Impact of landscapes Dynamics and Intensity on Ecological Land in Major Ethiopia Cities

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Research Article

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Impact of landscapes dynamics and intensity on ecological land in major Ethiopia cities

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Abstract

Background: Understanding the dependence of ecological land to dynamics of human-nature-coupled landscape is crucial for urban ecosystem resilience. The aim of present study is, explored and compared the spaciotemporal responses of ecological land to urban landscape dynamics in Bahir Dar, Addis Ababa, Adama and Hawassa cities for the last three decades (1990–2020). Three sets of Landsat satellite images from 1990 to 2020 and four urban land indexes were used to produce landscape maps and geospatial data analysis.

Result: The result analysis showed the substantial expansion in built up ecosystem which was manifested at the cost of ecological land. The built-up ecosystem totaled 17,491.2ha in 1990, which augmented to 42,298ha (141.8%) in 2020 with an average annual growth rate of 33.73%. 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 open space ecosystem. Besides, land use intensity (LUI) of each city in the years 1990 - 2020 were Addis Ababa (3.31), Hawassa (4.82), Adama (5.04), and Bahir Dar (3.56). Moreover, Integrated land use dynamics degree (ILUDD) was for Addis Ababa (1.7%), Bahir Dar (4.17%), Adama (2.25%) and Hawassa (4.83%). This confirmed that the spatial distribution LUI was significant consistency with ILUDD in all cities.

Conclusions: LUI dynamics pattern was followed "urban ecological land to multi-complex human-dominance ecosystem, with a significant 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 for ensure economic development and ecosystem resilience.

Keywords: *ecological land, landscape transitions, cities resilience, sustainable development*

1. Introduction

Urbanization and associated massive landscape change has led a substantial change on the quantity composition, structure, and function of ecological land (Liu et al., 2020a; Talukdar et al., 2020; Wangai et al., 2019) while, boosted the formation of human-dominated or human-nature-coupled ecosystems (Chen et al., 2021; Hu et al., 2019; Zhang et al., 2013; Zhang et al., 2018). During the past decades, most cities have experienced remarkable urban-rural expansion, mainly due to population growth and migration from rural to urban areas. According to Ye et al. (2018) 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 (Das and Das, 2019; Seto et al., 2012). Thus, these urbanization scenarios and its inference to ecological land dynamics particularly in rapidly developing cities and surrounding ecosystems are becoming as a common issue in policy discussions and scientific analysis (Ha et al., 2020; Mekasha et al., 2020).

In view of, accelerated urban agglomeration in megacities poses huge opportunities and objections for the sustainable development of a countries. For example, megacities become the hubs of technology and business activity while, generate a significant amount of urban metabolic waste and required more scientific and technology based resilient infrastructures and land management strategies than emerging cities. On the other hand, urbanization in the developing world depends on conversion of ecological land to unstainable urban fabric ecosystems. Later, created policy and institutional, socioeconomical, environmental, and technological related challenges (Ahmed et al., 2015; Gashaw et al., 2018; Kindu et al., 2015). Moreover, urbanization and land competition in major cities (Addis Ababa, Adama, Mekella, Bahir Dar, and Hawassa) and other emerging cities of Ethiopia followed similar scenario and will continue for the next few decades due to their uncontrolled fast-growing nature (Bulti and Abebe, 2020; Terfa et al., 2019; Wubie et al., 2020). In contrast, ecological lands (urban forest and greenery water bodies) are being converted to impervious surface and residential, industrial, and commercial systems. Generally, rapid sprawl has created social, economic, and political instabilities that can be attributed to governance and land use policy issues (Bhat et al., 2017; Das and Angadi, 2020; Mohamed and Worku, 2019; Zou and Wang, 2021).

Land dynamic studies are not new issues for Ethiopia. However, studies are mostly spatially limited and concentrated on 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 (Gebrehiwot et al., 2020; Mekasha et al., 2020; Mekuriaw et al., 2020; Temesgen et al., 2018; Tolessa et al., 2017) and single city based (Bulti and Abebe, 2020; Gashu and Gebre-Egziabher, 2018; Kinfu et al., 2019; Larsen et al., 2019; Terfa et al., 2019). Although, LULC dynamics and management vary significantly over time and from ecosystems to ecosystem. In contrast, the present study focused the dynamics in the human – ecological land nexus at different spatial and temporal scales of major active cities of Ethiopia have not studied before in holistic approach. Consequently, the aim of this study is 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 managemental approaches are effective in combating and controlling unsustainable dynamics in cities of Ethiopia for implication of urban ecological land resilience.

2. Material and Methods

2.1 Study area

This study was conducted in Addis Ababa, Hawassa, Adama, and Bahir Dar cities that have a high level of urban expansion, industrialization, and socioeconomic development in Ethiopia (Figure 1 and Table 1). Additionally, the cities were chosen for the study in order to maximize the probability of detecting changes in ecological landscapes due to urban sprawl. The size of four cities comprising the study total area was 102761.3ha.

2.2 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 TM, ETM+, and land OLI), which were retrieved on four distinct dates: 1990, 2000, 2010, and 2020 (Table 2). The images were taken in the dry season to reduce the impact of the cloud on the result. The radiometric correction, geometrical correction, and atmospheric correction of the images were done using the ERDAS 14 software. Later, a supervised (maximum likelihood algorithms) image classification technique was used for LULC classification. More than 50 spectral signatures have been taken as a typical signature for each LULC type, which has been acquired using a GPS device; Google Earth was applied for validation of the LULC type. The number of GCPs for each class was assigned by area proportion of the land uses. The LULC map of each city were categorized into five classes: urban forest and greenery, urban agriculture, urban built, bare, and water (Table 3). The LULC change detection was carried out using spatial automatic overlay analysis and the Zonal Tabulate Area function in ArcGIS version 10.4 to generate the Markov chain transition matrix of the study area. Then, the postclassification process was executed by recoding, majority filtering, clumping, elimination, and mosaicking of the classified maps to reduce errors in the produced maps.

