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Ekológia (Bratislava) - Journal of the Institute of Landscape Ecology, Slovak Academy of Sciences Vol. 43, No. 1, p. 91–98, 2024
DOI:10.2478/eko-2024-0009

LAND USE/COVER DYNAMICS AND ITS IMPLICATION ON THE SUSTAINABILITY OF URBAN AGRICULTURE IN SELECTED URBAN CENTERS OF ETHIOPIA

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Received: 12 July 2023 / **Accepted:** 24 January 2024

Abstract

Gibtan A., Abera W., Delelegn M., Maru M., Emiru A.: Land use/cover dynamics and its implication on the sustainability of urban agriculture in selected urban centers of Ethiopia. Ekológia (Bratislava), Vol. 43, No. 1, p. 91–98, 2024.

Analysis of urban Land Use/Land Cover (LULC) dynamics in light of urban agriculture (UA) helps to understand its implication for UA practice and in turn making the necessary interventions. Therefore, the main objective of this study was to examine the LULC dynamics in selected urban centers of Ethiopia (Addis Ababa, Bahir Dar, Adama, and Hawassa cities) for the last seventeen years (2006–2022). SPOT 5 satellite imagery for the year 2006 and 2016 and Sentinel image for the year 2022 were analyzed. In addition, data from key informant interviews, focus group discussions, and field observations were used to triangulate LULC analyses information and to identify the main causes of LULC dynamics in the studied urban centers. The findings reveled that there were rapid expansion of urban built-up areas at the expense of other urban LULC types mainly of peri urban horticultural lands for the last 17 years (2006–2022) in Addis Ababa, Hawassa, Bahir Dar, and Adama cities of Ethiopia. This has adverse impact on the sustainability of UA. Rapid urban population growth mainly because of high rural urban migration, expansion of squatter settlement, and increment of investment were the main driving forces of LULC dynamics. Based on the findings of this study (changes in LULC and driving factors) the studied cities administrations or authorities need to develop sustainable development plans by considering UA.

*Key word*s: urban agriculture, land use/cover, cities, sustainability.

Introduction

Human intervention in the natural environment influences the nature of ecosystem processes by conversion of various land uses (mainly farm land) into urban built-up area. Rapid growth of urban population and urbanization particularly in developing countries accelerates transformation of urban areas into non agricultural uses greatly (Coulibaly, Li, 2020). It is estimated that the world urban population will increase to 66% by 2050, and of this about 90% will be concentrated in Africa and Asia. This will lead to fast growth of built-up areas that consumes the surrounding productive land and encroaches on the necessary ecosystems (Gashu, Gebregziabher, 2018).

Despite urban centers having several advantages (e.g. job opportunity, prevalence of diverse culture, etc.), they have been challenged by fast population growth particularly in Africa. Urbanization leads to a continuous loss of agricultural land, both directly under the form of land taken for built-up area, and indirectly through the use of agricultural land for non-productive rural activities like recreation. Urban land-use forms that include features such as buildings, roads, power lines, airports, etc. are dynamic systems that can undergo continuous alteration over time. Hence, understanding this dynamic is essential in the management and planning of urban landscapes (Garzon et al., 2022).

The impact of urbanization on Urban Agriculture (UA) goes beyond the simple conversion of farming land into urban area. Increasing land rent at the urban fringe attracts speculators that buy farming land, not for farming but as a strategic investment, anticipating future land development possibilities and this typically leads to an increase of unused land in the urban fringe (Beckers et al., 2020).

Dozens of studies have been conducted on LULC dynamics in Ethiopia in the last decades. However, many of them overlooked LULC dynamics in urban centers, rather they have emphasized in rural areas. In addition, even studies that focused on LULC dynamics in urban centers in other areas (Moisa, Gemeda, 2021; Beckers et al., 2020; Assefa et al., 2021; Gashu, Gebregziabher, 2018; Verhoeve et al., 2015), they paid little or no attention to its implication on the development of UA. Urban farming activity needs to be expanded to meet the growing urban demand for

food, particularly in developing countries; however, there is a conflict between the maintenance of local agricultural production in these areas and the rapid and often uncontrolled consumption of land by growing urban activities and infrastructures (Aubry et al., 2012). Hence, spatial planning for farming practice particularly in peri-urban areas needs to receive attention from policymakers and land managers (Beckers et al., 2020; Aubry et al., 2012). Therefore, understanding of LULC dynamics and its implication for UA sustainable development in the urban centers is critical for development planning of UA practice. Thus, the objective of the study was to analyze dynamics of urban land use and its implication on suitability of UA in some selected major urban centers of Ethiopia.

