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# Land Use Land Cover Change and its Implications for Livestock Production and Food Security in Kuyu District, Ethiopia

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## Abstract

*Although Kuyu district has significant potential for animal-source food production due to its large livestock population and diverse species, the effects of land use and land cover (LULC) change on these resources remain underexplored. This study examines LULC changes over three decades (1991–2021) and their impact on livestock production and food security among rural households. Data from Landsat images from 1991, 2001, 2011, and 2021 were used to develop land use maps and quantify changes through visual interpretation and supervised classification using ArcGIS Version 10.7.1. Key informant interviews, focus group discussions, and transect walks were employed to complement the study with qualitative data. Six LULC classes were identified: forest/plantation, grass/shrub land, bare land, cropland, rural settlement, and urban built-up areas. Over the study period, cropland and bare land experienced net gains of 45.4% and 6.5%, respectively. In contrast, forest/plantation land and grass/shrub land showed net losses of 29.3% and 23.7%, respectively. The decline in grassland is a major cause of animal feed scarcity, although the expansion of croplands provides low-quality crop by-products as alternative feed sources. Livestock relying on such feeds exhibit poor production and health performance, jeopardizing food security for rural households. The LULC changes observed in this study underscore their adverse effects on livestock production. To mitigate the constraints on livestock production and improve food security, interventions such as diversifying livestock production, enhancing mixed crop-livestock farming, adopting agroecological practices, and implementing effective livestock development planning, policies, and strategies are recommended.*

**Keywords/Phrases**: Food security, Kuyu district, Land use land cover change, Landsat images, Livestock production

## 1 Introduction

### 1.1 Background

Ethiopia is located in the tropics and boasts a varied eco-environmental landscape, which includes arid and semiarid lowlands as well as cool afro-alpine highlands and mountains (Mekasha *et al*., 2014). The nation is marked by tropical monsoons, with local precipitation patterns shaped by elevation (Paracchini *et al*., 2020). Consequently, the highlands experience cool, humid conditions, whereas the lowlands are characterized by heat and aridity. These diverse geographic conditions allow rural communities to implement various land use systems for crop and livestock production, thereby enhancing food security and livelihoods. Nevertheless, Ethiopia's cultural and natural heritage faces threats from multiple factors, including global climate change, overpopulation, and land degradation (Mekasha *et al*., 2014). In this context, the Intergovernmental Panel on Climate Change (2022) emphasizes that increasing temperatures and erratic rainfall, caused by climate change, have reduced agricultural productivity throughout Ethiopia, worsening food insecurity.

Food insecurity remains a critical social challenge in Ethiopia, with significant disparities across regions and agroecological zones (Abebe, 2018). Studies indicate that 38.1% of households experience food insecurity nationally, while 31% lack adequate caloric intake and 20.5% face severe food shortages (Shone *et al.*, 2017). Compounding these challenges, 26.2% of Ethiopians live below the poverty line, with rural communities disproportionately affected by both poverty and food scarcity (CSA, 2019).

The issue of food insecurity remains a persistent challenge for many residents of Kuyu District. Despite its potential for crop and livestock production, the district has been classified as food insecure since 2005 (MoARD, 2017, as cited in Feleke, 2018). As of 2018, 3,301 households in Kuyu District received food aid, with this number rising significantly over time (Feleke, 2018). For instance, Phase 4 of 2020 recorded 5,900 beneficiaries, increasing to 14,758 by 2024 (KWAO, 2024). This indicates that many households struggle to cope with food insecurity due to various recurrent shocks. Current data reveal that a significant proportion of both the country's and the district's population is living in a state of chronic or transitory food insecurity. Therefore, addressing these interconnected issues is vital for ensuring food security.

Comprehensive studies conducted in Ethiopia have recorded changes in land use and land cover (LULC) concerning drought vulnerability (Biazin & Sterk, 2013) and community perceptions (Oba & Kaitira, 2006; Beyene, 2009). Although current research generally examines the drivers of LULC (Amsalu *et al.*, 2007; Meshesha *et al.*, 2012) and their consequences (Meshesha *et al.*, 2012), there is a scarcity of studies that concentrate on their systemic effects. For example, Alem-Meta and Singh (2017) examined LULC linkages to rural household food insecurity, while Mekasha *et al.* (2014) explored community perceptions of livestock feed availability, management strategies, and the capacity of degraded lands to sustain livestock productivity. Despite this body of work, integrated analyses of LULC dynamics and their impact on livestock systems and food security remain limited, particularly in contexts like Kuyu District, where mixed crop-livestock livelihoods dominate.

To our knowledge, only a few studies have been conducted in Kuyu District to explore the state of LULC change. For instance, Messay and Tsetargachwe (2013) studied the implications of spatiotemporal environmental dynamics on rural livelihoods in the Wasarbi-Garba Guracha Watershed, but their scope was confined to that specific watershed. Moreover, their study did not cover the entire district, limiting the applicability of their results. Additionally, they did not examine the relationship between LULC change and livestock production. Consequently, comprehending the patterns and degrees of Land Use and Land Cover (LULC) change is essential for producing practical insights for policymakers and development professionals regarding livestock production and food security.

This study addresses the critical research gap in understanding how LULC transformations in Kuyu District influence livestock production and rural household food security. It primarily aims to investigate LULC patterns in the district and assess how these changes impact livestock production, as well as their broader implications for rural households' food security.

## 2 Materials and Methods

### 2.1 Description of the study area

This research was carried out in the Kuyu District, which is one of the twelve districts within the North Shewa Zone of the Oromia Regional State, found in central Ethiopia. The district lies between 9°31'32" and 9°56'28" North Latitude, as well as 38°3' 1" and 38°30'14" East Longitude (refer to Figure 1).

The study covered three agroecological zones within the district: high altitude, mid-altitude, and low altitude. Climate data from 1981 to 2018, obtained from Ethiopia's National Meteorological Agency (ENMA), was utilized. The dataset indicates that over the 38-year period, the district's average annual rainfall ranges from 1,014 mm to 1,100 mm in the low-altitude agroecology and from 1,201 mm to 1,256 mm in the high-altitude agroecology. The average annual minimum temperature ranges from 14.2°C to 17.2°C in the low-altitude zone and from 7.4°C to 9.9°C in the high-altitude zone. Both annual mean rainfall and maximum temperatures show a slight increase over the years, while minimum temperatures exhibit a decreasing trend. These climatic variations reflect the district's diverse agroecological settings and their potential implications for land use, agricultural practices, and livelihood strategies. A summary of the disaggregated climate data for the district from 1981 to 2018 is presented in Table 1.

In the study area, agriculture is the primary economic activity, supporting more than 87% of the population (Messay & Tsetargachew, 2013). A mixed crop-livestock agricultural production system serves as the main livelihood for people across all agroecological zones of the district.

