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Impact of landscape dynamics and intensities on the ecological land of major cities in Ethiopia

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Abstract

Background: Understanding the dependence of ecological land and dynamics of the human-nature-coupled landscape is crucial for urban ecosystem resilience. In this study, we characterized and compared the Spatio-temporal responses of ecological land to urban landscape dynamics in Bahir Dar, Addis Ababa, Adama, and Hawassa cities in Ethiopia for the last three decades (1990–2020). Three sets of Landsat satellite images, field observations, and urban land indexes were used to produce landscape maps and geo-spatial data analysis.

Results: The results showed that in all cities ecological land has had changed intensely during 1990–2020 regarding its quantity, and spatial pattern. Besides, the substantial expansion of built-up ecosystems was manifested at the cost of ecological land. The built-up ecosystem was augmented by 17,341.0 ha (32.16%), 2151.27 ha (19.64%), 2715.21 ha (12.21%), and 2599.65 ha (15.71%) for Addis Ababa, Adama, Bahir Dar, and Hawassa cities respectively from 1990 to 2020 periods. A total of 40.97% of the prolonged built-up area was obtained from urban agricultural land alone. Moreover, urban sprawl is likely to continue, which will be outweighed by the loss of the open space ecosystem. The finding also confirmed the value of land-use intensity (LUI) of Addis Ababa (3.31), Bahir Dar (3.56), Hawassa (4.82), Adama (5.04) was augmented parallel with accelerated growth in the built-up ecosystems. Besides, the Integrated land-use dynamics degree (ILUDD) analysis confirmed that the spatial pattern of ecological land loss significantly consistent with LUI in all cities.

Conclusion: Land-use intensity (LUI) dynamics pattern was followed by urban ecological land to the multi-complex human-dominance ecosystem with a substantial influence on urban greenery and ecosystem services provides. Thus, in all cities, the implementation of effective ecological land management and urban planning policies are required to ensure economic development and ecosystem resilience.

Keywords: Ecological land, Landscape transitions, Cities resilience, Sustainable development

Introduction

Urbanization and associated a massive landscape change has led to a substantial change in the quantity of the composition, the structure, and the function of ecological land (Wangai et al. 2019; Liu et al. 2020a; Talukdar et al. 2020) while, boosted the formation of human-dominated or human-nature-coupled ecosystems (Zhang et al. 2013,

2018; Hu et al. 2019; Chen et al. 2021). During the past decades, most cities have experienced remarkable urban–rural expansion, mainly due to population growth and the migration from rural to urban areas. According to Ye et al. (2018), globally the number of people living in cities is going up a fast rate from 0.75 billion (29.6%) in 1950 to 6.34 billion (66.7%) projected by 2050 and demand 1.2 million km^2 cityscapes by 2030 (Seto et al. 2012; Das and Das 2019). Thus, these urbanization scenarios and their inference to ecological land dynamics particularly in rapidly developing cities and surrounding ecosystems are

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becoming a common issue in policy discussions and scientific analysis (Ha et al. 2020; Mekasha et al. 2020).

In a view, accelerated urban agglomeration in megacities poses huge opportunities and objections for the sustainable development of countries. For example, megacities become the hubs of technology (Meng et al. 2020) and business activity while generating a significant amount of urban metabolic waste (Peng et al. 2017; Bahers et al. 2019; Venkata Mohan et al. 2019) and required more science and green technology-based resilient infrastructures and strategies than emerging cities (Viitanen et al. 2014). On the other hand, urbanization in the developing world depends on the conversion of ecological land to unstainable urban fabric ecosystems (Peng et al. 2017; Bahers et al. 2019). Later, created policy and institutional, socioeconomic, environmental, and technological related challenges (Ahmed et al. 2015; Kindu et al. 2015; Gashaw et al. 2018).

Moreover, the urbanization, and the land competition in the major city (Addis Ababa, Adama, Mekella, Bahir Dar, and Hawassa) and other emerging cities of Ethiopia followed a similar scenario and will continue for the next few decades due to their uncontrolled fast-growing nature (Terfa et al. 2019; Bulti and Abebe 2020; Wubie et al. 2020). In the contrast, ecological lands (the urban forest and greenery, and water bodies) were converted to impervious surfaces; like residential, industrial, and commercial systems. Generally, the rapid sprawl has created social, economic, and political instabilities that can be attributed to governance, and land use policy issues (Bhat 2017; Mohamed and Worku 2019; Das and Angadi 2020; Zou and Wang 2021).

Land dynamic studies are not new issues for Ethiopia. However, studies are mostly spatially limited and concentrated on the specific ecosystem and land-use types. For example, central highland and forest ecosystem (Kindu et al. 2015, 2016; Minta et al. 2018; Yohannes et al. 2020), Northern highlands (Tolessa et al. 2017; Temesgen et al. 2018; Gebrehiwot et al. 2020; Mekasha et al. 2020; Mekuriaw et al. 2020) and single city-based (Gashu and Gebre-Egziabher 2018; Kinfu et al. 2019; Larsen et al. 2019; Terfa et al. 2019; Bulti and Abebe 2020). Although, LULC dynamics and management vary significantly over time and from ecosystems to ecosystems. In contrast, the present study focused on the dynamics in the human–ecological land nexus at different spatial and temporal scales of major active cities of Ethiopia that have not been studied before in a holistic approach. Consequently, this study aims to appraise the spatial patterns of deviations in ecological land and urban ecosystem and to evaluate to what degree the existing ecological land intervention processes and management approaches are effective in combating and controlling unsustainable dynamics in cities of Ethiopia for the implication of urban ecological land resilience.
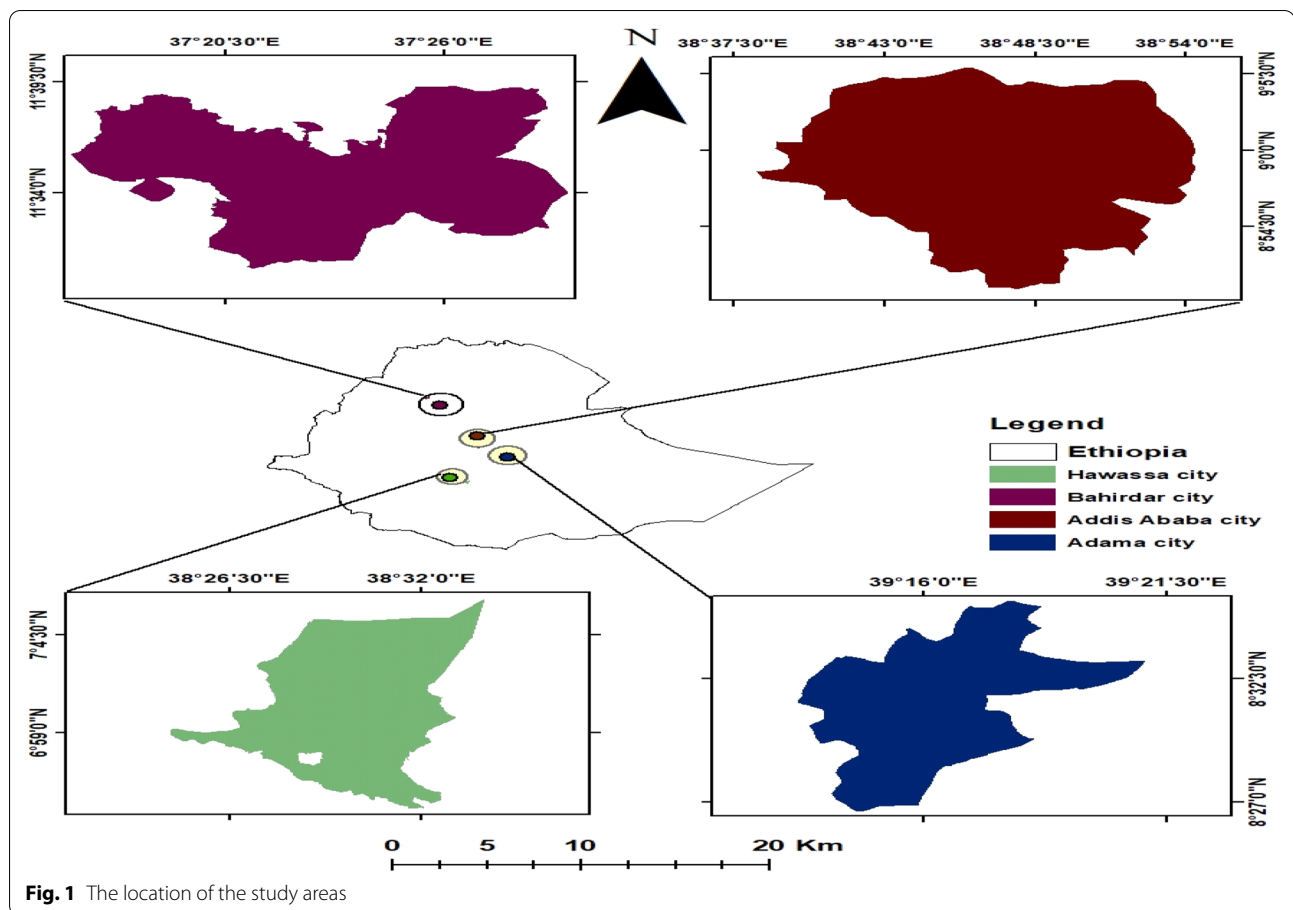
Material and methods
Study areas
The study areas fall in one metropolitan, and three regional capital cities (Addis Ababa, Hawassa, Adama, and Bahir Dar respectively) of Ethiopia (Fig. 1). These cities are among the largest and the fastest-growing urban centers of Ethiopia (Gashu and Gebre-Egziabher 2018; Terfa et al. 2020; Wubie et al. 2020). The cities are found in the central, northern, southern, and eastern parts of Ethiopia. Moreover, the cities were selected as study areas based on the following criteria (i) being the largest, a capital city or metropolitan (ii) being the main political, economic, and commercial center of their country (iii) being an active zone of industrialization and a rapid rate of the urban growth, (iv) experiencing rapid urbanization with the highest population in their respective cities of the country and (v) has relatively bettered availability of ecological land as compared to other cities in the order to maximize the probability of detecting changes in ecological land due to the urban sprawl (Gashu and Gebre-Egziabher 2018; Terfa et al. 2020; Wubie et al. 2020; Li et al. 2021).

