International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 11 Issue: 02 | Feb 2024 www.irjet.net p-ISSN: 2395-0072

Spatio-Temporal Dynamics of Agroforestry and Sustainable Land Management in Aleta Wondo, Southern Ethiopia: A Remote Sensing Approach

Adamu Assefa [a] Gedion Tsegay [a] Hu Xialin [a*]

[a] *UNEP-TONGJI Institute of Environment for Sustainable Development (IESD), College of Environmental Science and Engineering, Tongji University, 1239 Siping Road, Shanghai 200092, China*

---***---

Abstract

Environmental sustainability relies on a comprehensive analysis that integrates both land use and cover changes with locally adopted indigenous knowledge of land management practices. The study reveals a noteworthy increase in traditional agroforestry land, expanding spanning three decades (1993-2023). Utilizing Landsat Thematic Mapper (TM) images from 1993 and spot images from 2023, processed via ERDS IMAGINE V9.3, our investigation provides insights into the evolving regional landscape. The study reveals significant changes: Traditional agroforestry land increased from 10,808 to 18,145 hectares (46.28% to 77.71% of total land), indicating a notable shift in agricultural practices. In contrast, cropland decreased from 9,845 to 4,244 hectares (42.16% to 18.18% of the total area), signaling a substantial move away from traditional crop planting to agroforestry. Settlement areas grew by 106 hectares due to rapid population growth, while shrub and bare lands notably declined. These changes highlight a transition in land management practices towards agroforestry. Implications include positive impacts on biodiversity, ecosystem services, and soil health with agroforestry expansion. The reduction in cropland suggests a shift to more sustainable and diversified agricultural practices, potentially enhancing resilience to environmental changes. Settlement area growth underscores the need for sustainable urban planning to address increasing land demands, while the decline in shrub and bare lands raises concerns about habitat loss and potential impacts on local wild life.

Keywords: Land Use Change, Traditional agroforestry Practices, Satellite Imagery Analysis, Indigenous Knowledge, Environmental Sustainability

Article Highlights

- Land use/land cover change is significantly modified over the past three decades in the study area.
- Geospatial technology is a key tool for Land use/land cover change analysis.
- Agroforestry cover has substantially increased due to farmers' indigenous land management in the study area.

1 Introduction

Land use and land cover change (LU/LCC) analysis stands as a critical global concern, its impact resonating across generations by profoundly influencing both natural ecosystems and human societies (Chughtai, Abbasi et al. 2021, Nziguheba, Adewopo et al. 2021, Feng, Wang et al. 2023). This analytical framework serves as a fundamental indicator of environmental shifts, exerting significant effects on vital ecosystem processes, biological cycles, and overall biodiversity (Chang, Hou et al. 2018).

The dynamics of LU/LCC, largely instigated by human activities, have brought about substantial alterations in regional and local landscapes. These changes are primarily driven by the rapid growth and expansion of urbanization, burgeoning populations, technological advancements, and the persistent challenge of land scarcity(Geist, McConnell et al. 2006). The resulting transformations carry profound implications, influencing hydrological cycles, microclimates, groundwater resources, the gradual process of land degradation, and the methodologies employed in land management practices (Lambin and Geist 2003).

In the sub-Saharan African region, characterized by rapid population growth coupled with extensive natural resource exploitation, LU/LCC is notably affecting forest cover due to the expanding footprint of cultivable lands (Bassett and Zuéli

2000). Agroforestry, as part of a multifunctional working landscape, can play a major role in conserving and enhancing biodiversity from farms to the landscape level in both tropical and temperate regions of the world (Jose 2012).

Reflecting this trend, Ethiopia has witnessed a decline in forest cover, primarily attributed to agricultural encroachments and settlements (Tesfahunegn 2013, Kindu, Schneider et al. 2016). Concurrently, smallholder farmers across Ethiopia employ diverse agroforestry practices, varying according to socio-economic and biophysical contexts (Jamala 2013, Iiyama, Takahashi et al. 2017, Abrham, Beshir et al. 2020). Recent governmental initiatives have reported an increase in forest cover, attributed to national afforestation programs (Kassa, Abiyu et al. 2022). A meticulous understanding of LU/LCC alterations holds pivotal importance, guiding effective land use planning and management, particularly in discerning changes in forest cover(Shimizu, Ota et al. 2019).

Furthermore, the preservation and adaptation of traditional knowledge and practices, coupled with a decentralized autonomous governance system, showcase that local communities can not only be part of ecosystems with unique biodiversity but can also be the main actors in actively conserving biodiversity(Marentes, Venturi et al. 2022). Agroforestry systems, rooted in traditional forest-related knowledge, emerge as an effective alternative to conserving biodiversity and ecosystem services. This approach contrasts with strict nature protection where humans are perceived as a negative factor (Marentes, Venturi et al. 2022). Agroforestry systems support a greater variety of plant species, including native plants, and provide more complex habitat and landscape heterogeneity, resulting in higher biodiversity compared to conventional agricultural systems (Haggar, Pons et al. 2019).

Recent studies suggest that a wider implementation of agroforestry principles and practices can play a vital role in achieving more sustainable methods of producing food and fiber globally. This approach not only provides economic benefits to farmers but also yields environmental benefits for society(Pantera, Mosquera-Losada et al. 2021). Studies in Europe have revealed that traditional agroforestry enhances erosion control, biodiversity, and soil fertility. Agroforestry can increase land productivity as the combination of tree and crop systems leads to a more efficient capture of resources than separated tree or crop systems(Torralba, Fagerholm et al. 2016). The conservation of plant diversity in traditional agroforestry can compensate for deforestation in less protected areas (Meragiaw, Woldu et al. 2022).

The primary source of livelihood for farmers in the study area is agriculture, characterized by traditional production techniques. The dominant indigenous knowledge of agroforestry and agriculture practices has been passed down from generation to generation, with new inventions building upon what has been inherited over the years (Ware, Matewos et al. 2023). Farmers have adopted environmentally friendly traditions, high-value agricultural practices, land management, and agroforestry agricultural activities. Most smallholder farms are dominated by multipurpose species that have nutritional and economic importance, such as avocado trees, Wesse (false banana), and cabbage. Coffee and other fruits are grown as cash crops for income generation, while Wesse serves as a staple food—a highly indigenous and drought-resistant crop contributing to long-term food security in every household (Wana, Kudama et al. 2022).

A research gap exists in the current literature as previous studies in the field have addressed a range of issues, yet there is a notable dearth of comprehensive exploration into the role of indigenous knowledge in traditional agroforestry within the context of sustainable land use and land cover (LULC) management systems. This gap highlights the need for further investigation to better understand and integrate indigenous knowledge into the discourse surrounding sustainable land management practices, particularly in the realm of traditional agroforestry. This research aims to comprehensively analyze the land use and land cover (LULC) changes in the Aleta Wondo Woreda of Sidama, Southern Ethiopia, over the period from 1993 to 2023. The primary objectives include assessing the rate and nature of LULC change during this three-decade span, utilizing advanced techniques such as the LULC Change Detection Matrix. The study seeks to provide insights into the dynamic shifts in the regional landscape, with a specific focus on the implications of these changes on the environmental sustainability of the study area. By investigating the patterns and consequences of LULC changes, the research aims to contribute valuable information for informed decision-making in land management and sustainable development strategies.