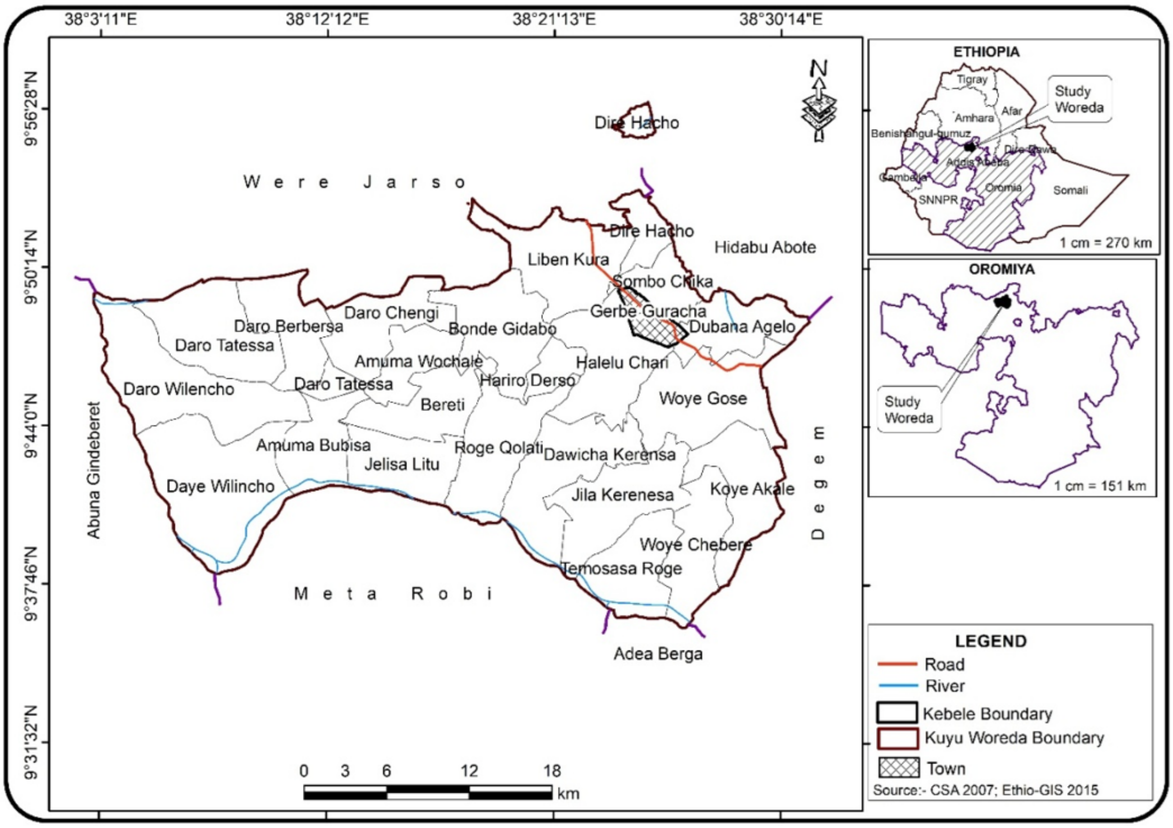


**Figure 1.** Location Map of the Study Area

**Table 1.** A disaggregated rainfall and temperature data of Kuyu District (1981-2018)

| Climate Elements | Years | | | |
|---|---|---|---|---|
| | 1981-1993 | 1994-2006 | 2007-2018 | 1981-2018 |
| Annual mean rainfall (mm) | 1008– 1178.5 | 1018.8-1257.8 | 1015- 1330.6 | 1014-1256 |
| Annual mean min. temperature (°C) | 7.8 -17.4 | 7.2-18.5 | 7.1-15.5 | 7.4-17.2 |
| Annual mean max. temperature (°C) | 21.0 - 28.1 | 22.1-29.1 | 21.5- 28.9 | 21.5- 28.9 |

Source: Computed from 1981-2018 meteorological data set obtained from ENMA.

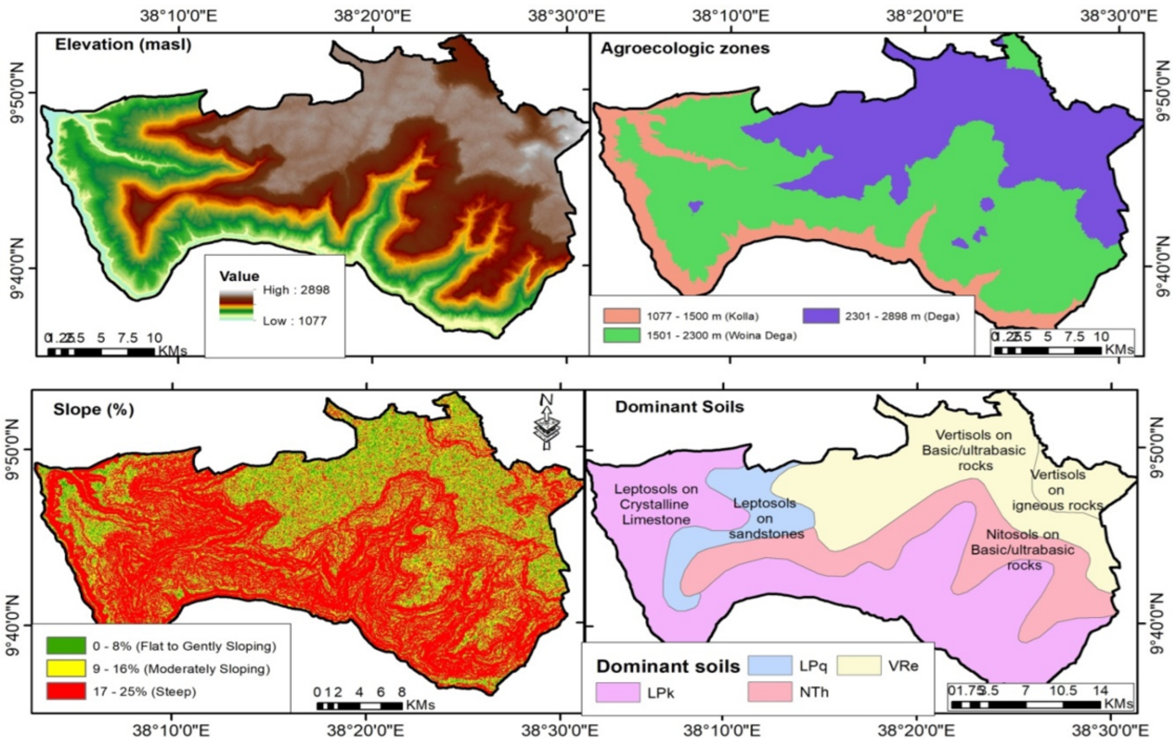


**Figure 2.** Physical characteristics of Kuyu District

An agroecological framework is employed to characterize the physical environment of the study area, as crop and livestock production in Ethiopia fundamentally depend on these conditions. The high-altitude agroecology (Dega-Baddaa in the local language) is primarily characterized by elevations ranging from 2,301 to 2,898 meters above sea level (masl), with flat to gently sloping terrain. The main soil types in this zone are vertisols found on basic or ultrabasic rocks and vertisols on igneous rocks.

The mid-altitude agroecology (Weinadaga-Badadaree in the local language) features elevations ranging from 1,501 to 2,300 masl, predominantly steep slopes but also some moderate slopes. The soil types here include nitosols on basic/ultrabasic rocks, leptosols on crystalline limestone, and leptosols on sandstones.

The low altitude agroecology (Kolla-Gammojjii in the local language) is characterized by elevations between 1,077 and 1,500 masl, primarily steep slopes with fewer moderate slopes. The main soil type in this zone is leptosols on sandstones, with leptosols on crystalline limestone also dominating the area. Figure 2 illustrates the physical characteristics of the study area.

## 2.2 Datasets and sampling approach

This study utilizes both quantitative and qualitative data, with the latter serving to augment the former. The quantitative data were gathered from satellite imagery, whereas the qualitative data were sourced from key informants and focus group discussions. In order to present a detailed overview of land use and land cover (LULC) patterns, the study categorized all rural Kebeles (the lower administrative units) of the district into three agroecological zones and utilized remotely sensed satellite imagery along with GIS to measure LULC changes across these zones.

Land Use and Land Cover (LULC) alterations within the study region were identified through a series of satellite images utilizing Remote Sensing (ERDAS Imagine 14) and Geographic Information System (GIS) software (ArcMap 10.7.1). Specifically, the following datasets were utilized: Landsat 5 Thematic Mapper (TM) (1991) with medium resolution (30 m) for LULC classification in 1991; Landsat 7 Enhanced Thematic Mapper (ETM+) (2001) with medium resolution (30 m) and panchromatic (15 m) for LULC classification in 2001; Landsat 7 ETM+ (2011) with medium resolution in blue, green, red, and near-infrared (30 m) and panchromatic (15

m) for LULC classification in 2011; and Landsat 8 OLI/TIRS (2021) with medium resolution in blue, green, red, and near-infrared (30 m) and panchromatic (15 m) for LULC classification in 2021.

