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Quantification of the land use/land cover dynamics and the degree of urban growth goodness for sustainable urban land use planning in Addis Ababa and the surrounding Oromia special zone

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Research Article

Quantification of the land use/land cover dynamics and the degree of urban growth goodness for sustainable urban land use planning in Addis Ababa and the surrounding Oromia special zone



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ABSTRACT

Uncontrolled urban growth and haphazard land developments are one of the crucial problems in Addis Ababa and the surrounding Oromia special zone causing environmental degradation and rural-urban land base conflicts. This is mostly because of the rapidly increasing built-up area that conquered large tracts of natural green spaces and prime agricultural lands. The research compared the land use-land cover (LULC) change, demographic dynamic, the sprawling patterns and the degree of built-up growth goodness. Methodologically, the study applied a multi-step geospatial and statistical modeling techniques, and it also employed the Shannon entropy index and the degree of freedom to measure the sprawling pattern and the degree of goodness of urban growth. Accordingly, the dynamic LULC change index identified the built-up area as the most dynamic land cover type and the intensity index depicted that a large part of the area was on the high-speed urban expansion level. Moreover, this study approved that the effects of the sprawling pattern have strong momentum to push the region's built-up dynamics than the population increase and it also confirmed that a prevalence of high built-up sprawling and bad urban growth conditions. Therefore, the study lay emphasis on an integrated urban-regional planning and management approach and quantifying the built-up intensity, sprawling and the degree of urban growth goodness as a tool to control the LULC dynamics and enhancement of a rational decision on sustainable urban growth planning and management.

1. Introduction

The current rapid urbanization is responsible for the complex and uncontrolled pattern of urban physical growth and the continuous LULC changes. Such urban growth is largely has been taken place in the developing countries and raised the questions of sustainability, particularly in terms of service delivery, Public investment, fiscal policy and political representation (Freire, 2006). Concurrently, (Kessides, 2006) evidenced that African countries' urban growth is approaching at a demographic climax point as the number of new urban residents projected to rise by over 300 million between 2000 and 2030, which is twice greater than the rural population increase (UNCCD, 2017). This rapid increases of the urban inhabitants' converts large tracts of land to urban use. Seto, Fragkias, and Gu (2011) also pointed out that globally the rate of urban land expansion is twofold greater than that of the rate of population growth.

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The experience of various developing countries shows urban physical growth has carried out mostly at their outskirts. So, it is common to see the city centers demand leapfrog urban sprawling to immediate urban fields without proper hinterland planning (Frumkin, 2002). This has an impact on the hinterlands socioeconomic and environmental conditions. For instance, the expansion cities to the surrounding peri-urban areas consumes the land of the farmers who have toiled on fragmented subsistence agriculture. So that, the persistence of their crop production is only possible with a heavy intensification of agrochemicals, as confirmed by Kumasi peri-urban land of Ghana (Adell, 1999). Therefore, it is necessary to adopt proper methods to control the problems related to urban land.

Number of methods have been applied to monitor the urban land. However, the LULC change Analysis becomes an important way when wide part of the earth's surface has changed and about one third to one half of the world's land cover converted into anthropogenic use (Schindler, 2009). The method have been used as a tool to control urban dynamism following the different modeling techniques in GIS and remote sensing technology (Deep, 2014; Pijanowski, 2009). Furthermore, the result of the LULC analysis have been required for advanced quantitative evaluation. For example, Zhao, Zhang, Fu, and Zhang (2012) applied it to measure the level of the LULC dynamism, and Zhao-ling, Pei-jun, and Da-zhi (2007) used it to calculate the intensity of a certain land cover type. Besides, the LULC was used to quantify the built-up sprawling and the degree of goodness of urban growth (Bhatta, 2009, Bian, Xie, Cui, & Zeng, 2013; Dadras, Shafri, Ahmad, Pradhan, & Safarpour, 2015). So, this method was used as an important instrument in the environmental and natural resource planning and management.