Material and methods

The study sites

Four urban centers (Addis Ababa, Bahir Dar, Hawassa, and Adama) (Fig. 1a-d) were selected purposively based on the following reasons: (i) being the largest and the fastest-growing urban centers of Ethiopia and having the highest urban population in the last three population census periods of Ethiopia (Gashu, Gebregziabher, 2018; Tsegaye, 2010). According to Central Statistical Agency of Ethiopia (CSA) (2013) projection, the population number of the sampled urban centers is 5,227,794 in Addis Ababa, 324,000 in Adama, 300,000 in Hawassa, and 455,901 in Bahir Dar; (ii) UA is prominent in these urban centers than in other towns; (iii) they are the largest and main political, economic, and commercial centers at their respective regions (Amhara, Oromya, Sidama) and at the country level (Addis Ababa) than other urban centers; and (iv) they represent the administrative regions diversity. Addis Ababa is the capital city of the government of Federal Democratic Republic of Ethiopia and serves as social, economic, and political center for the country. It is also a seat for African Union, United Nations Economic Commission for Africa, and other international organizations. It is located at 8°50′00″–9°06′00″N and 38°39′00″–38°55′00″E with an average altitude of 2380 m a.s.l.

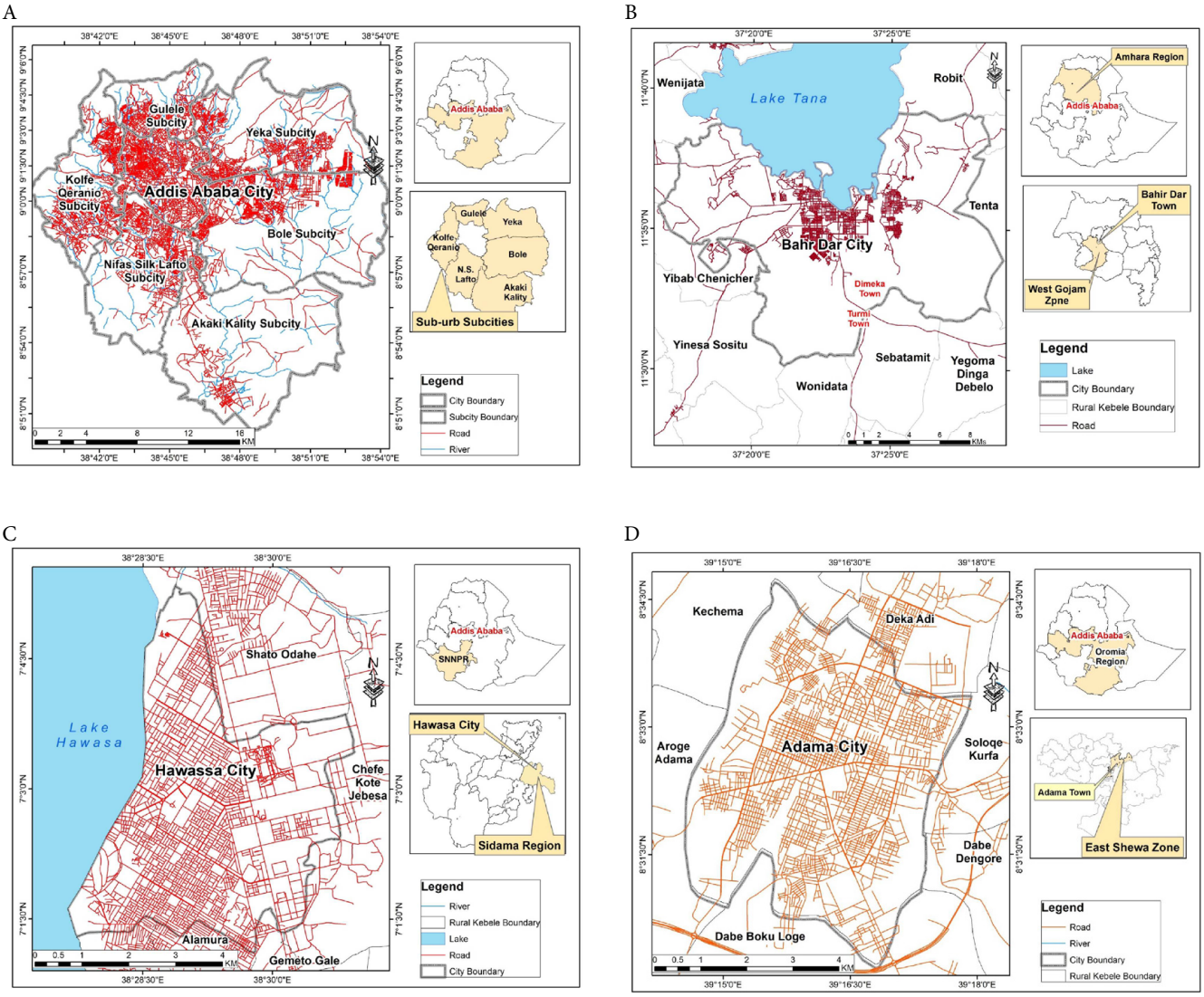


Fig. 1. Location map of study urban centers (A - Addis Ababa; B - Bahir Dar; C - Hawassa, D - Adama).

Table 1. LULC classes and their description.