2. Method and Materials.

2.1. Description of the study area

Aleta Wondo (Woreda) district is one of 30 rural administration structures in the Sidama region, which is situated in a central geographic position a little inclining towards southern Ethiopia. With respect to its absolute position, it is situated between 6◦31' - 6◦41'N latitude and 38°21'- 38°32'E longitude(Fig.1). The woreda has 30 kebeles (the smallest administration in Ethiopia), among this about 19 kebeles produce coffee. Based on the Woreda Administration report, 2022, the total population is 137,855, out of which male 68,238 and female 69,617, 101,593 are rural and 6262 are urban population and also the household number is 21,569 (Sidamareport 2020).

The total land area of the Woreda is 23, 350ha. Among these 64% is covered with forest and permanent crops, 25% with annual crops, 8% is covered by natural, cooperative, and private forests, 2% is covered by grazing land and the remaining 1% of the land is covered by others. Furthermore, the district is known for producing agro-forestry practices which make it greener.

As far as agro-climatic condition is concerned, 37% of the landmass of the district constitutes highland/dega agro-climatic condition while the remaining 63% is categorized under midland/woyina dega agro-climatic zone. The annual temperature of the district varies between 15.1°C to 22.5° while the annual rainfall ranges between 1200mm and 1600mm. The Farming system of the study area generally depends on rainfall agriculture and mixed farming system which involves both crop production and animal husbandry. The major growing in addition to coffee, seasonal crops such as maize, haricot bean, wheat and sweet potato, *wesse,* and maize are the main staple crops. Farmers grow *wesse* for multipurpose uses such as for food, and animal feed, to construct traditional houses(Borrell, Biswas et al. 2019, Ware, Matewos et al. 2023).

2.2 Data sources

2.2.1 Remote sensing data acquisition and processing

Landsat images from 1993, 2003, 2013 and 2023 were utilized to analyze the spatiotemporal LULC change in the Aleta Wondo District. ERDAS Imagine 2014 software is used to process the Landsat images. The study area LULC types were classifed over four years (1993, 2003, 2013 and 2023) using a supervised classifcation method with a maximum likelihood algorithm(Churches, Wampler et al. 2014, Wu, Du et al. 2017) to accomplish spatiotemporal LULC changes. For LULC classifcation, Landsat 5TM 1993, Landsat , 2003 Landsat7ETM, 2013 Landsat 8 OLI and TIRS and 2023 Landsat 9 OLI and were utilized (Table 1; Fig. 2). We use the Landsat images in the day of clear sky to avoid the impact of cloud cover on image quality. Moreover, we perform image pre-processing techniques.

The year 1993 is considered the starting point for LULC analysis due to its historical moment in the Ethiopian government structure. Change of government, declaration and implimentation of massive poverity allivation program. The year 2003 was chosen because of the government policy revesion and implimentation of agricultural led industrialization. 2013 was choosen to notice changes in ten years intervals. Finally, the year 2023 was chosen to assess changes and current status of land use land cover with respect farmers indiginous agroforetry practice.

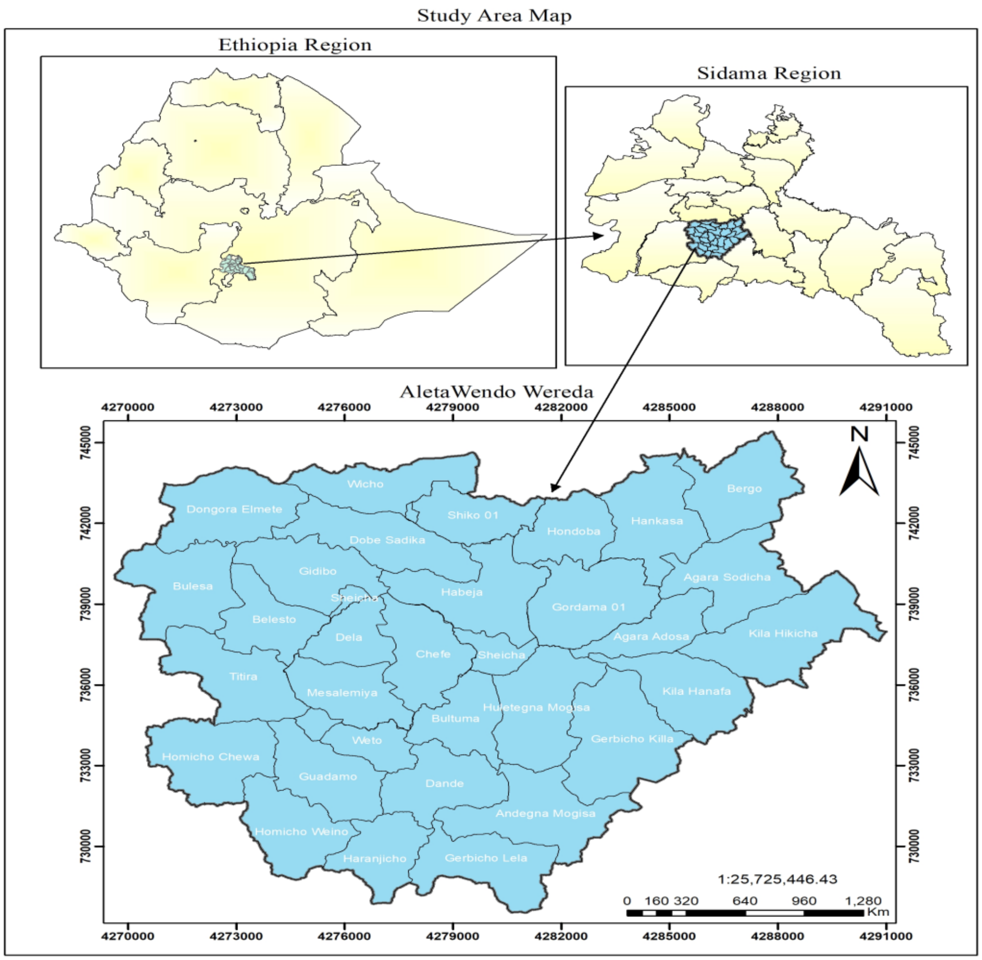

Fig 1: The location and map of study area (Aleta Wondo District)

Table.1. Data Description and source used in this study

GIS Data layer	Data Description	Data source
Vector (polygon)	District (Woreda) Boundary	CSA,2021
Satellite Image	1993 Landsat5 TM	USGS
	2003 Landsat7ETM	
	2013 Landsat 8 OLI and TIRS	
	2023 Landsat 9 OLI and TIRS	
Ground truth	Ground truth 2023	Field survey

2.2.2 Land use land cover analysis

In our research, we conducted a comprehensive Land Use and Land Cover (LULC) analysis of the study area, categorizing it into five major classes based on their dominance, as depicted in Table 2. These categories encompass essential components of the landscape: Agroforest Land, areas primarily dedicated to agroforestry practices integrating trees or woody perennials with agricultural crops or livestock; Settlement, zones predominantly occupied by residential infrastructure and associated facilities; Bareland, regions devoid of substantial vegetative cover often exhibiting exposed soil or limited vegetation; Bushland, areas characterized by dense, low-lying vegetation predominantly consisting of shrubs or bushes; and Cropland, designated areas focused on agricultural cultivation, specifically catering to crops or arable farming. Each classification represents a distinct facet of land use or land cover within the study area, delineating the diverse components shaping the landscape's composition. This comprehensive classification scheme serves as a foundational tool for understanding the spatial distribution and dynamics of various land uses, crucial for our research analysis.