Though Ethiopia has been experiencing a fast rate of urbanization, it is still recognized as the least urbanized nation (Schmidt & Kedir, 2009). As it is seen in many developing countries, the intensified problems following the rapid urbanization in Ethiopia causes the degradation environment and brought the rural-urban land base conflicts. Therefore, the subsequent LULC dynamics become a complex urban planning and management issues, which is basically triggered due to the lack of proper urban growth management tools and approaches. The Ethiopian capital Addis Ababa and the surrounding area become one of the important hot spots to show the problems of the dynamics.

Several examples could be raised to illustrate the problem of Addis Ababa's horizontal expansion towards the peri-urban area. As shown by Feyera and Terefe (2011), the year between 1961 and 1984, Addis Ababa area extended by 400 ha from 1984 to 1994 it appears about 30,814 ha and in 2005 its total area stretched to 54,000 ha. However, this expansion has taken place with the cost of forest degradation, loss of agricultural land and worsening of the hinterland communities' livelihoods. In line with this, the transformed urban land did not manage properly and contributed for the haphazard land development and several type urban anomalies (Gete, 2006; Leulsegged, Gete, Alemu, Hagos, & Heinimann, 2012). Moreover, the scattered and fragmented settlements transpired widely both in the formal and informal residents. As Minwuyelet (2005) depicted, in 2000, squats in Addis Ababa reach up to 60,000 units, which accounts for 20% of the total housing units and about 14% of the built-up area of the city. The implication of the city growth may beyond the real built-up area since they have a large ecological footprint which could be even more than their immediate hinterlands. This is due to the recurrent urban economic need for the extraction and use of building material, energy resources, etc. While it is responsible for the irreversible damage and loss of critical ecosystem functions and natural support system (Tadesse, 2010).

Currently, Addis Ababa's pace of horizontal expansion has declined and managers turn somehow to intensify their land use. In addition, the concerned organ of the government attempted an integrated urban planning scheme together with the surrounding Oromia towns, despite it cannot be realized. A number of research works also has been done so far, though they didn't quantitatively measure the LULC dynamics, the sprawling of built-up and the goodness of urban growth. Most of these works were again focused on Addis Ababa city only, however, these days urban growth and built-up expansion can't ignore the surrounding districts as they directly affected by the city core dynamics. In general, this area has to be discovered further to examine the pattern of urban expansion, and the consequent dynamics thoroughly. This research, therefore, devoted to quantifying the urban LULC dynamics, the extent of sprawling and the degree of goodness of urban growth for sustainable planning and management of the City region.

2. Materials and methods

2.1. The study area

The study area is found in the center of the country. The geographical coordinates of the region are 8°56'N to 9°32'N latitude and 38°25'E to 39°07'E longitude with a total area of 5444 sq.km (see Fig. 1). It incorporates the capital Addis Ababa and surrounding areas (six Oromia Special Zone districts). In this research, it is referred to as Addis Ababa and the surrounding Oromia City region. Currently, Addis Ababa city cannot horizontally expand further unless their demands move to the surrounding area. That is why the small towns around have grown at an alarming rate. For example, Burayu, Sebeta, and Dukem-Gelan are urbanizing even more than the country average. The city LULC analysis cannot, therefore, be complete unless it covers the surrounding areas since the city growth dimmed their boundaries and they suffer any stresses of the city core.

2.2. Data source and method

The study examined the City region LULC dynamics, by using geospatial and remote sensing techniques. The main data used in this study were the Landsat images from the United State Geological Survey (USGS). Several studies were made on urban LULC analysis using Landsat data, such as Ayila, Oluseyi, and Anas (2014), Badreldin and Goossens (2014), Moeller and Blaschke (2014). Table 1 presented the main and ancillary data type, source and collection techniques.



Fig. 1. Study area of Addis Ababa and surrounding Oromiya special zone districts.