The overall producer's accuracy of LULC maps over the study period of each city (AA, AD, BD, and HW) was 88.03%, 89.48%, 82.80%, and 85.2 respectively; overall user's accuracy of LULC maps over the study period was 88.10%, 89.13%, 82.63% and 87% for cities AA, AD, BD, and HW in that order; the Kappa statistics of each city was 0.84 (AA), 0.86 (AD), 0.78 (BD) and 0.87(HW) respectively. The overall accuracy of the LULC change dataset was 86.71% according to field survey data and records. This result is aligning with the recommended value of many scholars (Ha et al., 2020; Li et al., 2019).

To evidently reveal the spatial relations between LULC change and response for anthropogenic - sustainability in urban ecosystem nexus, we first compute LULC dynamics rate for a specific and integrated LULC transformation of each city and cityscape level from 1990 to 2020 period, using three effective 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 (Chen et al., 2019; Hu et al., 2019; Huang et al., 2019; Liu et al., 2020b; Shao et al., 2020; Song and Deng, 2017; Zorrilla-Miras et al., 2014) followed equation 1 to 4. SLUDD reveals the change rate of a single land use type, while ILUDD estimates the overall situation of land use change rate. 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 socioeconomic circumstances (Chen et al., 2020; Zorrilla-Miras et al., 2014). According to Chen et al. (2019) the intensity of interaction divided in to four (‘open space / bare land, was assigned the weighted value of 1, whereas urban built land was gives 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 in relations to the structure, richness, and complexity of different land use types.

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

$$\boldsymbol{ILUDD = \left(\sum_{i=1}^{n} \Delta LA_{i-j} \,\middle|\, \sum_{i=1}^{n} LA_{(i,t1)}\right) * \frac{1}{T} * 100\%} \quad \textbf{(2)}$$

$$\boldsymbol{LUI = \sum_{i=1}^{4} \frac{LA_{(i,t)}}{\sum_{i=1}^{n} LA_{(i,t)}} * D_i} \quad \textbf{(3)}$$

$$\boldsymbol{LUD = -\sum_{i=1}^{n} \frac{LA_{(i,t)}}{\sum_{i=1}^{n} LA_{(i,t)}} * \ln\left(\frac{LA_{(i,t)}}{\sum_{i=1}^{n} LA_{(i,t)}}\right)} \quad \textbf{(4)}$$

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.

Furthermore, to measure annual urban expansion, we chose and calculated two indexes–Annual Increase (AI) and Annual Growth Rate (AGR) of urban land (Meng et al., 2020; Wu, 2013; 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 (Meng et al., 2020). Indexes used to quantify the urban growth rates are defined using equation 9 and 10.

$$\boldsymbol{AL = \frac{A_{end} - A_{start}}{d}} \quad \textbf{(9)} \qquad \boldsymbol{AGR = 100\% * \left[\left(\frac{A_{end}}{A_{start}}\right)^{\frac{1}{d}} - 1\right]} \quad \textbf{(10)}$$

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 time span of study period (Figure 2).

3. Results

3.1 Land use, land cover dynamics during 1990 - 2020 cities

The spatio-temporal land use dynamics degree of each city with the corresponding proportion is illustrated in Table 3 - 7 and Figure 3. According to our LULC dynamics analysis, a substantial amount of urban ecosystem converted to build up (residential) ecosystem from 1990 to 2020, which was characterized by a net upsurge in building up and a large reduced of urban agriculture and bare land (open space) ecosystem (Figure 4 & 5). In general, the total built-up ecosystem was boosted by 24807.13 ha (141.8%) in the study period. Whereas, urban agricultural ecosystem was reduced by 7353.8 ha (13.63%). Besides, urban forest and greenery ecosystems grow from 20345.49ha in 1990 to 20916ha (2.8%) in 2020, due to the climate-resilient green economy (CRGE) strategies of the cities. On the other hand, the bare land (open space) ecosystem declined by 7.75%, 20.6% for 1990-2000, and 2000-2010 separately and generally dropped by 62.65 % and significant portion it transformed to build up land-use type and its dynamic degree was 20.79% (Table 3). Overall, the bare land category looked to decline and 8732.24ha of areas was changed to build up (residential) during 30 years of our assessment. Furthermore, the annual conversion rate of bare land was 3.28% per year from the 1990 to 2020 period, but the conversion rate was dramatically accelerated by 6.74% per year from 2010 to 2020.

In 1990, the urban agricultural ecosystem was accounted for about a half portion of the total areas of cities (45,572.82 ha) whereas, urban forest and greenery, built-up and, bare (open) land were covered 17,491.2 ha, 20,345.49 ha, and 14,968.43 ha respectively (Table 4). Conversely, the water body was accounted for 5% (4383.4 ha) of the total ecosystem of the cities. Specifically, in 1990 urban agricultural ecosystem was accounted for more than half of the total area in Hawassa city (56.30%) and Adama city (53.90%) followed Bahir Dar (40%), and Addis Ababa city (39.00%) respectively. 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 (Figure 4). On the other hand, built up area was accounted for in Addis Ababa city (23.40%), Adama city (15.70%), Hawassa (9.80%) and, Bahir Dar (6.50%) ascending. In 2000, the total urban agricultural ecosystem was more than two-third of the total cityscapes (41714.77 ha), followed by built-up ecosystem (18637.92 ha), urban forest and greenery (13819.05 ha), and bare land (4310.68 ha). The least ecosystem accounted for by water body (4310.68 ha) (Table 4). Furthermore, the urban agriculture, ecosystem was increased in the Addis Ababa city by 10%, followed by Adama city 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 bare land (open space), the increment was observed in Bahir Dar and Hawassa cities, while the conversion to other types of ecosystem was found in Addis Ababa and Adama cities (Table 3).

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 urban agricultural ecosystem, while the coverage of the urban agriculture in Adam city had shown increment with the cost of bare land utilization. Regarding, the built-up ecosystem, the largest agglomeration was found in the Addis Ababa city 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 3 & 7).

In 2020, the built-up ecosystem accounted a significant proportion in all cities, which accounts for 42298.33ha (more than double that of 1990). Additionally, the built-up ecosystem was augmented by 32.16% in the Addis Ababa city, 19.64% in Adama city, Bahir Dar city (12.72%), and by 15.72% in Hawassa city (Table 3). 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 Hawas cities in that order (Table 3). 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 448.11ha and 2121.3ha in the past three decades. Besides, the size of water bodies was declined in Adama, Bahir Dar, and Hawas cities by 13.27ha, 108.09ha, and 189.27ha in that order.