To identify spatial and temporal changes in land use and land cover (LULC), Landsat images from the years 1991, 2001, 2011, and 2021 were examined. Supervised classification methods, which utilize field survey data or high-resolution imagery, along with visual interpretation, were applied using ArcGIS Version 10.7.1 software. True-color composites were generated using bands such as green, gray, dark gold, yellow, brown, and red. Microsoft Excel was employed to create summary tables and figures. Very high-resolution images from Geo-Eye (2021) obtained through Google Earth Pro (1 m resolution) were utilized for the purpose of accuracy assessment, aiding in the validation of classifications via the Kappa Index of Agreement and a confusion matrix.

Supplementary qualitative data gathered through six focus group discussions with elder farmers, interviews with six local leaders, and field observations conducted in three randomly selected Kebeles, one from each agroecological zone. Elder farmers contributed to identifying patterns of LULC changes, key livestock feed resources, and discussed the challenges of livestock production, the causes of these challenges, and priorities for improvement. Further details were acquired through an examination of literature, governmental reports, and other pertinent publications. Table 2 provides a summary of the features of the remote sensing data.

**Table 2.** Description of remote sensing data

| Satellite Images | Sensor | Path/Row | Resolution or Pixel size (m) | Year of Data Data Acquisition | Source |
|---|---|---|---|---|---|
| Landsat 5 | TM | 169/053 | 30x30 | 10/01/1991 | USGS |
| Landsat 7 | ETM + | 169/053 | 30x30 | 23/01/2001 | USGS |
| Landsat 7 | ETM+ | 169/053 | 30x30 | 18/01/2011 | USGS |
| Landsat 8 | OLI/TIRS | 169/053 | 30x30 | 15/01/2021 | USGS |
| Accuracy Assessment | Geo-eye | —- | —- | 17/01/2021 | Google Earth Pro |

## 2.3 Data analysis

The qualitative data are narrated and summarized, while the quantitative data undergo cleaning, coding, and analysis through descriptive statistics. The results are presented in tables, maps, or figures utilizing Excel Software Version 2016. The analysis of land use and land cover (LULC) changes is conducted using time-series satellite imagery obtained from the United States Geological Survey (USGS) website (https://earthexplorer.usgs.gov). Consequently, the LULC categories for the study area were classified into forestland, grassland, bare land, cropland, and construction land across four distinct periods.

**Table 3.** Description of LULC categories

| LULC type | Description |
|---|---|
| Forest/plantation | The land that includes natural and plantation forest |
| Grass/shrub land | Is the land that includes areas covered with grass land and shrub land |
| Bareland | Land that covers areas with no vegetation, degraded or quarries, or road segments |
| Cropland | The land that dominantly expressed by mosaic of small holder farms |
| Rural Settlement | Land that includes small villages or areas with agglomeration of huts or iron sheet roofed houses but at distance of at least 200m from urban built-up structures |
| Built-up area | This land coverage includes urban built-up, iron sheet roofed houses, and roads structures. |

Source: Adapted from Anderson *et al*. 1976.

The LULC classes employed and their corresponding descriptions are detailed in Table 3. The classified images were vectorized by exporting them from the ERDAS Imagine 9.1 image analysis software to ArcGIS Version 10.7.1. Based on the computed results, the LULC changes between the analyzed periods were quantified to facilitate a comparison of changes across the study periods.

## 3 Results and Discussion

### 3.1 Land use land cover change detection

Time series analysis of LULC changes in Kuyu District identified six distinct classes: forest/plantation, grass/shrubland, bare land, cropland, rural settlement, and urban built-up areas (Table 3). Multi-temporal LULC maps were generated using satellite images from 1991, 2001, 2011, and 2021, illustrating the spatial and temporal evolution of these categories (Figure 3). The results, summarized in Table 2 above, also indicate that the satellite images from different periods maintain consistent spatial and radiometric resolution. Below, Figure 3 presents the LULC maps and Landsat images of the district under study.

The district's empirical data on LULC area coverage statistics and changes from 1991 to 2021 are summarized in Tables 4 and 5, respectively. The analysis reveals significant spatial and temporal differences in LULC changes during the study periods, emphasizing the dynamic shifts in land use patterns over time.