2.3 Classifcation accuracy assessment

The overall accuracy index (Congalton 1991) is calculated by dividing all properly identified pixels by the total number of pixels in the matrix (Eq. 1). The kappa coefficient measure the degree of agreement between two maps when all elements of the error matrix are taken into account (Eq. 2).

$$\text{Overall accuracy}= \frac{\text{Sum of the diagonal elements}}{\text{Total number of accuracy sites(Pixels)}}\times 100 \qquad (1)$$

$$Kappa=\frac{Obs-exp}{1-exp} \qquad (2)$$

where: Obs is it represents accuracy reported in error matrix (overall accuracy) and Exp is it represents correct classifcation.

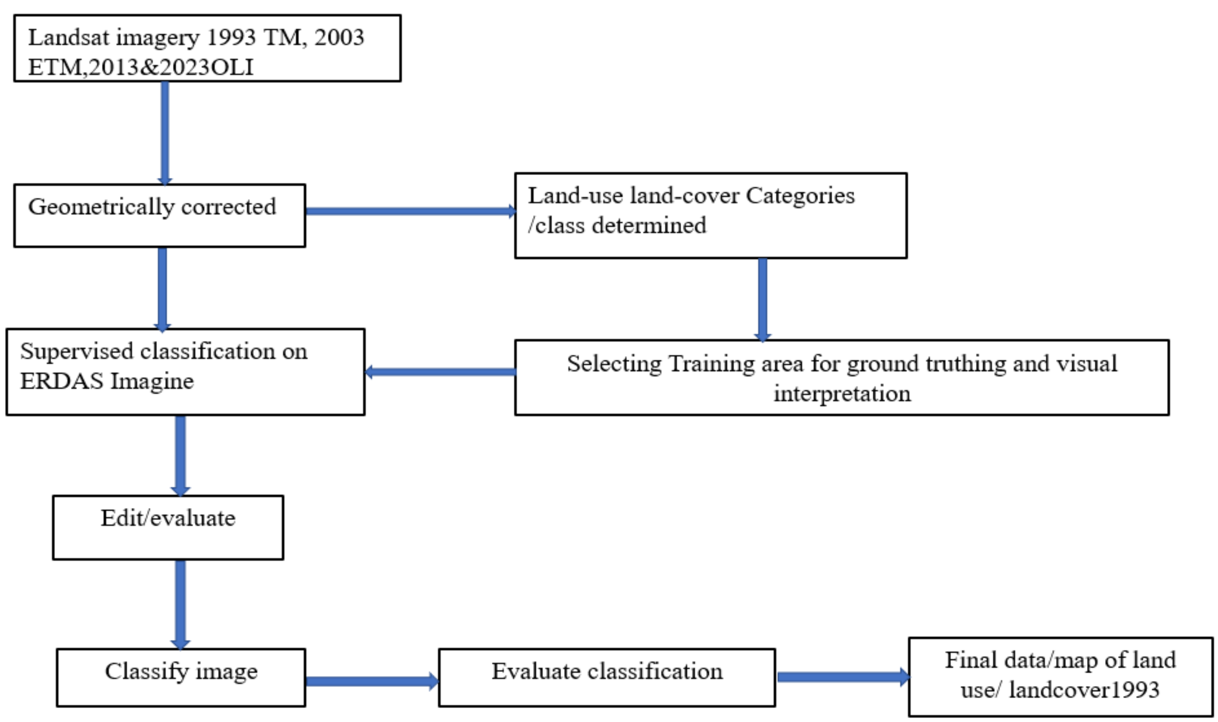

Fig.2 Methodological flowchart for the determination of LULC change

Table. 2 Descriptions of LULC classes used in the study area

Lu/Lc Classes	Discripition
Settlements	Areas allotted for permanent residential, commercial areas, institution and infrastructures
ShrubLand	Areas a plant community characterized vegetation dominated by shrubs, including grasses, herbs.
BareLand	land is areas with no vegetation cover on and when we classy as bare land
AgroForest Land	land covered by forest and crops both perennial and seasonal crops.
Crop Land	category that includes areas used for the production of adapted crops for harvest.

2.4 Spatio-temporal land use land cover change detection

The amount of changed area and extent of change should be examined to identify the magnitudes of change in terms of LULC change (Taddese 2020). Furthermore, the percent of change and rate of change were computed (Eq. 3) to show the magnitude of the changes between two periods(Gessesse, Alemie et al. 2016, Abebe, Derebew et al. 2019, Negassa, Mallie et al. 2020).

$$\text{Rate of Change} = \left(\frac{km2}{year}\right) = \frac{A2-A1}{Z} \qquad (3)$$

where A_2 is an area of LULC (Hectar) in time 2, A_1 is an area of LULC (Hectar) in time 1; Z is Time Interval between A_2 and A_1 in years. The technique of post-classifcation was used to detect LULC change(Yang, Zheng et al. 2012). The LULC change matrix was created to show the overall LULC change between 1993 and 2023.

3 Results and discussions

3.1 Analysis of land use land cover change (1993 to 2023)

Thematic Mapper imagery from 1993, Enhanced Thematic Mapper Plus, and Operational Land Imager data from 2023 were employed to scrutinize the spatiotemporal changes in Land Use and Land Cover (LULC). The study area's LULC was categorized into agroforest land, bushland, bare land, settlement, and cropland. Across the study period, there was a significant expansion in agroforest land, as evidenced in the provided table. This growth coincided with a notable reduction in cropland, attributed to the adoption of agroforestry agricultural practices by local farmers.

From 1993 to 2023, there was a clear trend: agroforest and settlement lands increased while cropland, shrubland, and bare land diminished. Conversion dynamics, such as the transformation of cropland, shrubland, and bare land into agroforestry land and settlements within the Aleta Wondo District, were observed(Manderso 2019).

This transformation was propelled by a combination of traditional agroforestry practices and the population surge linked to the widespread adoption of agroforestry agricultural practices(Pantera, Mosquera-Losada et al. 2021, Meragiaw, Woldu et al. 2022, Shukla and Dhyani 2023). Studies have reported a significant increase in agroforest land within the Aleta Wondo Woreda, attributing it to human activities that contributed to the area's forest cover enhancement. Traditional farming management practices played a vital role in maintaining and improving soil fertility and crop productivity. The cultivation of trees and the development of effective mixtures of various components, evolved over time without external input, have been noted in the area. However, the understanding of the impact of indigenous farm trees on soil fertility remains largely confined to local farmers' knowledge(Zebene and Ågren 2007) (Fig. 3).

Back in 1993, the agroforestry land within Aleta Wondo Woreda encompassed 10,808.00 hectares (46.28%), while cropland, shrubland, bare land, and settlement occupied 9,845.00 hectares (42.16%), 2,215.00 hectares (9.49%), 377.00 hectares (1.61%), and 106.00 hectares (0.45%), respectively. Over time, there has been a substantial increase in both agroforest land and settlement. The agroforestry land expanded by 79.3%, covering an additional 7,337 hectares, while settlement land increased by 410%, totaling an extra 435 hectares.