Addis Ababa metropolitan: the capital city of Ethiopia and the diplomatic center of Africa. It is one of the fastest-growing cities on the continent, located at $8°50'00''–9°06'00''$ N and $38°39'00''–38°55'00''$E with an average altitude of 2380 m, and the city is covering an area of approximately 526 km^2. Based on the 2007 population census the population of Addis Ababa was estimated at 3.4 million with an annual growth rate of 3.8% (CSA 2007). Moreover, UN-HABITAT estimates that this number will continue to rise, reaching 12 million in 2024. Average daily minimum and maximum temperatures are 10.7 °C and 23.3 °C, respectively (Ethiopian Meteorology Agency, 2012), with an average of 1255 mm rainfall per year.

Adama city: the city is located about 100 km southeast of the capital Addis Ababa. It is situated at $8° 30' 0.00''–8°35'00''$N, and $39° 13'00''–39° 18'00''$E that ranges from 1444 to 1974 m.a.s.l and covering 134.1 km^2. The city found between the bottoms of an escarpment to the west, and therefore, the Great valley to the east. The average annual temperature and precipitation are 20.5 °C and 804 mm, respectively. According to the 2007 Census of Ethiopia, this city has a total population of 220,212 with an annual growth rate of 3.8% (CSA, 2007).

Bahir Dar is the capital city of the Amhara National Regional State, which is situated at $11° 34' 00''–11° 37'00''$ N and $37° 20'00''–37° 26'00''$ E ranges from 1717 to 2010 m.a.s.l and covering 134.1 km^2. It is distanced about 578 km northwest of the capital city of the country. The

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Fig. 1 The location of the study areas

population of Bahir Dar city was 180,094 with an annual growth rate of 3.8% (CSA, 2007). Based on the projection of the 2007 census, the population was estimated to be more than eight-fold by 2040. The mean maximum and minimum annual temperatures are 28.3 °C and 11.4 °C, respectively.

Hawassa: the capital city of Sidam Regional State, which is situated at 7° 00′ 30″–7° 06′ 00″ N and 38° 28′ 34.86″–38° 32′ 00″ E and the average elevation of the city is 1708 m.a.s.l and it is distanced 275 km south of Addis Ababa. The city administration has an area of 157.2Km^2. Based on 2007, census the population of Hawassa was 57,139, and estimated the population of Hawassa in 2017 to be 315,267 (CSA, 2017). Hawassa has a mean annual temperature and precipitation of 20.8 °C and 993.4 mm respectively (NMA, 2020). It is one of the main urban areas of Ethiopia located inside the greater Ethiopian valley.

Table 1 List of satellite data and acquisition date of the study areas

Cities	Path/row	Image acquisition date				Source
		1990	2000	2010	2020	
Addis Ababa	168/054	04/02/1990[a]	05/02/2000[a]	31/01/2010[b]	29/01/2020[c]	USGS
Adama	168/054	04/02/1990[a]	05/02/2000[a]	31/01/2010[b]	29/01/2020[c]	USGS
Bahir Dar	170/052	02/02/1990[a]	11/02/2000[a]	14/02/2010[b]	18/02/2020[c]	USGS
Hawassa	168/055	19/01/1990[a]	12/01/2000[a]	31/01/2010[b]	19/01/2020[c]	USGS

[a] Landsat TM: [b]Landsat ETM +: [c]Landsat OLS

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Table 2 Types of LULC and its description

LULC type	Description
Urban forest and greenery	Areas occupied by plantation forest and urban green parks with 65% canopy cover or higher, evergreen and mixed urban forests and greenery and other vegetation that is relatively tall and dense, as well as areas covered with both indigenous and exotic tree
Urban agriculture	The purpose of which is used for urban crop production and livestock husbandry grazing land by peri-urban field farmers, although cultivated land use is relatively different in terms of size, soil fertility, use of input, and other important variables from rural agriculture. Includes, grazing areas, cultivated lands, community open lands and areas along the lake shore that are used for agricultural purposes when the lake level retreats following the long dry-season
Water bodies	Permanent natural water bodies such as lakes, rivers, ponds reservoirs, and man-made water bodies, the water table in irrigated land
Built up	The built-up area with congested buildings includes all types of artificial surfaces, residential and scattered settlements in urban fringe zones, commercial, industrial land uses as well as transportation infrastructure
Bare land	The land consists of roads, rocky outcrops, and degraded lands, where the area is dominated by the regular movement of trucks, quarry for road construction, and abandoned lands as a result of gully formation etc

Source: (Gashu and Gebre-Egziabher 2018)

Satellite data acquisition and preparation

In this study, three decades' time-series LULC change maps for each city were prepared by utilized multispectral Landsat imagery (Landsat 7 TM, ETM$^+$, and Landsat 8 OLI), which were retrieved on four distinct dates: 1990, 2000, 2010, and 2020 free of charge from the United States Geological Survey (USGS) website (https://earth explorer.usgs.gov). All images were retrieved more or less during the same period during the dry seasons of the particular years (Table 1). Since most land-surface features show reliable reflectance characteristics regardless of the year of acquisition. Moreover, the retrieved images were exported to ArcGIS and re-projected in the WGS 84 system of the Universal Transverse Mercator (UTM) projection fuse of 37 N.

The pre-processing of satellite images was accomplished using color composites in RGB transformation. To categorize LULC classes, a false-color grid composite image was generated using ERDAS virtual Geographical Information System (GIS) analyzer. Primary, to get the major ecosystem types of each city an unsupervised classification technique was made, which then used for supervised classification. Spectral signatures and ground verification using Geographical Positioning System (GPS) were used to verify the accuracy of the LULC map of 2020 with field points. About 1000 (50 for each LULC type per city) random ground truth points and high-resolution images of Google earth points were acquired for confirmation of LULC classification results. Later, the ecosystem type classification was done using the maximum likelihood classifier (Yang et al. 1999; Feyisa et al. 2016; Feyissa and Gebremariam 2018; Minta et al. 2018; Hoque et al. 2020).

Finally, the LULC map with five distinguished ecosystem classes of respective reference years (1990, 2000, 2010, and 2020) and temporal changes in LULC change per city was generated and analyzed for interpretation. The five classes were: urban forest and greenery, urban agriculture, urban built, bare land, and water (Table 2). These five-LULC classification systems were chosen considering the standard classes explained by the National Aeronautics and Space Administration (NASA) and the US Geological Survey (USGS) as well as the study detail and objectives (Mohan et al. 2011; Gashu and Gebre-Egziabher 2018).

Data analysis

This study uses the post-classification changes detection method. Due to its nature of clearly identified change, trends, and rate of ecosystem dynamics (Lu et al. 2004; Gashu and Gebre-Egziabher 2018). The post-classification was executed by recoding, majority filtering, clumping, elimination, and mosaicking of the classified maps to reduce errors of all LULC maps using the ArcMap GIS. Zonal statistics in ArcGIS Spatial Analyst's tool was applied to assess the LULC dynamics of each city by using cross tabulating pairs of time intervals i.e., 1990–2000, 2000–2010, and 2010–2020. Moreover, quantified values of the changes between the different LULC classes were used for statistical analysis to reveal the extent of the dynamics in the study areas. The percentage of change within the same LULC class between two-time points is computed using Eq. 1 and interpreted if the values are positive suggest again, whereas negative values imply a loss in extent. Moreover, the LULC change rate was also detected using formula 2.

$$\text{Change } (\%) = \frac{(A_{tn} - A_{tn-1}) * 100}{A_{tn-1}} \tag{1}$$

$$r = \frac{1}{\Delta t ln(A_2 - A_1)} \tag{2}$$

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where: A_{tn}: area of specific land use land cover class at time t_n; A_{tn-1}—an area of the same land use land cover class at time t_{n-1}; Change (%)—percent change in the area of specific land use land cover class between times t_n and t_{n-1}; r is the annual rate of change in %, Δt is the time interval in years during the LULCC being assessed; ln is the base of the natural logarithm function.

Besides, to reveal the spatial relations between LULC change and response for anthropogenic—sustainability nexus, we first compute LULC dynamics rate for a specific and integrated land use land cover transformation of each city from 1990 to 2020 period, using three effective integrated parameters: land use dynamic degree (single land use dynamic degree (SLUDD), integrated land use dynamic degree (ILUDD), land-use intensity (LUI) and land-use diversity (LUD) methods (Zorrilla-Miras et al. 2014; Song and Deng 2017; Chen et al. 2019; Hu et al. 2019; Huang et al. 2019; Liu et al. 2020b; Shao et al. 2020) followed Eqs. 3–6.

Single land use dynamic degree (SLUDD) reveals the change rate of a single land-use type of each city, while Integrated Land Use Dynamic Degree (ILUDD) estimates the overall situation of land-use change rate (Chu et al. 2018; Chen et al. 2021). Besides, Land use intensity (LUI) is revealing the breadth and depth of land use, which can be determined as a reply to the material and energy flows between natural and human ecosystems and can be used to evaluate the intensity of the adaptations of a land-use system to the changing physical and socio-economic circumstances (Zorrilla-Miras et al. 2014; Chen et al. 2020). According to Chen et al. (2019) the intensity of interaction divided into four ('open space/bare land, was assigned the weighted value of 1, whereas urban built land was given the weighted value 4. Urban Forest and greenery land and water areas, were given the weighted value 2, while urban agriculture land was assigned the weighted value of 3) based on the equilibrium states of physical and socioeconomic influences on the land-use systems. Furthermore, land-use diversity (LUD) represents LULC dynamics about the structure, richness, and complexity of different land-use types.

$$SLUDD = \frac{LA_{I,t2} - LA_{I,t1}}{LA_{I,t1}} * \frac{1}{T} * 100\% \quad (3)$$

$$ILUDD = \left(\sum_{i=1}^{n} \Delta LA_{i-j} \,\Big|\, \sum_{i=1}^{n} LA_{(I,t1)} \right) * \frac{1}{T} * 100\% \quad (4)$$

$$LUI = \sum_{i=1}^{4} \frac{LA_{(I,t)}}{\sum_{i=1}^{n} LA_{(I,t)}} * D_{I} \quad (5)$$

$$LUD = -\sum_{i=1}^{n} \frac{LA_{(I,t)}}{\sum_{i=1}^{n} LA_{(I,t)}} * \ln \left(\frac{LA_{(I,t)}}{\sum_{i=1}^{n} LA_{(I,t)}} \right) \quad (6)$$

where $LA_{(I,t1)}$ and $LA_{(I,t2)}$ characterize the area of land use type I at time t_1 and t_2, respectively. ΔLA_{i-j} is the area of land use type I transformed to land use type j (j = 1, 2, n, $I \neq j$) during the study period, n is the number of land-use types in the study area, T is the study period, and D_i is the weighted value of each land-use type mentioned previously (Fig. 3).