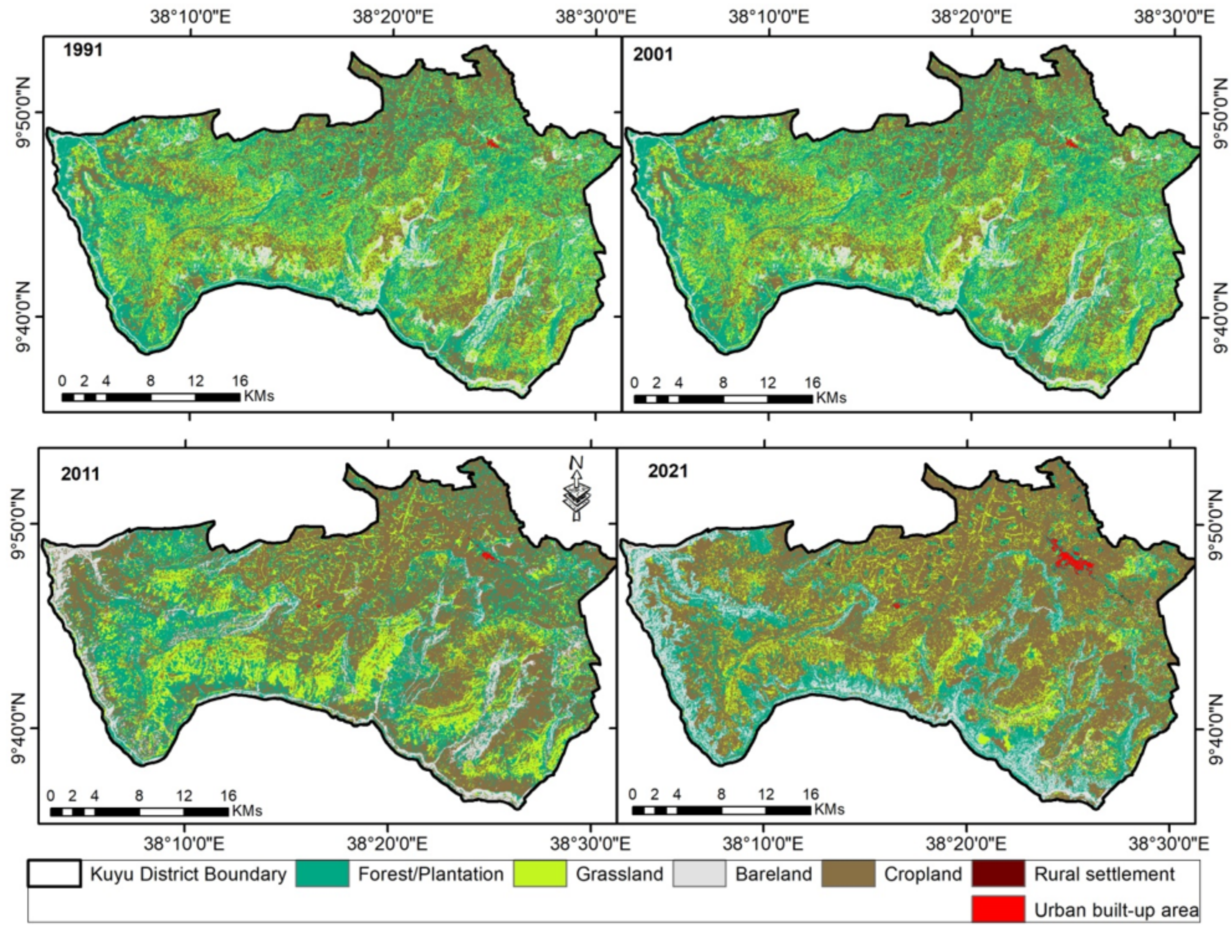


**Figure 3.** Land Use Land Cover Map of Kuyu District from 1991 – 2021

**Table 4.** Area (ha) and percentages of LULC in Kuyu District (1991 – 2021)

| LULC type | 1991 | | 2001 | | 2011 | | 2021 | |
|---|---|---|---|---|---|---|---|---|
| | ha | % | ha | % | ha | % | ha | % |
| Forest/plantation | 36072 | 38 | 27253 | 29 | 26103 | 28 | 20351 | 22 |
| Grass/shrub land | 26567 | 28 | 18399 | 20 | 16986 | 18 | 13862 | 15 |
| Bareland | 6618 | 7 | 8691 | 9.2 | 7978 | 8.4 | 10114 | 11 |
| Cropland | 25180 | 27 | 40089 | 42 | 43379 | 46 | 49544 | 52 |
| Rural Settlement | 40 | 0 | 43 | 0 | 20 | 0 | 264 | 0.3 |
| Built-up area | 74 | 0.1 | 76 | 0.1 | 86 | 0.1 | 416 | 0.4 |
| Total | 94551 | 100 | 94551 | 100 | 94551 | 100 | 94551 | 100 |

The absolute (ha) and relative (%) measurements of LULC in the district demonstrate significant dynamism. Notably, there has been a shrinkage of forestland and grass/shrubland, leading to the expansion of cropland and bare lands. This substantial change is corroborated by insights from older respondents, whose firsthand accounts closely align with findings derived from satellite imagery analysis. Empirical studies by Taye *et al.* (2024) and Getahun *et al.* (2024) examined LULC changes across different agroecologies and their drivers in Ethiopia, respectively, yielding results consistent with those of the current study. Similarly, Mehari *et al.* (2022), in their study conducted in Southern Ethiopia, reported similar patterns of LULC changes linked to population growth, settlement, and farmland expansion.

**Table 5.** Absolute (ha) and relative (%) LULC change (1991 – 2021)

| LULC type | 1991-2001 | | 2001-2011 | | 2011-2021 | | 1991-2021 | |
|---|---|---|---|---|---|---|---|---|
| | ha | % | ha | % | ha | % | ha | % |
| Forestland/plantation | -8818.6 | -24 | -1150.8 | -4.2 | -5751.5 | -22 | -15720.8 | -43.6 |
| Grass/shrubland | -8168.2 | -31 | -1412.9 | -7.7 | -3123.8 | -18.4 | -12704.9 | -47.8 |
| Bareland | 2073 | 31.3 | -712.53 | -8.2 | 2135.79 | 26.8 | 3496.23 | 52.8 |
| Cropland | 14908.9 | 59.2 | 3290.13 | 8.2 | 6164.64 | 14.2 | 24363.6 | 96.8 |
| Rural Settlement | 3.2 | 8.1 | -23.4 | -54 | 244.71 | 1242 | 224.55 | 563.2 |
| Built-up Area | 1.7 | 2.3 | 9.54 | 12.5 | 330.12 | 385.3 | 341.37 | 458.6 |
| Total | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 |

The patterns of land use and land cover (LULC) in the examined region have evolved over the years, mainly transitioning from grazing and forest areas to cropland and degraded land. The transformation of land into cropland presents a beneficial aspect, as crop residues provide a substantial feed source within the mixed crop-livestock production system. However, the study also reveals that vast areas of land are experiencing degradation and an expansion of bare land.

The most substantial changes in LULC occurred during distinct reference periods. Between 1991 and 2001, forestland experienced the highest decline (-24.4%), while bare land increased significantly (59.2%). This period coincided with the political transition from the Derg regime to the Federal Democratic Republic of Ethiopia, which precipitated sweeping governance and policy reforms that destabilized cooperative afforestation initiatives and led to widespread deforestation. The resultant loss of forest cover likely accelerated land degradation and harmed ecosystems.

From 2001 to 2011, grass/shrub land saw the highest decline (-15.9%), while cropland expanded dramatically by 1,241.6% between 2011 and 2021. This increase can be attributed to population growth, excessive cropping pressure, and overgrazing. Drastic LULC changes during 2011-2021 included a 1,241.6% increase in rural settlements and a 385% rise in urban built-up areas. Qualitative findings from the study revealed that these shifts are driven by population growth, the establishment of new households in highland agroecologies, the planting of eucalyptus trees, and construction activities. Respondents also noted the migration of farmers from rural areas to nearby towns, particularly Garba Gurraacha and Britii, as an immediate cause of urban expansion. Wealthier farmers are investing in urban housing, further driving the expansion of these urban areas, which is accelerated by internal factors within the towns themselves.

A recent study conducted in Southwest Ethiopia identified similar patterns of LULC changes, reporting a 15.7% increase in cultivation and settlement land between 1984 and 2017, while dense forest, light vegetation, and grazing land declined by 9.2%, 4.97%, and 1.85%, respectively (Mesfin, 2022). Another study revealed that population growth, poverty, and food insecurity are immediate drivers of LULC change, alongside underlying factors such as farmland and settlement expansion, firewood collection, uncontrolled grazing, and forest fires (Getahun *et al.*, 2024). Similarly, Alem-Meta and Singh (2017) identified population pressure, unplanned agricultural expansion, and overgrazing as key drivers of LULC change in Ethiopia's Teleyayen sub-watershed. Mesfin (2022) identified population pressure, rising resource demands, and resettlement programs as significant drivers of LULC change. Such demographic pressures trigger overgrazing, which degrades vegetation, biodiversity, and soil fertility. The resulting livestock feed deficits undermine agricultural productivity, exacerbating food insecurity among rural households. According to Nyariki *et al.* (2009), severe overgrazing can escalate into desertification, compounding ecological and socioeconomic vulnerabilities.

Several studies align with the findings of the current research. For instance, Jie Xu *et al.* (2023) noted a consistent increase in built-up and aquaculture land globally, with forest and grassland areas initially declining from 1990 to 2016, followed by a slight recovery due to policies encouraging farmland reforestation. Similarly, Pérez-Vega *et al.* (2013) and Kolb *et al.* (2012) highlighted that, over the past 300 years, LULC changes worldwide have been marked by agricultural expansion at the expense of forests. Furthermore, the FAO (2015) noted that LULC changes are often associated with agricultural expansion, urbanization, and deforestation. From the holistic discussions presented, it is clear that advances in earth observation data analysis have not only enhanced the understanding of these processes but also created opportunities to develop targeted solutions for the associated social, economic, and environmental challenges (Lu *et al.*, 2004).

### 3.2 Accuracy Assessment

An accuracy assessment was conducted on the 2021 image data (Table 6) by comparing it with pseudo-ground-truth data derived from high-resolution Google Earth imagery. Error matrices were generated to evaluate overall accuracy, user's accuracy, producer's accuracy, and Kappa statistics. These metrics assess the classification map's accuracy relative to the reference data. The LULC outputs from the four periods were converted to .dbf format and imported into Microsoft Excel for further analysis. The data were presented as percentages for different LULC classes, and a change detection matrix was created to identify LULC transitions between 1991 and 2021.

The current study utilized very high-resolution imagery to assess the classification accuracy of LULC, achieving a Kappa Index of Agreement of 0.816 (or 81.6%) and employing a confusion matrix (Cohen, 1960). According to established standards, a Kappa Index greater than 0.80 indicates strong accuracy, a value between 0.40 and 0.80 reflects moderate accuracy, and a value below 0.40 represents weak accuracy. The overall classification accuracy for the 2021 map in this study was 82.5% (or 0.825), suggesting a high degree of agreement, as the calculated accuracy value exceeds the Kappa Index threshold (Table 6).