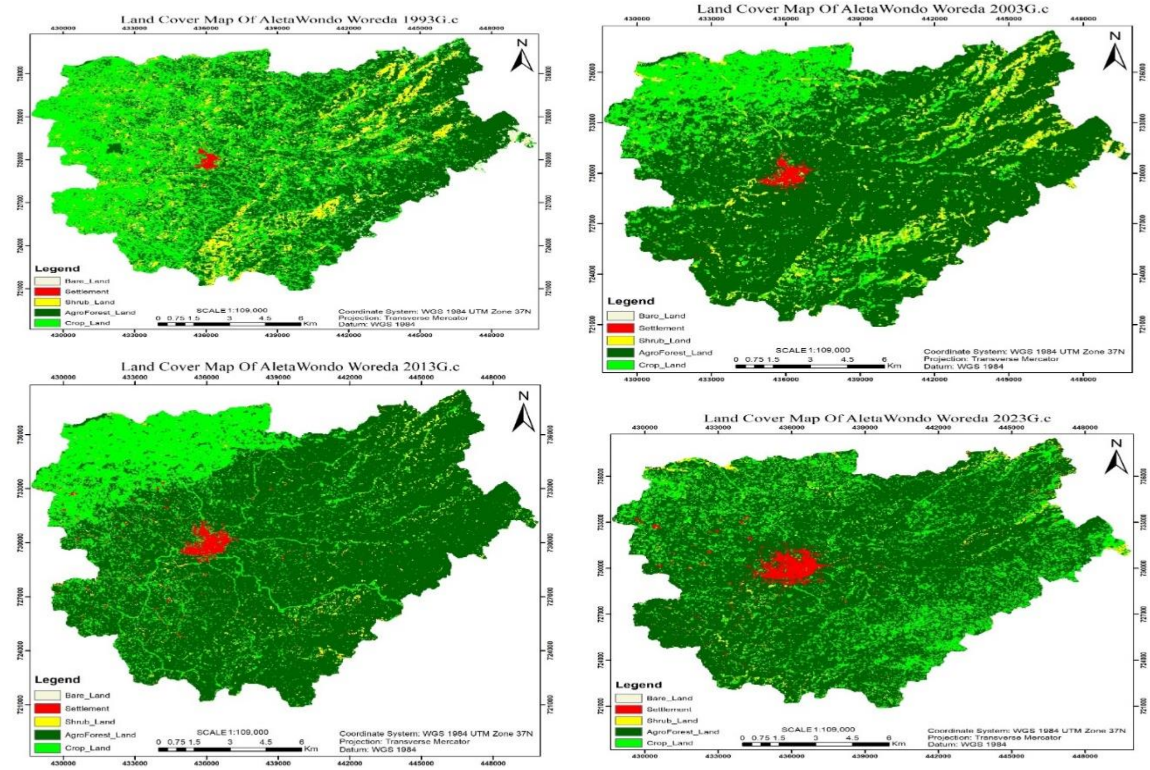

Fig. 3 LULC map of Aleta Wondo Woreda where the changes shows in 1993 , 2003 ,2013 and 2023

Table 3. Land use land cover change 1993 to 2023

land Cover Change					
1993			**2023**		
Land Cover Type	Area (Ha)	Area (%)	Area (Ha)		Change in Hectare
Settlements	106.00	0.45	541.00	2.32	435.00
Shrub Land	2215.00	9.45	380.00	1.63	1835.00
Bare Land	377.00	1.61	40.00	0.17	337.00
Agroforestry Land	10,808.00	46.28	18,145.00	77.71	7337.00
Crop Land	9,845.00	42.16	4244.00	18.18	5601.00
Total	23,352.00	100.00	23,350.00	100	15,545.00

These changes parallel the findings o(Deribew and Wana 2019) , highlighting the impact of population pressure and local agricultural practices on land use patterns By 2023, the landscape had undergone significant alterations. Cropland, shrubland, and bare land had decreased substantially by 5,601 hectares (132%), 1,835 hectares (483%), and 337 hectares (842%), respectively. Conversely, agroforestry land expanded by 18,145 hectares (77.71%), while settlement land increased by 541 hectares (2.32%).Our analysis underscores a clear trend: the remarkable increase in agroforestry land has come at the expense of cropland, shrubland, and other LULC categories over the past three decades within the study area, as delineated in the LULC change assessment (refer to Table 3).

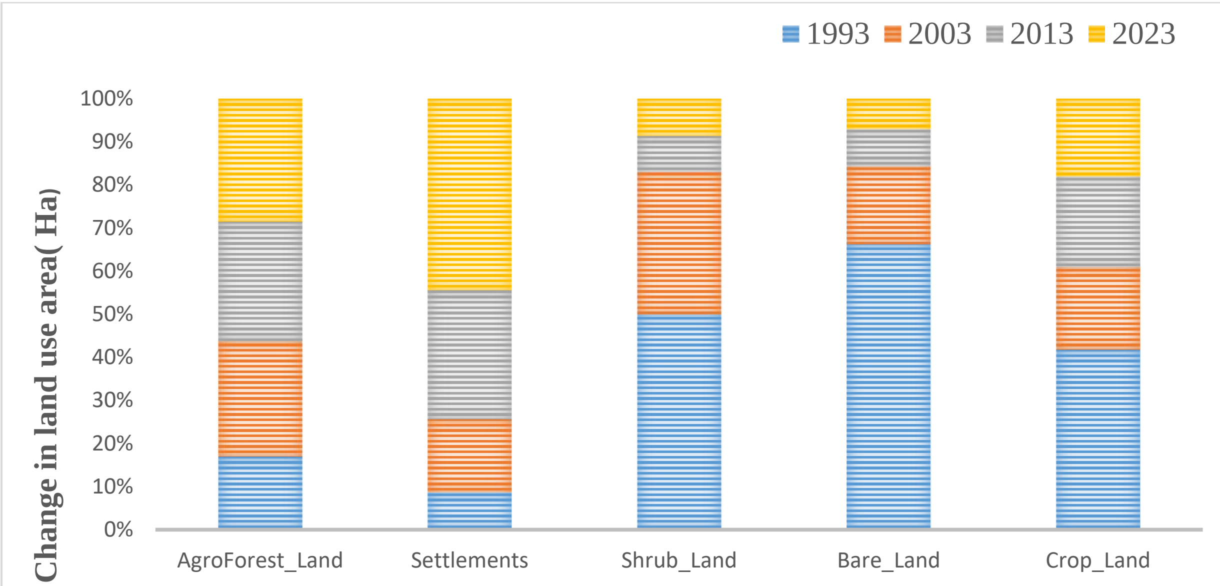

Fig.4. Change in Land use land cover in Aleta Wondo Woreda 1993 to 2023

The reliability of the data is 97.3% with kappa values of 0.80, 0.99, 0.99, and 1, the total classification accuracies for the study periods of 1993, 2003, 2013, and 2023 were 82.2%, 99.7%, 83.1%and 87.6%, respectively. A kappa score of larger than (>) 0.80 (80%) indicates a significant agreement, while a value of between 0.60 (60%) and 0.80 (80%) indicates a substantial agreement(Landis and Koch 1977).