LULC classes	Description
Urban built up	Areas with all types of artifcial surfaces, including residential, commercial, and industrial land uses as well as transportation infrastructure etc
Forest	Areas occupied by trees that formed nearly closed canopies and have thick under growth with an area of greater or equal to 0.5 ha
Shrub land	Land area covered by sparsely grown short thorny trees and bushes
Grassland	Areas covered with grasses and herbaceous vegetations
Bare land	Open space or area which have no or very little vegetation cover
Farm land	Areas used for farming
Rural Settlement	Areas occupied by rural settlement
Water body	Areas occupied by lakes, rivers, pond etc

Bahir Dar is the capital city of Amhara National Regional State. It is located at 11° 36′N and 37° 23′E and has an average elevation of 1801 m a.s.l. It is one of the fast-growing cities in Ethiopia and has a city administration with nine sub cities. In addition, the city is located at 565 km to northwest of Addis Ababa, on the southern shore of Lake Tana, the source of the Blue Nile (Abay) river. On the other hand, Hawassa is located at 07° 03′N and 30° 28′E with an average elevation of 1708 m a.s.l. It is one of the major urban areas of Ethiopia located within the lakes region of the Ethiopian rift valley. Similar to Bahir Dar, Hawassa has a city administration status and has eight sub cities. It is also a seat for Sidama Regional State.

Adama city is located in East Shoa Zone of Oromia National Regional State. The town is located about 100 km southeast of Addis Ababa, the capital of Ethiopia. Geographically, it is situated at 8° 33′ 35″– 8°36′46″N latitude and 39° 11′57″–39°21′15″E longitude. The town has an elevation that ranges from 1444 to 1974 m a.s.l. and an area of 134.1 km^2.

Data sources and analysis

The required geospatial information was gathered by the interpretation of remote sensing data that was supported by qualitative information (interview, Focus Group Discussion (FGD) and field observation). Five-meter resolution (SPOT 5) satellite imageries of the year 2006 and 2016, and Sentinel 2 image for the year 2022 were used to generate geospatial data. Satellite imageries were geo-referenced based on Universal Transverse Mercator (UTM) projection using 1:50,000 topographic map as a base map. Visual observation and supervised classification with maximum likelihood algorism were employed to classify land use on satellite images and generate discrete land use types. Training areas for each LULC classes were identified and taken by GPS receiver from urban agricultural lands (crop/plant cultivation land) in the field. Eight land-cover classes (Table 1) were considered based on National Aeronautics and Space Administration (NASA) and the US Geological Survey (USGS) (Gashu, Gebriegziabher, 2018), as well as the objective of the three time series (2006, 2016, 2022) maps were produced for each sample urban center. The main reasons for the selection of these specific years are the availability of the required satellite imageries (SPOT 5 and Sentinel 2) and the interval between these three years is sufficient to see the land-use dynamics. Satellite images resampling using nearest neighbor algorism was applied in order to have similar resolution between SPOT 5 and Sentinel 2 imageries. Change detection (transformation matrices for the periods 2006–2016 and 2016–2022 for each sample urban center were performed and the rate of change of LULC classes (%) was calculated using:

$$R\Delta\ (\%)=\frac{At2-At1}{At1}x100\ ,$$

where change of one type of LULC in present between initial time At1 and subsequent period At2.

To substantiate LULC dynamics analysis, Key Informant Interview (KII), FGD, and field observation were carried out to obtain additional information to triangulate image analysis and identify major drivers of LULC dynamics in urban centers. Ten community elders (60–81years old) who lived more than twenty years in their respective urban centers from ten sub cities of Addis Ababa and twelve from the regional cities (Hawasa, Bahr Dar, and Adama i.e. four from each of them) who were believed to have enough knowledge about the LULC change in their respective city were interviewed. In addition, four FGDs (one for each sampled urban center) having eight participants were conducted.

Results and discussion

LULC classifications and analysis of their dynamics

Satellite imageries analysis revealed LULC map for each study year (Figs 2–5), which depicts the distribution of the eight LULC classes in the sampled cities. As depicted in Tables 2 and 3, the dominant LULC type of Addis Ababa City in the year 2006 was the farm land (49.8%), but in the years 2016 and 2022 about 44.8 and 47.5% of the areas, respectively, occupied urban built-up area. In Adama City, although the farm land shows a decline trend throughout the study period, it was the prominent land-use type in 2006 (58.3%) and 2016 (47.5%); conversely, urban built-up area was dominant in 2022 (41.4%). Similarly, the farm land was major LULC type in the years 2006 (49%) and 2016 (44.8%) in Bahir Dar City, but in 2022 urban built-up area (36.9%) domination exceeded other LULC types. In Hawassa City, the farm land exceeds other LULC types in the year 2006 (30.1%), shrub land (28.6%), and urban built-up area (28.4%) dominated in 2016. However, in the year 2022, urban built-up area (37.1%) was the dominant of all LULC types in Hawassa City.