Furthermore, to measure annual urban expansion, we chose and calculated two indexes–Annual Increase (AI) and Annual Growth Rate (AGR) of urban land (Wu 2013; Meng et al. 2020; Zhao and Fan 2020). Annual increase (AI) is efficient to compare the expansion rates for the same city among different periods, while annual growth rate (AGR) is more suitable for comparison among different cities (Alawamy et al. 2020; Meng et al. 2020). Indexes used to quantify the urban growth rates are defined using Eqs. 7 and 8.
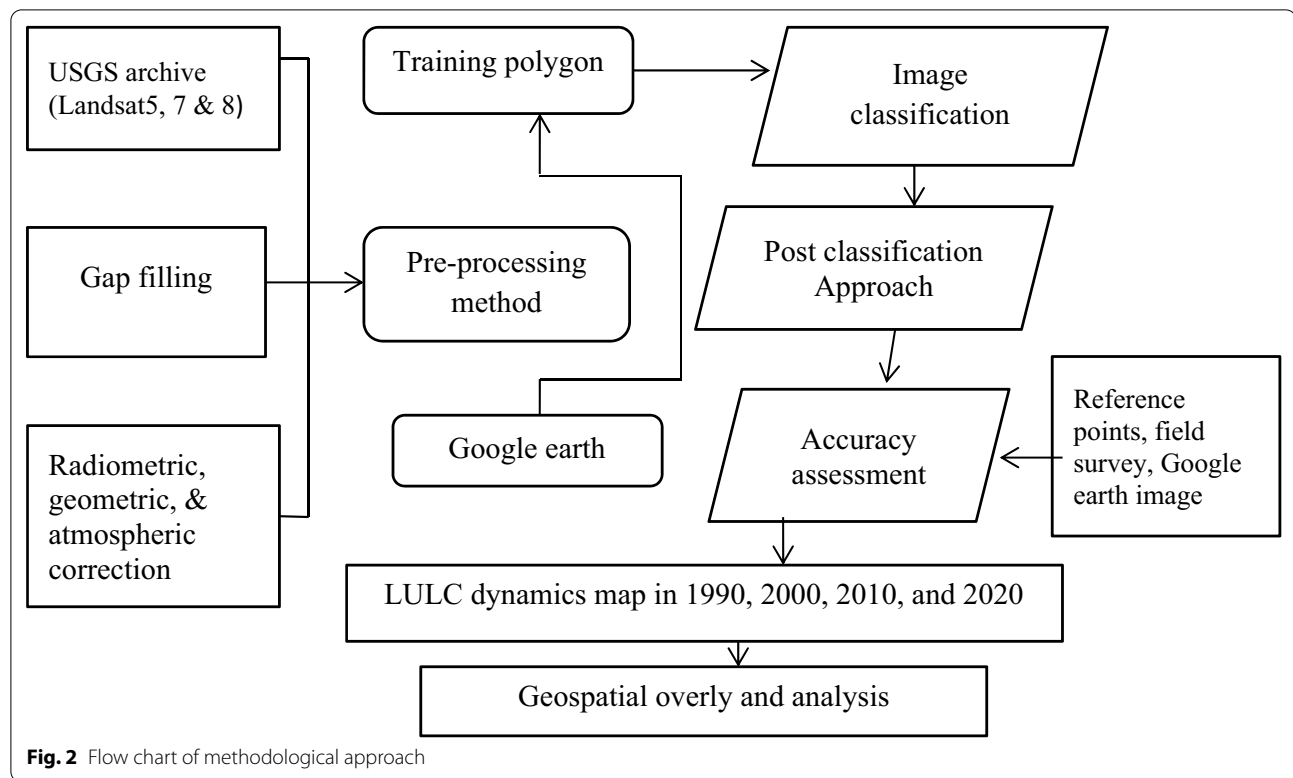
$$AL = \frac{A_{end} - A_{start}}{d} \quad (7)$$

$$AGR = 100\% * \left[\left(\frac{A_{end}}{A_{start}} \right)^{\frac{1}{d}} - 1 \right] \quad (8)$$

where A_{start} and A_{end} are the areas of urban land at the initial and end time, respectively, and d (in years) is defined as the period of the study period (Fig. 2).

The classification accuracy assessments of the resulting LULC types of satellite images were carried out by comparing the sample LULC class of the classified layer and the reference layer (Gashaw et al. 2018; Gashu and Gebre-Egziabher 2018). Since image classification without accuracy assessment mostly affects the confidence of the findings (Yang et al. 1999). The overall accuracy and Kappa scrutiny were calculated to appraise the degree of classification accuracy of the error matrix (Story et al. 1986; Yang et al. 1999). Overall accuracy is the ratio of a total number of randomly generated reference values of the error matrix to the sum of correctly classified values (Minta et al. 2018; Yu et al. 2019). While, the Kappa coefficient, is a statistical measure of inter-rater reliability (actual and chance agreement) that is compared to reference data. The formula for computing producer accuracy, user accuracy, overall accuracy, and Kappa index coefficient was computed using Eqs. 9–12.

The overall accuracies of 88.75% (Addis abba), 89.13% (Adama), 86.63% (Hawassa), and 86.68% (Bahir Dar) were achieved (Table 3). The kappa index results showed that

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Fig. 2 Flow chart of methodological approach

Table 3 Accuracy assessment for classified images of Addis Ababa, Adama, Bahir Dar and Hawassa

Reference year	Classified image	Overall classification accuracy (%)	Overall kappa coefficient	Reference year	Classified image	Overall classification accuracy (%)	Overall kappa coefficient
Addis Ababa				Adama			
1990	Landsat 5 TM[a]	89.50%	0.86	1990	Landsat 5 TM	86.50%	0.83
2000	Landsat 5 TM	90.00%	0.87	2000	Landsat 5 TM	88.50%	0.86
2010	Landsat 7 ETM+[b]	88.00%	0.84	2010	Landsat 7 ETM+	90.00%	0.88
2020	Landsat 8 OLI[c]	87.50%	0.82	2020	Landsat 8 OLI	91.50%	0.89
Bahir Dar				Hawassa			
1990	Landsat 5 TM	85.00%	0.82	1990	Landsat 5 TM	89.00%	0.86
2000	Landsat 5 TM	86.50%	0.84	2000	Landsat 5 TM	85.00%	0.81
2010	Landsat 7 ETM+	88.00%	0.87	2010	Landsat 7 ETM+	85.50%	0.82
2020	Landsat 8 OLI	87.00%	0.85	2020	Landsat 8 OLI	88.00%	0.86

[a] Multi-spectral Scanner: [b]Thematic Mapper: [c]Operational Land Imager

all of the images met the minimum of 85% accuracy in LULC change analysis to each classified ecosystem that intersects a given reference ecosystem. This result is aligning with the recommended value of many scholars (Lu et al. 2004; Li et al. 2019; Ha et al. 2020).

$$\text{Producer's accuracy i} = \frac{\text{nii}}{\text{Gii}} \qquad (9)$$

$$\text{User's accuracy i} = \frac{\text{nii}}{\text{Cii}} \qquad (10)$$

$$\text{Overall accuracy} = \frac{\sum_{i=1}^{k} nii}{n} \qquad (11)$$

$$\text{Kappa coefficient } K = \frac{N \sum_{i=1}^{rk} xab - \sum_{i=1}^{r} (xa * b)}{N^2 - \sum_{i=1}^{k} (xa + *xb)} \qquad (12)$$

where: i is the class number, n is the total number of classified pixels that are being compared to ground truth, nii is the number of pixels belonging to the ground truth class i, that have also been classified with class i, Ci is the total number of classified pixels belonging to class i and Gi is the total number of ground truth pixels belonging to class I, Khat = Kappa coefficient; N is a total number of values; $\sum i = 1^K X_{ab}$ is observed accuracy, and $\sum i = 1K$ $(X_a \times X_b)$ is change accuracy.

Results

Land use land cover dynamics

The Spatio-temporal land-use dynamics degree of each city with the corresponding percentage is illustrated in Tables 4, 5, 6, 7 and Fig. 3. This study showed that a substantial amount of ecological land was converted to build-up from 1990 to 2020, which was characterized by a net upsurge in building up and a large reduction of the urban forest, urban agriculture, and bare land ecosystem (Figs. 4 and 5). In general, from 1990 to 2020 the total built-up ecosystem was boosted by 17,341.0 ha (32.16%), 2151.27 ha (19.64%), 2715.21 ha (12.21%), and 2599.65 ha (15.71%) for Addis Ababa, Adama, Bahir Dar, and Hawassa cities respectively. Whereas, the urban agricultural ecosystems were reduced by 13.63%, 19.1%,22.9%, and 9.33% for Addis Ababa, Adama, Bahir Dar, and Hawassa cities respectively and a significant portion was transformed to build up the ecosystem and its dynamic degree was 20.79% (Table 4).

Besides, urban forest and greenery ecosystems of Adma and Bahir Dar cities were grown by 443.11 ha (4.09%) and 2121.3 ha (9.94%) respectively that of 1990. On the other hand, the size of urban forest and greenery ecosystems of Addis Ababa and Hawassa cities were reduced by1496.94 ha (2.77%) and 507.96 ha (3.07%) in that orders from the initial period (Tables 4 and 5). Furthermore, the annual conversion rate of bare land to build up was 16.1%, 4.56%, 0.82%, and 2.17% per year for Addis Ababa, Adama, Bahir Dar, and Hawassa cities respectively from the 1990 to 2020 period.

Specifically, in 1990 urban agricultural ecosystem was accounted for more than half of the total area of Hawassa (56.30%) and Adama (53.90%) followed by Bahir Dar (40%), and Addis Ababa (39.00%). Moreover, the highest urban forest and greenery portion was found in Bahir Dar (43.90%), followed by Hawassa (20.10%), Adama (16.40%), and Addis Ababa (13%) cities (Fig. 4). On the other hand, the built-up area was accounted for in Addis Ababa (23.40%), Adama (15.70%), Hawassa (9.80%) and, Bahir Dar (6.50%) ascending order. In 2000, the urban agriculture ecosystem was increased in Addis Ababa by 10%, followed by Adama by 2%, whereas, it was declined

by 20% and 2% from Bahir Dar and Hawassa cities respectively from 1990 coverage. In the case of the urban built-up, the highest agglomeration was found in Addis Ababa and Adama cities by 4%, followed by Hawassa and Bahir Dar by 2% for the initial year. In contrast, the urban forest and greenery cover was significantly increased in Bahir Dar by 13% (2206.7 ha). Conversely, the cover was declined in other cities. Vis-à-vis the size of bare land was increased in Bahir Dar and Hawassa cities, while the conversion to other types of the ecosystem was rapid in Addis Ababa and Adama cities (Table 4).