**Table 6.** Accuracy assessment for the 2021 LULC classification

| LULC Types | | No. of LULC Classes Observed from GPS/ Google Earth | | | | | | User Accuracy | |
|---|---|---|---|---|---|---|---|---|---|
| | | PF | GL | BL | CL | RS | BA | No. | % |
| | Forest/plantation (FP) | 9 | 1 | 1 | 0 | 0 | 0 | 11 | 81.8 |
| | Grassland/shrub (GL) | 1 | 10 | 1 | 0 | 0 | 0 | 12 | 83.3 |
| LULC Classes | Bareland (BL) | 0 | 1 | 10 | 2 | 0 | 0 | 13 | 76.9 |
| Interpreted | Cropland (CL) | 0 | 1 | 1 | 20 | 0 | 0 | 22 | 90.9 |
| | Rural Settlement (RS) | 1 | 2 | 0 | 0 | 9 | 0 | 12 | 75 |
| | Built-up Area (BA) | 0 | 0 | 0 | 1 | 1 | 8 | 10 | 80 |
| Producer | No. | 11 | 15 | 13 | 23 | 10 | 8 | 80 | 82.5 |
| Accuracy | % | 82 | 67 | 77 | 87 | 90 | 100 | | |

The producer and user accuracies, which measure the map's reliability in identifying specific LULC classes, ranged from 67% to 100% and 75% to 90.9%, respectively. These variations highlight differences in classification accuracy among LULC types. Despite these differences, the study achieved a robust level of classification accuracy, supporting the reliability of the LULC change analysis over the study period.

### 3.3 Net Land use land cover change

The net change in LULC from 1991 to 2021 is summarized in Table 7. The analysis indicates that the district has undergone extensive LULC changes since 1991 due to several factors, including increased agricultural expansion, deforestation, urbanization, land degradation, and a growing human population. To evaluate the susceptibility of land cover types to change, the loss-to-persistence ratio (Braimoh, 2006) was calculated for each LULC class within the study area. A ratio exceeding 1 indicates that a particular class has a higher propensity to transition to other land cover types, while a ratio below 1 suggests greater stability and a lower likelihood of change.

The results of the current study show that all land use classes, except rural settlement and urban built-up areas, have loss percentage values greater than 1, indicating a higher tendency for these areas to undergo transitions. Consequently, land cover transitions were most prominent in cropland, forest/plantation land, and grassland, with only slight changes observed in bare land.

The persistence, defined as the percentage of the landscape that remained unaffected, was 35.7% between 1991 and 2021. This means that approximately 64.3% of the landscape experienced transitions during this period, highlighting a high level of instability in LULC in the district. This instability may disrupt mixed crop-livestock production, affect the availability of feed for livestock, and ultimately impact household food security.

The trend in LULC change over the 31 years indicates a net gain of 45.4% in cropland and 6.5% in bare land (Table 7). However, this is accompanied by a net decrease of 29.3% in forest/plantation land and 23.7% in grass/shrubland. The loss of forest and grassland has significantly contributed to the net gain in cropland and bare land during the study period. Cropland is the most favored land use, while forest/plantation and grassland are the most negatively affected.

The net change in rural settlement and urban built-up areas is also positive, albeit at a minimal level, with percentage changes in both cases being less than 1% (Table 7). These classes are identified as areas where no significant changes have occurred. In agreement with the findings of the current study, a recent assessment of LULC change conducted by Anteneh *et al*. (2018) in the Gode district of the Somali region of Ethiopia reveals increases in bare land, agricultural land, and settlement areas. Conversely, woody shrubland declined from 30% to 10%, and grassland decreased from 46% to 32.7%, indicating a declining trend.

Change matrix for LULC in the district is analyzed and presented in Table 8. It generally shows the transition of LULC from grass/shrub land and forest/planation and to cropland, bareland, rural settlement and urban built up.

**Table 7.** Net LULC change in Kuyu district (1991 – 2021)

| LULC Type | Persistence | | Gains | | Losses | | Net Change | |
|---|---|---|---|---|---|---|---|---|
| | ha | % | Gains (ha) | % | Losses (ha) | % | ha | % |
| Forest/Plantation | 9809.4 | 27 | 10541.7 | 19.6 | -26262.5 | -48.9 | -15721 | -29 |
| Grassland/shrub | 5236.2 | 20 | 8626 | 16.1 | -21330.9 | -39.7 | -12705 | -24 |
| Bareland | 1802.3 | 27 | 8311.7 | 15.5 | -4815.5 | -9 | 3496.2 | 6.5 |
| Cropland | 16841 | 67 | 32703.5 | 60.9 | -8339.9 | -15.5 | 24363.6 | 45.4 |
| Rural Settlement | 5.1 | 13 | 259.3 | 0.48 | -34.7 | -0.1 | 224.6 | 0.4 |
| Urban Built-up Area | 59 | 79 | 356.9 | 0.66 | -15.5 | 0 | 341.4 | 0.6 |
| Total | 33752 | 36 | 60799 | 113 | -60799 | -113 | 0 | 0 |

**Table 8.** LULC change matrix (1991- 2021)

| LULC Type (1991) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Forest/ Plantation (FP) | | Grassland (GL) | | Bare land (BL) | | Cropland (CL) | | (RS) Rural Settlement | | Built-up Area (BA) | | Total | |
| -2021 | Ha | % | ha | % | Ha | % | ha | % | ha | % | ha | % | ha | % |
| FP | 9809.4 | 27.2 | 5676.8 | 21.4 | 1889.3 | 28.5 | 2937 | 11.7 | 24.9 | 63 | 13.8 | 18.5 | 20351 | 21.5 |
| GL | 4098.9 | 11.4 | 5236.2 | 19.7 | 725.9 | 11 | 3792.2 | 15.1 | 7.9 | 20 | 1.1 | 1.5 | 13862 | 14.7 |
| BL | 5289.1 | 14.7 | 1557.3 | 5.9 | 1802.3 | 27.2 | 1465.3 | 5.8 | 0 | 0 | 0 | 0 | 10114 | 10.7 |
| CL | 16565 | 45.9 | 13953 | 52.5 | 2182.4 | 33 | 16841 | 66.9 | 1.9 | 4.7 | 0.6 | 0.8 | 49544 | 52.4 |
| RS | 94.4 | 0.3 | 61.7 | 0.2 | 3.6 | 0.1 | 99.5 | 0.4 | 5.1 | 13 | 0 | 0 | 264.4 | 0.3 |
| BA | 215 | 0.6 | 81.7 | 0.3 | 14.3 | 0.2 | 45.8 | 0.2 | 0 | 0 | 59 | 79.2 | 415.8 | 0.4 |
| Total | 36072 | 100 | 26567 | 100 | 6618 | 100 | 25180 | 100 | 40 | 100 | 74 | 100 | 94551 | 100 |

Table 9 presents details of current LULC practices by agroecology. The share of forest/plantation land is highest (38.6%) in the low-altitude agroecology of Kuyu district, while the lowest forest cover (13.7%) is found in the high-altitude zone. Similarly, vast areas of bare land (43.5%) are identified in the low-altitude agroecology, whereas this category is minimal (2.1%) in the high-altitude agroecology. Furthermore, the rural settlement area is larger in the high-altitude agroecology, with the urban built-up area primarily located in this zone.

The study reveals consistent LULC transition trends across both agroecological zones and district-level analysis. Forest/plantation cover and grasslands exhibit a persistent decline in all agroecological zones, while barren land and cropland show steady expansion over the observed period. One potential reason for these patterns is the inter-agroecological differences in topography, slope, and major soil types (Figure 2 and Table 9), which facilitate soil erosion and expose the land to degradation. To support this finding with qualitative data, farmers were asked to identify the causes of LULC changes in their district and surrounding areas. Respondents noted that climate change has contributed to the expansion of cropland as a response to soil fertility reduction, shrinking livestock populations due to a lack of grazing lands, and widespread deforestation. Driven by socioeconomic constraints, farmers often clear forests to expand cropland and produce charcoal for income generations to secure their households' livelihoods.