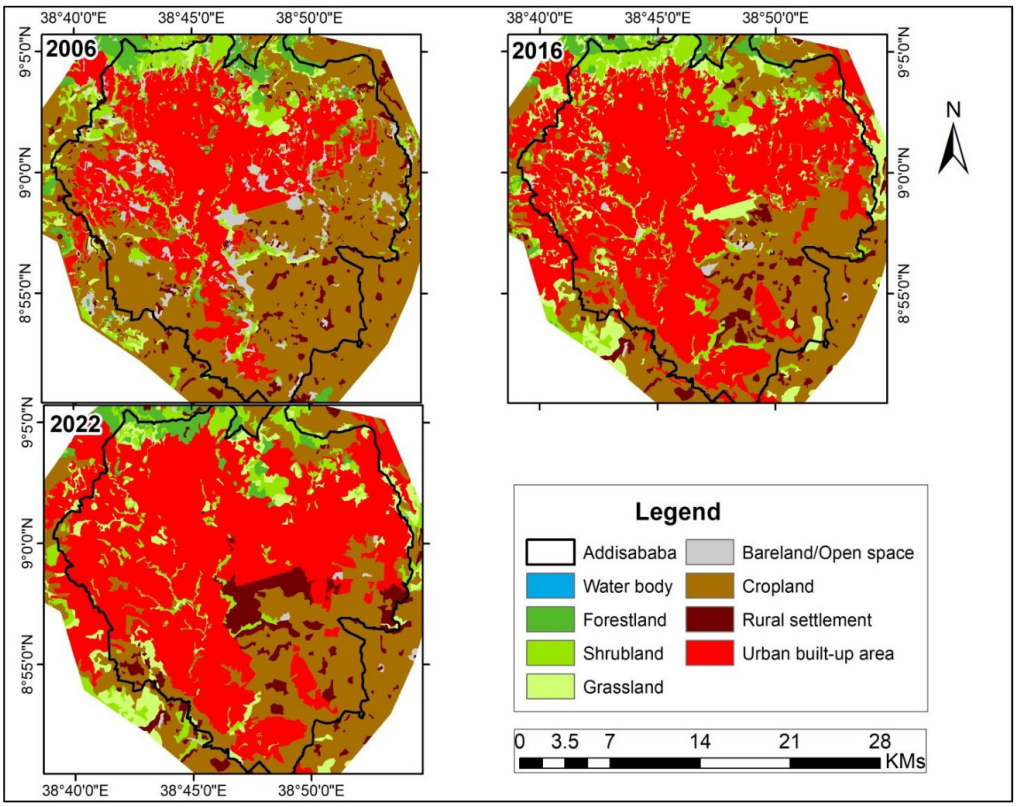


Fig. 2. LULC map of Addis Ababa city (2006–2022).

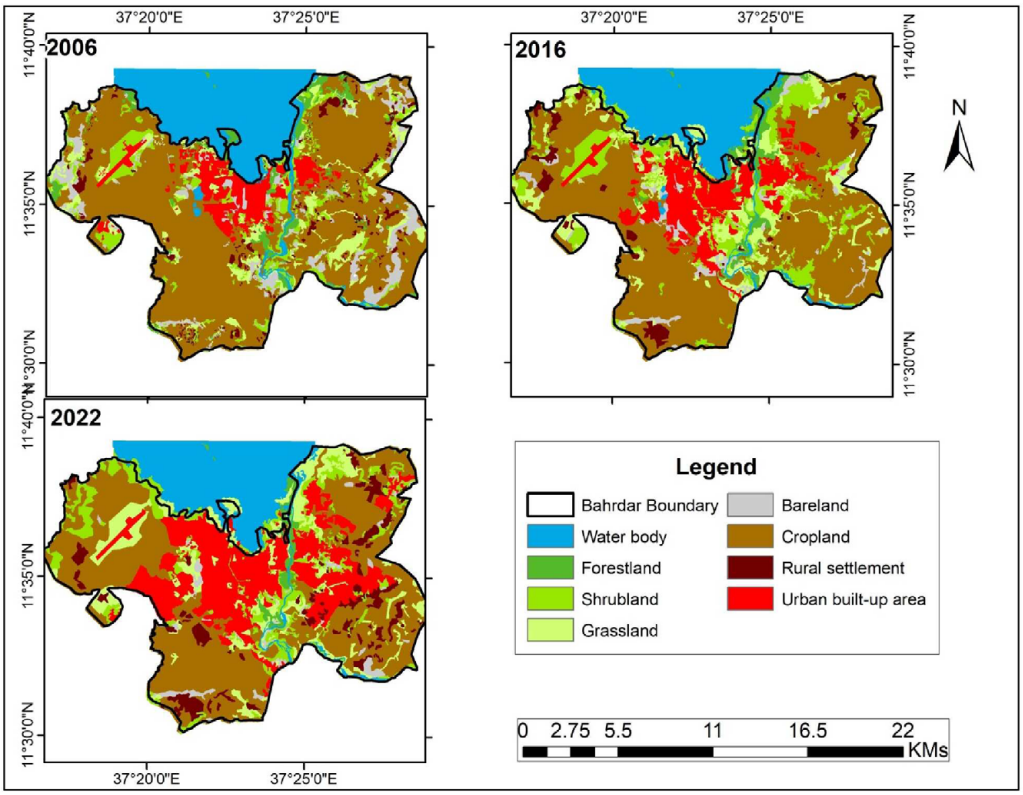


Fig. 3. LULC map of Bahir Dar city (2006–2022).

