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Chali Etefa Chali * , Dereje Teklemariam Dereje * , Endalew Addis Endalew *

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Spatial-Temporal Trend of Urban Sprawl with Land Use Land Cover Change in Central Ethiopia, Addis Ababa

Chali Etefa [1,*], Dereje Teklemariam [2] and Endalew Addis Ambelu [3]

[1] Ethiopian Civil Service University and Ethiopian Policy Studies Institute, Addis Ababa, Ethiopia; Email: yomes2018@gmail.com phone: +251920821021
[2] Ethiopian Civil Service University, Department of Public Management, Addis Ababa, Ethiopia; Email: dere44@yahoo.com phone: +251912736838
[3] Ethiopian Civil Service University, Department of Public Management, Addis Ababa, Ethiopia; Email: endalew24@gmail.com phone: +251911656458
* Crosspondence: Email: yomes2018@gmail.com

Abstract: Urban land expansion is one of the most obvious, swift, and a permanent type of land cover/use changes in recent human history and is a major force behind numerous environmental and socioeconomic changes on a variety of scales. This study was aim to assess the spatial-temporal trends of urban expansion with land use/land cover change dynamics over a period of 30 years in Addis Ababa. The source of data were Land sat satellite imagery freely available by the United States Geological Survey, Addis Ababa City plan map obtained from Addis Ababa city governance planning and development commission, and Ethiopia Space Science and Geospatial Agency. The data obtained were analysed by using QGIS, and ERDAS software. The finding showed that over the last thirty years Addis Ababa city was highly spreads with (Urban Expansion Intensity Index(UEII)=1.524%); building-up land increased faster (dynamic degree (K) = -6.22 and Annual Urban Expansion Rate(AUER) is 3.56. From the finding, Addis Ababa is spreading speedily. This will have impacts on ecosystem services and agricultural dependent peri-urban farmers' livelihood. It has also undesirable implication for climatic change, and livelihood assets. It suggests understanding the issue will help to develop governance strategies and policy decisions to achieve sustainable development agenda.

Keywords: spatial-temporal; urban expansion/sprawl; sustainable development; peri-urban; land use/land cover change; policy

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4. Introduction

Since 1892, Addis Ababa has been the capital city of Ethiopia. From the time of its foundation as a military town and establishment as a political-economy center, Addis Ababa has been encroaching on fertile agricultural land coercively and "by will," resulting in the emigration of a number of farmers (Pankhurst, 1961). Originally, the Oromo people occupying the land where Addis Abba was established called it "*Finfinne*", from the healing mineral spring of hot water.

People used to come and bathe in the hot mineral springs to get relief for their health problem. As Pankhurst mentioned in the same literature, among those visitors, the grandfather of Menelik II, Sahle Sellassie of *Ankober*, was one of them. From that time onward (c. 1843), the king of *Shoa* conceived the idea of establishing his capital at *Finfinne*, attracted by the beauty of its natural landscape, convenient climate conditions, and natural gifts. Menelik II, in order to realize the conceived ambition of his grandfather, had camped somewhere in the area of Mount *Wachacha*. A few years later (C. 1881), Menelik shifted his camp around Entoto due to exposure to the attack from "*Galla,"* according to Gustavo Bianchi and Dr. Linclon D. Castro, and therepon, *Entoto* was established as a traditional Ethiopian army camp, or essentially a military town.

The city established was unsatisfactory since it was situated on a mountain ranging some 2800 meters high, poorly supplied with wood and water, very cold and windy, and exhaustive to climb. The inconvenience of Entoto necessitated the move southward to lower, fertile, and warm land. At

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the founding of the city, Ras Makonnen, father of Emperor Haile Selassie, had occupied the southernmost quarter, which was somewhat less exposed than the rest. The empress, Taitu, was further interested in hot springs or *Finfinne* water, the so-called *Hora Finfinne* by the endogenous people.

According to the chronicles, Sahle Sillassie's prophecy statement was "O land, today you are full of "gallas", but the day will come when my grandson will build a house here and make you a city". As it was mentioned in some literature, the beginning of Taitu's building house around the top views of the "*Hora Finfine*" was considered fulfilling "the will of God" to realize the prophecy of Sahle Sillassie. At the first step in the 1860s, the king confiscated the land from the Oromo pastoralists. The Oromo people, against the confiscation, distributed the land among themselves for farming and pastoralists. To stop the revolt, Menelik II took aggressive measures and permanently controlled it (Tufa, 2008). Several literature and oral accounts indicate the origin of Addis Ababa was not as early as 1877. Some authors also elaborated that the name Addis Ababa, or new flower, was the new name given by Taitu after observing the flowers of mimosa trees growing in the area. There were also those who saw Addis Ababa as a modernization in the model of a European city (Centers et al., 1990). From that time on, Addis Ababa developed into an urban center in the Horn of Africa.

Urbanization is a complex socio-economic process that transforms the environment, converting formerly rural settlements into urban settlements while also shifting the spatial distribution of a population from rural to urban areas (UN, 2018). The conversion of a former rural area into an urban settlement impacts the environment and peri-urban farmers' livelihoods. Its environmental impacts on climate change, runoff water, and flooding, including urban Iceland heat, were becoming global challenges (Wübbelmann et al., 2023). Furthermore, the loss of agricultural land causes food security problem, landlessness, emigration, and the loss of jobs (Szabo, 2016).

Urbanization is the process of land use changes (Mahtta et al., 2022). In order to prevent unpleasant futures, land management policies and policy decisions can be developed with an understanding of how urbanization affects land use changes throughout time. Furthermore, it could be useful to discuss the reasons and mechanisms how urbanization causes the loss of agricultural land and affect the expansion of forests, as well as the functioning of ecosystems, all of which have an effect on ecosystem services as a whole. But, there is little understanding about urban expansion and its dynamics in different urban context.

The United Nations report indicated that around the Globe, more people are living in urban areas than in the rural area (UN, 2018) which is similar to the idea of Danan Gu "the world is urbanizing" (Gu, 2019, p:1). Urbanization of formerly rural areas and transformation of the lives of those living in the areas around the cities is inevitable (Mahtta et al., 2022; UN Department of Economic and Social Affairs, 2018). Driven by a combination of several factors, the number and size of urban will continue to grow (Mahtta et al., 2022). Various empirical studies show that in the trends of urban expansion, population growth and economic growth is urban dependent (Mahtta et al., 2022; Rudel, 2021; Alawamy et al., 2020;). For instance, Cities with higher Urban Land Expansion growth rates than economic growth are concentrated in Africa (Mahtta et al., 2022). Owing to several pulling factors and natural processes, the urban population has been growing rapidly.

The United Nations World Urbanization prospects report revealed that "in 1950, 30 per cent of the world's population was urban, and by 2050, 68 per cent of the world's population is projected to be urban"(United Nations, 2018 p:19). Urbanization and the pressure of population projection are two main challenges to urban planning and management, especially for cities in developing countries (Wakode et al., 2014).