Table 1

Presentation of data type, source and collection technique.

Data type and materials	Data source	Method of data collection		
Topographical sheet Landsat TM 1984,1994 Landsat ETM + 2005 Landsat OLI 2013 The city and District boundary Ground survey field attributes /Training data	EMA USGS online USGS online USGS online ORUPI Field measurement and observation	Purchase (with 1:50000) Download (with row and path number of 168 by 54) Download(with row and path number of 168 by 54) Download (with row and path number of 168 by 54) Gathered from concerned offices		
Ancillary data Queckbird image 2006 Orthophotos 2011 Google Earth image 2015 Landscape Scenic / structural characters	EMA AASOIP Online sources Field observation	Purchase Gathered from concerned offices Download photograph, interview key informants, check list		

The study purposefully selected the Landsat images of the given time for their various reasons. To relate the national census result, the study used the 1984 and 1994 Landsat image. Afterward, the 2005 image was the Only Landsat Tm data available in a gallery within the second half of the decade free from stripes. So as to hold the periodic extent, it used the 2015 image. The collected data were then evaluated in the preprocessing stage as it is in a proper condition. Lu, Mausel, Batistella, and Moran (2004) showed the significance of temporal, spatial and radiometric corrections for the multi-temporal change detection study, as it controls the success and failure of it. Before the classification work the research made geometric and spectral correction of the images pertaining to 1:50,000 topo-sheets and other vector data, to select the proper band combination and to extract correct end-members representing the area.

The research, first applied unsupervised classification based on indices (for water bodies, vegetation cover, bare land and builtup) to have a brief picture of the region. Consequently, the study produced the LULC map of the area using a maximum likelihood algorithm supervised classification. In order to handle the classification, it took sixty ground truths (training samples) of each type of LULC. The Current training samples were selected from the field. In addition, topo maps and aerial photographs were employed for the years 1984 and 1994 training samples and a very high–resolution Google Earth image and aerial photographs were considered for



Fig. 2. Methodological structure of urban built-up dynamics measure.

2005. The urban land cover samples again take into account the GPS point measurement of old historical buildings. In order to sharpen the signatures, the research used the Quick Bird image of 2006, the orthophoto of 2011 and Google earth image.

This study thus identified six main LULC types. These are water bodies, forest, mixed woodland, cultivated land, bare land and urban built-up. Water bodies include reservoirs and dams. Forest land cover type is essentially forest patches. Mixed woodland comprises woody grassland and shrubs. Cultivated land is a land use with crops and harvested areas. Bare land is an area includes dried vegetation, quarries, and exposed rocks. The built-up cover represents roads, parking lots and buildings. Accordingly, this research applied a confusion matrix technique to assess the accuracy of the classification. So, the producer, user, overall accuracy, and the Kappa coefficients were calculated to check the image classification and signature selection dependability.

The LULC change analysis requires post classification assessment of the data. This study employed map to map comparison than image differencing or change-no-change technique. Therefore, the change detection analysis applied an integrated GIS and remote sensing method. According to Lu et al. (2004) review, it is a widely applied technique of urban land use change and sprawling analysis. Fig. 2 showed that the overall methodological framework of this study.

Once the research assessed the change detection, it quantified the study area LULC dynamism. The dynamic LULC change index compares the given LULC classes thus the index helps to detect the most dynamic LULC type and shows the degree of dynamism of each class. As used by Zhao et al. (2012) the index calculation is shown in the formula (Eq. (1)).

$$K = \frac{U_b - U_a}{U_a} * \frac{1}{T} * 100$$
(1)

Where K is the rate of LULC change

U_a is area of a certain LULC type at the begging.

 U_b is area of a certain LULC type at the end.

T is length of time.