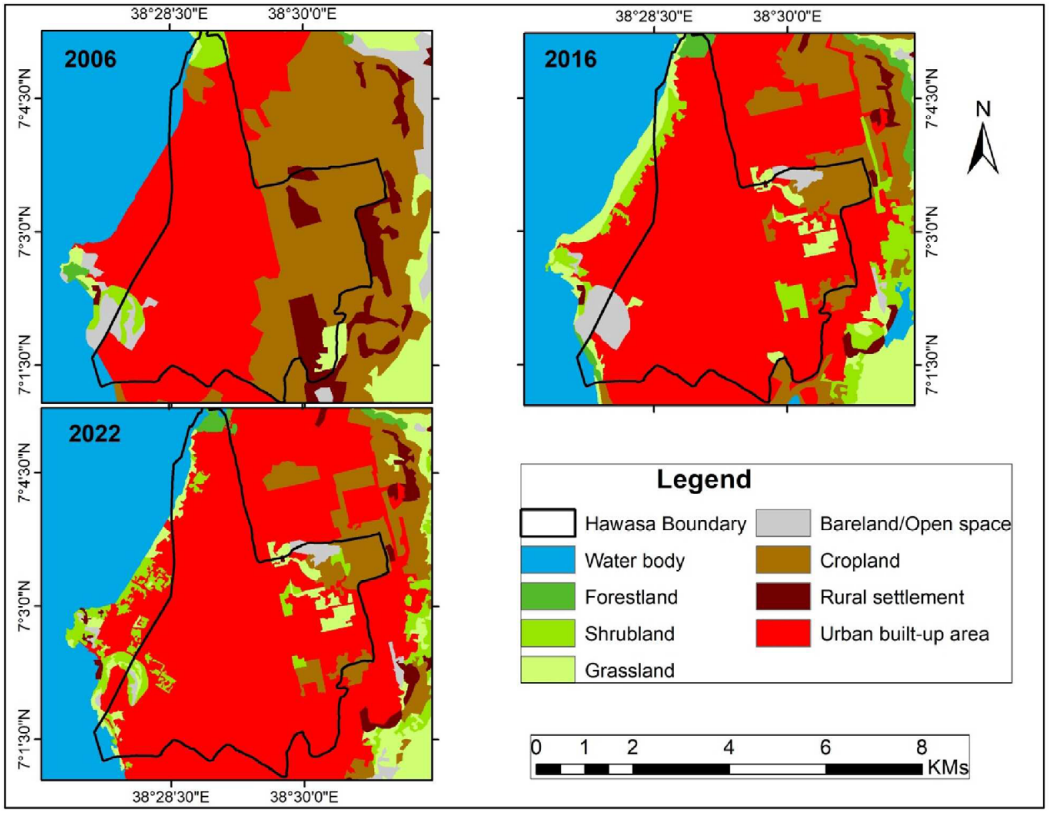


Fig. 4. LULC map of Hawassa city (2006–2022).