Furthermore, Table 4 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 least loss is water body (0.1%). In Bahir Dar, the urban ecosystem 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 city and 48% of Hawassa city's urban ecosystem 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 change of LULC dynamics in Hawassa city than in Bahir Dar city in the last four decades (Table 3& 4 and Figure 3).

In Addis Ababa city, bare land experienced the least persistent, whereas urban built up were the most persistent ecosystem type (Table 4). The net change in persistence ratio was large for bare land (negative), urban agriculture land (negative), urban forest, and greenery (negative), and built-up land (positive). Overall, 22841.5 ha of the total ecosystem remains unaffected (Table 4). Moreover, the mass land of the dynamics was shown from urban agriculture to build up, as compared to other land uses. Besides, in Adama city, water bodies experienced the least persistent, whereas urban built up and bare land was the most persistent ecosystem type (Table 4). 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 4).

3.1.1. 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 (Figure 5). 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 (Figure 3 & 5). Generally, Bahir Dar and Adama cities were manifested by a mono-nuclei agglomerating from its urban center, and two secondary nuclei rapidly stretched out after 2010, forming a tri-core urbanization pattern (Figure 5d & a). Addis Ababa and Hawasa cities have shown a multicore urban agglomeration and new development was sprinkled across all directions from the initial period of urbanization in 2020 (Figure 5b & 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.

3.1.2 Extent and rates of urban agglomeration

During the 1990 s, 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 5 & Figure 4). 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 city constantly augments from 1990 to 2020 while, cities like Hawassa, Adama, and, Bahir Dar were declined substantially to 35.69ha, 15.37ha, and 33.20ha in the second period of 2000 -2010 respectively and exponentially augmented between 2010−2020. 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 rate over the past three decades, while the AGR of Bahir Dar was double of the AGR of other cities in 2010 -2020 (Table 5). 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.

3.1.3 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 (residential) ecosystem type in Bahir Dar city (8.08%) followed Addis Ababa, Adama and Hawass cities respectively (Figure 6). On the other hand, urban agriculture declined by 22.99% in Bahir Dar city, followed 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 Hawasa cities by 1.65% and 0.83% (Figure 5).

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 3). 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 lowest 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 built-up ecosystem, water bodies and urban forest and greenery were significantly high, whereas the urban agricultural ecosystem and, bare land (open space) 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 Hawass 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 (Figure 8).

The high-value ecosystem of ILUDD were found in 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 rapid land use change, mainly caused by rapid urbanization and expansion of industrial zones. Moreover, Bahir Dar city also saw rapid land use change with higher ILUDD were mainly located in central with the bi-fractured direction of the city (Figure 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 overall augmented by 42% from 1990 to 2020 (Table 5). 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 Ethiopia cities (Figure 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.

4. Discussion

4.1 Comparisons of spatial temporal urban agglomeration and possible drivers

On account of rapid urbanization, large scale rural-urban population migrations, 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 implement of urban land policy, have led dynamics in land use of cities of Ethiopia (Bulti and Abebe, 2020; Kinfu et al., 2019; Woldegerima et al., 2017). Overall, LULC change in urban ecosystem are strongly an anthropogenic-driven process (Das and Das, 2019; Mamat et al., 2018; Peng et al., 2016). 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 cites. Specifically, the urban ecosystem of Addis Ababa augmented 2.4 times Adama city, 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, 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 (Admasu et al., 2020; Bulti and Abebe, 2020; Kinfu et al., 2019; Larsen et al., 2019; Wubie et al., 2020).

Overall, the present study confirmed that, cities expanding horizontally with different intensity, land use diversity and followed urban agriculture → open space → urban forest ecosystem → build up an ecosystem pattern of dynamics. For example, in the case of Addis Ababa city, the presence of the Entoto Mountain in the northern part is limited the outskirt patter to the eastern, southern, and southwest directions (Figure 7 & 8). While, due to the appearance of lake Tanna and Abayi river the agglomeration of the Bahir Dar city is fractured into two parts and shows unpredicted pattern. Moreover, because of the existence of Lake Hawassa of the western, and Mountain on the south direction, the spreading out of Hawassa city determined to the northeast, east, and southeast parts (Figure7 & 8). Conversely, in the case of Adama city, because of the occurrence of the mountain along the east direction, the city expands towards north, northeast, and southwest directions (Figure 7 & 8). The finding is coherent with the recent study in the Addis Ababa city (Larsen et al., 2019), Hawassa city (Kinfu et al., 2019), Adama city (Bulti and Abebe, 2020) and Bahir Dar city (Wubie et al., 2020). While, the priority of driving factors and urban growth pace inversely proportional to each other.

4.2 Dynamics between land uses

The result of this study exhibited that significant slice of the landscapes in the in each city exposed to changes in land use and land covers. Built up development, the most outstanding incident, is most related with 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 as expense of urban forest ecosystem (Azagew and Worku, 2020; Fitawok et al., 2020; Gashu and Gebre-Egziabher, 2018; Kinfu et al., 2019; Larsen et al., 2019; Zou and Wang, 2021). Moreover, the lost 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 first and second period 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 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 of housing and urban facilities to the residentials. Overall, urban landscapes transitions are multiple factored and irreversible dynamics.

4.3 Urban ecosystem growth and direction

Studying where active urbanization has exist and at what pattern and orientations is very vital for ecological land management and resilience(Larsen et al., 2019; Rimal et al., 2019; Rimal et al., 2018). Since, the cities centers are mostly the active hub of socioeconomic and human- ecological land interaction. In the present work, cities expansion started from urban center than rapidly expand to all direction of ecological land (Figure 7 and 8). Additionally, the overall ILUDD analysis shows that all cities have positive expansion rate in all orientation with concentrated to 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 shown that cities experienced rapid urban development, While, it was lowest in Addis Ababa city (-0.36%). Later, the ILUDD negatively declined, and the cities center-based orientations of urban growth was observed. This is possibly associated to the decline trend of socio-economic development of the country (Bulti and Abebe, 2020; Kinfu et al., 2019; Larsen et al., 2019; Minta et al., 2018). Besides, LUI resalt shows the degree of human interface on ecological land dynamics because intensity analysis shows the association between socioeconomical factors and the magnitude of impacts of each land use types. Thus, the spatial distribution of LUI change during these study periods demonstrated significant consistency with ILUDD in Ethiopia cities (Figure 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).