The dynamic LULC change index has shown built-up the most dynamic land cover type. Simultaneously, the analysis extended to calculate the momentum of the built-up dynamics through the annual expansion intensity index. Besides, the index value gave a grade for the different part of the study area. Based on Zhao-ling et al. (2007) the index value classified as:

1.92 - high-speed expansion,
1.05–1.92 -fast speed expansion,
0.59–1.05 - medium expansion,
0.59-0.28 - slow speed expansion and
< 0.28 slow expansion.

Thus the growth intensity index was calculated as Zhao-ling et al. (2007) shown by the formula (Eq. (2)).

$$B_{it+n} = \left\lfloor \frac{(U_{it+n} - U_{it})}{T} * 100 \right\rfloor$$

Where

Bi t+n is the annual expansion intensity of spatial unit i

Uit + n is urban area at the spatial unit i at time t + n

Ui t is urban area at the spatial unit i at time t

T is the land area of at the spatial unit i

In addition, this LULC change should be compared with the population, which is one of the underpinning factors So that the research has evaluated the link between LULC and demographic dynamics. The ratio or percentage changes of population and builtup growth was computed over the given period at the same time the analysis calculated the urban population density. In this case, it did not apply the usual number of people per total area instead the built-up area appears the denominator of the population density formula. That means it figured out a ratio of urban population per the built-up area.

In addition, this research measured the pattern of sprawling and degree of urban growth goodness. Many developed countries measure their urban growth goodness through the continuous data recording, computation, and analysis. In the developing countries, it is difficult to collect such continues data, thus the analysis is computed by generating the expected urban growth values and by using simple Pearson's degree of freedom (X²). The Shannon entropy and the degree of freedom index, therefore, measured the region's built-up pattern. First, the two layers were produced which overlay on the built-up land cover map. The first one based on geographical quadrants develop from the center of the built-up area, and the second one based on the stripes of a concentric circle with a distance of 5 km interval starting from the same center (see Fig. 3). By using this division of the layer, the research computed the level of the built-up dynamics in each quadrant and each strip of circular distance. To make a detailed analysis the two layers were calculated. The chi-square test measures the degree of freedom with the evaluation of the actual and theoretically expected urban growth. Likewise, Paul and Das Gupta (2013) used the chi-square to find out the degree of freedom or difference between the actual and the expected values. Bhatta (2009), Bian et al. (2013) and Nigatu, Øystein, and Tveite (2014) also marked the advantage of this chi-square computation as it helps to cover the shortage of continuously recorded urban growth data in developing countries. Finally, the study evaluated the pattern of urban growth based on the actual and expected values of urban growth for a given



Fig. 3. The region built-up pattern by category of the two methods (a) geographic quadrants and (b) circular distances.

(2)

temporal and spatial dimensions.

To calculate the expected urban growth and the chi-square, formula (Eq. (3)) and (Eq. (4)) were used, respectively:

$$Ub_{ij}^{E} = \frac{Ub_{ix}^{s}Ub_{j}^{s}}{Ub_{g}}$$
(3)

Where: Ub_{ii}^E is expected urban built-up growth

Ub_i^s is row total

Ub^s_i is column total

 Ub_g is grand total = $\sum_{i=1}^n \sum_{j=1}^n$

$$X_i^2 = \frac{\left(Ub_j - Ub_j^E\right)^2}{Ub_i^E}$$

Where: X_i² is degree of freedom ith temporal span

Ub_j is actual urban growth jth column of the specific row

Ub^E_j is expected urban growth jth column of the specific row

The Shannon entropy measured the variation of built-up dispersion over space, which is widely applicable in estimating urban sprawling. Paul, Das gupta (2013), Deka, Tripathi, and Khan (2012), Ramachandra, Bharath, and Sowmyashree (2014) and Yeh and Xla (2001) documented the use and way to interpret the index. The equation is given by the formula (Eq. (5)):

$$H_j = -\sum_{i=1}^{m} p_i \ln(p_i)$$
(5)