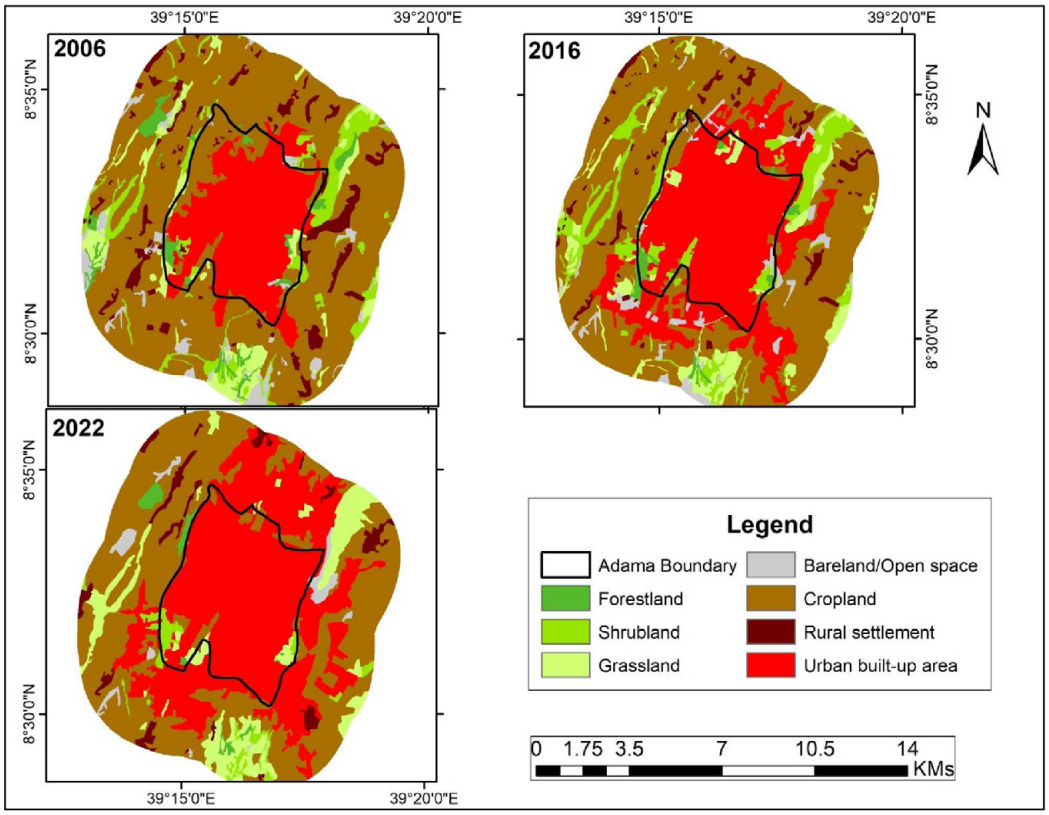


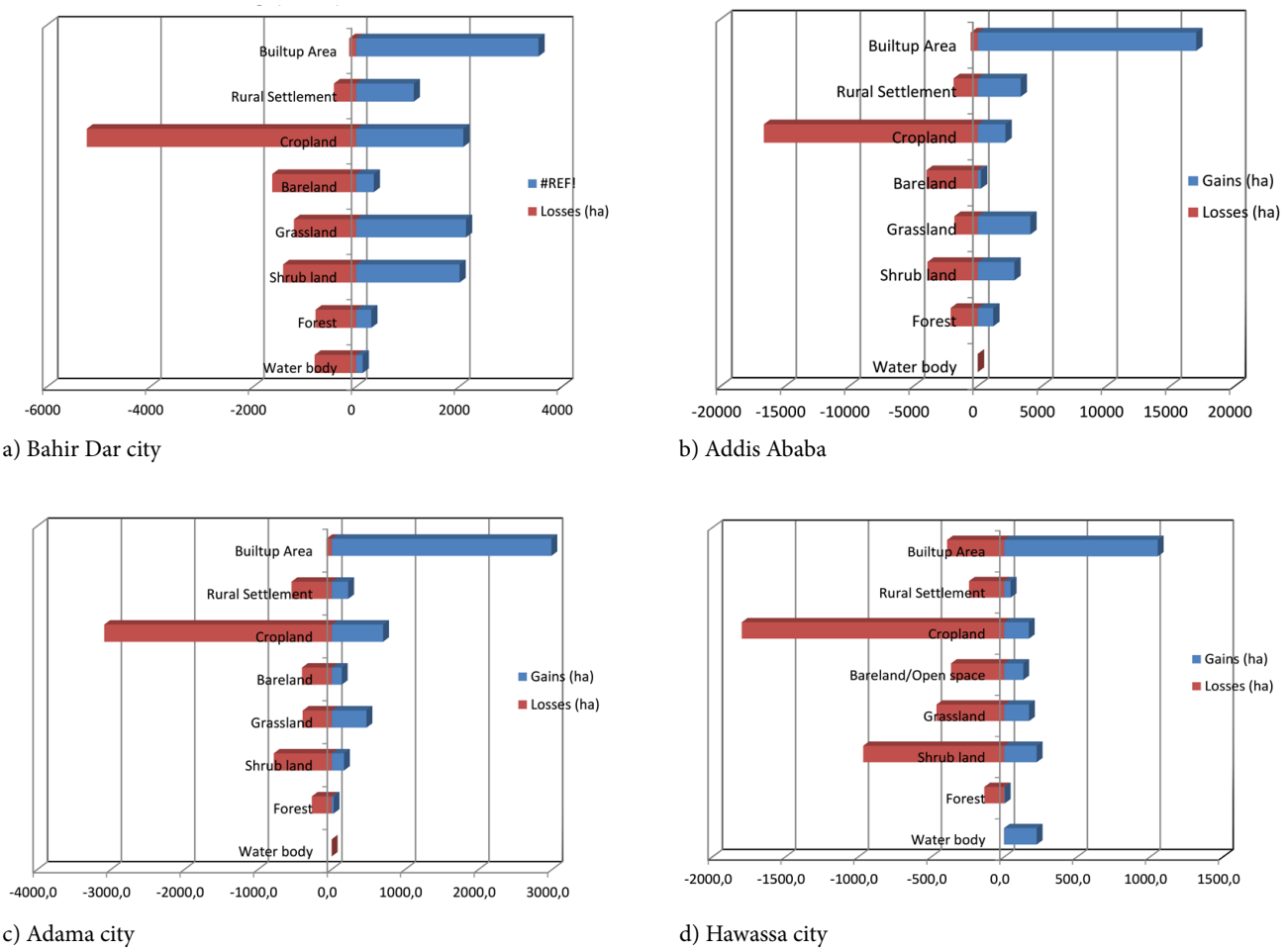
Fig. 5. LULC of maps of Adama city (2006–2022).

Table 2. LULC pattern and change in Addis Ababa and Adama cities.