In 2010, the ecosystem under urban agriculture was covered by 44,698.66 ha of the total cityscapes, afterward, the built-up area and urban forest and greenery accounted for 25, 652.17 ha, 13,819.05 ha respectively, while the coverage of water body was declined to 2645.28 ha (Table 3). Moreover, Addis Ababa, Hawassa, and Bahir Dar cities were shown the declining trend of the urban agricultural ecosystem, while the coverage of the urban agriculture in Adam had shown increment with the cost of bare land utilization. Regarding, the built-up ecosystem, the largest agglomeration was found in Addis Ababa and increased by 14.60% from 1990, consequently other cities sprawl by 4% from 1990. In contrast, bare land (open space) and urban forest ecosystems were reduced dramatically and replaced by built up an ecosystem (Table 5).

In 2020, the built-up ecosystem accounted for a significant proportion in all cities, which accounts for more than double that of 1990. The built-up ecosystem was augmented by 32.16% in Addis Ababa city, 19.64% in Adama, Bahir Dar (12.72%), and by 15.72% in Hawassa (Table 4). Besides, the urban agriculture ecosystem was decreased by 8694.26 ha, 499.41 ha, 177.93 ha, and 358.74 ha from Addis Ababa, Adama, Bahir Dar, and Hawassa cities in that order (Table 4). Similarly, the urban forest and greenery ecosystem of Addis Ababa and Hawassa cities were declined from 1490.94 ha (2.77%) and 507.96 ha (3.07%) respectively. However, an increment was observed in Adama and Bahir Dar cities by 448.11 ha and 2121.3 ha in the past three decades. Besides, the size of water bodies was declined in Adama, Bahir Dar, and Hawassa cities by 13.27 ha, 108.09 ha, and 189.27 ha in that order.

Furthermore, Table 5 shows the persistence, gains, losses and net changes of different LULC change accordingly, in Hawassa city, built up has shown a higher persistence value and accounted for 55.56% followed by urban agriculture ecosystem (30.54%) while bare land (open space) has shown a higher loss (55%). Besides, the ecosystem type which persisted the least is urban forest and greenery (4.8%) and the ecosystem with the least loss is water body (0.1%). In Bahir Dar, the urban ecosystem

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Table 4 LULC change (ha) in Addis Ababa, Adama, Bahir Dar and Hawassa cities (1990–2020)

Year	UA (ha)	%	BL (ha)	%	BU (ha)	%	UFG (ha)	%	W (ha)	%
Addis Ababa										
1990	21,046.9	39.03	10,142	18.81	12,606.9	23.38	7006.95	13.00	3116.97	5.78
2000	21,711.1	40.27	6957.63	12.90	14,564.5	27.01	7506.63	13.92	3179.88	5.90
2010	20,723.1	38.43	5207.4	9.66	18,653.5	34.59	7813.89	14.49	1521.81	2.82
2020	13,693.1	25.40	1447.74	2.68	29,947.9	55.54	5516.01	10.23	3314.97	6.15
Total	53,919.72		53,919.72		53,919.72		53,919.72		53,919.72	
1991–2000	664.2	1.23	− 3184.37	− 5.91	1957.6	3.63	499.68	0.93	62.91	0.12
2000–2010	− 988	− 1.83	− 1750.23	− 3.25	4089	7.58	307.26	0.57	− 1658.07	− 3.1
2010–2020	− 7030	− 13.0	− 3759.66	− 6.97	11,294.4	20.95	− 2297.88	− 4.26	1793.16	3.33
1991–2020	− 7353.8	− 13.6	− 8694.26	− 16.1	17,341.0	32.16	− 1490.94	− 2.77	198	0.37
Bahir Dar										
1990	12,009.8	56.27	2445.48	11.46	2087.91	9.78	4280.49	20.05	520.2	2.44
2000	10,491.84	49.16	3979.26	18.64	2609.73	12.23	3732.3	17.49	530.73	2.49
2010	10,756.9	50.40	3268.44	15.31	2966.67	13.90	3805.38	17.83	546.48	2.56
2020	7103.43	33.28	2623.41	12.29	4803.12	22.50	6401.79	29.99	412.11	1.93
Total	21,343.88		21,343.88		21,343.88		21,343.88		21,343.88	
1990–2000	− 1517.96	− 7.11	1533.78	7.19	521.82	2.44	− 548.19	− 2.57	10.53	0.05
2000–2010	265.06	1.24	− 710.82	− 3.33	356.94	1.67	73.08	0.34	15.75	0.07
2010–2020	− 3653.47	− 17.1	− 645.03	− 3.02	1836.45	8.60	2596.41	12.16	− 134.37	− 0.6
1990_2020	− 4906.37	− 22.9	177.93	0.83	2715.21	12.72	2121.3	9.94	− 108.09	− 0.5

Year	UA (ha)	%	BL (ha)	%	BU (ha)	%	UFG (ha)	%	W (ha)	%
Adama										
1990	5902.20	53.89	1411.20	12.88	1723.77	15.74	1799.28	16.43	116.50	1.06
2000	6038.46	55.13	1242.99	11.35	2125.44	19.41	1122.30	10.25	270.00	2.47
2010	6679.71	60.99	864.90	7.90	2279.16	20.81	1052.01	9.60	230.85	2.11
2020	3815.46	34.83	911.79	8.32	3875.04	35.38	2247.39	20.52	103.23	0.94
Total	10,952.95		10,952.95		10,952.95		10,952.95		10,952.95	
1991–2000	136.26	1.24	− 168.21	− 1.54	555.39	5.07	− 676.98	− 6.18	153.50	1.40
2000–2010	641.25	5.9	− 378.09	− 3.45	153.72	1.40	− 70.29	− 0.64	− 39.15	− 0.4
2010–2020	− 2864.25	− 26.2	46.89	0.43	1595.88	14.57	1195.38	10.91	− 127.62	− 1.2
1991–2020	− 2086.74	− 19.1	− 499.41	− 4.56	2151.27	19.64	448.11	4.09	− 13.27	− 0.1
Hawassa										
1990	6613.92	39.98	969.75	5.86	1072.62	6.48	7258.77	43.87	629.73	3.81
2000	3473.37	20.99	1639.17	9.91	1420.83	8.59	9464.94	57.21	546.48	3.30
2010	6538.95	39.52	1630.17	9.85	1752.84	10.59	6276.69	37.94	346.14	2.09
2020	5070.15	30.64	611.01	3.69	3672.27	22.20	6750.81	40.80	440.46	2.66
Total	16,544.79		16,544.79		16,544.79		16,544.79		16,544.79	
1990–2000	− 3140.55	− 18.9	669.42	4.05	348.21	2.10	2206.17	13.3	− 83.25	− 0.5
2000–2010	3065.58	18.53	− 9.00	− 0.05	332.01	2.01	− 3188.25	− 19.2	− 200.34	− 1.2
2010–2020	− 1468.80	− 8.88	− 1019.16	− 6.16	1919.43	11.60	474.12	2.87	94.32	0.57
1990_2020	− 1543.77	− 9.33	− 358.74	− 2.17	2599.65	15.71	− 507.96	− 3.07	− 189.27	− 1.1

UA Urban Agricultural, *BA* Bare land, *BU* Built up area, *UFG* Urban forest & greenery, *W* Water ecosystem

Table 5 Land use land cover transition matrix of major changes (ha) in cities of Ethiopia (1990–2020)

LULC-2020	UA	BL	BU	UFG	W	Total 1990	% total	Loss	UA	BL	BU	UFG	W	Total 1990	% total	Loss
Addis Ababa									**Adama**							
Urban agricultural	**8452**	236.52	10,431	713.52	1213.7	21,046.9	37.79	12,594.9	**2431.6**	572.94	2171.1	706.5	20.07	5902.2	53.8	3470.58
Bare land	4578.7	**760.41**	5634.8	509.4	428.94	11,912.2	21.39	7333.56	706.5	**127.44**	363.78	208.44	5.04	1411.2	12.9	704.7
Built up area	1089	118.08	**9867.1**	711.63	821.16	12,606.9	22.64	11,517.9	212.22	112.95	**1120.2**	261.72	16.65	1723.8	15.7	1511.55
UF&G	649.44	319.59	2095.4	**3426.7**	515.88	7006.95	12.58	6357.51	454.23	94.77	204.84	**1019.8**	25.65	1799.3	16.4	1345.05
Water	694.26	13.14	1919.4	154.8	**335.34**	3116.97	5.6	2422.71	10.89	14.8	15.12	50.94	**35.82**	127.57	1.16	116.68
Total 2020	15,463	1447.74	29,948	5516	3315	**22,841.5**[a]			3815.5	922.9	3875	2247.4	103.2	**4734.9**[a]		
% total	27.77	2.6	53.78	9.9	5.95	**55,690**			34.8	8.42	35.34	20.5	0.94	**10,964**		
Gain	7011.4	687.33	20,081	2089.4	2979.6				1383.8	795.46	2754.8	1227.6	67.41			
Net change [b]	− 5583.5	− 6646.2	8562.9	− 4268.2	556.92				− 2087	90.76	1243.3	− 117.5	− 49.3			
Net persistence (NP)	− 0.66	− 8.74	0.87	− 1.25	1.66				− 0.86	0.71	1.11	− 0.12	− 1.38			
Direction of change	− 10.03	− 18.79	31.14	− 2.68	0.36				− 19.03	− 4.45	19.62	4.09	− 0.22			
Bahir Dar									**Hawassa**							
Urban Agricultural	**5264.3**	1875.9	2651.5	2199.8	18.4	12,009.8	56.3	6745.5	**2732.4**	354.5	2075.4	1438.5	13.1	6613.9	18.3	3881.5
Bare land	715.6	**211.9**	715.1	793.8	9.2	2445.5	11.5	1729.9	348.1	**152.0**	20,018.6	60.8	12.5	20,592.0	56.9	20,243.9
Built up area	400.3	248.0	**731.1**	675.7	32.9	2087.9	9.8	1687.6	157.0	53.0	**796.6**	34.8	31.2	1072.6	3.0	915.7
UF&G	722.5	286.4	679.1	**2517.2**	75.3	4280.5	20.1	3558.0	1723.1	51.5	402.6	**4981.8**	99.8	7258.8	20.1	5535.6
Water	0.7	1.4	26.5	215.3	**276.4**	520.2	2.4	519.5	109.5	0.0	1.4	235.0	**283.8**	629.7	1.7	520.2
Total 2020	7103.4	2623.4	4803.1	6401.8	412.1	**9000.8**[a]			5070.2	611.0	23,294.6	6750.8	440.5	**8946.5**[a]		
% total	33.3	12.3	22.5	30.0	1.9	**21,343.9**			14.0	1.7	64.4	18.7	1.2	**36,167.0**		
Gain	1839.2	2411.6	4072.1	3884.6	135.7				2337.8	459.0	22,498.0	1769.0	156.7			
Net change[b]	− 4906.4	681.7	2384.5	326.6	− 383.8				− 1543	− 19,784	21,582	− 3766	− 363			
Net persistence (NP)	− 0.9	3.2	3.3	0.1	− 1.4				− 0.6	− 130.2	27.1	− 0.8	− 1.3			
Direction of change	− 23.0	0.8	12.7	9.9	− 0.5				− 4.3	− 55.2	61.4	− 1.4	− 0.5			