Resources are scarce to improve the quality of human lives and eliminate poverty. In contrast, the population has been increasing each year (World Commission on Environment and Development, 2000). The World commission on environment and Development report mention that "…poverty itself pollutes the environment. The poor and hungry destroy their environment despite population growth poses pressure on the environment" (World Commission on Environment and Development, 2000 p: 40). They overuse peripheral land and are growing congested into cities. In addition, the economic growth achieved by ignoring the unanticipated or unintended consequences of the extensive use of raw materials and the creation of pollution are ecologically challenging. On the other hand, the authorities are stressed to provide residents with basic amenities such as housing/building up land, transportation, roads, electricity, and clean water. Such stress on land use or other natural resources can be noticed in many cities in developing countries and newly industrialized developing (Wakode et al., 2014).

Urbanization in the 21st century is the major cause of land use change in most parts of the world and escalates at a high rate (Briassoulis, 2019). The conversion of a given land cover to urban uses is an important type of land-use change because of its serious socio-economic and ecological implications (Alawamy et al., 2020). Literature has reported the existence of a linkage between urban expansion, ecosystem services, and climatic change (Mahtta et al., 2022).

Efficient or high-quality urban development calls for the protection, restoration, and incorporation of ecosystem services in urban planning and management (Wang et al., 2022). Most importantly, urban residents' quality of life depends on locally generated ecosystem services (Wagstaff & Wortman, 2015), and the production of ecosystem services in urban areas promotes residents' well-being or quality of life in several ways (Hall et al., 2021; Brauman & Daily, 2008 Dłużewska, 2016;); ecosystem services also contribute to the inhalation of clean air and the enjoyment of aesthetic environment (Tuhkanen et al., 2022).

In contrast, uncontrolled and rapid spread of urbanization distresses natural climatic conditions and phenomena, such as urban Iceland heat, flooding, pollution, habitat loss, water body degradation, deforestation, and food scarcity, which are mostly brought on by urbanization's challenges to ecosystems (Hailu et al., 2020; Manzoor et al., 2019). Because of the uncontrolled spread of urban development in potential ecosystem service areas, the aesthetic, recreational, and health beneficiary ecosystem sites were altered (Yang et al., 2021).

Urban expansion causes a shift in demographic, economic, and social conditions (Vasenev et al., 2020), and urban life is exposed to pollution, climate change, and traffic congestion. In addition, the relationship between social and ecological systems is disrupted by both ecosystem degradation and urbanization, resulting in unpleasant urban living (Lapointe et al., 2021).

In addition to creating environmental stress, rapid urbanization swallows productive agricultural land. The availability of food is threatened by urbanization owing to shifting consumption patterns and approaches to food production and supply. Despite the agricultural area being transformed into built-up space, there will still be more food accessible for urban residents (Szabo, 2016). However, despite the fact that the issue of rapid urbanization is a topic of scholarly investigation on a global scale, little attention has been paid to how urban growth impacts countries' food security and whether this link is affected by a country's degree of development.

From our day to day observation, productive agricultural land is vulnerable to urban development, which has led to a paradox in which food producers are food consumers. However, the investigation of urban resilience, adaptation, vulnerability context, and livelihood strategies of peri-urban region populations' agricultural livelihoods has received little attention. One study showed that rapid urbanization resulted in large net buyers of food that invite volatile food prices (Szabo, 2016). The other side of the negative impact of urbanization is agricultural labor. The rural productive force of agriculture migrated to urban areas for a better life or to search for job opportunities.

Ethiopia has undergone tremendous urbanization, which has significantly altered the landscape of the city (Ermias et al., 2020). A shift in the previous pattern of land use or land cover has resulted in urban expansion or outskirt growth. The transformation of undeveloped land into built-up space is not uniform in all directions. Even during the same period, it is dynamically active in some parts of the city, while it is less dynamic in other parts of the city. It has been observed that ecological sites such as agricultural land, trees, and water bodies around the city have become victims of urban encroachment during urban expansion. Studies in Ethiopia have indicated that urbanization negatively affects peri-urban farmers' means of subsistence by reducing the natural resources at their disposal (Mohammed et al., 2017).

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The purpose of this study is to examine horizontal outskirt urban development impacts on land cover change with in a period of 30 years trend. A few researchers have attempted to describe and analyse about horizontal expansion of Addis Ababa, and its related factors in different context and methods (Leulsegged et al., 2012; Tegenu, 2010). It is believed that an understanding of urban expansion dynamics would help in enhancing inclusive and sustainable approaches to planning, policymaking, and governance.

Currently, almost all of Ethiopia is moving towards becoming more urbanized, so it is important to learn about urban growth trends and how they affect ecosystem services and the way of life in peri-urban areas. To prevent or limit unsustainable urban development, it is essential to understand the trends of urban development along surrounding boundaries. It is also helpful to monitor and regulate the impact of urban expansion on neighbourhoods.

The rationales behind examining the spatiotemporal trends of urban expansion in the study area are: first, the area is interesting and innovative; second, the importance of understanding the extent of expansion to enhance effective land resource management and reduce the multi-dimensional impacts of urban expansion; third, it may contribute to scientific knowledge; and fourth, it may re-visit institutional and policy orientation towards urban governance. Fifth, it may help as a foundation to raise several topics and issues that may serve as research gaps. Lastly, it may serve as input in the planning process, policy formulation, land management, wise use of resources, and ecosystem service governance.

The study specifically focuses on examining spatiotemporal trends of urban expansion with land use and land cover change dynamics over a period of 30 years: 1993–2003, 2003–2013, and 2013–2023. In the investigation, the magnitude of expansion and its extents has been examined and explained across global trends.

As a result, policymakers, planners, and urban governance actors may understand the scope and rate of expansion and its impacts on peri-urban arable productive agricultural land and the ecological environment. So it may initiate the governance strategies, decision-making and future sustainability agenda at all levels.

4.1. Methods and Materials

Earth observation satellite technology is enabling researchers to analyse changes and phenomena on the Earth surface by obtaining data from remote-sense satellite technology. Currently, remote sensing methods, including object-based segmentation and classification integrated with geographic information systems (GIS) and spatial metric techniques, enable the analysis and quantification of spatial-temporal patterns and dynamics of land use changes and urban expansion (Hamel et al., 2021; Wakode et al., 2014). Similarly, in this study, the satellite images of four decades, namely 1993, 2003, 2013, and 2023, were considered. The rationale for selecting these years was the availability of free data and the period of a new regime governing the country.

A series of Landsat imagery was used, and the sensors were Thematic Mapper (TM) Enhanced Thematic Mapper Plus (ETM+), Operational Land Image, and Thermal Inferred Sensor (OLI-TIRS) for Landsat 5, Landsat 7, and Landsat 8, respectively. The data source was Landsat imagery downloaded from https://earthexplorer.usgs.gov/ with a spatial resolution of 30m; path and row 168/054 were extracted on the dates 13/03/1993, 12/01/2003, 01/12/2013, and 19/01/2023, depending on the cloud-free season. In order to make False Colour Composite (FCC), out of the available bands: for Landsat 5 and Landsat 7, band 432; and for Landsat 8, band 543.