4.4 Implications for planning for sustainable development

Our assessments of the dynamics of LULC change result play significant role for urban ecological land study providing empirical evidences that can work for cities resilient and sustainable development purposes. Additionally, it will serve as baseline to compare and estimate the extent of urban landscapes change, and open discussion during urban policy preparations, and in different features of intervention strategies for green city resilience. Besides, if the one applied the output of this work other areas, it would be filling some gaps of existing literature.

5. Conclusions

The present study analyzed the dynamics between land and urbanization of four rapidly developing cities of Ethiopia from economical value and spatial point of view. There were substantial dynamics in the urban to built-up ecosystem of each city over the study period, and the overall spatial pattern was followed “urban agriculture → urban forest and greenery → open space → built up” from urban agricultural to 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 the cities. In all cities, better use of existing ecological land resources needs holistic land use policy and strategic planning that ensure both economic and environmental benefits.

Abbreviation

ESs - ecosystem services
ESV- ecosystem serves valuation
LUD - land use diversity
LUI - land use diversity
ILUDD - integrated land use dynamic degree
SLM - spatial lag model
SEM - spatial error model
LULC- land use land cover
AA- Addis Ababa
BD- Bahir Dar
HW- Hawassa
AD- Adama
AGR- Annual Growth Rate

Declarations

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Consent for Publication

All authors read the manuscript and agreed to publication.

Ethics approval and consent to participate

There is no ethical conflict.

Authors' contributions

All authors equally contribute in designed, conducted review, analyzed the data and drafted and writing manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Figures