Where: H_i is Shannon entropy value

 p_i is proportion of the variable in the ithcolumn(i.e., proportion of built-up growth rate inith zone, calculated by: built-up growth in ithzone/ sum of built-up growth rates for all zones)

m is number of zones

Shannon entropy index computes how the urban built-up pixels gathered and dispersed spatially. The index value ranges between 0 and $\ln(n)$, n is the number of groups used to delineate the study region. In this study, the first method used 0 to $\ln(8)$, and the second method used 0 to $\ln(9)$. Thus, if the value is near to $\ln(n)$, it shows a dispersed built-up and near to 0, it is more concentrated. However, the analysis puts a boundary line of $\frac{\ln(n)}{2}$ (Bhatta, 2009; Nigatu et al., 2014). Thus, when the calculated entropy value is greater than $\frac{\ln(n)}{2}$, it revealed the sprawled type of built-up and the reverse is also true.

The degree of goodness of urban growth, on the other hand, measures how well the growth takes place in the area over time. The measure of the degree of freedom and sprawling is not enough to determine how good the urban growth is so that the index interpretation related to the degree of freedom since it calculates the extent of compactness. The formula drawn from the expected urban growth and the measured one and it used the formula shown by (Eq. (6)).

$$G_{i} = \ln \left[\frac{1}{x_{i}^{2} \left(\frac{H_{i}}{\ln(m)} \right)} \right]$$
(6)

The overall (the study area) degree of goodness is given by the formula (Eq. (7)).

$$G = \ln \left[\frac{1}{x^2 \left(\frac{H}{\ln(nxm)} \right)} \right]$$

Where: G_i is degree of goodness

x_i² is degree of freedom

H_i is Shannon entropy

G is overall degree of goodness

i isith temporal interval

m is total number of zones

H is over all degree of sprawling

A vital issue in the application of this technique is that the result interpretation. Dadras et al. (2015) provided that the way of interpreting the degree of urban growth goodness. Thus if the index value is negative the built-up growth is bad and it will be good when it is positive. The size of the value depicts the extent of the built-up growth goodness.

3. Result and discussions

3.1. Results

Sustainable urban land use planning and management need a good understanding of the dynamic LULC pattern. To meet the

(7)

(4)



Fig. 4. The Land use-land cover map of the study area by the period of investigation.

intended outcome, this research applied geospatial techniques to quantify the study area LULC dynamics that helps to monitor the urban growth pattern and to suggest an approach for the regional urban development planning and management strategies. The study thus figured out the LULC dynamics, the land conversion and the extent of built-up dynamics intensity, this built-up growth also compared with the demographic pattern. Finally, the sprawling and the degree of goodness of urban growth were quantified and mapped.

3.1.1. Urban LULC dynamics and the land conversion pattern

The study first classified Landsat satellite images of 1984, 1994, 2005 and 2015 to compute the urban LULC change of Addis Ababa and the surrounding Oromia special zone. Alongside, the change detection analysis showed that a strong LULC tradeoff prevailed in all directions of the study area throughout the period of investigation. The change detection used a map to map analysis, and the maps are produced as portrayed in Fig. 4.

The produced maps configure six major LULC types. These are water bodies, forest, mixed woodland, cultivated land, bare land and built-up. The LULC classification accuracy assessment result was presented in Table 2, which portrayed 86%, 86%, 86% and 87% overall accuracy and 0.84, 0.84, 0.83 and 0.84 overall kappa coefficient of 1984, 1994, 2005 and 2015 maps, respectively.

Table 3 showed the LULC classes of a given time dimension and it portrayed that the percentage share of the built-up was growing from 1.5% in 1984 to 2.4% in 1994, 3.7% in 2005 and 6.7% in 2015. During this period, water bodies, forest, and mixed woodland were in continuous decline, while cultivated land and bare land cover types shown a varying pattern.