The TM consists of seven spectral bands, with six of them having a 30m resolution and band 6 thermal with a 120m resolution; the ETM+ consists of eight spectral bands, with six of them having a 30m resolution, except band 6 thermal and band 8 panchromatic with a 60m resolution and 15m resolution. OLI_TIRS consists of eleven spectral bands, of which bands 8, 10, and 11 have 15m, 100 m, and 100m resolutions, respectively, and the rest have 30m resolutions.

Apart from the satellite data, the structural map of Addis Ababa City was obtained from the Addis Ababa City governance planning and development commission and the Ethiopian Space Science and Geospatial Institute. It was scanned and cross-checked with the satellite imagery. Since

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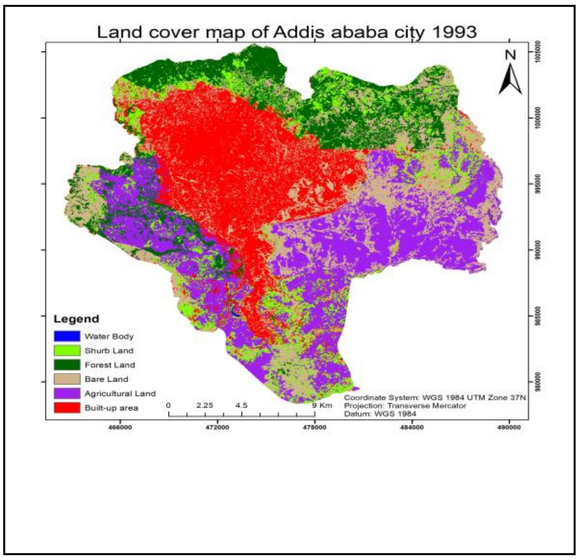
the collection of ground-truth coordinate data was expensive, an optionally classification-referenced dataset of overlying data on Google Earth and spatial metrics were carried out. Accordingly, six land-use classes were identified: built-up area, agricultural/farmlands, bare/open-space lands, forest lands, shrub lands, and water bodies. The identified classes were re-classified into built-up (buildings and physical structures) and non-built-up (agricultural/farmland, bare/open space lands, forest lands, shrub/bush, grasslands, and water bodies) classes. Geographic Information System tools such as Quantum GIS (QGIS) and Earth Resource Data Analysis System (ERDAS Imagine) were used to run supervised classification and further analysis.

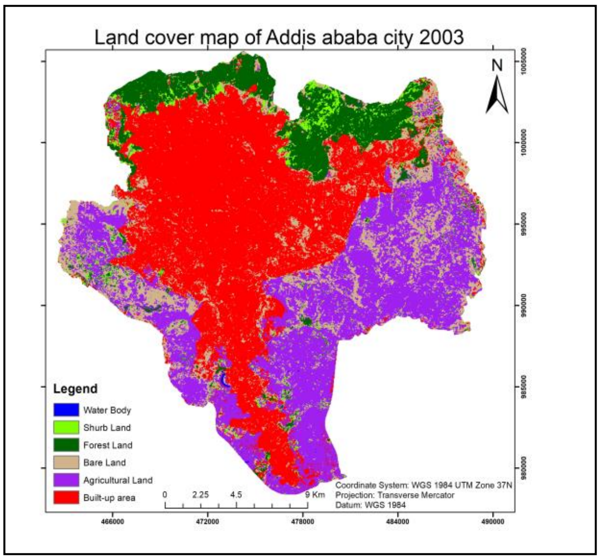
4.2. Results and Discussion

4.2.1. Results

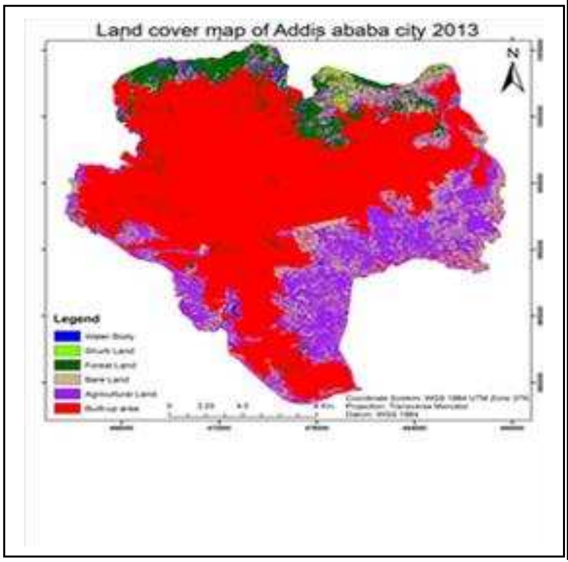
4.2.1.1. Classified Land use land cover change (LULCC) 1993, 2003, 2013, and 2023

A) 1993 B) 2003





A) 2013 B) 2023



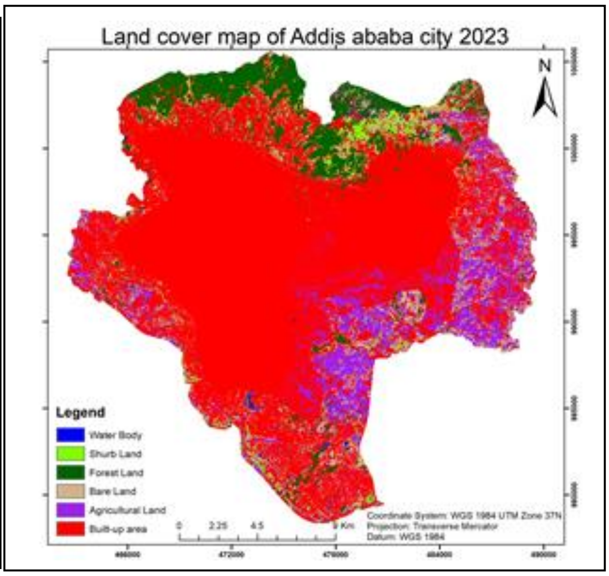


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Figure 3.4. Classified Land use land cover change (LULCC) 1993, 2003, 2013, and 2023: Source: Earthexplorer.USGS.gov and Addis Ababa city governance, planning and urban development commission, 2023

4.2.1.2. Accuracy Assessment

To ensure the accuracy of the land use and land cover (LULC) classification, an assessment was conducted using a confusion matrix. This assessment involved calculating the overall accuracy and Kappa statistics. Ground control points were collected for each LULC class through the use of the Global Positioning System and Google Earth (Mishra et al., 2020). The overall accuracy was determined by dividing the number of pixels correctly classified by the total number of pixels in the matrix.