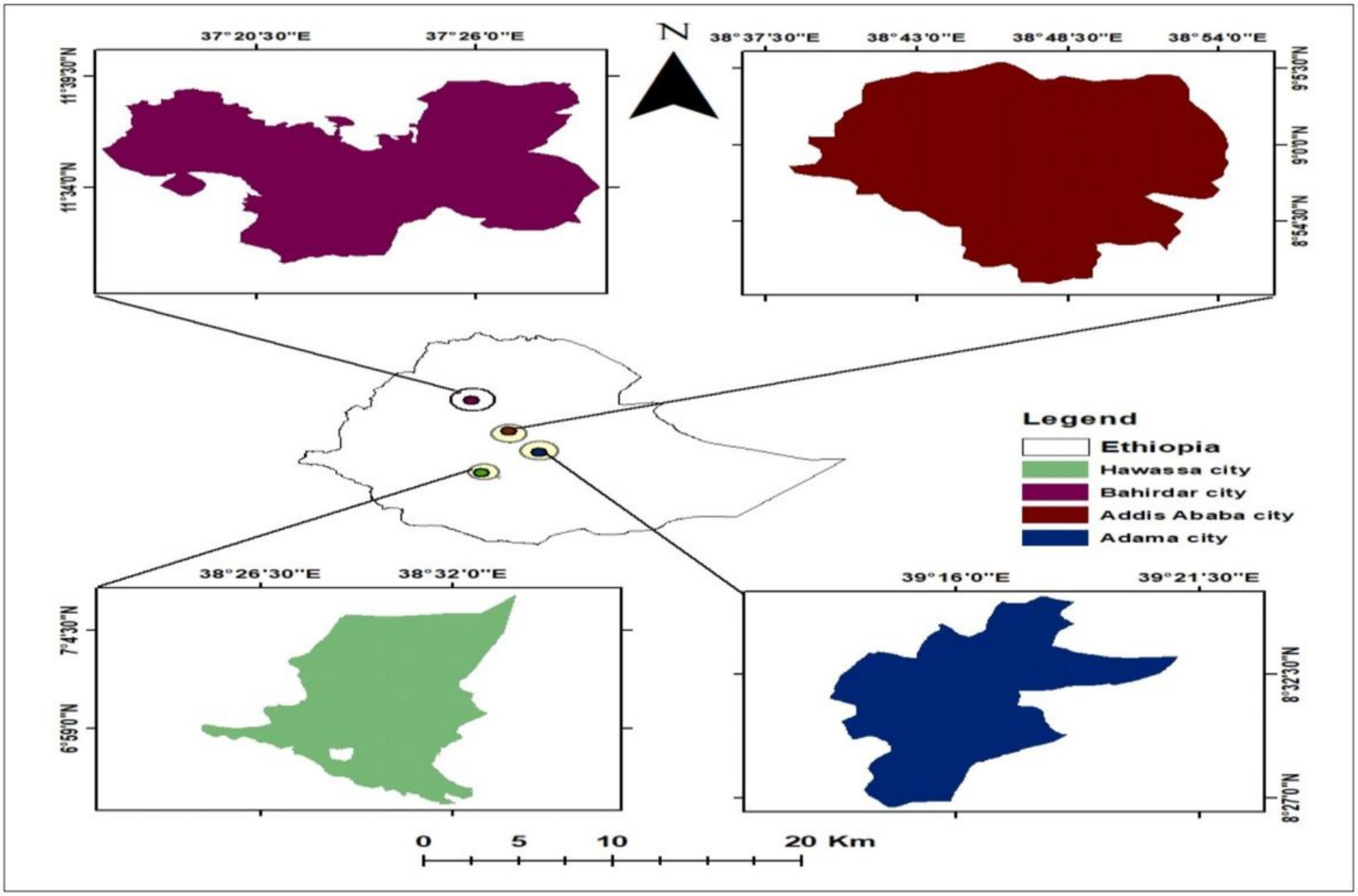

Figure 1

The location of the areas Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

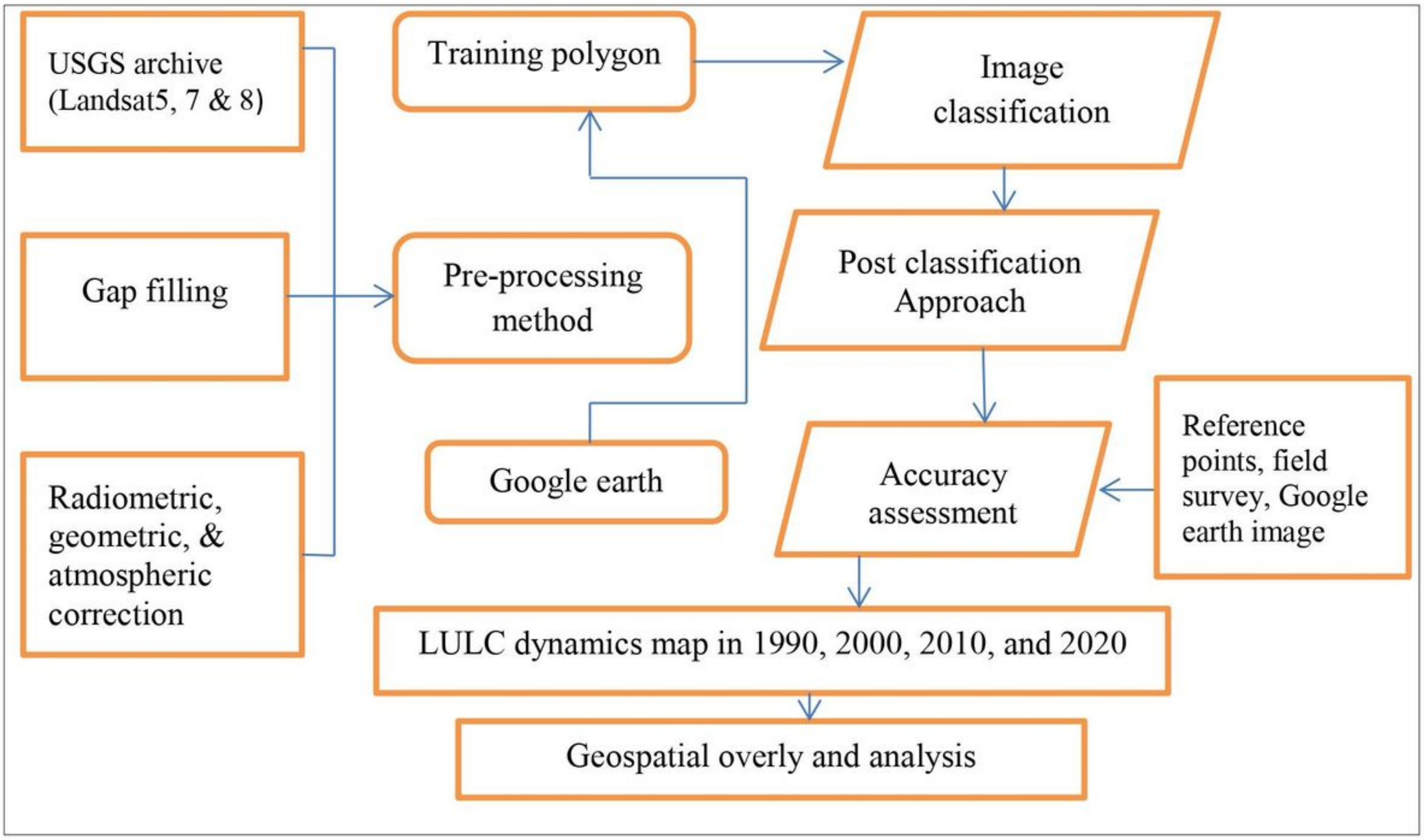

Figure 2

Flow chart of methodological approach

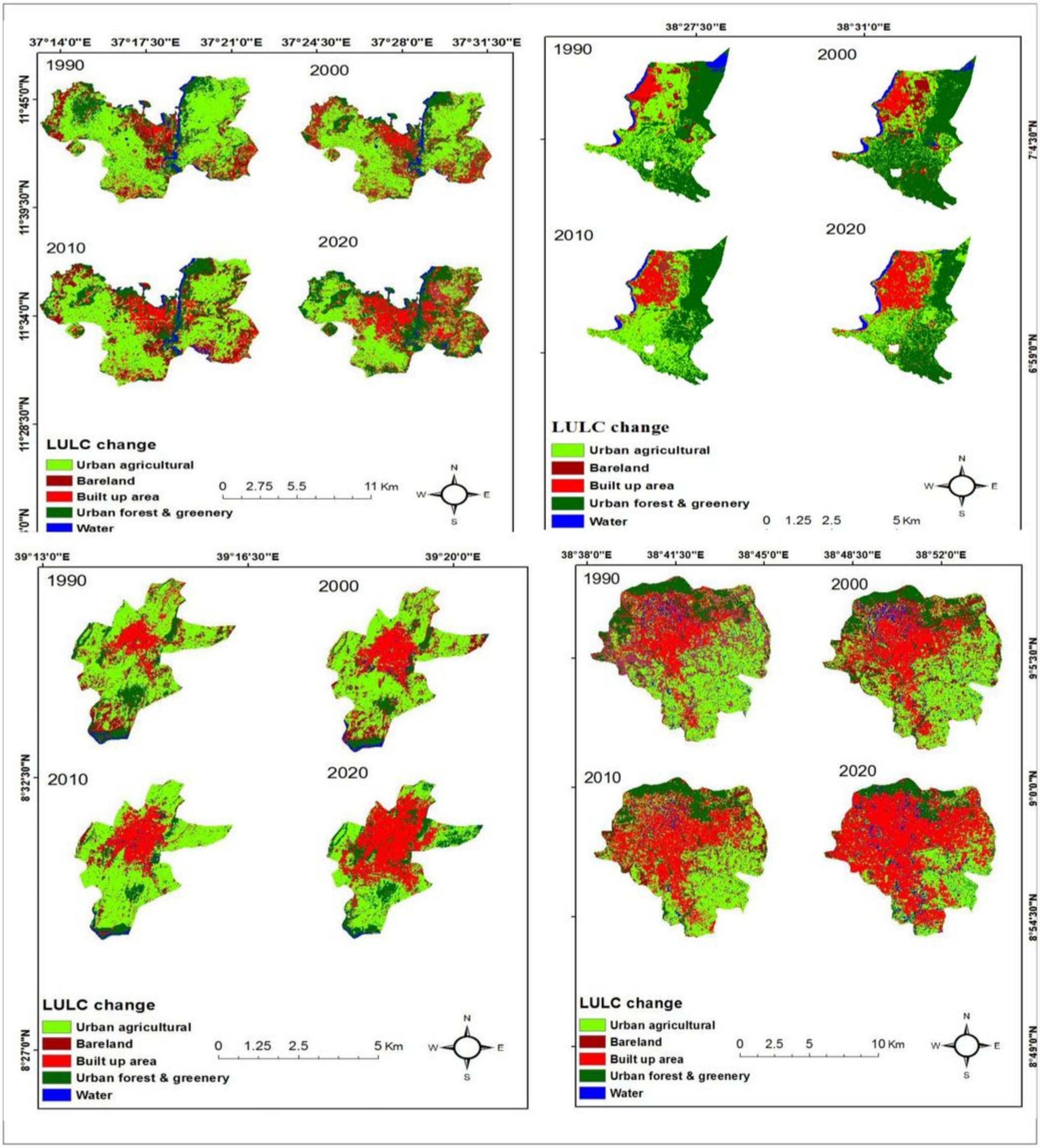

Figure 3