3.2 Rate of land use land cover change

Between 1993 and 2023, while cropland, shrubland, and bareland experienced declines at rates of 186.7 hectares/year, 61.2 hectares/year, and 11.2 hectares/year, respectively, the economy of the study area, reliant on agriculture, witnessed a surge in agroforestry agricultural land and settlement construction. This surge was necessitated by rapid population growth, driving the decline in shrubland, bare land, and even conventional farm cropland, positively influencing agroforest ecosystems. Over three decades, agroforestry agricultural land expanded at a rate of 244.6 hectares/year, while settlements grew by 14.5 hectares/year (refer to Fig. 4).

Our findings indicate a consistent increase in agroforest cover within Aleta Wondo Woreda, aligning with prior research(Gómez, Bueno et al. 2022) ,(Pellikka, Heikinheimo et al. 2018, Geeraert, Hulsmans et al. 2019). Concurrently, similar declining trends were observed in cropland, shrubland, and bareland. Notably, nearly 132% of croplands transitioned to agroforestry land in the past 30 years, owing to farmers' adherence to traditional agroforestry practices. Home gardening has remained integral to the local subsistence economy for centuries, crucial for food security(Quandt, Neufeldt et al. 2023). These gardens, mirroring native vegetation in the tropics, aid in conserving local biodiversity and meeting the increasing demands of the community (Tk 2014). Despite significant increases in agroforestry and substantial declines in cropland over 30 years, settlement land expanded by over 410%, rising from 106 hectares in 1993 to 541 hectares in 2023 due to housing and infrastructure development driven by rapid population growth. Conversely, cropland, shrubland, and bareland witnessed dramatic declines of 5601 hectares (132%), 1835 hectares (483%), and 377 hectares (843%), respectively, during this period (refer to Fig. 5) This shift indicates a trade-off between agroforestry and these other land uses, specifically highlighting farmers' shift from monoculture crop cultivation to traditional agroforestry practices. This observed change indicates a decline of shrubland and cropland direct result of farmers' land use change from monoculture crop cultivation to traditional agroforestry agricultural practices.

Our result is consistent with a previous study by(Woldesenbet, Wudmatas et al. 2020), emphasizing the positive impact of Enset-based agroforestry practices in reducing soil erosion risks in watersheds, necessitating immediate integrated land use management interventions.

However, alongside cropland, shrubland, and bareland, there have been significant declines of 1835 hectares (483%) and 377 hectares (843%), respectively, over the study period, signaling the substantial impact of rapid population growth on diminishing agricultural land use intensity(Jiang, Deng et al. 2013). Farmers, striving to cultivate all available lands, including previously peripheral bare lands, contribute to this decline. Furthermore, with a household population of approximately 21,569 and a total land area of 23,350 hectares, the land holding per capita stands at nearly 1 hectare/person. This tight ratio illustrates how rapid population growth negatively affects land use and land cover management in the area (refer to Fig. 5).

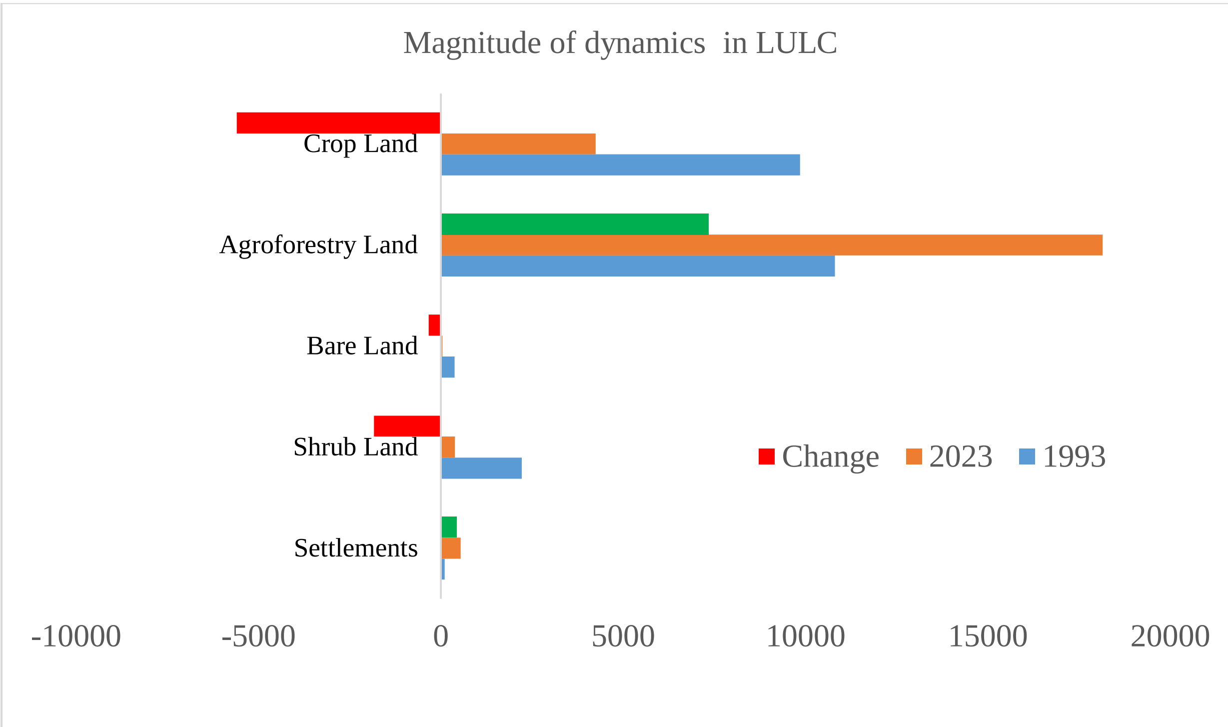

Fig.5. Magnitudes of dynamics of land use and land cover

3.3. LULC Change detection matrix of Aleta Wondo Woreda 1993 to 2023

The Change Detection Matrix offers a comprehensive view of how different land use types transition into other categories, showcasing the transformations across the landscape. During the period from 1993 to 2023, notable shifts were observed, exemplified by varying rates of change among different land use types. Between 1993 and 2023, there was an average increase of 67% in settlement areas and a 23% rise in agroforestry cover. In contrast, cropland, shrubland, and bare land experienced average decreases of 22%, 28%, and 30%, respectively. This overall analysis of Land Use and Land Cover (LULC) change detection revealed a reduction in land area across three LULC categories and an expansion in two others.

To illustrate, consider the state of agroforestry land in 1993, totaling 10,807 hectares. Over the subsequent thirty years, 7,635 hectares, 1,471 hectares, and 10 hectares transitioned from cropland, bare land, and shrubland, respectively, leaving 8,862 hectares unchanged by 2023 (refer to Fig. 6). This matrix provides a detailed snapshot of the dynamic alterations within the landscape, showcasing how various land use types transformed and contributed to the shifts observed over the studied period. It delineates the intricate patterns of conversion and stability among different land use categories, elucidating the evolving nature of the Aleta Wondo Woreda's landscape.