The Kappa coefficient, on the other hand, is a measure of agreement between two maps, taking into account all elements of the confusion matrix. These assessments are essential in ensuring the accuracy of the LULC classification. The results of the classification methods or training sites, such as built-up, agricultural, forest, bare, and water bodies, were compared with the referenced datasets. Accordingly, the following accuracy assessment formula was applied to calculate the results:

$$User\ Accuracy = \frac{Numbrof\ correctly\ classified\ pixles\ in\ each\ category}{Total\ number\ of\ classified\ pixles\ in\ that\ category(the\ row\ total)} * 100$$

$$Producer\ Accuracy = \frac{Numbrof\ correctly\ classified\ pixles\ in\ each\ category}{Total\ number\ of\ reference\ pixles\ in\ that\ category(the\ column\ total)} * 100$$

$$Over\boldsymbol{all}\ Accuracy = \frac{Numbrof\ correctly\ classified\ pixles\ in\ each\ category(diagonal)}{Total\ number\ of\ referenced\ pixles} * 100 \text{ Or}$$

$$kappa\ cofficient(T) = \frac{(TS*TCS)-\sum(Column\ Total*Row\ Total\ )}{TS2-\sum(Column\ Total-Row\ Total)} * 100$$

Or Kappa coefficient (Khat) can also be also calculated by $Khat = \frac{Obs-Exp}{1-Exp}$

To ensure the accuracy of the data, ground truth (coordinate) confirmation by GPS or referenced data, kappa coefficient, and the same season can be considered to obtain a better resolution. For this study, five bands of land use and land cover classification were considered: built-up (residential, commercial, industrial and amenities), agricultural land (cropland and pastures), barren land (open lands), and forest (vegetation) land (deciduous, evergreen, and mixed forest land), and shrub land (herbaceous, mixed range land), and water bodies (river and wetland).

Before undergoing the supervised classification [hard classification method], at least 20 points were identified regarding the class to improve the accuracy assessment between the classified area and training site. A satellite image analysis method was used to show the existing changes with an interval of 10 years using the Hectare and Percentage algorithm. In 2019, John E.K. Abubia and Antje Bruns cited Atman (1991), who stated that indices between 0 and 1 were used for interpreting the kappa statistic results.

A Kappa value of 0.20 indicates a poor agreement, values within the bracket of 0.21–0.40 represent fair agreement, and values within the range of 0.41–0.60 connote moderate agreement, whilst values ranging from 0.61–0.80 and 0.81–1.00 suggest good and very good agreement, respectively (Akubia & Bruns, 2019:p8). According to this guideline, the accuracy assessment

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measure indicated that there was very good agreement between the user and producer accuracies for both years

Table 8.4. Accuracy assessment.

	1993		2003		2013		2023	
	producer	user	producer	user	producer	user	producer	user
Built-up area	100	100	100	100	100	100	100	100
Agricultural Land	100	95.24	96.67	100	98	98	90	96.43
Bare Land	100	95.24	100	100	98	96.08	96.67	90.63
Forest Land	95	100	90	100	95	97.44	100	96.77
Shrub Land	95	100	100	100	88.89	88.89	90	100
Water Body	100	100	100	100	100	100	100	100

Source: extracted and calculated based on 1993, 2003, 2013 and 2023 classified imagery, 2023.

The dynamic degree of land-use types to indicate or show the quantitative variation of the land-use category at a certain time was calculated using the following formula **k(%)=((Za-Zb))/Za*(1/T)*100** (Wakode et al., 2014).

Where k represents the dynamic degree of land use category, Za represents the area of the land use category before the change, Zb represents the area of the land use category after the change, T represents the time interval. The area of the land use category *increases if k value is negative and decreases if k value is positive.*

Table 9.4. Total area covered by land use classes from 1993 up to 2023(in hectare).

Total area covered by land use classes from 1993 to 2023						
Land use classes	Area covered in 1993(ha)	Area covered in 2003(ha)	Area covered in 2013(ha)	Area covered in 2023(ha)	Change of area 1993 to 2023 (ha)	Dynamic degree (*K*) (%)
Built-up area	10516.8 (24.25%)	17769.36 (40.97%)	26108.84 (60.20%)	30344.6 (69.97%)	-19827.8	-6.22
Agricultural/farmlands	11356.37 (26.19%)	12855.29 (29.64%)	9190.08 (21.19%)	4343.85 (10.02%)	7012.52	2.04
Bare Land	10303.8 (23.76%)	6603.93 (15.23%)	4129.47 (9.52%)	3913.71 (9.02%)	6390.09	2.05
Forest Land	6155.64 (14.19%)	4626.54 (10.67%)	2844.27 (6.56%)	3750.21 (8.65%)	2405.43	1.29
Shrub Land	5025.96 (11.59)	1479.06 (3.41%)	975.48 (2.25%)	812.34 (1.87%)	4213.62	2.77
Water Bodies	10.26	34.65	120.69	204.12	-193.86	-62.35

	(0.02%)	(0.08%)	(0.8%)	(0.47%)		
Total	43368.83 (100)	43368.83 (100)	43368.83 (100)	43368.83 (100)	0.00	0

Source: Extracted and calculated based on 1993, 2003, 2013 and 2023 classified imagery, 2023.

The change detection statistics of Addis Ababa city expansion shows the nature of the conversion of each land class into another class, from the initial state class (1993) to the final state class (2023). Out of the 11356.37ha (26.19%) that was agricultural land, 10303.8ha (23.76%) bare land, 6155.64ha (14.19%) forest land, 5025.96ha (11.59%) shrub land in 1993, 7012.52 ha of agricultural land, 6390.09 ha of bare land, 2405.43 ha of forest land, 4213.62 ha of shrub land were converted into built-up areas respectively.

The water body increased by 193.86 ha in 2023 from that of 10.26 ha of 1993, for most probably the expansion of the city to the river available area, for instance, the Akaki River and the regeneration of water bodies by the Shegar beautification project.

Generally, urban land size grew from 10516.8 ha to 30344.6 ha at an average rate of 34.66 % per year and therefore added about 19827.8ha new urban land-use.

4.2.1.3. Spatial Development of the Addis Ababa city area

The conversion of each land use class from 1993 to 2023 can be observed in the map below. From the map, the growth of Addis Ababa to the Northern direction, in comparison with the other directions, is restricted due to topography. Because of the chain of Entoto Mountain, the green forest, from visual observation composed of eucalyptus trees, is reserved as observed from the map.

Table 10.4. Direction (Zones) of spread area in Km2.

Year	Direction(Zones) of spread area in Km^2								Column Total
	NNE	NEE	NNW	NWW	SSE	SEE	SSW	SWW	
1993	3.30425	4.48334	6.28361	9.9134	36.3873	17.6862	19.781	8.64399	106.4831
2003	8.67688	14.8934	8.4999	12.5094	57.5989	28.5795	33.8824	13.3172	177.9576
2013	8.70886	22.0379	9.40852	14.9219	75.3949	56.1139	47.0386	27.5519	261.1765
2023	8.92817	22.8639	9.98401	15.2985	91.8776	71.1013	57.3108	28.3648	305.7291
Row Total	29.61816	64.27854	34.17604	52.6432	261.2587	173.4809	158.0128	77.87789	851.3462

Source: Extracted and measured based on 1993, 2003, 2013 and 2023 imagery, 2023.

