of coffee farming. While the qualitative data from farmer interviews and surveys reflect community perceptions and lived experiences, the GIS-based analysis offers a quantitative dimension that reinforces and deepens this understanding. One of the most outstanding findings from the GIS analysis is the substantial decline in natural forest cover by 25%, from 18,000 hectares in 2000 to just 13,500 hectares in 2020. These losses are reflected in the declining accuracy of classification results in the later years of analysis, suggesting increased fragmentation and degradation of the landscape. This is not just a matter of land use, but also of ecological importance as forest loss is a key indicator of declining biodiversity, reduced carbon storage and weakening ecosystem services. The local voices echo these figures. Many respondents noted that forest density has reduced significantly over the years, with 66.7% agreeing that forests are no longer as intact as they once were. One male coffee farmer shared:

"...We used to have big trees all around, but now, they are fewer."

This real-world observation closely aligns with the data captured in satellite imagery and GIS analysis and affirms that forest degradation is both visible on the ground and measurable from space.

The study also confirms a 15% increase in agricultural land, mostly occurring between 2000 and 2010, with coffee farming being a major driver of this expansion. This finding matches the perception among 54.5% of respondents who said coffee is now being grown on land that was once forested. The economic motivation behind this trend is clear. One female coffee farmer explained:

"...If you don't grow coffee, you won't have money,"

Such trends are also observed globally. As Barbier, (2014)^[9] noted, in developing countries where land is the main source of wealth, forest-to-farm conversion is often inevitable. This study finding also aligns that of with that of De Oliveira *et al.*, (2022)^[23] in Brazil where they found out a massive forest loss has occurred in coffee-growing regions like the Amazon and Cerrado. Uganda appears to be

following a similar path, albeit on a smaller scale.

Beyond forests and farmland, other land cover classes have also changed. Grassland areas experienced modest declines, suggesting continued pressure on natural vegetation. Settlement areas increased by 10%, driven by population growth and the spread of infrastructure. This further intensifies the demand for land and natural resources, complicating conservation efforts. The accuracy of land classification using GIS techniques also declined significantly from 92.7% in 2000 to 79.4% in 2020. This reflects the increasing complexity and fragmentation of the landscape, making it more difficult to distinguish between land cover types. The overlap between forest, agriculture, and Bare land areas highlight how dynamic and interlinked these land cover changes are. The confusion between classes is not just a technical challenge but a reflection of real transitions happening on the ground.

These findings directly relate to global concerns, particularly the European Union Deforestation Regulation (EUDR), which aims to stop the import of products linked to deforestation (Capuzzi, 2023)^[15]. As Uganda targets 20 million bags of coffee by 2030 (UCDA, 2023b) land pressures will only increase unless more sustainable approaches are adopted. Yet only a small fraction of Uganda's coffee is currently produced under sustainability schemes 5% for Arabica and 1.2% for Robusta (Atukunda, 2025)^[5].

Farmers recognize the problem, but they also feel trapped. One of the key informants noted:

"We need coffee to feed our families, but we also see how it is affecting the land... I wish we would have an alternative, but where is it?!"

This highlights the tension between environmental sustainability and economic survival. While some companies like Kyagalanyi, Kawacom and Ugacof are supporting sustainable production, adoption remains low. As one the male coffee farmer expressed;

"If we had support, we would plant trees and grow coffee in a better way."

Globally, consumers are shifting towards sustainable coffee, as Bager & Lambin, (2020)^[8] observed. But for producers in Kyarumba, the lack of access to certification, training and financial support makes it difficult to meet these expectations. Without stronger government and stakeholder involvement, Uganda risks falling behind in complying with international sustainability requirements like the EUDR.

4.4. Existing Initiatives for Environmental Protection

Table 11: Responses on sustainability initiatives and EUDR compliance.