Bolded diagonal elements represent proportions of each land-use/cover class that were static (persisted) between 1990 and 2020. The loss column and gain row indicate the proportion of the landscape that experienced gross loss and gain in each class, respectively. All the figures in the table are in percent except Np, which is a ratio

[the] bolded figure is the sum of diagonals and represents the overall persistence

[b] Net change = gain–loss

Np refers to the net change to persistence ratio (i.e., net change/diagonals of each class)

UA: Urban agricultural land, BL: bare land, BU: built up, UF&G: urban forest and greenery, and W: water

Table 6 Annual Increase (AI) and Annual Growth Rate (AGR) of each city

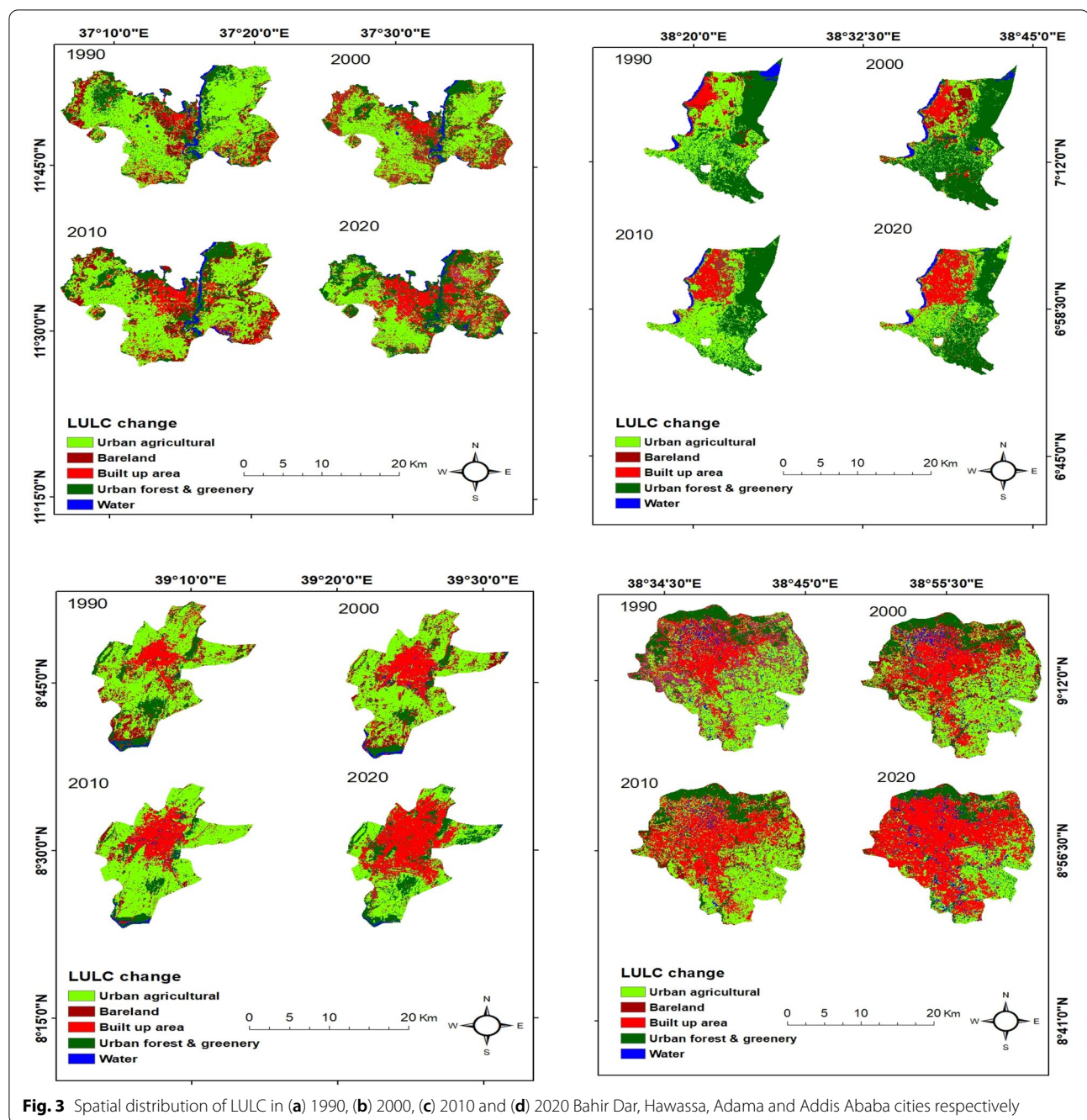| AI (ha)	1990–2000	2000–2010	2010–2000	Average
Addis Ababa	195.76	408.90	1129.44	578.03
Hawassa	52.18	35.69	183.65	90.51
Adama	40.17	15.37	159.59	71.71
Bahir Dar	34.82	33.20	191.94	86.66
AGR (%)	1990–2000	2000–2010	2010–2000	Average
Addis Ababa	27.68	41.54	77.43	46.89
Hawassa	38.14	25.63	78.93	47.57
Adama	36.27	18.51	87.90	47.56
Bahir Dar	46.39	36.34	131.54	71.42

land (negative), urban forest, and greenery (negative), and built-up land (positive). Overall, 22,841.5 ha of the total ecosystem remains unaffected (Table 5). Moreover, the mass land of the dynamics was shown from urban agriculture to build up, as compared to other land uses. Besides, in Adama, water bodies experienced the least persistent, whereas urban built-up and bare land was the most persistent ecosystem type (Table 5). The net change in persistence ratio was large for water body (negative), urban agriculture land (negative), urban forest and greenery (positive), and built-up land (positive). Overall, 9000.8 ha of the total landscape remains unaffected (Table 5).

with the highest persistence in urban agriculture, ecosystem (60%) and that with the highest loss is urban forest and greenery (70%). Whereas built-up ecosystem has shown low persistence and losses, but a higher gain percentage. Overall, the results show that 53% of Bahir Dar and 48% of Hawassa urban ecosystems remained unchanged over the 1990–2020 periods. On the other hand, 47% of Bahir Dar and 52% of Hawassa LULC changed during 1990–2020. This indicates that there is a higher rate of LULC dynamics in Hawassa city than in Bahir Dar city in the last four decades (Tables 4 and 5: Fig. 3).

In Addis Ababa, bare land experienced the least persistent, whereas urban built-up was the most persistent ecosystem type (Table 5). The net change in persistence ratio was large for bare land (negative), urban agriculture

Spatial patterns of land use land cover change

The spatial distribution LULC dynamics have been scrutinized in four phases, such as 1990–2000, 2000–2010, 2010–2010, and 1990–2020 to explore the changes that took place among the ecosystems (Figs. 3 and 4). Spatial patterns of ecosystem types in the cityscapes level had shown "urban agriculture > urban forest and greenery > bare land / open space > built up" from urban agricultural and/or forest ecosystem to multi-complex human-made built up an ecosystem (Figs. 3 and 4). Generally, Bahir Dar and Adama cities were manifested by a mono-nuclei agglomerating from their urban center, and two secondary nuclei rapidly stretched out after 2010, forming a tri-core urbanization pattern (Fig. 4a, d). Addis Ababa and Hawassa cities have shown a multicore urban agglomeration and new development was sprinkled

Table 7 Land use dynamic degree (SLUDD and ILUDD) in cities from 1900 – 2020 (%)

Cities	Addis Ababa city				Bahir Dar city			
LULC type/year	1990–2000	2000–2010	2010–2020	1990–2020	1990–2000	2000–2010	2010–2020	1990–2020
Urban agricultural	0.32	− 0.46	− 3.39	− 1.20	− 1.26	0.25	− 3.40	− 1.36
Bare land	− 3.14	− 2.52	− 7.22	− 2.96	6.27	− 1.79	− 1.97	0.24
Built up area	1.55	2.81	6.05	7.48	2.50	1.37	6.19	4.33
Urban forest & greenery	0.71	0.41	− 2.94	− 0.73	− 1.28	0.20	6.82	1.65
Water	0.20	− 5.21	11.78	− 0.89	0.20	0.30	− 2.46	− 0.69
ILUDD	− 0.36	− 4.97	3.07	1.70	6.43	0.33	5.18	4.17
Cities	Adama city				Hawassa city			
LULC type/year	1990–2000	2000–2010	2010–2020	1990–2020	1990–2000	2000–2010	2010–2020	1990–2020
Urban agricultural	0.23	1.06	− 4.29	− 1.18	− 4.75	8.83	− 2.25	− 0.78
Bare land	− 1.19	− 3.04	0.54	− 1.18	6.90	− 0.05	− 6.25	− 1.23
Built up area	2.33	0.72	7.00	4.16	3.25	2.34	10.95	8.08
Urban forest & greenery	− 3.76	− 0.63	11.36	0.83	3.04	− 3.37	0.76	− 0.23
Water	13.18	− 1.45	− 5.53	− 0.38	− 1.32	− 3.67	2.72	− 1.00
ILUDD	10.78	− 3.33	9.09	2.25	7.12	4.07	5.93	4.83

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Fig. 3 Spatial distribution of LULC in (**a**) 1990, (**b**) 2000, (**c**) 2010 and (**d**) 2020 Bahir Dar, Hawassa, Adama and Addis Ababa cities respectively

across all directions from the initial period of urbanization in 2020 (Fig. 4b, c). Particularly, the built-up ecosystem growth of Addis Ababa concerted mainly in the northwest, which was the initial economic zone of the city, and then stretched to the southwest parts of the city over 2010, due to the new house development program by the city government.