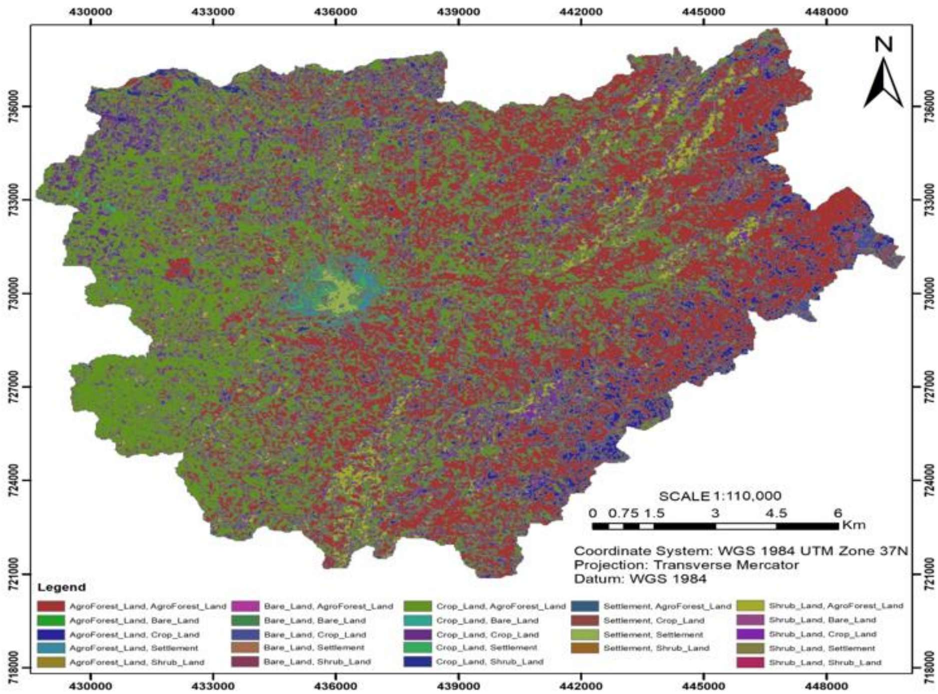

Fig.6. Change detection map of Aleta Wondo 1993-2023

3.4. Implications of Land Use /Land Cover Change in Study Area

Land Use and Land Cover (LULC) changes exert a continuous and multi-scalar impact on various environmental aspects, influencing air and water quality, watershed function, waste generation, wildlife habitat extent and quality, climate, and human health. In the study area, major LULC changes are primarily driven by the intensive engagement of farmers in traditional agroforestry practices and the settlement-related infrastructural developments induced by rapid population growth.

Farmers in the study area actively choose traditional agroforestry for several reasons. The integration of trees provides an additional crop that safeguards against poor harvests, and fruits, staple crops, or timber serve as alternative income streams if the primary crop fails due to adverse conditions, such as wet summers or mild winters. However, the poor documentation of data in the region necessitated an analysis of the major crops produced and supplied to the central market over a 17-year period.

The analysis unveiled that, despite other environmental and economic factors, the significant increase in coffee production and improved supply to the central market can be predominantly attributed to the intensification of traditional agroforestry practices. This finding aligns with previous studies in nearby areas, indicating that a fruit-based traditional agroforestry system yields multiple products and is economically more profitable compared to monocropping (Adane, Legesse et al. 2019). From 2005 to 2022, coffee production in the study area increased from 19,132,523 quintals in 2005 to 24,564,178 quintals in 2022, reflecting a growth rate of 28.4%. Concurrently, the supply to the central market surged from 2,667,980 quintals in 2005 to 4,856,419 quintals in 2022, demonstrating an 82% increase. While coffee production exhibited positive growth rates for every year except 2010, 2012, and 2015, the supply to the central market consistently increased throughout the entire study period. Thus, intensive traditional agroforestry emerges as a primary driving force for the overall rise in coffee production and supply in the study area (Fig.7).

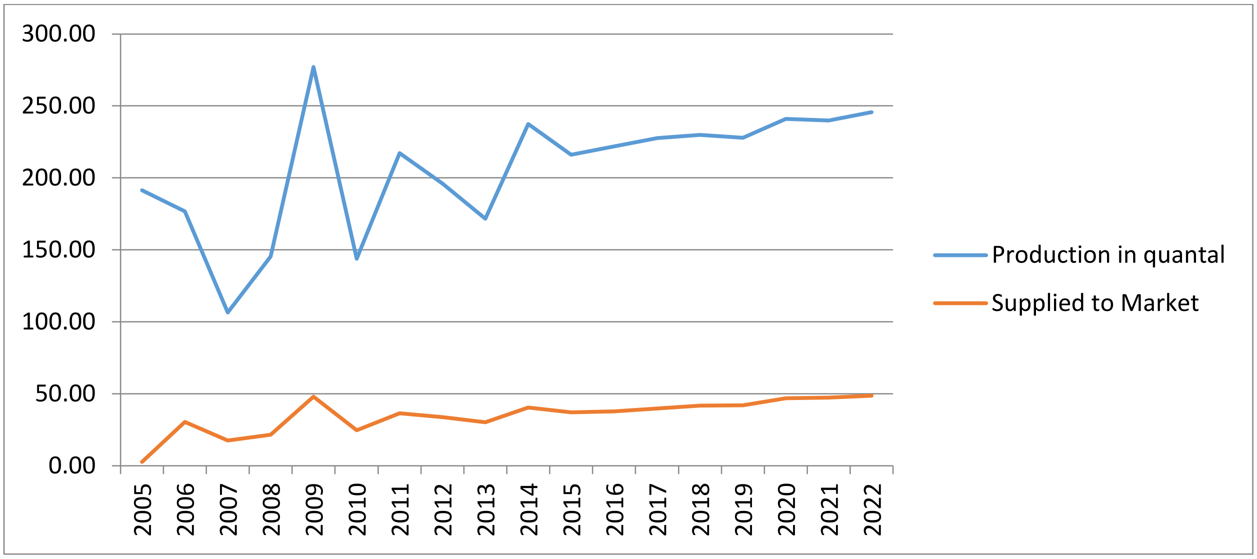

Fig 7. Coffee Production and Supply to Central Market trends (2005-2022) *1000

Within similar physical features and neighboring locations, studies have confirmed that agroforestry practitioners utilizing mango trees report various environmental benefits. These advantages include enhanced soil fertility, reduced crop damage by wind, and improved microclimates for crops and livestock due to shading. Farmers incorporating mango trees into their practices have experienced more significant benefits compared to those who do not (Gochera and Worku 2022).

In essence, traditional agroforestry systems have been deeply rooted in the Aleta Wondo and Sidama region, constituting a crucial element of local livelihoods. This is particularly evident in their significant role in fostering the thriving cultivation of coffee in the shaded understory of the region. These systems play a crucial role in preserving ecosystem services and biodiversity corridors, maintaining traditional agroecological practices on small-scale family farms. These farms, characterized by a diverse mix of crops, livestock, vegetable gardens, and productive forest areas, are essential for local food and income generation. The practices of farmers provide valuable insights into the synergy between agroforestry shifts, indigenous knowledge, and the sustainable landscape of Aleta Wondo.

4. Conclusions

Utilizing geospatial technologies, this study scrutinized Land Use and Land Cover (LULC) changes within the study area. The analysis of Landsat imagery spanning four years delineated significant shifts in land cover. Notably, agroforest land experienced a substantial increase, potentially impacting microclimates and local livelihoods. Over the study period, agroforestry land expanded by 7,337 hectares, while cropland, shrubland, and bare land decreased by 5,601 hectares, 1,835 hectares, and 377 hectares, respectively (1993 to 2023). The drivers behind these changes involved transitioning from monoculture to agroforestry practices, rapid population growth, and expanding built-up areas. While the rise in agroforestry land presents economic, social, and environmental potential, exponential settlement growth raises concerns about land degradation, resource overuse, and climate impacts. Addressing the high rural population growth might necessitate exploring off-farm employment opportunities, especially for the youth.