Spatial distribution of LULC in (a) 1990, (b) 2000, (c) 2010 and (d) 2020 Bahir Dar, Hawassa, Adama and Addis Ababa cities respectively Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

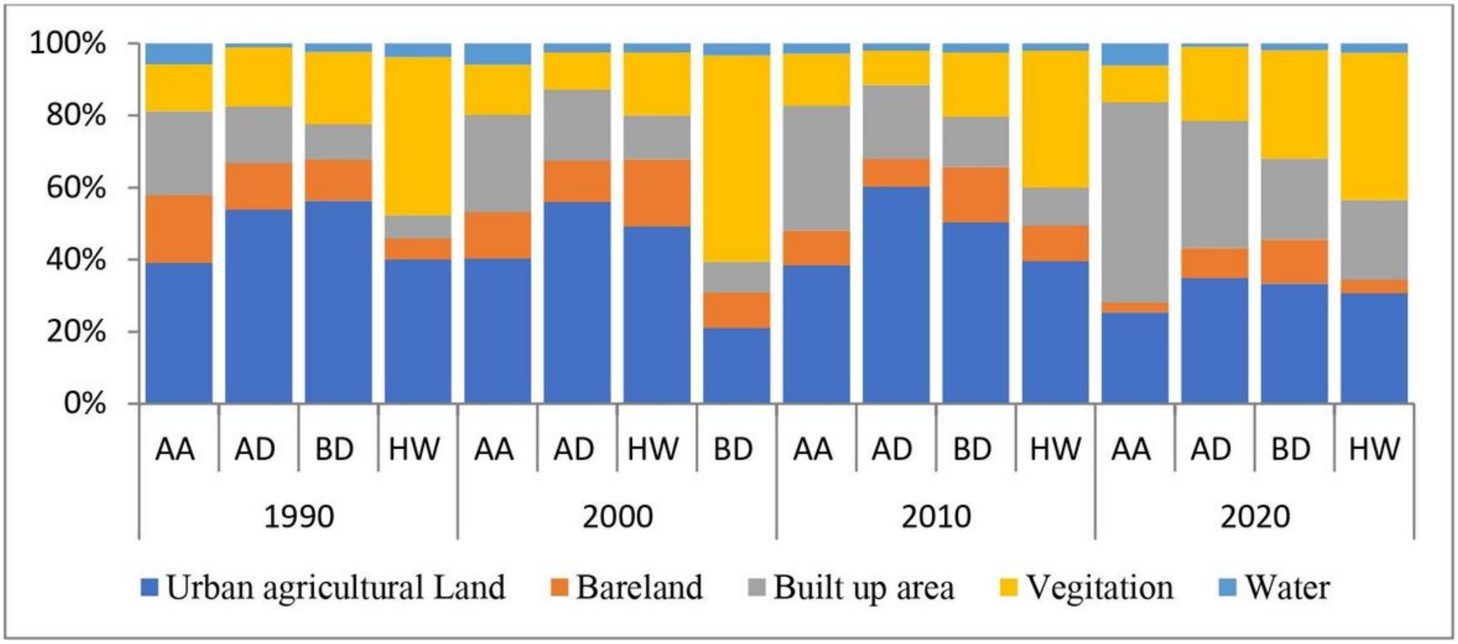

Figure 4

Size and percentage contribution of each of five ecosystem types in each city and the total study area