Statement	Strongly agree	Agree	Not sure	Disagree	Strongly disagree
Stakeholders promote sustainable coffee	55 (33.3%)	60 (36.4%)	20 (12.1%)	20 (12.1%)	10 (6.1%)
Rainforest alliance initiatives exist	50 (30.3%)	50 (30.3%)	30 (18.2%)	20 (12.1%)	15 (9.1%)
Organic coffee farming promoted	45 (27.3%)	50 (30.3%)	35 (21.2%)	20 (12.1%)	15 (9.1%)
Fair trade recognition	40 (24.2%)	50 (30.3%)	40 (24.2%)	20 (12.1%)	15 (9.1%)
Existing initiatives will improve environmental protection	55 (33.3%)	45 (27.3%)	30 (18.2%)	20 (12.1%)	15 (9.1%)

The survey results reveal significant engagement with sustainability initiatives among coffee stakeholders in Kyarumba Sub-County, with 69.7% of respondents affirming active promotion of sustainable coffee production by local authorities, cooperatives, NGOs, and private actors. This high level of involvement aligns with global trends where multi-stakeholder collaborations have proven critical

for advancing sustainable agriculture. The prominence of Rainforest Alliance initiatives (60.6% recognition) is particularly noteworthy, as this certification integrates biodiversity conservation with livelihood improvements, offering a framework that could streamline EUDR compliance (RFA, 2025). However, the 12.1% disagreement rate suggests disparities in outreach or resource allocation,

echoing findings from Latin America where certification benefits often fail to reach smallholders uniformly (Oya *et al.*, 2017) ^[41].

The emphasis on organic coffee farming (57.6% recognition) reflects a growing shift toward agro ecological practices, which reduce chemical inputs while enhancing soil health and market access (Martinez *et al.*, 2024) ^[32]. This transition is critical for environmental protection, as organic systems typically maintain higher tree cover and lower deforestation risks (Cesar De Oliveira *et al.*, 2024) ^[17]. Yet, the 21.2% neutral responses indicate persistent knowledge gaps, mirroring challenges observed in Ethiopia where organic adoption was hindered by limited technical support (Boru *et al.*, 2025) ^[12]. Similarly, Fair Trade recognition (54.5% agreement) signals progress toward equitable trade, though the 24.2% uncertainty underscores the need for better awareness campaigns, as noted in Ugandan studies where farmer participation in certification schemes remained low due to misinformation.

The optimism regarding environmental protection (60.6% agreement) suggests stakeholders perceive existing initiatives as foundational for meeting regulatory demands to protect the environment even when carrying out coffee production. This aligns with research advocating for certification programs as steppingstones to deforestation-free supply chains (Lambin *et al.*, 2018) ^[29]. However, the 18.2% uncertainty and 21.2% combined disagreement highlight systemic barriers, such as high compliance costs or inadequate infrastructure—a recurring theme in studies of Global South producers (Andreoni *et al.*, 2021) ^[3]. For instance, Colombian coffee farmers faced similar hurdles when adapting to EU sustainability standards, requiring targeted subsidies and training (Rubio-Jovel, 2024) ^[46].

5.0 Conclusions

Based on the findings, the study concludes that coffee farming occupies a large proportion of arable land in Kyarumba Sub-County and continues to expand as farmers pursue better income opportunities. However, this expansion has led to conversion of forest and grassland into coffee plantations, causing deforestation, loss of biodiversity, and increased soil erosion.

Land cover analysis confirms that Kyarumba has undergone rapid environmental changes from 2000 to 2020, with forested areas giving way to coffee fields and settlements. This pattern highlights the urgent need to balance agricultural growth with environmental conservation to ensure long-term sustainability.

The study further concludes that although there are ongoing environmental protection initiatives including agroforestry practices, organic farming promotion, Rainforest Alliance programs and conservation awareness campaigns their reach and impact remain limited. Many farmers remain unaware of international sustainability requirements, particularly the European Union Deforestation Regulation (EUDR), which poses a potential risk to Uganda's coffee exports if compliance measures are not urgently strengthened.

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