Policy interventions, especially in managing traditional agroforestry systems, offer nature-based solutions for biodiversity conservation and ecosystem maintenance. Further research focusing on traditional agroforestry practices is crucial for understanding their role in nature management, combating land degradation, and enhancing global climate resilience.

In summary, this study highlights the intricate relationship between land use, human activities, and environmental repercussions. Strategic policies and ongoing research are essential for sustainable land management and mitigating the adverse impacts of evolving land cover patterns

Availability of data Available in the manuscript

Declarations ; The authors declare that they have no known competing financial

interests or personal relationships that could have appeared to influence

the work reported in this paper**.**

Credit authorship and contribution statement

Adamu Assefa: Conceptualization, Methodology, Software, Formal analysis, Data Curation, Writing- Original draft preparation. Gedion Tsegay: Software, Visualization, Validation, Data curation Writing - Review & Editing. Hu Xialin: Conceptualization, Writing - Review & Editing, Visualization, Supervision, Project administration, Funding acquisition

References

Abebe, M., K. T. Derebew and D. O. Gemeda (2019). "Exploiting temporal-spatial patterns of informal settlements using GIS and remote sensing technique: a case study of Jimma city, Southwestern Ethiopia." Environmental Systems Research **8**: 1-11 DOI: https://doi.org/10.1186/s40068-019-0133-5.

Abrham, T., H. Beshir and A. Haile (2020). "Sweetpotato production practices, constraints, and variety evaluation under different storage types." Food and Energy Security **9**: 12 DOI: https://doi.org/10.1002/fes3.263.

Adane, F., A. Legesse, T. Weldeamanuel and T. Belay (2019). "The contribution of a fruit tree-based agroforestry system for household income to smallholder farmers in Dale District, Sidama Zone, Southern Ethiopia." Adv Plants Agric Res **9**(1): 78-84 DOI: https://doi.org/10.15406/apar.2019.09.00415.

Bassett, T. J. and K. B. Zuéli (2000). "Environmental Discourses and the Ivorian Savanna." Annals of the Association of American Geographers **90**(1): 67-95 DOI: https://doi.org/10.1111/0004-5608.00184.

Borrell, J. S., M. K. Biswas, M. Goodwin, G. Blomme, T. Schwarzacher, J. S. Heslop-Harrison, A. M. Wendawek, A. Berhanu, S. Kallow, S. Janssens, E. L. Molla, A. P. Davis, F. Woldeyes, K. Willis, S. Demissew and P. Wilkin (2019). "Enset in Ethiopia: a poorly characterized but resilient starch staple." Annals of Botany **123**(5): 747-766 DOI: https://doi.org/10.1093/aob/mcy214.

Chang, Y., K. Hou, X. Li, Y. Zhang and P. Chen (2018). "Review of Land Use and Land Cover Change research progress." IOP Conference Series: Earth and Environmental Science **113**(1): 012087 DOI: https://doi.org/10.1088/1755-1315/113/1/012087.

Chughtai, A. H., H. Abbasi and I. R. Karas (2021). "A review on change detection method and accuracy assessment for land use land cover." Remote Sensing Applications: Society and Environment **22**: 100482 DOI: https://doi.org/10.1016/j.rsase.2021.100482.

Churches, C. E., P. J. Wampler, W. Sun and A. J. Smith (2014). "Evaluation of forest cover estimates for Haiti using supervised classification of Landsat data." International Journal of Applied Earth Observation and Geoinformation **30**: 203-216 DOI: https://doi.org/10.1016/j.jag.2014.01.020.

Congalton, R. G. (1991). "A review of assessing the accuracy of classifications of remotely sensed data." Remote Sensing of Environment **37**(1): 35-46 DOI: https://doi.org/10.1016/0034-4257(91)90048-B.

Deribew, K. and D. Wana (2019). "Land use and forest cover dynamics in the North-eastern Addis Ababa, central highlands of Ethiopia." Environmental Systems Research **8** DOI: https://doi.org/10.1186/s40068-019-0137-1.

Feng, H., S. Wang, B. Zou, Y. Nie, S. Ye, Y. Ding and S. Zhu (2023). "Land use and cover change (LUCC) impacts on Earth's eco-environments: Research progress and prospects." Advances in Space Research **71**(3): 1418-1435 DOI: https://doi.org/10.1016/j.asr.2022.09.054.

Geeraert, L., E. Hulsmans, K. Helsen, G. Berecha, R. Aerts and O. Honnay (2019). "Rapid diversity and structure degradation over time through continued coffee cultivation in remnant Ethiopian Afromontane forests." Biological Conservation **236**: 8-16 DOI: https://doi.org/10.1016/j.biocon.2019.05.014.

Geist, H., W. McConnell, E. F. Lambin, E. Moran, D. Alves and T. Rudel (2006). Causes and Trajectories of Land-Use/Cover Change. Land-Use and Land-Cover Change: Local Processes and Global Impacts. E. F. Lambin and H. Geist. Berlin, Heidelberg, Springer Berlin Heidelberg: 41-70.

Gessesse, A., T. Alemie, T. Feyisa and A. Jemal (2016). "Impact Assessment of Land Use/ Land Cover Change on Soil Erosion and Rural Livelihood in Andit Tid Watershed, North Shewa, Ethiopia." Archives of Current Research International **3**: 1-10 DOI: https://doi.org/10.9734/ACRI/2016/22268.

Gochera, A. and H. Worku (2022). "Mangifera indica (L.) tree as agroforestry component: Environmental and socio-economic roles in Abaya-Chamo catchments of the Southern Rift Valley of Ethiopia." Cogent Food & Agriculture **8**(1): 2098587 DOI: https://doi.org/10.1080/23311932.2022.2098587.

Gómez, M. U., A. L. Bueno, A. C. León, J. I. Uribe Bernal and S. A. Hernández Aguirre (2022). "Traditional agroforestry systems: a methodological proposal for its analysis, intervention, and development." Agroforestry Systems **96**(3): 491-503 DOI: https://doi.org/10.1007/s10457-021-00692-w.

Haggar, J., D. Pons, L. Saenz and M. Vides (2019). "Contribution of agroforestry systems to sustaining biodiversity in fragmented forest landscapes." Agriculture, Ecosystems & Environment **283**: 106567 DOI: https://doi.org/10.1016/j.agee.2019.06.006.

Iiyama, K., E. Takahashi, J. Lee, H. Mon, M. Morishita, T. Kusakabe and C. Yasunaga-Aoki (2017). "Alkaline protease contributes to pyocyanin production in Pseudomonas aeruginosa." FEMS microbiology letters **364** DOI: https://doi.org/10.1093/femsle/fnx051.

Jamala, G. (2013). "The Scope and Potentials of Fodder Trees and Shrubs in Agroforestry." IOSR Journal of Agriculture and Veterinary Science **5**: 11-17 DOI: https://doi.org/10.9790/2380-0541117.

Jiang, L., X. Deng and K. C. Seto (2013). "The impact of urban expansion on agricultural land use intensity in China." Land Use Policy **35**: 33-39 DOI: https://doi.org/10.1016/j.landusepol.2013.04.011.