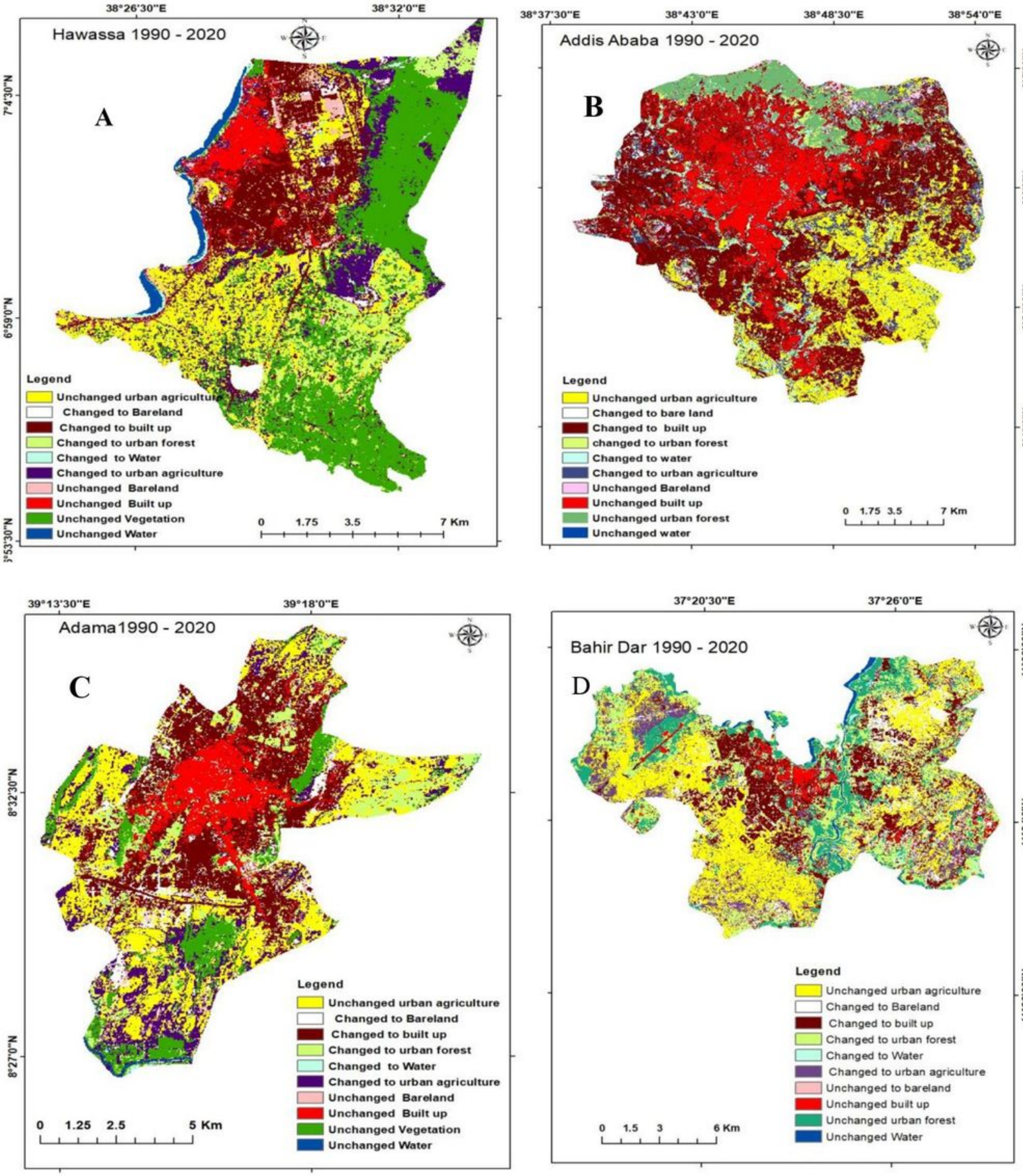

Figure 5

Spatial patterns and LULC change transition of cities from 1990 to 2020 Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

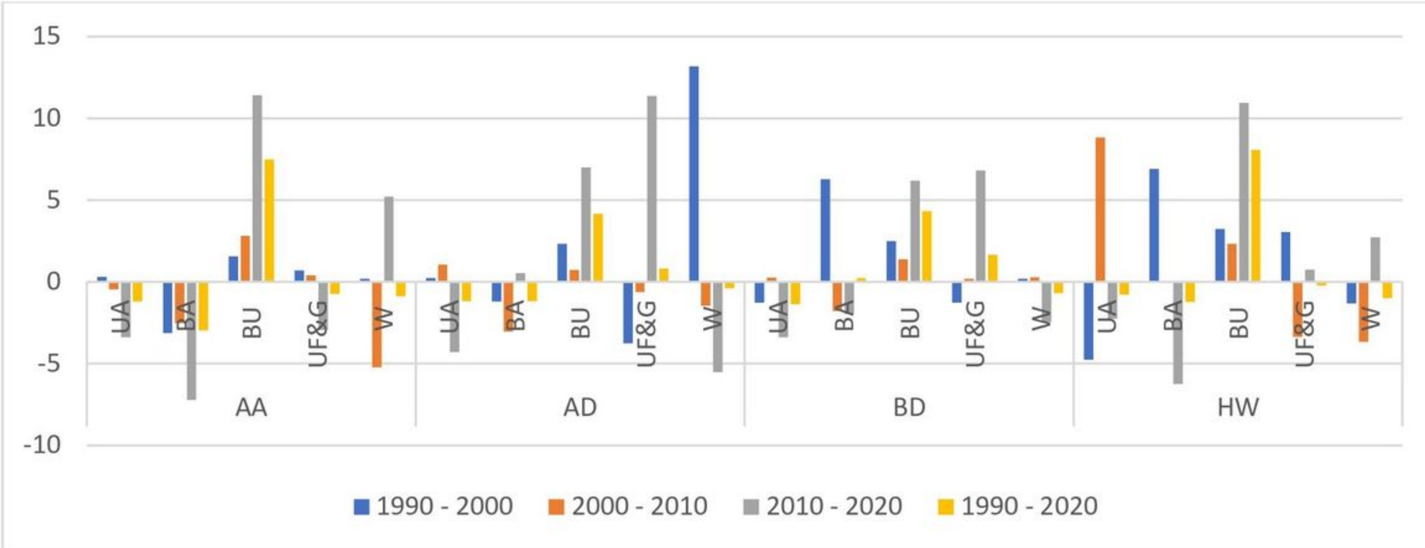

Figure 6

The percentage of the SLUDD of LULC in cities *AA: Addis Ababa, AD: Adama, BD: Bahirdar and HW: Hawassa, UA: Urban agriculture, BL: bare land, BU: built up, W: water, and UF&G: urban forest & greenery