Similarly, the symmetrical representation of Fig. 5 portraying the dynamics of the different LULC type throughout the given time dimensions. Though built-up represents a continuous increment of the area, other land cover types like mixed woodland, water bodies, forest were declining. On the other hand, as cultivated land has first shown a big rise, bare land cover revealed remarkable declining in the period of 1984–1994, while the reverse pattern was seen in the next periods.

The dynamic LULC change index used to show the most dynamic LULC type. Based on this comparison, urban built-up has shown the highest level of land cover interchange. So it plays an essential part in the region's LULC dynamism (see Fig. 6).

The annual urban expansion index measures the built-up dynamics intensity. This index used the unionized layer of the geographic quadrant and strips of circular distances and the output of this analysis presented in Fig. 7. According to the index, in 1984–1994 time dimensions the urban dynamics was serious in the S, SE and NW direction, which reach up to high-speed urban expansion level. The intensity also reached at the highest level in NW and SE direction within 0–5 km circular distance and in the S

Table 2

Accuracy assessment result by study period.

UA
100
96.6
77.2
80.3
78.3
87.3
-

Table 3

Land use-land cover of the study area by year of investigation.

LULC Type	1984		1994		2005		2015	
	Area sq. km	%						
Water Bodies	22.5	0.4	22.1	0.4	18.5	0.3	13.3	0.2
Forest	464.6	8.6	384.2	7.1	375.9	6.9	356.3	6.6
Mixed Woodland	2266.2	41.8	2147.0	39.6	2159.8	39.8	2016.6	37.2
Cultivated Land	1023.8	18.9	1688.7	31.1	1443.7	26.6	1511.2	27.9
Bare Land	1566.6	28.9	1049.6	19.3	1227.8	22.6	1162.5	21.4
Urban Built-up	80.6	1.5	132.8	2.4	198.7	3.7	364.5	6.7
Total	5424.4	100.0	5424.4	100.0	5424.4	100.0	5424.4	100.0







Fig. 6. Dynamic index of Land use-land cover transformation intensity.

within 5–10 km circular distance. However, in 1994–2005 the dynamism was shifted to SW direction within 5 to 10 km circular distance and in the E direction 10 to 15 km circular distance, which represents the fast speed urban expansion. In 2005–2015, the urban dynamics became enormous in all directions and, it extends more distance outward. The fast speed urban expansion also extended up to 20 km circular distances, which had been limited to 15 km in both the earlier time dimension (1984–1994 and 1994–2005). In addition, the high-speed urban expansion has taken a broader extent. A high-speed expansion spread out within 0–5 km circular distance in the E and NW direction, 10–15 km circular distances in the E, and 5–10 km circular distance in S and SW direction (see Fig. 7).

To look at the built-up cover increase impact on the other LULC classes, it is necessary to detect the contribution of each land cover type for the built-up area growth. Accordingly, Fig. 8 shows the proportion of each LULC type involvement for built-up in each time dimension. The leading land cover type converted into built-up in all temporal dimensions was mixed-woodland, which contributed about 23% in 1984–1994, 25% in 1994–2005 and 24% in 2005–2015. The next higher transformation was from cultivated



Fig. 7. Annual urban built-up dynamics intensity level by the overlaying sectoral area.



Fig. 8. The different land use-land cover types contribution level to urban built-up.

land to built-up in all temporal dimensions except from 1984 to 1994 that give less than bare land. Besides, a large area of bare land also converted to a built-up area that contributed about 16%, 6% and 8% in 1984–1994, 1994–2005 and 2005–2015 time dimensions, respectively. Forest contributes the remaining small part, and water bodies gave none.

This continuous rapid urban growth assessed further with other underpinning causes, for instance, this study evaluates the link between the built-up growth and population change pattern.