Grass/shrub land coverage is minimal (2.4%) in low-altitude agroecology, suggesting that grazing land is particularly problematic in this zone. Therefore, it may be more productive to rear browsers like goats in this area, as opposed to grazers such as cattle, equines, and sheep. Participants from different agroecologies affirmed that agricultural practices align with their respective zones. For instance, farmers in the lowland agroecology primarily grow sorghum as a staple food and rear goats and cattle, while those in the highland agroecology produce teff (*Eragrostis tef*) as a staple and raise cattle, sheep, and equines.

**Table 9.** Current LULC practices by agroecology (1991-2021)

| LULC Classes | Low altitude (1077 - 1500 m) | | Mid-altitude (1501 - 2300 m) | | High-altitude (2301 - 2838 m) | | Total | |
|---|---|---|---|---|---|---|---|---|
| | ha | % | ha | % | ha | % | ha | % |
| Forest/Plantation | 4982 | 38.6 | 10836 | 22.42 | 4546.3 | 13.7 | 20365 | 22 |
| Grass/shrubland | 315.1 | 2.441 | 8489.4 | 17.57 | 5058.7 | 15.2 | 13863 | 15 |
| Bare land | 5615 | 43.5 | 3756.8 | 7.77 | 696.5 | 2.1 | 10068 | 11 |
| Cropland | 1995 | 15.46 | 25215 | 52.17 | 22333 | 67.1 | 49544 | 52 |
| Rural Settlement | 0.6 | 0.004 | 31.9 | 0.07 | 239.9 | 0.7 | 272.4 | 0.3 |
| Urban Built-up Area | 0 | 0 | 0 | 0 | 416 | 1.2 | 416 | 0.4 |
| Total | 12908 | 100 | 48330 | 100 | 33290 | 100 | 94528 | 100 |

Vegetable and fruit production supported by spring-fed irrigation is common in the low- and mid-altitude agroecologies, while diversified cereal production is more evident in the highland agroecology.

Numerous studies affirm that LULC changes are driven by the interplay of socioeconomic and environmental factors, as reported by Assefa and Singh (2017). Dinka and Chaka (2019) also highlight that inappropriate farming practices, overgrazing, rapid population growth, and weak institutional frameworks are key anthropogenic drivers of LULC changes. The rapid increase in human populations leads to encroachment on fragile land, including farming and grazing.

Moreover, literature asserts that resource constraints related to water, soil, biodiversity, and land will impact agricultural systems in the coming decades (Pretty & Bharucha, 2014). Many respondents argue that population growth is a major driver of LULC changes, as the existing land-use policy prevents new households from acquiring land. Consequently, newly emerging households share farmland with their parents, which forces them to utilize grazing and forest lands for crop production. Combined with this, the conversion of grazing land to other land cover types exacerbates the shortage of animal feeds, negatively affecting livestock production and productivity. One of the social outcomes of such livestock production constraints is food insecurity, a phenomenon from which rural households in the study area are suffering.

### 3.4 Implications of LULC change for livestock production and food security

Feed is one of the most critical requirements for livestock farming. Sarwar *et al.* (2002) emphasize that both the quantitative and qualitative supply of feed play a key role in determining the productivity and profitability of animal farms. Similarly, Nyariki *et al.* (2009) argue that the availability of grazing land or feed directly influences the calving, lambing, and kidding rates of herds. In other words, the availability of feed can limit the number of livestock that farmers can rear, directly affecting livestock-derived services and access to nutrient-rich animal-source foods. This issue undermines the vital role of livestock in enhancing household food security, as restricted herd sizes reduce the production and availability of quality protein and dietary diversity.

Additionally, both the quantity and quality of feed supply have been identified as major factors affecting livestock production in Ethiopia. Livestock feeds primarily come from annual foraging across large grazing areas (Mekasha *et al.*, 2014). A study by Duguma and Janssens (2021) in Southwest Ethiopia revealed that natural pastures, crop residues, grazing, and roadside grasses are the primary sources of animal feed, in that order. A significant amount of feed also comes from crop residues, agro-industrial by-products, and other farm and non-farm products (Tolera *et al.*, 2012). Feeding practices in the current study area reflect similar patterns, with fibrous crop residues and grazing being the typical feed resources for ruminant animals, often the only available feed during extended dry seasons (Mesfin *et al.*, 2009). This low-quality roughage serves as the basal feed, which is deficient in nitrogen, energy, vitamins, and minerals, leading to poor livestock production (Kabaiji & Little, 1988).

The current LULC analysis reveals a persistent reduction in grazing land, triggering overgrazing, a key driver of soil erosion and degradation. This reduction in natural pasture diminishes the land's carrying capacity, ultimately lowering livestock populations, productivity, and overall agricultural output. Moreover, the uncontrolled open grazing system leads to overgrazing, negatively impacting livestock production and productivity, and resulting in the underutilization of the district's livestock resources. This situation has significant effects on various aspects of food security and the livelihoods of rural households in the area. Consistent with the findings of this study, Anteneh *et al.* (2018) assessed LULC change in Eastern Ethiopia and found it negatively impacted local communities, livestock, and the environment.

Literature indicates that irreversible human activities, such as forest clearing, cultivation, overgrazing, settlement expansion, industrialization, urbanization, and other forms of land management, are causing changes in LULC patterns (Garedew *et al.*, 2009; Lambin & Meyfroid, 2011), resulting in shifts in livestock feed resource composition and feed deficits. Consequently, the proportional contribution of different feed resources varies according to agroecosystems, farming systems, and the types of animals reared (Rahman *et al.*, 2008). Overall, deficits in feed quantity and quality lead to poor body condition in livestock, often reflected as emaciation, which prevents animals from reaching their optimal production potential. This situation can result in low market prices for animals intended for income generation. The imbalance between income from livestock and food prices may lead to food insecurity, as income from animal sales might not be sufficient to cover food costs.

In the current study area, land management practices have significantly altered the availability of feed resources, reflecting variations in agroecology. Farmers increasingly rely on scarce green pasture during the wet season and dry pasture and crop residues during harvesting and dry seasons. Many farmers also utilize traditionally prepared hay, which is of similar quality to crop residues. Qualitative data indicate that traditional untreated hay is primarily used for fattening animals, lactating cows, and draught oxen. In areas with limited grassland, small ruminants and equines, especially sheep and donkeys, are more efficient at utilizing available feed by grazing pasture down to the roots. This suggests that diversifying livestock species according to the diverse agroecological zones can benefit rural farmers, enhancing food security in resource-scarce environments.

It can be argued that due to these dynamic changes, traditional feed resources and existing feeding strategies are no longer adequate to sustain livestock production (Sarwar *et al.*, 2002). This necessitates the search for alternative livestock and crop production systems, including new feeding regimes. Prioritizing mixed crop-livestock farming systems can offer multiple advantages. Mixed crop-livestock production provides various opportunities for farming communities (Paris, 2002) and represents the most integrated type of agricultural production, fostering farm diversification. Research indicates that farms with greater diversity achieve 19% higher caloric crop yields compared to less-diversified farms (Hadgu *et al.*, 2009). Thus, implementing diversified mixed crop-livestock production and relevant agroecological practices is essential for addressing the challenges of livestock production and food security.

The current qualitative data analysis reveals that goats are primarily reared in low- and mid-altitude agroecological zones, where shrub and bush are relatively abundant, although grazing land remains scarce. In contrast, cattle, sheep, and equines are mainly kept in mid- and high-altitude agroecologies. Moreover, improved crossbreeding practices for cattle are common in highland agroecology, while such practices are absent in lowland areas due to differences in weather conditions and the availability of adequate natural grass and crop byproducts. This differentiation allows farmers to take advantage of agroecological variations by rearing animal species that are well-suited to specific zones and responsive to food insecurity.