Extent and rates of urban agglomeration

During the 1990s, urban agricultural land, and urban forest and greenery were predominant ecosystem types in all cities. Built-up and water bodies accounted for the comparatively small ecosystem (Table 6 and Fig. 5). However, in 2020 the ecosystems were substantially declined concurrent with the significant increases in urbanization throughout the cities. The Annual Increase (AI) of urbanization of Addis Ababa

Fig. 4 Spatial patterns and LULC change transition of cities from 1990 to 2020
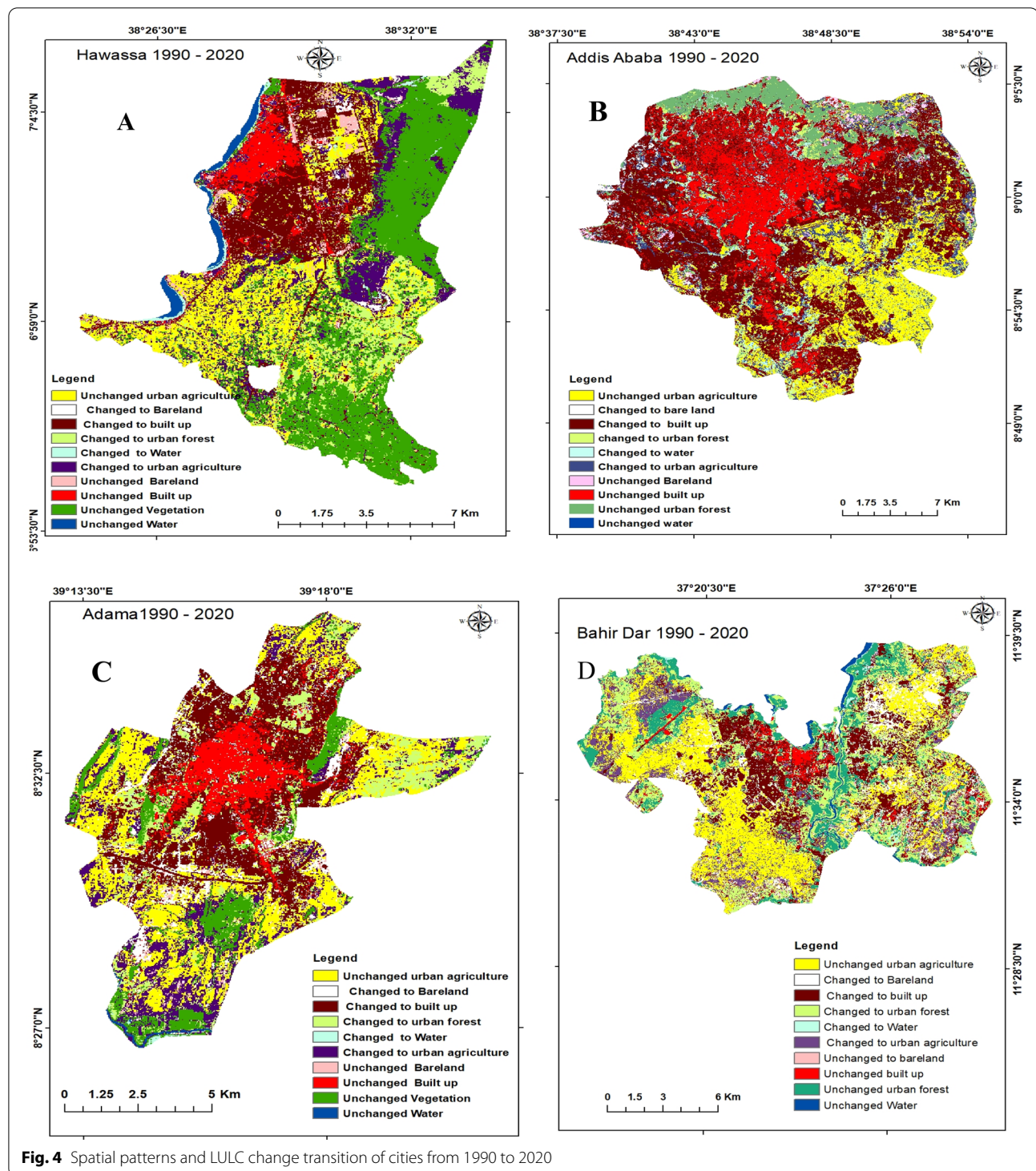
city constantly augments from 1990 to 2020 while, cities like Hawassa, Adama, and, Bahir Dar were declined substantially to 35.69 ha, 15.37 ha, and 33.20 ha in the second period of 2000–2010 respectively and exponentially augmented between 2010 and 2020. Moreover, after removing the effect of city size, the annual

spreading out rate (AGR) of Addis Ababa city has become 48.89%, and the Bahir Dar city was substantially increased by 71.42%. For all cities, the AGR was the highest during the 2010–2020 period of the past three decades. During 2000–2010, Hawassa, Adama and, Bahir Dar cities reached their lowest expansion

Fig. 5 Size and percentage contribution of each of five ecosystem types in each city and the total study area
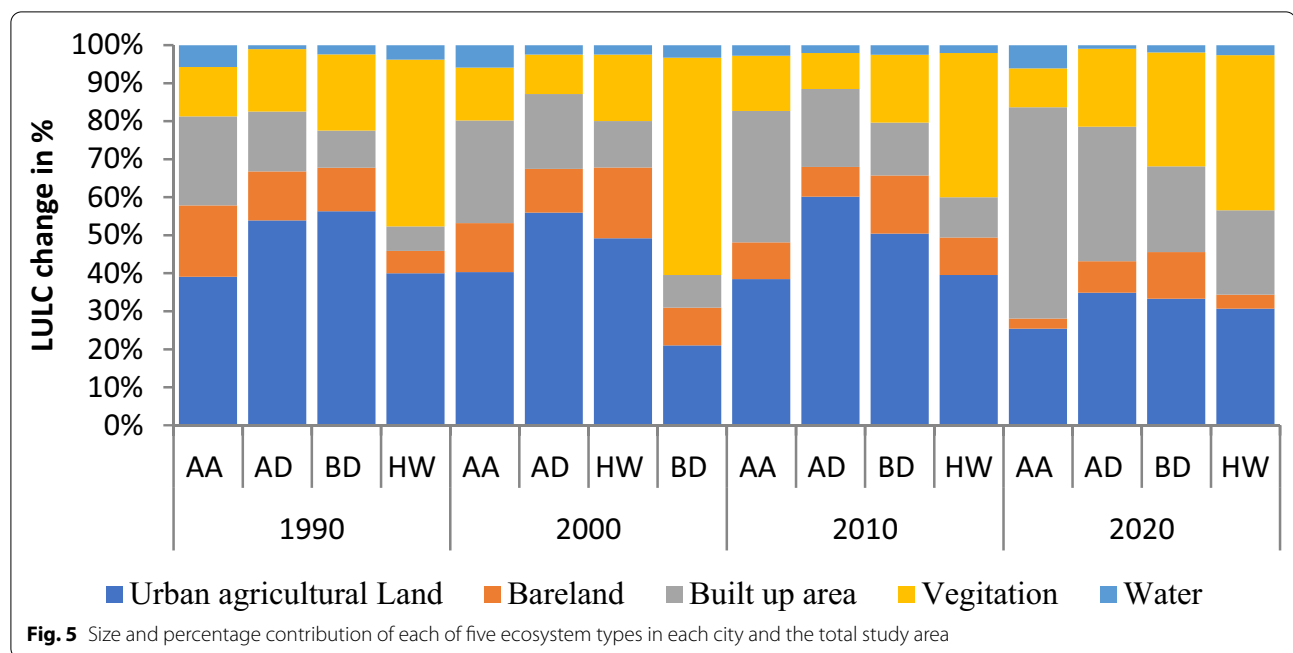
rate over the past three decades, while the AGR of Bahir Dar was double the AGR of other cities in 2010–2020 (Table 6). This shows that the dynamics degree of the none built-up area upsurge in built-up land in the last 10 years has accelerated, as the result of new housing construction strategies of the country and illegal shifting bare land and urban agriculture to build up.

Temporal and spatial analysis of SLUDD, ILUDD, LUI, and LUD

Single land use dynamic degree (SLUDD) result shows that a substantial variation between the cities in the past three decades. The highest SLUDD was identified for building up ecosystem type in Bahir Dar city (8.08%) followed by Addis Ababa, Adama, and Hawassa cities respectively (Fig. 6). On the other hand, urban agriculture declined by 22.99% in Bahir Dar city, followed by Adama and Addis Ababa cities by 19.05% and 13.64% respectively. The SLUDD of bare land (open space) was decreased annually by 16.20%, 4.56%, and 3.07% in Addis Ababa, Adama, and Hawass cities, and most of the portions were converted to build up an ecosystem. However, the SLUDD value of urban forests and greenery was augmented in Adama and Hawassa cities by 1.65% and 0.83% (Fig. 6).

Conversely, from 1990 to 2020, the ILUDD in Addis Ababa, Bahir Dar, Adama, and Hawassa cities were 1.7%, 4.17%, 2.25%, and, 4.83% respectively (Table 7). Moreover, the ILUDD was highest in the first period (1990 to 2000) of the study in Bahir Dar, Adama, and Hawassa cities. This indicated that cities experienced rapid land-use

dynamics during this period, with the ILUDD at 6.43%, 10.78%, and 7.12%. While it was negative in Addis Ababa city (0.36%). After 2000, the ILUDD negatively declined, and it was the lowest from 2000 to 2010 at 4.97%, 3.3%, and 3.33% degree in Addis Ababa, Bahir Dar, Adama cities. Besides, comparing the dynamics degree in different LULC types, the conversion rate of the built-up ecosystem, water bodies, and urban forest and greenery were significantly high, whereas the urban agricultural ecosystem and, bare land exhibited a reduced trend.