3.1.2. Relationship between urban built-up growth and urban demography

The trend of population growth in Addis Ababa and the surrounding Oromia urban centers is presented in Fig. 9. The annual growth rate of Oromia special zone urban population appears higher, particularly in the year 1994–2005, which ranges up to 13%. When it is compared with Addis Ababa that is less than 4%, even in its highest period (1984–1994). The Addis Ababa's annual growth rate influences the total population and it is not greater than 4% yet. The trend lines also illustrate the similar result, which has the highest value in 1984–1994 and it continues to decline up to 2005–2015, however, the total population annual growth rate is a bit higher in the time dimension 1994–2005.

On the other hand, when Addis Ababa population growth rate was highest, the Oromia special zone population growth rate was lower. When the annual population growth rate of Addis Ababa started to decline, the special zone growth rate was increasing. However, the comparison of the demographic trends and the built-up growth rate may represent that the presence of sub-urbanization or sprawling. Since, the annual growth rate of built-up is greater than that of the population growth rate, especially in the period 2005–2015. The contribution of the present multistoried built-up attempts of densification is less than the horizontal expansion and sprawling effect. The trend line of the total population and urban built-up area seems to converge in the year 1994–2005 but diverge in the year 2005–2015. This was also recounted by the density of urban populations to a built-up area that shows the continuous declining pattern with increasing built-up. It was 182 people per hectare in 1984, and it declined to 162 in 1994. This pattern continued to diminish in 146 and 96 in the year 2005 and 2015, respectively. That means the built-up growth is faster than



Fig. 9. Trends of annual urban population and built-up area growth in the study area.

the population growth. Therefore, it is necessary to quantify and evaluate the built-up sprawling and the degree of goodness of urban growth further.

3.1.3. A Measure of sprawling and the goodness of urban growth

The sprawling and the degree of urban growth condition are not uniformly distributed throughout the study area. This investigation thus takes into account the two methods shown in Fig. 3. The first method classified the area by the expanding geographic quadrants and eight quadrants were outlined. The second method categorized the region by stripes of circular distance with 5 km interval from the center and nine zones were set out where the built-up cover was spread over.

Table 4 shows the entropy level of the study area with respect to the time dimension and the two methods. The entropy level of urban built-up was significantly higher than the given limit $\frac{\ln(n)}{2}$ in the two methods that portrayed the sprawled pattern. Although these methods depicted a similar result, the value of the second method was lower than the first method. Besides, the second method entropy level was declined significantly in 1994–2005. It is thus necessary to see that the specific entropy value of the two methods and the given time dimension.

Based on the expanding geographic quadrant, the SE quadrant revealed the highest sprawling effect followed by the W quadrant with the entropy value of 1.09 and 1.06, respectively. Nevertheless, all the expanding geographic quadrants depicted noticeable sprawling condition (see Table 5).

On the other hand, the strips of circular distance computation have shown a different magnitude of the study area sprawling. The 2^{nd} zone (at a distance 5 to 10 km) has the highest entropy value, followed by the 5^{th} zone (at a distance 20 to 25 km) with the entropy value 1.08 and 1.06 respectively. Alongside, except in zone 6 and 9, all other zones were in a sprawled situation (see Table 6).

Likewise, the evaluation of the overall sprawling measure also proved that the area was in a strong sprawling condition. Based on the geographical quadrant assessment, the calculated value is about 3.06 entropy with 3.18 ln(nm) and 1.59, $\frac{l(nm)}{2}$ which is a far higher value from the stated line of sprawling. Method two also showed the same higher value about 2.81 overall entropy with 3.30 ln(nm) and 1.65 $\frac{l(nm)}{2}$ value.

For higher level LULC monitoring and decision-making, it is important to extend the evaluation of the degree of goodness of urban growth. So, according to this study, while the year 1984–1994 was the worst period, the index value is continuously declining during the study period. Although both methods have presented the same pattern, the first method exhibited the faster decline (see Table 7).

In fact, the two methods have shown a different specific result of each subdivision. The output of the geographical quadrant in Table 8 depicted that the urban built-up growth was bad in all directions except in the NW and NE quadrant, where little built-up was seen, and it was worst in the S with the index value about -2.65.