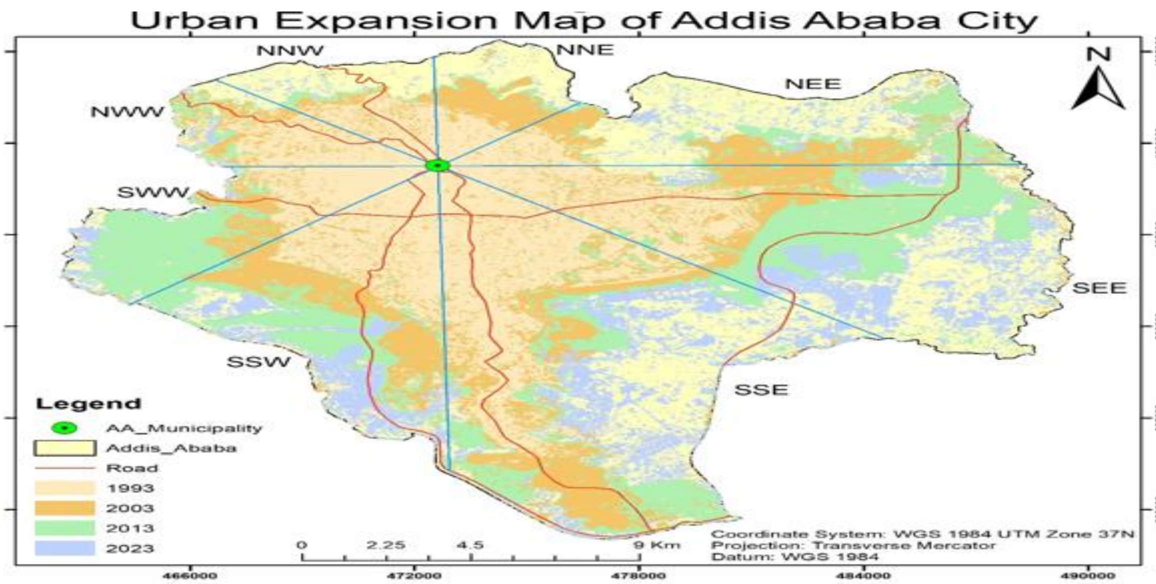
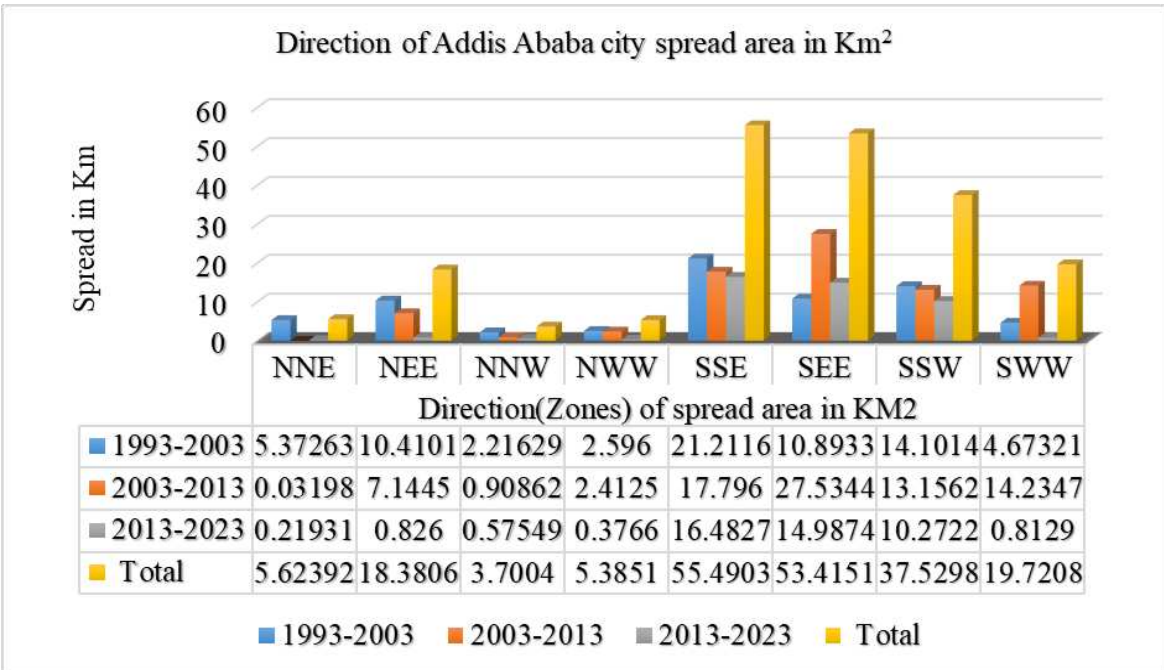


Figure 8.4. Urban expansion map of Addis Ababa from reference point municipality. ***Source:*** Addis Ababa city governance, planning and urban development commission, 2023

The structural map of Addis Abba illustrates the spread of the city taking the root of the road. The Northern direction shows the restriction of the city development as a result of topography. Studies also shows topography constrain the direction of urban expansion (Sun et al., 2020). Historically Addis Ababa was established as the military town on the top of Entoto Mountain that chain into Menagesha. But later on, it was shifted to the downward south west, fertile land for resources (Tufa, 2008).

Several literatures also validate the topographic and resource factor as determinant for directing urban expansion (Rana & Sarkar, 2021). This implies topography and resource availability plays a significant role in shaping urban expansion. On the other hand, urban expansion can take place following the route path of the road from the center of the city(M.A. Siro, 2017). This has several implication for planning the road and consideration of the consequence of settlement along the road path.



	NNE	NEE	NNW	NWW	SSE	SEE	SSW	SWW
1993-2003	5.37263	10.4101	2.21629	2.596	21.2116	10.8933	14.1014	4.67321
2003-2013	0.03198	7.1445	0.90862	2.4125	17.796	27.5344	13.1562	14.2347
2013-2023	0.21931	0.826	0.57549	0.3766	16.4827	14.9874	10.2722	0.8129
Total	5.62392	18.3806	3.7004	5.3851	55.4903	53.4151	37.5298	19.7208

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Chart 1.4: Graphical illustration of direction (zones) of spread

From the directional point of observation or zonal classification analysis, Addis Ababa spread in the South-South East (55.4903), South East (53.4151), South-South West (37.5298), South West-West (19.7208), and North East-East (18.3806) in the kilometer squire (Km²) respectively**.** It is much less spread to the North-North West (3.7004Km²) because of the topographic constraint.