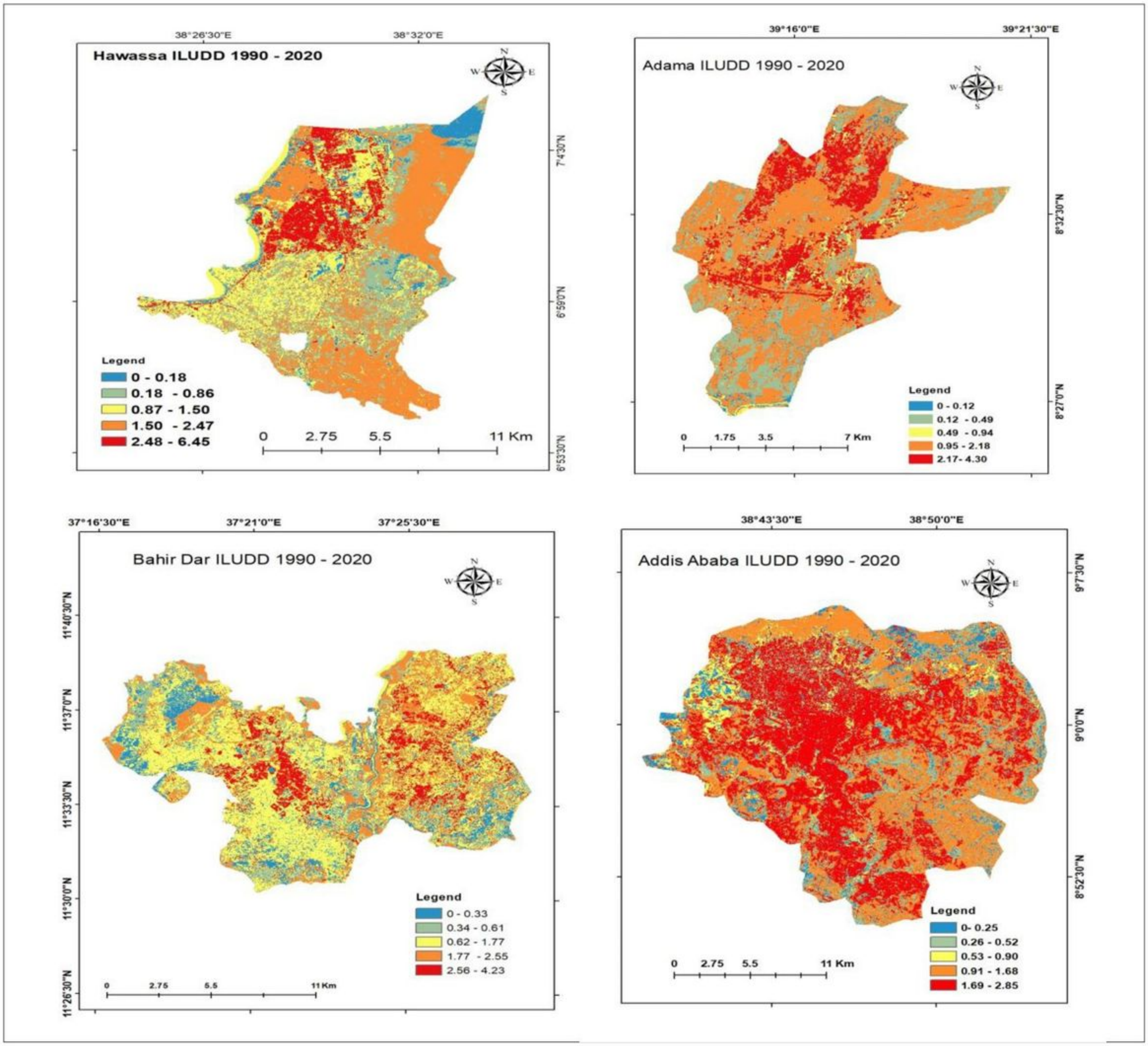

Figure 7

The ILUDD of cities from1990 to 2020 Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

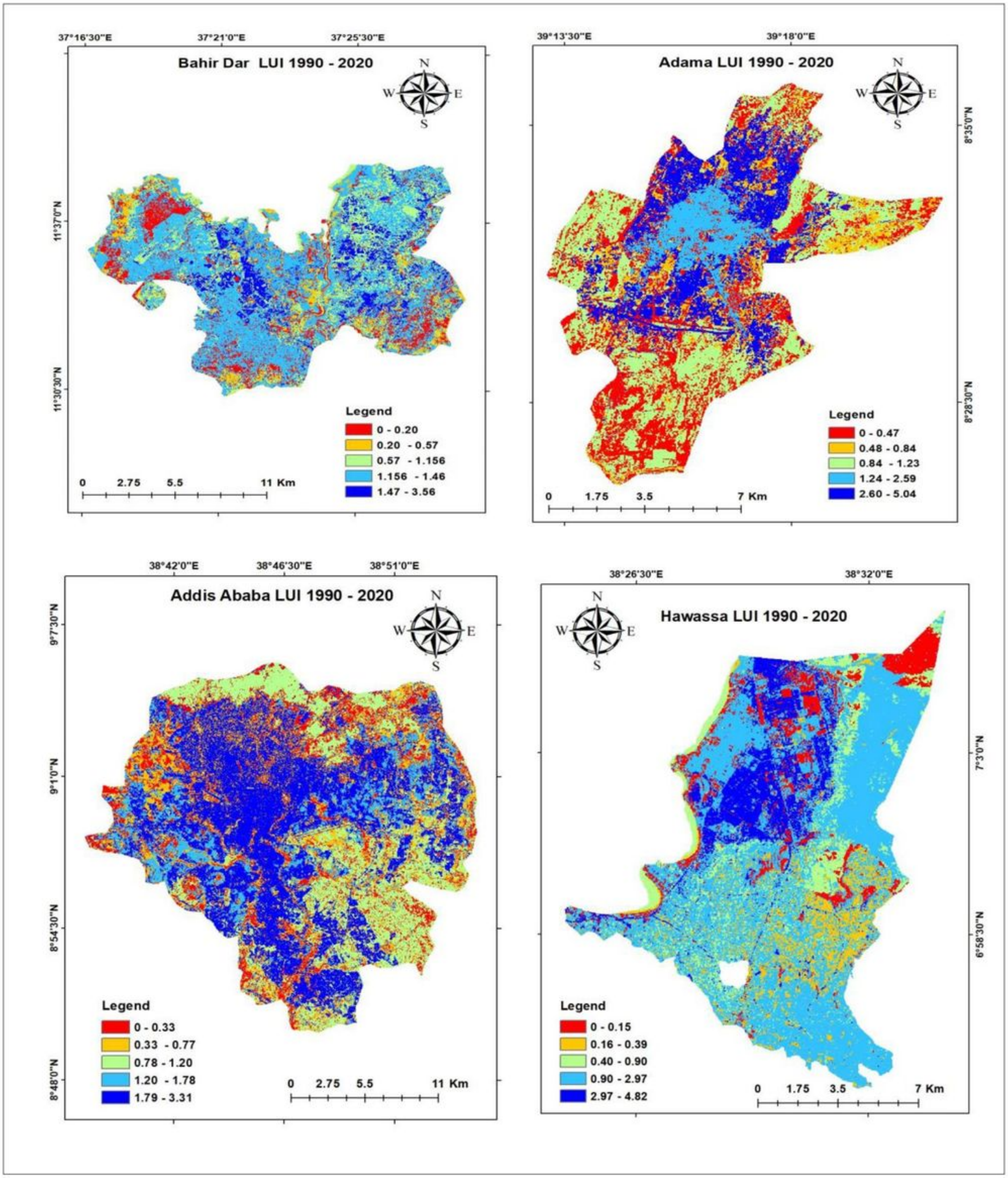

Figure 8

The LUI of cities from1990 to 2020 Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.