Variations in agroecology present opportunities for farmers to diversify their agricultural practices. One such opportunity is the expansion of agroforestry, which can help maximize benefits derived from these agroecological differences. By focusing on the development of multipurpose fodder trees and implementing appropriate conservation measures, farmers can mitigate challenges related to feed quality and environmental degradation.

Adam *et al.* (2021) projected a rising global demand for livestock-derived foods, driven by population and income growth, with South Asia and sub-Saharan Africa expected to see the fastest increases. Similarly, studies on livestock production suggest that growing human populations lead to higher demand for food, particularly livestock products and grains (Nyariki *et al.*, 2009). These authors emphasize that without increased livestock production, there will inevitably be a reduction in the number of livestock per person, leading to decreased availability of milk and meat. This shortage will increase the need for supplementing household diets. To improve food security in the study area, boosting livestock productivity is essential. However, efforts to enhance livestock production must align with initiatives aimed at minimizing potential conflicts between environmental conservation and crop production.

In addition to the challenges of securing adequate and quality feeds, another pressing issue in the study area is water scarcity. During the LULC classification of Kuyu district, water bodies were not identified as a distinct LULC class, indicating the absence of adequate permanent water sources or reservoirs for irrigation and other agricultural activities. This suggests that agricultural practices, both livestock and crop production, rely primarily on rainfall and limited water sources such as rivers or springs, which are increasingly under pressure from climate change.

Water, a critical component of feed nutrients, is essential for livestock physiological functions. Limited water supply severely restricts livestock performance. Combined with the seasonal availability of poor-quality feeds, such as dry pasture and crop residues, inadequate water supply results in poor animal performance.

Different agroecological farming practices, such as intercropping, soil bunds, grass strips, agroforestry systems, water conservation methods, and integrated crop-livestock farming systems, offer viable solutions that complement livestock production in the study area. These practices not only help conserve resources but also reduce input costs, improving the economic situation of farmers (Hadgu *et al.*, 2009). Seasonal feed shortages in Ethiopia, especially severe in drought-prone areas, could be addressed through climate-smart forage production systems to support sustainable livestock production amid LULC changes (Diriba *et al.*, 2023). Therefore, livestock development planning should incorporate policies and strategies that support livestock commercialization while emphasizing indoor animal feeding management. This approach would help reduce the impacts of overgrazing, promote the treatment of poor-quality roughages, enhance livestock productivity, and ultimately foster efforts to ensure food security.

## 4 Conclusion

This study employed ArcGIS 10.7.1 to classify LULC types through supervised classification, utilizing satellite imagery analysis complemented by qualitative data for enhanced accuracy. The classification results demonstrate the effectiveness of satellite imagery in precisely delineating ground features and land cover dynamics. The study reveals that Kuyu district has been experiencing LULC changes since 1991, identifying six distinct LULC types. These changes have affected all three agroecological zones of the district, with the most significant net changes observed in cropland, forest land, grassland, and bare land, in that order. The alterations in LULC, particularly those negatively impacting grassland and other feed resources, are expected to lead to reduced livestock production and productivity, which could have serious implications for food security in the area.

Assessing the current LULC changes has provided valuable remotely sensed satellite imagery and GIS-based empirical data on the surface coverage of different LULC categories across the district, offering an overview of its three agroecological zones. The insights gained from this study could assist the district in designing appropriate strategies and planning to enhance livestock production and food security.

To mitigate the constraints identified and improve livestock production and food security for rural households in Kuyu District, it is recommended to enhance the mixed crop-livestock farming system, develop multipurpose and leguminous fodder trees, implement agroforestry practices, promote diversified livestock production and alternative feed sources, treat poor-quality feed, and apply relevant agroecological practices.

### Limitation of the Study

This study did not incorporate livestock data over the years to articulate the growth trend of the livestock population in relation to the LULC change patterns in the study area, due to a lack of continuous and valid data. Additionally, the study lacks a robust justification for identifying the key determinants of livestock production.

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## References

Abebe G. (2018). Household food insecurity in the Sidama zone of southern Ethiopia: factors, coping and adaptation strategies. Series of dissertations No. 690 Faculty of Social Sciences, University of Oslo. ISSN: 1564–3991.

Adam M. K., Shahnila D., Dolapo E., H. Charles J. G., Mario H., Daniel M.D, Karl M. R. , Peter S., Marco S., Timothy B. S., Keith W., & Dirk W. (2021). Income, consumer preferences, and the future of livestock-derived food demand. *Global environmental challenges*. 70 (2021)102343. https://doi.org/10.1016/j.gloenvcha.2021.102343

Alem-meta, A. A., & Singh, K. N. (2017). The implications of land use and land cover changes for rural household food insecurity in the Northeastern Highlands of Ethiopia: the case of the Teleyayen sub-watershed. *Agric & Food Secur*. (6) 56. DOI 10.1186/s40066-017-0134-4

Anderson, J. R., Hardy, E. E., Roach, J. T., & Witmer, R. E. (1976). A land use and land cover classification system for use with remote sensor data. U. S. Geological Survey, Professional Paper 964. USGS, Washington, D.C.

Amsalu, A., Stroosnijder, L., & de Graaff, J. (2007). Long-term dynamics in land resource use and the driving forces in the Beressa watershed, highlands of Ethiopia. *J. Environ. Manage*. 83 (4):448–459.

Anteneh Worku, Efrem Garedew & FantawYimer (2018). Assessment of land use land cover change and its implication on agro-pastoral area of Gode District, Somali Regional State, Ethiopia. *Journal of Environment and Earth Science*. Vol.8, No.1, 2018

Assefa. A, and K. N. Singh (2017). Implications of land use and land cover change for rural household food insecurity in the northeastern highlands of Ethiopia: the case of Teleyayen subwatershed. *Agricultural and Food Security*, 6 (56). https://doi.org/10.1186/s40066-017-0134-4.

Beyene, F. (2009). Property rights conflict, customary institutions and the state: the case of agropastoralists in Mieso District, Eastern Ethiopia. *J. Mod. Afr. Stud*. 47(2): 213–239.

Biazin, B., Sterk, G. (2013). Drought vulnerability drives land-use and land cover changes in the Rift Valley dry lands of Ethiopia. *Agric. Ecosyst. Environ*. (164):100–113.

Braimoh, A. K. (2006). Random and systematic land-cover transitions in northern Ghana. *Agriculture, Ecosystems & Environment*, 113 (1-4), 254-263).

Cohen, J. (1960). A coefficient of agreement for nominal scales. *Educational and Psychological Measurement*, 20(1): 37-46.

CSA. (2019). Agricultural sample survey report on livestock and livestock characteristics (Private Peasant Holdings), Volume II. Statistical Bulletin 588. Federal Democratic Republic of Ethiopia, Addis Ababa.

Diriba T., Sileshi G., Feyisa H., & Erana K. (2023). Review Article: Contribution of Climate-Smart Forage and Fodder Production for Sustainable Livestock Production and Environment: Lessons and Challenges from Ethiopia. *Advances in Agriculture*. https://doi.org/10.1155/2023/8067776.

Duguma, B., & Janssens, G.P.J. (2021). Assessment of Livestock Feed Resources and Coping Strategies with Dry Season Feed Scarcity in Mixed Crop–Livestock Farming Systems around the Gilgel Gibe Catchment, Southwest Ethiopia. *Sustainability*. 13,2021:10713 https://doi.org/10.3390/su131910713.

FAO. (2015). Climate change and food security: risks and responses. Food and Agriculture Organization: Rome, Italy.

Feleke Yehuwalashet M. (2018). Determinants of crop production failure in Kuyu District, North Shoa, Oromia Regional State, Ethiopia. Food Science and Quality Management www.iiste.org ISSN 2224-6088 (Paper) ISSN 2225-0557 (Online) Vol.72.