The SLUDD of built up of all cities has shown a linear continuously increasing trend from 1990 to 2020 (7.48%, 4.33%, 4.16%, and 8.08% in Addis Ababa, Bahir Dar, Adama, and Hawassa, respectively), while a continuous negative reduction was found in the dynamic in farmland 1.20%, 1.36%, 1.18%, and 0.78% in Addis Ababa, Bahir Dar, Adama, and Hawassa, in that order). The spatial transformation in land use dynamics was meticulously associated with urbanization. Between 1990 and 2020, the ILUDD of Hawassa city in the central part was considerably higher than in other parts of the city and expand to northeastern and southeastern parts of the city (Fig. 7).

The overall dynamics LUIs of each city in the years 1990–2020 were 3.31, 4.82, 5.04, and 3.56, for Addis Ababa, Hawassa, Adama, and Bahir Dar cities respectively. In all cities, LUIs growing tendency was found from 1990 to 2000 at a growth rate of 4%. However, the magnitude of the growth rate of LUI was slightly increased with the rate of 15% in the period of 2000 to 2010 and 23% in the period of 2010 to 2020, and 42%, and

Fig. 6 The percentage of the SLUDD of LULC in cities. *AA: Addis Ababa, AD: Adama, BD: Bahir Dar and HW: Hawassa, UA: Urban agriculture, BL: bare land, BU: built up, W: water, and UF&G: urban forest & greenery
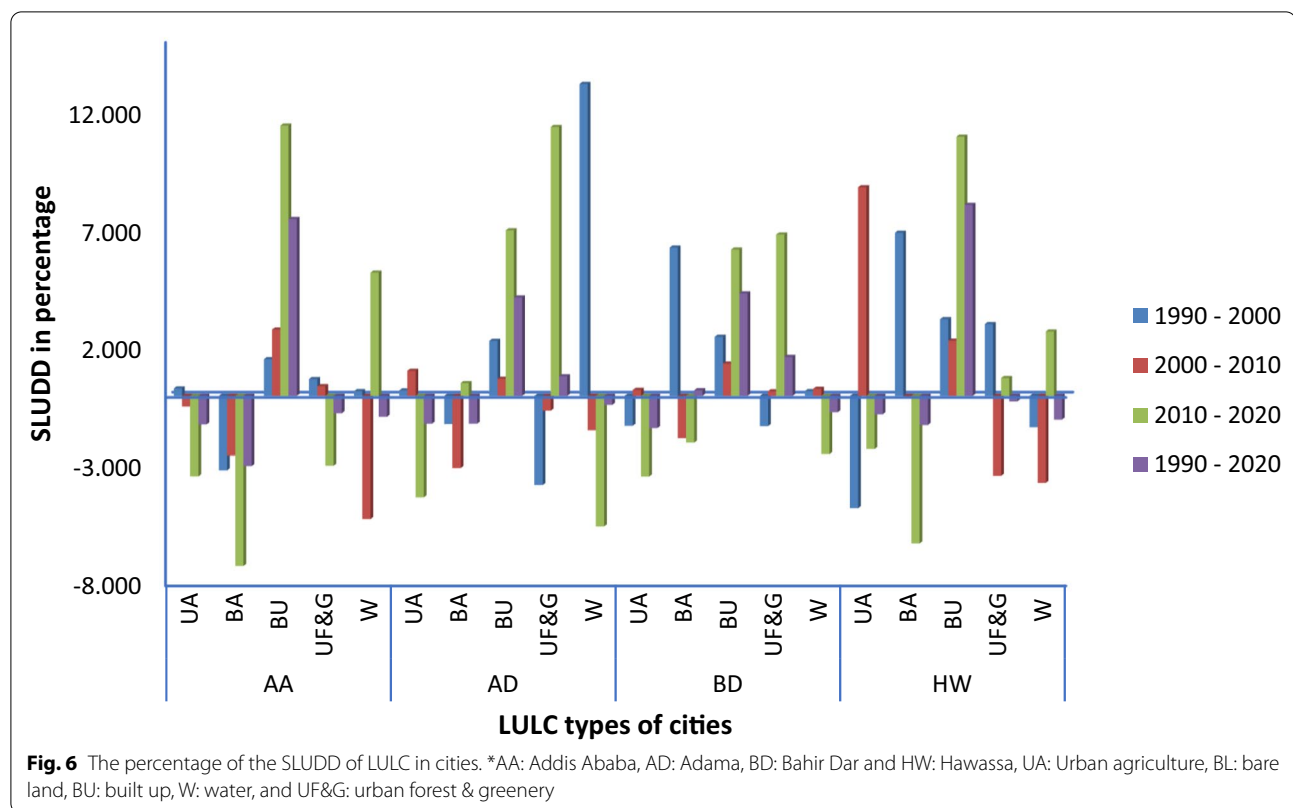
overall augmented by 42% from 1990 to 2020 (Table 6). The results also show that both the land-use intensity and the growth rate continued to increase from 1990 to 2020. The spatial distribution of LUI change during these study periods demonstrated significant consistency with ILUDD in Ethiopian cities (Fig. 7). Moreover, cities with rapid economic development in Ethiopia commonly have high input and high output on land, cities with higher LUI increases were mainly located in rapidly developing economic cities.

The high-value ecosystem of ILUDD was found in the urban center and then augmented to the north and southwest parts of Addis Ababa city. The northern part was dominated by urban forest and greenery, and the economic development was slower than that of other parts. Adama city that experienced higher ILUDD between the periods 1990–2020 was mainly distributed on the northeast and southeast parts also saw the rapid land-use change, mainly caused by rapid urbanization and expansion of industrial zones. Moreover, Bahir Dar city also saw a rapid land-use change with higher ILUDD were mainly located in central with the bi-fractured direction of the city (Fig. 8).

Discussion
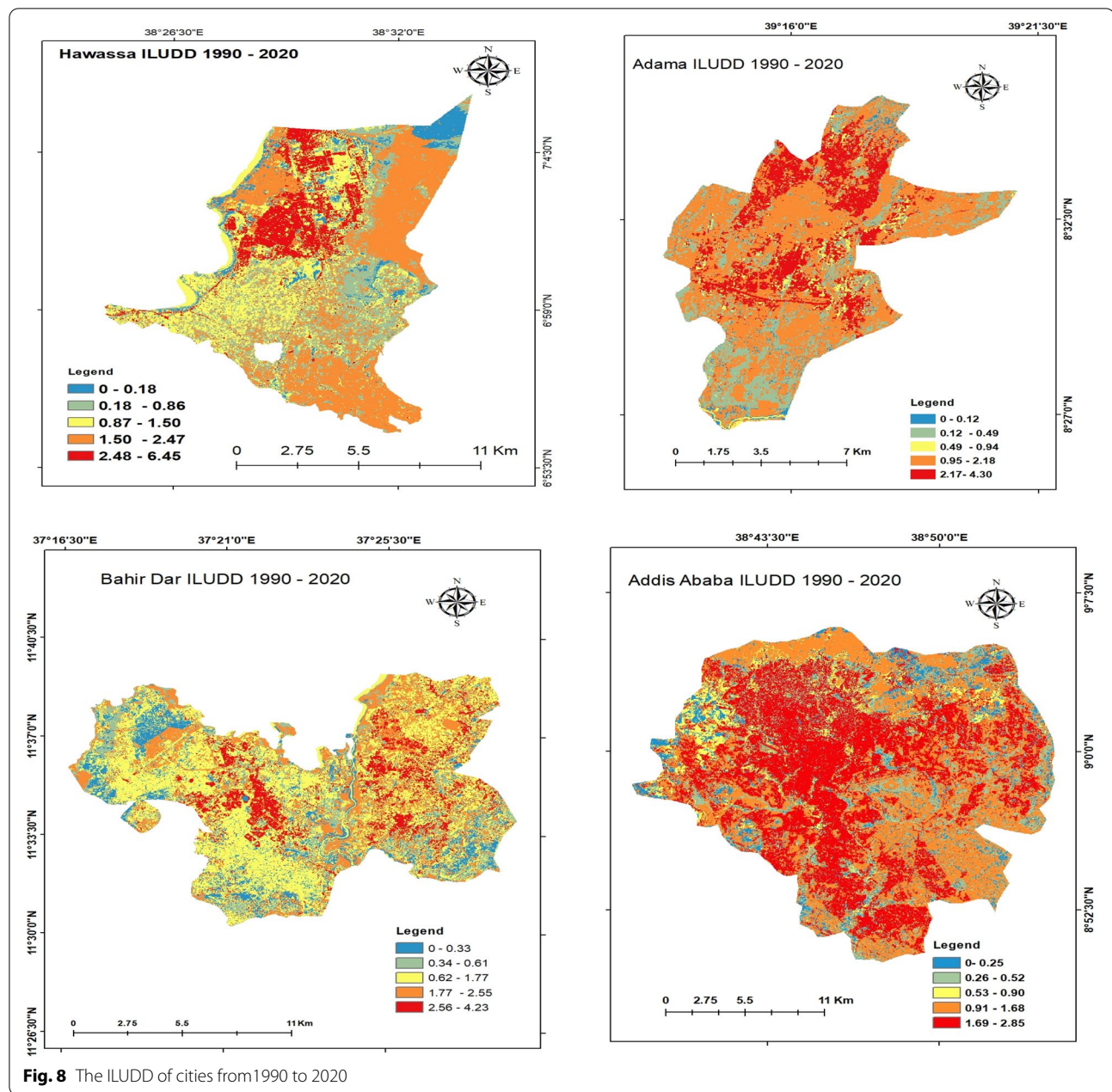### Comparisons of spatial–temporal urban agglomeration and possible drivers
On account of rapid urbanization, large scale rural–urban population migrations, an illegal settlement in and around cities, and unplanned utilization of urban ecosystem have occurred since 1990, the urban ecosystems configuration and physical morphology are significantly changed in Ethiopia (Larsen et al. 2019; Terfa et al. 2019; Wubie et al. 2020). In addition, rapid economic development, and inconsistence reform, and implementation of urban land policy, have led to dynamics in the land use of cities of Ethiopia (Woldegerima et al. 2017; Kinfu et al. 2019; Bulti and Abebe 2020). Overall, LULC change in the urban ecosystem is strongly an anthropogenic-driven process (Peng et al. 2016; Mamat et al. 2018; Das and Das 2019). Notwithstanding the rapid urban agglomeration of study periods (1990–2020), the spatiotemporal configurations significantly varied among the cities of Bahir Dar, Addis Ababa, Adama, and Hawassa and within the cities. Specifically, the urban ecosystem of Addis Ababa augmented 2.4 times Adama, and 3.54 and 11.23 folding of Bahir Dar, and Hawassa cities respectively while that of Adama, Bahir Dar, and Hawassa cities augmented by 2.25%, 2.3%, and 3.42%, in that order. Additionally,
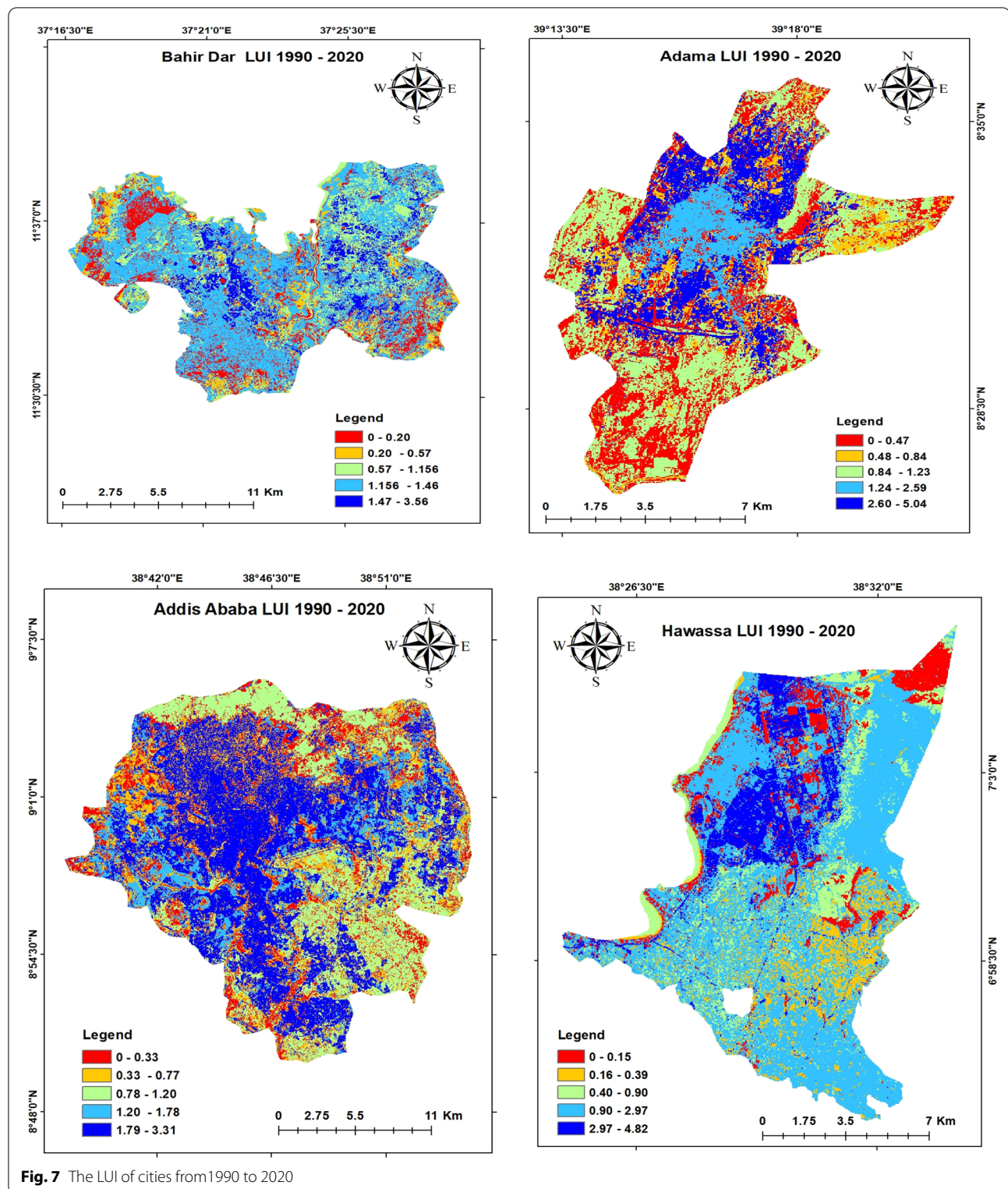
Fig. 7 The LUI of cities from 1990 to 2020