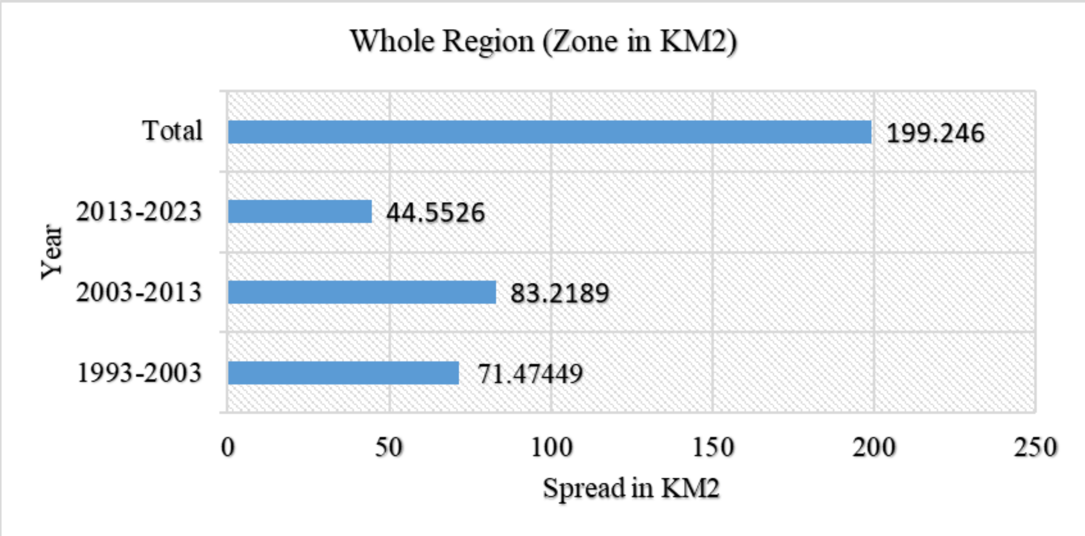

Chart 2.4: Whole region (Zone in Km2)

The overall spread of Addis Ababa City in the whole direction was highest from the year 2003-2013 and lowest from to 2013-2023. The possible reasons for this might be the full-scale implementation of lease, condominiums, and housing policies. In contrast to the opposition to the Addis Ababa integrated master plan, the following movements might be the reason for the lower spread of Addis Ababa from to 2013-2023.

Horizontal expansion of Addis Ababa, by displacing indigenous people was part of the building state. It was characterized by unchecked expansion and land grabbing the lands throughout the past regime involving multilayers actors. Land lease have been the mechanism of communization of agricultural land, grazing area, cultural and open scattered places.

The political economy behind unchecked expansion of Addis Ababa/Finfinne was activated the power of resistance in 2014 following government announcement of its readiness to implement Addis Ababa Integrated Regional Development (also called master plan) (Regassa, 2016). The politics of unchecked expansion of Addis Ababa/Finfinne rooted in dispassion Oromo's land use rights, and eviction from the land as some scholars argued (Debelo & Soboka, 2023)

4.2.1.4. Reclassification of land use change

In this study, images from the previous 30 years were further divided into two unique land use classes—"built-up" and "non-built-up"—with the aim of assessing the rate and patterns of urban sprawl in the form of expansion.

Reclassification into Non-built Versus Built-up Area

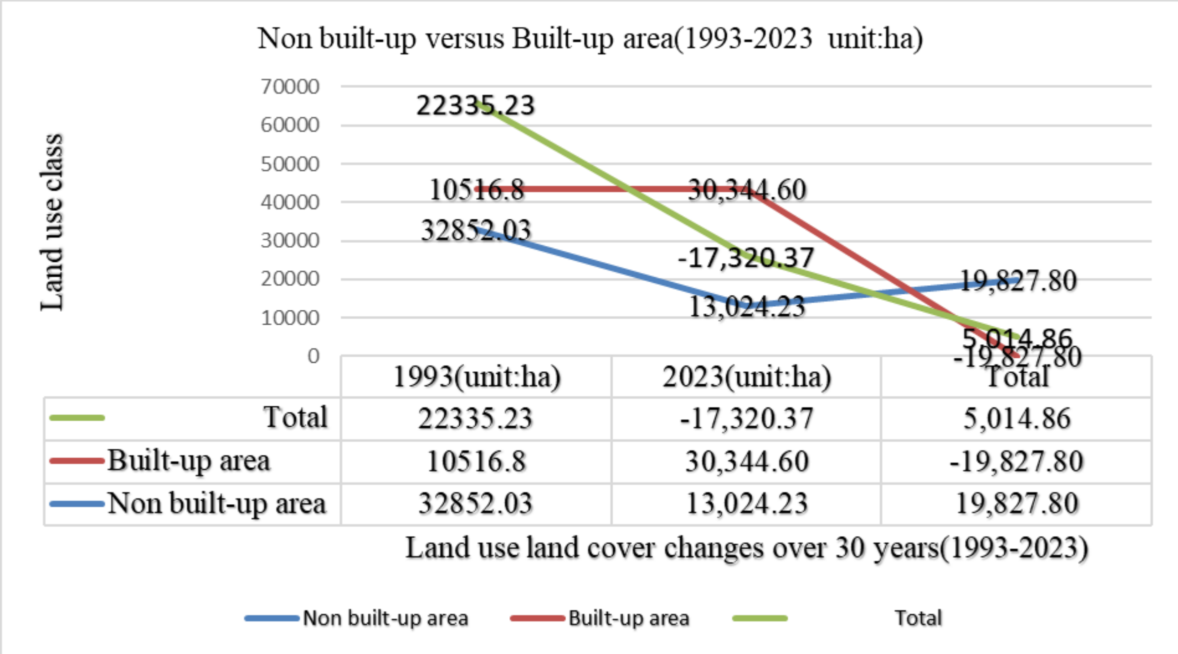

Chart 3.4: Reclassification into non-built versus built-up area

A comparison of the total land class of non-built-up and built-up areas shows that out of the total 32852.03 hectare of non-built-up areas in 1993 decreased by 19827.80 hectare, whereas, The built-up area was increasing by 19827.80 hectare in 2023. In 1993, the difference between non-built-up and built-up area was 22335.23 hectare and -17,230.37 hectare in 2023. The total difference between non-built-up and built-up areas in 1993 and 2023 was 5,014.86 hectare.

4.2.1.5. Intensity of urban land use change

According to (Akubia & Bruns, 2019a), Urban Expansion Intensity Index(UEII reflects the future direction and potential of urban expansion and compares the speed or intensity of urban land-use change in different periods. The following indices were designed as benchmarks for interpreting UEII output values (P: 22). It ranges from <0.28 (very slow expansion), 0.28–0.59 (slow expansion), 0.5–1.05 (medium-speed expansion), 1.05–1.92 (high-speed expansion), and >1.92 (very high-speed expansion).

From the calculated result of UEII, 1.524, the city of Addis Ababa, compared with the speed or intensity of urban land-use change, shows high-speed expansion. This implies that rapid and extensive urban land use has changed into built-up areas. The built-up area increased (19827.8 hectare; k=-6.22%) within the period to 1993-2023. And agricultural land decreased by 7012.52 hectare, bare land 6390.09 ha by forest 2405.43 ha by shrub by 4213.62ha, whereas, water body shows increment by (-193.86 hectare; *k= -62.36%*) most probably for two reasons: The first reason is urban expansion to the available water body area and the second is the revitalization of the water body by Sheger project.