LULC type	2006		2016		2022		LULC dynamics					
							2006--2016		2016—2022		2006--2022	
	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
Addis Ababa												
Water body	0.0	0.0	6.2	0.0	3.0	0.0	6.2	-	-3.2	-51.2	3.0	-
Forest	3285.5	4.3	2375.6	3.1	2381.1	3.1	-909.9	-27.7	5.5	0.2	-904.4	-27.5
Shrub land	6343.7	8.3	6165.8	8.1	5261.8	6.9	-177.9	-2.8	-904.0	-14.7	-1081.9	-17.1
Grassland	2255.6	3.0	6448.8	8.4	4538.0	6.0	4193.2	185.9	-1910.7	-29.6	2282.5	101.2
Bare land	4036.5	5.3	536.7	0.7	288.8	0.4	-3499.8	-86.7	-247.9	-46.2	-3747.7	-92.8
Farm land	37994	49.8	24148	31.6	23052	30.4	-13846	-36.4	-1096.2	-4.5	-14942	-39.3
Rural Settlement	2856.2	3.7	2477.0	3.2	4318.0	5.7	-379.2	-13.3	1840.9	74.3	1461.8	51.2
Urban built up	19584	25.6	34198	44.8	36049	47.5	14613.6	74.6	1851.0	5.4	16464.6	84.1
Total	76356	100	76356	100	75891	100	0	0.0	-464.5	-0.6	-464.5	-0.6
Adama city												
Water body	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	-	-	-
Forest	332.1	2.6	139.5	1.1	131.4	1.0	-192.6	-58.0	-8.1	-5.8	-200.8	-60.4
Shrub land	841.7	6.6	1051.2	8.1	278.8	2.3	209.5	24.9	-772.4	-73.5	-562.8	-66.9
Grassland	674.3	5.2	755.9	5.9	1124.8	8.7	81.7	12.1	368.9	48.8	450.6	66.8
Bare land	417.9	3.2	387.1	3.0	220.3	1.7	-30.8	-7.4	-166.8	-43.1	-197.6	-47.3
Farm land	7518.4	58.3	6123.9	47.5	5343.3	41.4	-1394.5	-18.5	-780.6	-12.7	-2175.1	-28.9
Rural Settlement	689.0	5.3	337.7	2.6	392.2	3.0	-351.3	-51.0	54.4	16.1	-296.9	-43.1
Urban built up	2422.2	18.8	4100.2	31.8	5404.6	41.9	1678.1	69.3	1304.4	31.8	2982.5	123.1
Total	12896	100	12896	100	12895	100	0	0.0	-0.2	0.0	-0.2	0.0

Table 3. LULC pattern and change in Bahir Dar and Hawassa cities.

LULC type	2006		2016		2022		LULC dynamics					
							2006--2016		2016--2022		2006--2022	
	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
Bahir Dar city												
Water body	4889.6	18.7	4267.2	16.4	4211.8	16.1	-622.4	-13	-55.4	-1.3	-677.7	-14
Forest	840.0	3.2	744.8	2.9	344.3	1.3	-95.2	-11.3	-400.5	-53.8	-495.7	-59.0
Shrub land	1855.6	7.1	2881.9	11.0	2448.0	9.4	1026.3	55.3	-433.8	-15.1	592.4	31.9
Grassland	1601.3	6.1	2413.0	9.2	2529.1	9.7	811.8	50.7	116.1	4.8	927.8	57.9
Bare land	1766.2	6.8	777.4	3.0	478.1	1.8	-988.8	-56.0	-299.3	-38.5	-1288.1	-72.9
Farm land	12787	49.0	11686	44.8	9642	36.9	-1101	-8.6	-2044.4	-17.5	-3145	-24.6
Rural Settlement	683.6	2.6	589.1	2.3	1370.9	5.3	-94.5	-13.8	781.8	132.7	687.3	100.5
Urban built up	1674	6.4	2737	10.5	5080	19.5	1063.8	63.6	2342.3	85.6	3406.1	203.5
Total	26097	100	26097	100	26103	100	0	0.0	7	0.0	7	0.0
Hawassa city												
Water body	3155.5	25.7	3024.9	24.6	3202.3	26.0	-130.7	-4.1	177.4	5.9	46.7	1.5
Forest	71.0	0.6	158.5	1.3	75.0	0.6	87.5	123.2	-83.6	-52.7	3.9	5.5
Shrub land	100.8	26.4	499.8	28.6	653.9	31.3	399.0	395.9	154.0	30.8	553.1	548.7
Grassland	1408.5	11.5	2124.6	17.3	1844.8	15.0	716.1	50.8	-279.8	-13.2	436.3	31.0
Bare land	1180.3	9.6	197.7	1.6	207.0	1.7	-982.6	-83.3	9.3	4.7	-973.3	-82.5
Farm land	3696.4	30.1	2538.5	20.6	1568.3	12.8	-1157.9	-31.3	-970.2	-38.2	-2128.1	-57.6
Rural Settlement	653.3	5.3	266.6	2.2	179.9	1.5	-386.7	-59.2	-86.7	-32.5	-473.4	-72.5
Urban built up	2033.0	16.5	3488.3	28.4	4567.9	37.1	1455.3	71.6	1079.6	31.0	2534.9	124.7
Total	12299	100	12299	100	12299	100	0	0.0	0.0	0.0	0.0	0.0



a) Bahir Dar city

b) Addis Ababa

c) Adama city

d) Hawassa city

Fig. 6. Gain and loss of LULC categories between 2006 and 2022 in the sampled urban centers.