Jose, S. (2012). "Agroforestry for conserving and enhancing biodiversity." Agroforestry Systems **85**(1): 1-8 DOI: https://doi.org/10.1007/s10457-012-9517-5.

Kassa, H., A. Abiyu, N. Hagazi, M. Mokria, T. Kassawmar and V. Gitz (2022). "Forest landscape restoration in Ethiopia: Progress and challenges." Frontiers in Forests and Global Change **5** DOI: https://doi.org/10.3389/ffgc.2022.796106.

Kindu, M., T. Schneider, D. Teketay and T. Knoke (2016). "Changes of ecosystem service values in response to land use/land cover dynamics in Munessa-Shashemene landscape of the Ethiopian highlands." Sci Total Environ **547**: 137-147 DOI: https://doi.org/10.1016/j.scitotenv.2015.12.127.

Lambin, E. F. and H. J. Geist (2003). "Regional Differences in Tropical Deforestation." Environment: Science and Policy for Sustainable Development **45**(6): 22-36 DOI: https://doi.org/10.1080/00139157.2003.10544695.

Landis, J. R. and G. G. Koch (1977). "The measurement of observer agreement for categorical data." Biometrics **33 1**: 159-174 DOI: https://doi.org/10.2307/2529310.

Manderso, T. (2019). "Evaluating Impact of Land-use/land-cover change on Surface runoff using Arc SWAT model in Sore and Geba watershed, Ethiopia." DOI: 10.7176/JEES/9-10-02.

Marentes, M. A. H., M. Venturi, S. Scaramuzzi, M. Focacci and A. Santoro (2022). "Traditional forest-related knowledge and agrobiodiversity preservation: the case of the <i>chagras</i> in the Indigenous Reserve of Monochoa (Colombia)."

Biodiversity and Conservation **31**(10): 2243-2258 DOI: https://doi.org/10.1007/s10531-021-02263-y.

Meragiaw, M., Z. Woldu and B. R. Singh (2022). "Land use and land cover dynamics and traditional agroforestry practices in Wonchi District, Ethiopia." PeerJ **10**: e12898 DOI: 10.7717/peerj.12898.

Negassa, M., D. Mallie and D. Gemeda (2020). "Forest cover change detection using Geographic Information Systems and remote sensing techniques: a spatio-temporal study on Komto Protected forest priority area, East Wollega Zone, Ethiopia." ENVIRONMENTAL SYSTEMS RESEARCH **9** DOI: https://doi.org/10.1186/s40068-020-0163-z.

Nziguheba, G., J. B. Adewopo, C. Masso, N. L. Nabahungu, J. Six, H. Sseguya, G. Taulya and B. Vanlauwe (2021). "Assessment of sustainable land use: linking land management practices to sustainable land use indicators." International Journal of Agricultural Sustainability **20**: 265 - 288 DOI: https://doi.org/10.1080/14735903.2021.1926150.

Pantera, A., M. R. Mosquera-Losada, F. Herzog and M. den Herder (2021). "Agroforestry and the environment." Agroforestry Systems **95**(5): 767-774 DOI: 10.1007/s10457-021-00640-8.

Pellikka, P. K. E., V. Heikinheimo, J. Hietanen, E. Schäfer, M. Siljander and J. Heiskanen (2018). "Impact of land cover change on aboveground carbon stocks in Afromontane landscape in Kenya." Applied Geography **94**: 178-189 DOI: https://doi.org/10.1016/j.apgeog.2018.03.017.

Quandt, A., H. Neufeldt and K. Gorman (2023). "Climate change adaptation through agroforestry: opportunities and gaps." Current Opinion in Environmental Sustainability **60**: 101244 DOI: https://doi.org/10.1016/j.cosust.2022.101244.

Shimizu, K., T. Ota and N. Mizoue (2019). "Detecting Forest Changes Using Dense Landsat 8 and Sentinel-1 Time Series Data in Tropical Seasonal Forests." Remote. Sens. **11**: 1899.

Shukla, J. and S. Dhyani (2023). Potential of Traditional Agroforestry Systems for Intensification of Agriculture and Meeting Global Goals: Lessons from Asia and Africa. Agroforestry for Sustainable Intensification of Agriculture in Asia and Africa. J. C. Dagar, S. R. Gupta and G. W. Sileshi. Singapore, Springer Nature Singapore**:** 665-683.

Sidamareport (2020). Regional Finance bureau of Sidama, yearl report of 2020.

Taddese, S. (2020). "ASSESSMENT OF SOIL EROSION AND LAND USE LAND COVER CHANGE USING RUSLE MODEL, GIS AND REMOTE SENSING: A CASE STUDY OF WOMBEYA WATERSHED, A." International Journal of Current Research **11**: 5730-5738 DOI: 10.24941/ijcr.35603.07.2019.

Tesfahunegn, G. (2013). "Soil Quality Indicators Response to Land Use and Soil Management Systems in Northern Ethiopia's Catchment." Land Degradation & Development **27** DOI: https://doi.org/10.1002/ldr.2245.

Tk, K. (2014). TROPICAL HOMEGARDENS**:** 365-375.

Torralba, M., N. Fagerholm, P. J. Burgess, G. Moreno and T. Plieninger (2016). "Do European agroforestry systems enhance biodiversity and ecosystem services? A meta-analysis." Agriculture, Ecosystems & Environment **230**: 150-161 DOI: https://doi.org/10.1016/j.agee.2016.06.002.

Wana, H., G. Kudama, A. Tilahun, F. Dereje, N. Ababulgu, G. Gobena, B. Tadese and B. Chalchisa (2022). "Indigenous knowledge and traditional agroforestry practices and their implications for food security: the case of Wollega Zones, Western Ethiopia." GeoJournal **88**: 2787 - 2798 DOI: https://doi.org/10.1007/s10708-022-10772-8.

Ware, M., T. Matewos, M. Guye, A. Tura and Y. Mohammed (2023). Spatiotemporal characteristics and trend analysis of rainfall and temperature in Sidama Regional State, Ethiopia.

Woldesenbet, A. B., S. D. Wudmatas, M. A. Denboba and A. G. Gebremariam (2020). "Enset-based land use land cover change detection and its impact on soil erosion in Meki river watershed, Western Lake Ziway Sub-Basin, Central Rift Valley of Ethiopia." Environmental Systems Research **9**(1): 37 DOI: https://doi.org/10.1186/s40068-020-00198-x.

Wu, C., B. Du, X. Cui and L. Zhang (2017). "A post-classification change detection method based on iterative slow feature analysis and Bayesian soft fusion." Remote Sensing of Environment **199**: 241-255 DOI: https://doi.org/10.1016/j.rse.2017.07.009.

Yang, X., X.-Q. Zheng and L.-N. Lv (2012). "A spatiotemporal model of land use change based on ant colony optimization, Markov chain and cellular automata." Ecological Modelling **233**: 11-19 DOI: https://doi.org/10.1016/j.ecolmodel.2012.03.011.

Zebene, A. and G. I. Ågren (2007). "Farmers' local knowledge and topsoil properties of agroforestry practices in Sidama, Southern Ethiopia." Agroforestry Systems **71**(1): 35-48 DOI: 10.1007/s10457-007-9087-0.