Table 1.4: Intensity of urban land use change

$ULA_{t.b}$	$ULA_{t.a}$	$ULA_{t.b}$-$ULA_{t.a}$	t	$\frac{ULAt.b - ULAt.a}{t}$	TLA_t	$\frac{ULAt.b - ULAt.a}{TLAt * \Delta t}$	UEII
30,344.60	10516.8	19,827.80	30	660.9266667	43,368.83	0.01523967	1.523967

$$\text{UEII (Urban expansion Intensity Index)} = \frac{ULAt.b - ULAt.a}{TLAt * \Delta t} * 100$$

$$= 1.524\% \; (high\ spread)$$

Annual Urban Expansion Rate $(AUER = [(ULA_{t.b}/ULA_{t.a})^{(1/tb-ta)}-1]*100=[(2.885)^{0.033}-1]*100=\underline{3.56}$

Is it economic development or other political-economy forces that drive the horizontal urban expansion? There are lots of literatures including an article on areas of master plan of Addis Ababa Expansion of 2019 and massive Oromo resistance against the plan. The article raises the question "Addis Ababa master development plan: A program for development or for ethnic cleansing?" and revealed that coercively imposed development plan without consulting and considering the consequences of urban expansion on the local indigenous community was what were experienced, but face challenges in the 2019 (Degefa, 2019). Some also linked the rapid and unchecked expansion of Addis Ababa with the continuity of the state building legacy which coercively evicted the indigenous habitats (Pankhurst, 1961; Tufa, 2008). (Regassa, 2016) raised the question in his article "why Oromo resisting the master plan?" After several discussion and explanation of the legal point of view, he comes up with the answer that it is because of "Oromo's special interest in Addis Ababa since it is situated in the centre of Oromia National Regional State."

4.2.2. Discussion

These results built on existing methodological evidence of land use land cover change analysis technic such as supervised classification, accuracy assessment, and illustration of direction of expansion (Mishra et al., 2020; Moisa & Gemeda, 2021; Rana & Sarkar, 2021). The existing global evidence, by Shi et al., (2016) revealed that, with an average yearly growth rate of 13.36%, China's total urban area grew from 31,076 km2 in 2001 to 80,887 km2 in 2013. 33,080 km2 of agricultural land were consumed during this time by this extensive urban growth. Likely, studies in India showed the massive urban encroachment of productive agricultural land (Bhat et al., 2017; Bhattacharjee & Ghosh, 2015), which has impacts on peri-urban socioeconomic and productive arable lands (Youssef et al., 2020). Furthermore, studies in sub-Saharan Africa also find out that the expansion of built-up areas impacts ecosystem services and water resources (Congedo & Macchi, 2015).

In similar manner, (Moisa & Gemeda, 2021) find out, the built-up area has increased by 83.2 km^2 from 1990 to 2020, while agriculture and grassland have decreased by 80.4 km^2 and 53.4 km^2, respectively. During the same period, 41.1 km^2 of agriculture and 17.3 km^2 of grassland were converted to built-up areas.

This study also finds out that the direction of expansion mainly took place taking the rout of the roads. Similarly, studies in Greater Cairo region showed that distance from the nearest road was driving factor for urban expansion(Youssef et al., 2020). The findings also confirm with Sector or wage theory suggestion of the role of road rout in urban expansion. Likewise it shows the relationship between transport and urban space technical theory that suggest accessibility as determinant of the direction of urban sprawl. This suggests that the infrastructure in general and road in particular contributes for urban expansion. Studies in Ethiopia claimed that the public sponsored infrastructure such as roads has been increasing access to peri-urban lands and encourage urban expansion (Lamson-Hall et al., 2019).

The study finds out that the Northern direction expansion constrained by the chain of Entoto Mountain. This suggests the topographic restriction of urban expansion and consistent with the idea of sector or wedge theory (Obaid & Ali Salman Al-Shammary, 2022).

This result suggests that the rapid expansion of urban to the adjacent rural agricultural, and vegetation area reducing the potential productive and ecological sites as it negatively affects the production and climatic regulation. This implies uncontrolled spread might affect the peri-urban community's livelihood (Afriyie et al., 2020; Coulibaly & Li, 2020) and potential ecosystem services by altering agricultural/farmland which can be led to food insecurity, and environmental deterioration (Shao et al., 2021; Yuan et al., 2019).

4.3. Summary of main findings

The result of the study has revealed that over the last thirty years, Addis Ababa city has highly spread with (Urban Expansion Intensity Index (UEII) =1.524%); building-up land increased faster (dynamic degree (K) = -6.22 and Annual Urban Expansion Rate (AUER) is 3.56. From the finding, Addis Ababa is spreading speedily. While it has sprawl in the form of expansion in the size mentioned in different scale of agricultural fertile land, bare land, forest land, shrub land and water bodies were converted into built up area. These suggest the need to revisit expansion policy, land use policy, and drivers to enhance sustainable development.

4.4. Conclusion and Recommendation

4.4.1. Conclusion

This study investigated the swelling expansion of Addis Ababa. The findings showed that Addis Ababa has been highly spreading with the Urban Expansion Intensity Index (UEII=1.524%); built-up land increased faster (dynamic degree (K) = -6.22); and the *Annual Urban Expansion Rate (AUER) is 3.56*. Satellite image analysis and visual observation analysis showed that the spread of Addis Ababa to the adjacent area follows the road path, unevenly swallowing thousands of acres of productive fertile land for agriculture, including vegetation and bare lands. The rapid horizontal growth of Addis Ababa seems to have not received attention or consideration from the government. As a result, potential agricultural, grassland and vegetation areas are converted into built-up area. So, agricultural production decreased as farmland conversion into built-up increases. Likewise, conversion of grassland and vegetation areas adversely affects animals' food and air quality.

4.4.2. Recommendation

Unchecked urban expansion and land grabbing can impact sustainable and healthy development. Rapid urban expansion has several policy implications. First, policy implications for unequal treatment of land ownership and land holding rights; next, its implications for scarce land resource governance; third, policy implications for rural-urban migration and population policy; fourth, policy implications for fairness in the land transfer system; fifth, policy implications for land-related corruption; six, policy implications for expansion without creating jobs and facilitating job loss for agricultural livelihood dependence.

From the angle of policy implications, it is suggested that the government should work on a strong governance of land resources. Secondly, the driving force behind the rapid expansion of the city and urban encroachment should get policy attention and concerns from all actors in the area. Thirdly, urbanization should not be biased by economic growth. Rather, it should be reframed practically in the scope of sustainable future development; fourthly, by understanding the expansion rate, the concerned body should revise the planning, implementation, and decision-making processes in the area. Furthermore, urban encroachment-induced problems should be addressed in urban planning, policy, institutions, and programs. Beyond its economic advantage, the adverse effects of horizontal urban expansion should get governmental attention.