the direction, pattern, and location of urban spreading out in each city have been mainly connected with discrepancies in their illegal settlement in and around cities and unplanned utilization of urban ecosystem, administrative conditions, loopholes of the nation's land policy inter alia, and urban master plans (Kinfu et al. 2019; Larsen et al. 2019; Admasu et al. 2020; Bulti and Abebe 2020; Wubie et al. 2020).

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Fig. 8 The ILUDD of cities from 1990 to 2020

Overall, the present study confirmed that cities expanding horizontally with different intensities, land use diversity, and followed urban agriculture → bare land → urban forest and greenery → build up an ecosystem pattern of dynamics. For example, in the case of Addis Ababa, the presence of the Entoto Mountain in the northern part is limited to the outskirt pattern to the eastern, southern, and southwest directions (Figs. 7 and 8). While due to the appearance of lake Tanna and Abayi river the agglomeration of the Bahir Dar is fractured into two parts and shows an unpredicted pattern. Moreover, because of the

existence of Lake Hawassa of the western, and Mountain in the south direction, the spreading out of Hawassa determined to the northeast, east, and southeast parts (Figs. 7 and 8). Conversely, in the case of Adama, because of the occurrence of the mountain along the east direction, the city expands towards north, northeast, and southwest directions (Figs. 7 and 8). The finding is coherent with the recent study in Addis Ababa (Larsen et al. 2019), Hawassa city (Kinfu et al. 2019), Adama (Bulti and Abebe 2020), and Bahir Dar (Wubie et al. 2020). While

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the priority of driving factors and urban growth pace inversely proportional to each other.

Dynamics between land uses

The result of this study exhibited that a significant slice of the landscapes in each city exposed to changes in land use and land covers. Built-up development, the most outstanding incident, is most related to large-scale deterioration in urban agricultural land. This is maybe happening as the result of secondary land use dynamics and shows a dissimilar trend in that, most studies reported built-up upsurge at the expense of urban forest ecosystem (Gashu and Gebre-Egziabher 2018; Kinfu et al. 2019; Larsen et al. 2019; Azagew and Worku 2020; Fitawok et al. 2020; Zou and Wang 2021). Moreover, the loss rate of urban forest and greenery was also high, mainly in ecosystems which are found as fragmented in around urban agricultural ecosystem and border area of the cities. Additionally, the transition of urban agriculture and/ or urban forest change was slightly varying before and after the first and second periods of study (Table 4). Earlier 1990 to 2000, urban agricultural/ forest land expansion into built-up had fast rate than 2000 to 2010 and had a very slow rate that of 2010 to 2020 (Larsen et al. 2019). In the final periods, the devastating increase of ecological land into built up to fulfill the need for housing and urban facilities for the residents. Overall, urban landscape transitions are multiple factored and irreversible dynamics.

Urban ecosystem growth and direction

Studying where active urbanization has to exists and at what pattern and orientations are very vital for ecological land management and resilience (Rimal et al. 2018, 2019; Bahers et al. 2019; Larsen et al. 2019). Since the city centers are mostly the active hub of socioeconomic and human-ecological land interaction. In the present work, city expansion started from the urban centers then rapidly expand to all directions of ecological land (Figs. 7 and 8). Additionally, the overall ILUDD analysis shows that all cities have positive expansion rates in all orientations with a concentration on the newly converted ecosystem (Table 3). Moreover, during the first phase of the study, the ILUDD was highest in Bahir Dar, Adama, and Hawassa cities. This shows that cities experienced rapid urban development, While, it was lowest in Addis Ababa city (− 0.36%). Later, the ILUDD negatively declined, and the city center-based orientations of urban growth were observed. This is possibly associated with the declining trend of socio-economic development of the country (Minta et al. 2018; Kinfu et al. 2019; Larsen et al.

2019; Bulti and Abebe 2020). Besides, LUI resalt shows the degree of the human interface on ecological land dynamics because intensity analysis shows the association between socioeconomic factors and the magnitude of impacts of each land-use type. Thus, the spatial distribution of LUI change during these study periods demonstrated significant consistency with ILUDD in Ethiopian cities (Fig. 7). Moreover, cities with rapid economic development in Ethiopia commonly have high input and high output on ecological land, cities with higher LUI increases were mainly located in rapidly developing economic cities (Huang et al. 2018; Shao et al. 2020).

Implications for planning and sustainable development

Our assessments of the dynamics of LULC change result play a significant role in the urban ecological land study providing empirical pieces of evidence that can work for cities resilient and sustainable development purposes. Additionally, it will serve as a baseline to compare and estimate the extent of urban landscape change, and open discussion during urban policy preparations, and indifferent features of intervention strategies for green city resilience. Besides, if the one applied the output of this work in other countries, it would be filling some gaps of existing literature and indicated the need for an integrated ecological land management approach to regulate human activities and restore previously degraded ecological land by following think globally and act locally approach.

Conclusions

The present study analyzed the dynamics between land and urbanization of four rapidly developing cities of Ethiopia from an economical value and spatial point of view. There were substantial dynamics in the urban to the built-up ecosystem of each city over the study period, and the overall magnitude of the spatial pattern was followed "urban agriculture > urban forest and greenery > open space > built up" from urban agricultural to the multi-complex human-dominance ecosystem, with a significant influence on ecological land and ecosystem services provides. Moreover, the direction, pattern, and location of urban spreading out in each city have been mainly connected with discrepancies in their illegal settlement in and around cities and unplanned utilization of urban ecosystem, administrative conditions, loopholes of the nation's land policy inter alia, and urban master plans. Notwithstanding, the rapid urban agglomeration of study periods the spatiotemporal configurations significantly varied among

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the cities. In all cities, better use of existing ecological land resources needs a holistic land-use policy and strategic planning that ensure both economic and environmental benefits.

Abbreviations
ESs: Ecosystem services; ESV: Ecosystem serves valuation; LUD: Land-use diversity; LUI: Land-use diversity; ILUDD: Integrated land use a dynamic degree; LULC: Land use land cover; AA: Addis Ababa; BD: Bahir Dar; HW: Hawassa; AD: Adama; AGR: Annual Growth Rate.

Authors' contributions
All authors equally contribute in designed, conducted reviews, analyzed the data, and drafted and writing manuscripts. All authors read and approved the final manuscript.

Availability of data and materials
The datasets analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
There is no ethical conflict.

Consent for publication
All authors read the manuscript and agreed to publication.

Competing interests
The authors declare that they have no competing interests.

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