LULC dynamics analysis revealed that in all selected urban centers, while urban built-up area has increased, farm and bare lands showed almost continuous reduction throughout the study period (2006—2022) (Tables 2, 3, and Figs 2–5) as a result of rapid horizontal urban expansion. There was significant expansion of urban built-up area in all selected urban centers for the last seventeen years (2006-2022). It increased by 84.1% (16464.6 ha) and 123.1% (2982.5 ha) in Addis Ababa and Adama, respectively. Similarly, it expanded by 203.5% (3406.1 ha) and 124.7% (2534.9 ha) in Bahir Dar and Hawassa urban centers, respectively. Conversely, farm land was reduced by 39.3% (14942 ha), 28.9% (2175.1ha), 24.6% (3145 ha), and 57.6% (2128.1 ha) in the respective aforementioned cities. Similarly, while bare land showed reduction in all sampled urban centers, forest and shrub lands had declined by 27.5% (904.4 ha) and 17.1% (1081.9 ha) in Addis Ababa, 60.4% (200.8 ha) and 66.9% (562.8 ha) in Adama and 14% (677.7 ha) and 59% (495.7 ha) in Bahir Dar cities. But, they showed increment in Hawassa city in the study period (2006-2022) (Tables 2, 3). This finding is disagree with the findings of Gondwe et al. (2021) which revealed agricultural land increment over this 20-year time frame (from 1999 to 2019) in Blantyre city of Malawi. But it coincides with other findings (e.g. Gashu, Gebregziabhere, 2018; Moisa, Gemeda, 2021), which revealed expansion of urban built-up area at the expense of other LULC types in Bahir Dar and Addis Ababa cities.

This implies that more emphasis was given for urban built-up, horizontal expansion at the expense of several LULC types, mainly farm and bare lands; however, UA, particularly horticulture development, was overlooked for the study period (2006-2022). As reported by key informant interviewees and FGD discussants, the LULC changes in the study area were attributed mainly to rapid urbanization and population growth. Another factor that contributed to the rapid expansion of built-up land was the lack of enforcement of the city's plans and regulations, which resulted in informal settlements. Such unplanned urban sprawls take over significant parts of the city that were not initially intended for residential purposes (Gondwe et al., 2021).

As shown in Fig. 6A-D, nearly 15,000 ha, 3000 ha, 2500 ha, and 3000 ha of urban built-up area have gained in Addis Ababa, Bahir Dar, Hawassa, and Adama cities, respectively, through 2006 to 2022 at the expense of mainly peri-urban horticultural lands. This finding coincides with the work of Abdella (2012) who revealed the expansion of residential areas in Khartoum, Sudan, significantly reduced arable land for food and feed production in and around the city. Similarly, Skalský et al. (2020) reported that there is decreasing of farm land at the expense of expansion of other land uses in northeast Slovakia.

A fundamental challenge to horticulture UA is the limited space available for food production. In most countries around

the world, on going urban expansion is causing a continuing trend of conversion of land from agricultural to non agricultural purposes, which threatens both urban and peri-urban agriculture (FAO, Rikolto and RUAF, 2022).

Implications of LULC dynamics on suitability of urban agriculture

Throughout the study period (2006–2022), urban built-up LULC category showed continuous trends of expansion mainly at the expense of farm land and bare land. This can have several implications such as in terms of loss of urban farm land and extensive conversion of bare/open land into urban built-up area by overlooking UA, which has significant contribution in enhancing food security, job opportunities, and urban greenery in turn moderating climate, particularly in urban centers, of developing countries like Ethiopia in which challenges that emanated from rapid urban population growth and urbanization are common. The key informant interviewees and FGD participants underlined that continuous conversion of substantial size land to urban built-up area by paying little or no attention to UA practice, endangered the sustainability of UA, particularly horticulture activity. They also stated that land efficient UA practice enhancement, technology support, etc. have not yet well developed. This, in turn, adversely affects food security and income generating opportunities of mainly middle- and lower-income urban dwellers. This implies that necessary interventions are needed to reverse current trends of LULC changes (e.g. reduction of urban agricultural land). For this, it is important to give emphasis to urban land-use strategies that scale up UA and expanding land-efficient UA technologies.

Key informant interviewees and FGD participants also reported that rapid urban population growth mainly because of high rural urban migration, expansion of squatter settlement, and increment of investment were the main driving forces of LULC dynamics (expansion of urban built-up area) in the selected urban centers.

Conclusion

The findings of this study provided important insights about Ethiopian urban centers LULC dynamics. Urban built-up area expanded rapidly at the expense of mainly peri-urban horticultural lands. This implies that the sustainability of UA, mainly horticulture practices is overlooked. Therefore, it is recommended that comprehensive and appropriate land use planning and strategies should be implemented so as to reduce rapid transformation of urban agricultural land to urban built-up area. In addition, cities administrators should prioritize UA as it has significant contribution for enhancing food security, job opportunity, income and ecological beautification of urban centers. Strategies that encourage UA incorporation and practice in various sectors that concern with food security, job creation mainly for unemployed youth, and environmental protection need to be developed and implemented at different level (kebele up to municipality level). Moreover, further studies on issues like how to develop UA practice in line with the fast horizontal expansion of urban built-up area should be emphasized.

Acknowledgements

The authors would like to thank respondents for their cooperation in the provision of the required information and Policy Studies Institution (PSI) of Ethiopia for providing financial support for this research.

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