Garedew Efrem, Mats Sandewall, Ulf Söderberg, Bruce M. Campbell. (2009). Land-Use and Land-Cover Dynamics in the Central Rift Valley of Ethiopia. *Environmental Management*. 44 (4) :683-694

Getahun Sisay, Berhan Gessesse, de Aza. C. H., Meseret Kassie, & Belaynesh Kebede.(2024). Exploring drivers of land use/land cover transformations in Goang watershed Ethiopia: Integrating local community perceptions with remote sensing data. *Environmental Challenges*. 17 (2024):101043. https://doi.org/10.1016/j.envc.2024.101043

Hadgu KM, Rossing WA, Kooistra L, Van Bruggen AHC. (2009). Spatial variation in biodiversity, soil degradation and productivity in agricultural landscapes in the highlands of Tigray, Northern Ethiopia. *Food Sec*. (1):83–97 DOI 10.1007/s12571-008-0008-5

Intergovernmental Panel on Climate Change. (2022). AR6 working group II: Impacts, adaptation, and vulnerability. Accessed in July 2025 from https://www.ipcc.ch/report/ar6/wg2/.

Kabaiji E., & Little D.A. (1988). Nutrient quality of forages in Ethiopia with particular reference to mineral elements. In: B H Dzowela (Editor), Pasture Network for Eastern and Southern Africa (Panesa). Proceeding of 3$^{rd}$ workshop, Arusha, Tanzania, 27-30. April 1987. ILCA, Addis Ababa. pp. 440-448.

KWAO. (2024). Annual report data on food security project. Unpublished document. Garba Guracha, Ethiopia.

Kolb, M., Mas, J.F., Galicia, L. (2012). Evaluating drivers of land-use change and transition potential models in a complex landscape in Southern Mexico. *Int. J. Geogr. Inf. Sci*. 2013 (27): 1804–1827.

Lambin, E.F., & Meyfroid, P. (2011). Global land use change, economic globalization, and the looming land scarcity. *Proc. Natl. Acad. Sci*. U.S.A. 108 (9): 3465–3472.

Lu D., Mausel P., Brondizio E., Moran E. (2004) - Change detection techniques. *International Journal of Remote Sensing*. (25): 2365-2407. doi: http://dx.doi.org/10.1080/0143116031000139863.

Mehari M., Li J., & Melesse M. (2022). Land use and land cover change, and analysis of its drivers in Ojoje watershed, Southern Ethiopia. *Heliyon*. 8 (2022). https://doi.org/10.1016/j.heliyon.2022.e09267

Mekasha, A., Gerard, B., Tesfaye, K., Nigatu, L., & Duncan, J.A. (2014). Inter-connection between land use land cover change and herders'/farmers' livestock feed resource management strategies: A case study from three Ethiopian eco-environments. Published by Elsevier B.V. *Agriculture, Ecosystems and Environment*, (188): 150–162

Mesfin A. (2022). Analysis of land use land cover change and its implication on natural resources of the Dedo Watershed, Southwest Ethiopia. *Scientific World Journal*, Volume 2022, Article ID 6471291, 10 pages https://doi.org/10.1155/2022/6471291

Mesfin Dejene, Seyoum Bediye, Aemiro Kehaliw, Getu Kitaw & Kedir Nesha. (2009). On-farm evaluation of lactating crossbred (Bos taurus x Bos indicus) dairy cows fed a basal diet of urea treated teff (Eragrostis tef) straw supplemented with escape protein source during the dry season in crop-livestock production system of North Shoa, Ethiopia. *Livestock Research for Rural Development*. 21 (5) 2009.

Meshesha, D.T., Tsunekawa, A., & Tsubo, M. (2012). Continuing land degradation: cause–effect in Ethiopia's Central Rift Valley. *Land Degrad. Dev*. (23):130–143.

Messay Mulugeta & Tsetargachew Legese. (2013). Spatiotemporal environmental dynamics and its implications on rural livelihoods in Wasarbi-Garba Guracha Watershed, Central Ethiopia. *Journal of Sustainable Development in Africa*. 15 (8): 155-18.

M. O. Dinka and D. D. Chaka (2019.). Analysis of land use land cover change in Adei Watershed, Central Highlands of Ethiopia. *Journal of Water and Land Development*, 41 (1): 146–153.

Muhammad A. (2008). Using Remote Sensing and GIS to Study Land-Use and Land- Cover Change in Alachua County, Florida from 1993 to 2003. Msc Thesis Presented to the Graduate School of The University of Florida in Partial Fulfillment of the Requirements for the Degree of Master of Science University of Florida.

Nyariki, D. M., Mwang'ombe, A. W., & Thompsonc, M. D. (2009). Land-Use Change and Livestock Production Challenges in an Integrated System: The Masai-Mara Ecosystem, Kenya. *J Hum Ecol*, 26 (3): 163-173

Oba, G. & Kaitira, L.M. (2006). Herder knowledge of landscape assessments in arid rangelands in northern Tanzania. *J. Arid Environ*, (66):168–186.

Paracchini M.L., Justes E., Wezel A., Zingari P.C., Kahane R., Madsen S., Scopel E., Héraut A. BhérerBreton P., Buckley R., Colbert E., Kapalla D., Sorge M., Adu Asieduwaa G., Bezner Kerr R., Maes O., Negre T. (2020). Agroecological practices supporting food production and reducing food insecurity in developing countries. A study on scientific literature in 17 countries. EUR 30329 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-76-21077-1, doi:10.2760/82475, JRC121570.

Paris T.R. (2002). Crop-animal systems in Asia: Socio-economic benefits and impacts on rural livelihoods. *Agricultural Systems*. (71): 147-168.

Pérez-Vega, A., Mas, J.F., Ligmann-Zielinska, A. (2013). Comparing two approaches to land use/cover change modeling and their implications for the assessment of biodiversity loss in a deciduous tropical forest. *Environ. Model Softw*. 2012, (29): 11–23.

Pretty J., & Bharucha Z. P. (2014). Invited Review. Sustainable intensification in agricultural systems. *Annals of Botany*. (114): 1571–1596. doi:10.1093/aob/mcu205

Rahman, A., Duncan, A.J., Miller, D.W., Clemens, J., Frutos, P., Gordon, I.J., Rehman, A., Baig, A., Ali, F., Wright, I.A. (2008). Livestock feed resources, production and management in the agro-pastoral system of the Hindu Kush-Karakoram-Himalayan region of Pakistan: The effect of accessibility. *Agric. Syst*. (96):26–36.

Sarwar, M., Khan, M.A., & Iqbal, Z. (2002). Feed resources for livestock in Pakistan. *Int. J. Agric. Biol*. 4 (1):186–192.

Shone, M., Demissie, T., Yohannes, B., & Yohannis, M. (2017). Household food insecurity and associated factors in West Abaya district, southern Ethiopia. *Agriculture & Food Security*, 6(2):1–9. https://doi.org/10.1186/s40066-016-0080-6

Taye M.M., Atsushi T., Nigussie H., *et al*. (2024). Agroecology-based LULC change detection, prediction and its implications for land degradation: A case study in the Upper Blue Nile Basin. *International Soil and Water Conservation Research*, https://doi.org/10.1016/j.iswcr.2024.02.002

Tolera, A., Assefa, G., Geleti, D., Gizachew, L., & Mengistu, A. (2012). Feed resources availability and quality. In: Tolera, A., Yami, A., Alemu, D. (Eds.), Livestock Feed Resources in Ethiopia: Challenges, Opportunities and the Need for Transformation. Ethiopian Animal Feeds Industry Association, Addis Ababa, Ethiopia, pp.37–46.

Xu, J.,Mu, M., Liu, Y., Zhou, Z., Zhuo, H., Qiu, G., Chen, J., Lei, M., Huang, X., Zhang, Y., and Ren, Z. (2023). Assessing 30-Year Land Use and Land Cover Change and the Driving Forces in Qianjiang, China, Using Multitemporal Remote Sensing Images. *Water*. (15) 3322. https://doi.org/10.3390/w15183322