In a nutshell, the findings suggest that land-related governance, urban policy, urban population policy, agricultural policy, land policy, and environmental and urban planning should be revised. The research also suggests that the interface or intermingling area, also called the peri-urban area, should receive policy attention for its unique features in urban and rural areas.

Reference

Akubia, J. E. K., & Bruns, A. (2019). Unravelling the Frontiers of Urban Growth : SpatioTemporal Dynamics of Land-Use Change and. 1–23.

Bhat, P. A., Shafiq, M. ul, Mir, A. A., & Ahmed, P. (2017). Urban sprawl and its impact on landuse/land cover dynamics of Dehradun City, India. International Journal of Sustainable Built Environment, 6(2), 513–521. https://doi.org/10.1016/j.ijsbe.2017.10.003

Bhattacharjee, S., & Ghosh, S. K. (2015). SPATIO-TEMPORAL CHANGE MODELING of LULC: A SEMANTIC KRIGING APPROACH. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 2(4W2), 177–184. https://doi.org/10.5194/isprsannals-II-4-W2-177-2015

Congedo, L., & Macchi, S. (2015). The demographic dimension of climate change vulnerability: Exploring the relation between population growth and urban sprawl in Dar es Salaam. Current Opinion in Environmental Sustainability, 13, 1–10.

Debelo, A. R., & Soboka, T. E. (2023). Urban Development and the Making of Frontiers in/from Addis Ababa/Finfinne, Ethiopia. Journal of Asian and African Studies, 58(5), 708–724. https://doi.org/10.1177/00219096211069647

Degefa, A. (2019). Addis Ababa master development plan: A program for development or for ethnic cleansing? RUDN Journal of Sociology, 19(1), 31–39. https://doi.org/10.22363/2313- 2272-2019-19-1-31-39

Fang, X., Ghazali, S., Azadi, H., Skominas, R., & Scheffran, J. (2023). Agricultural land conversion and ecosystem services loss: a meta-analysis. Environment, Development and Sustainability. https://doi.org/10.1007/s10668-023-03597-z

Koroso, N. H., Lengoiboni, M., & Zevenbergen, J. A. (2021). Urbanization and urban land use efficiency: Evidence from regional and Addis Ababa satellite cities, Ethiopia. Habitat International, 117(October), 102437. https://doi.org/10.1016/j.habitatint.2021.102437

Lamson-Hall, P., Angel, S., DeGroot, D., Martin, R., & Tafesse, T. (2019). A new plan for African cities: The Ethiopia Urban Expansion Initiative. Urban Studies, 56(6), 1234–1249. https://doi.org/10.1177/0042098018757601

M.A. Siro, B. (2017). Analysis of the Impact of New Road Infrastructure Development on Urban Sprawl and Modelling Using Remote Sensing (A case study of Thika Road superhighway and Eastern bypass of the Nairobi Metropolitan, Kenya). IOSR Journal of Environmental Science, Toxicology and Food Technology, 11(03), 41–49. https://doi.org/10.9790/2402- 1103034149

Mishra, P. K., Rai, A., & Rai, S. C. (2020). Land use and land cover change detection using geospatial techniques in the Sikkim Himalaya, India. Egyptian Journal of Remote Sensing and Space Science, 23(2), 133–143. https://doi.org/10.1016/j.ejrs.2019.02.001

Moisa, M. B., & Gemeda, D. O. (2021). Analysis of urban expansion and land use/land cover changes using geospatial techniques: a case of Addis Ababa City, Ethiopia. Applied Geomatics, 13(4), 853–861. https://doi.org/10.1007/s12518-021-00397-w

Pankhurst, R. (1961). Menelik and the Foundation of Addis. 2(1), 103–117. Power, A. G. (2010). Ecosystem services and agriculture: Tradeoffs and synergies. Philosophical Transactions of the Royal Society B: Biological Sciences, 365(1554), 2959–2971. https://doi.org/10.1098/rstb.2010.0143

Rana, M. S., & Sarkar, S. (2021). Prediction of urban expansion by using land cover change detection approach. Heliyon, 7(11), e08437. https://doi.org/10.1016/j.heliyon.2021.e08437

Regassa, T. (2016). Why Resist the Addis Ababa Master Plan : A Constitutional Legal Exploration Why resist the Addis Abeba Master Plan ? – A constitutional legal exploration. September 2015.

Shi, K., Chen, Y., Yu, B., Xu, T., Li, L., Huang, C., & Liu, R. (2016). Urban Expansion and Agricultural Land Loss in China : A Multiscale Perspective. 1–16. https://doi.org/10.3390/su8080790

Sun, W., Shan, J., Wang, Z., Wang, L., Lu, D., Jin, Z., & Yu, K. (2020). Geospatial Analysis of Urban Expansion Using Remote Sensing Methods and Data: A Case Study of Yangtze River Delta, China. Complexity, 2020. https://doi.org/10.1155/2020/3239471

Tufa, D. (2008). Historical Development of Addis Ababa : plans and realities. 41(1), 27–59.

Yiran, G. A. B., Ablo, A. D., Asem, F. E., & Owusu, G. (2020). Urban Sprawl in sub-Saharan Africa: A review of the literature in selected countries. Ghana Journal of Geography, 12(1), 1–28. https://doi.org/10.4314/gjg.v12i1.1

Youssef, A., Sewilam, H., & Khadr, Z. (2020). Impact of Urban Sprawl on Agriculture Lands in Greater Cairo. Journal of Urban Planning and Development, 146(4), 1–12. https://doi.org/10.1061/(asce)up.1943-5444.0000623

Yizhen Zhang, L. W. (2022). Spatial effects of urban expansion on air pollution and ecoefficiency: Evidence from multisource remote sensing and statistical data in China. Journal of Cleaner Production, 367.

Details

Chali Etefa works at the Ethiopian Policy Studies Institute and is a former lecturer at Mettu University who is now pursuing a Ph.D. in public management at Ethiopian Civil Service University. The dissertation topic of Chali focuses on the dynamics and driving forces of urban sprawl, urban expansion/sprawl, and ecosystem services, as well as on urban sprawl and peri-urban livelihood, resilience and adaptive methods for how government responds to urban sprawl, and ecosystem services and livelihoods.

Dr. Dereje Techlemariam is an associate professor of management and development studies at Ethiopian Civil Service University. Dereje's research combines business, economic development, environmental, and management studies. Dereje is also experienced with the applications and tools of mixed research methods and socio-economic and environmental assessment models to investigate the dynamics of interactions among business, investment, livelihood, and environment and their ramifications on socio-economic parameters and sustainability.

Dr. Endalew Addis is an assistant professor of development studies at the Ethiopian Civil Service University. His research areas include climate change vulnerability, adaptation and resilience, sustainable livelihoods and agriculture, food security, poverty, social protection, gender, employment/unemployment, migration, and good governance.