Conversely, the second method, which applied stripes of circular distance, depicted that almost all zones have positive values except 2nd and 8th zone. These were areas found in the circular distance of 5 to 10 km and 35 to 40 km that represents an expansion zone of Addis Ababa and the special zone Oromia urban centers. However, zone 1 and zone 4 were in the best condition, which was

Table 4

The	Shannon	entropy	values	by	time	interva	l.
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Time interval	by geographic quadrant			by stripe of circula	by stripe of circular distances		
	Entropy (Hi)	ln (n)	ln (n)/2	Entropy (Hi)	ln (n)	ln (n)/2	
1984–1994	2.00	2.08	1.04	1.82	2.20	1.10	
1994-2005	1.98	2.08	1.04	1.65	2.20	1.10	
2005–2015	2.00	2.08	1.04	1.99	2.20	1.10	

Table 5

The Shannon entropy values by expanding geographic quadrant.

	E	SE	S	SW	W	NW	Ν	NE
Entropy (Hi)	1.02	1.09	0.91	1.00	1.06	1.05	0.85	1.02
ln (n)	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
$\frac{ln(n)}{2}$	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55

Table 6

The Shannon entropy values by stripe of circular distance.

	Zone_1	Zone_2	Zone_3	Zone_4	Zone_5	Zone_6	Zone_7	Zone_8	Zone_9
Entropy (Hi)	0.96	1.08	1.06	0.98	1.06	0.46	1.04	0.81	0
ln (n)	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10
$\frac{ln(n)}{2}$	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55

Time interval	Degree of urban growth goodness	
	By geographic quadrants	By stripe of circular distances
1984–1994	-2.91	-2.53
1994–2005	-1.81	-2.47
2005-2015	-1.37	-2.32

Table 8

Urban growth goodness by the expanding geographical quadrant.

	E	SE	S	SW	W	NW	Ν	NE
Goodness	-1.39	-0.18	-2.65	-0.67	-0.30	2.01	-0.82	1.67

between the circular distance of 0 to 5 km and 15 to 20 km, respectively. These were areas where the center of Addis Ababa and Oromia special zone major towns, which have a long history of built-up (see Table 9).

The overall goodness index analysis also shows that the worst condition the built-up growth in the two methods. The value also nearly similar (about -3.34) with the geographic quadrant and (-3.58) the stripe of circular distance-based analysis.

These two methods of measurements and abstraction gave a general picture of the area. So, it is better to see the sprawling and urban growth goodness based on more specific locations. To specify the analysis, this research used the unionized geographic quadrant and stripe of circular distance zoning layers. The union of these two maps creates a sector like areas, which helps to map the localized sprawling and bad urban growth conditions.

The sprawling effect extended continuously in the N and E direction from the center to 15 km circular distance. The area between 5 and 10 km circular distances the sprawling pattern was depicted in all quadrants, which is at the periphery of Addis Ababa city administration. This effect also observed a bit outward to the city. The first one is in the W between 15 and 25 km circular distance, which is along the way to Burayu town. The second highest sprawling was in SW direction 15–20 km circular distance along the way to Sebeta town. The third one is in the southern direction within a circular distance of 20 to 25 km, it occupied the area around the dehydrating water body of Abasamueal Dam. In the SE direction, 30–35 km circular distance is an area of another important sprawling, which comprises Gelan and Dukem town (see Fig. 10).

Concerning, the degree of goodness of urban growth analysis, Fig. 11 illustrates the zone of bad urban growth conditions. So, the bad urban growth condition was radiating out from the center in the E, S and SE direction up to 20 km circular distance. A similar pattern was observed in SW direction up to 15 km, in the W up to 10 km and in the NW up to 5 km circular distance. Another bad urban growth condition also observed in the W within the area from 25 to 35 km and in the E and SE direction within the sector area

 Table 9

 Urban growth goodness by stripe of circular distance.

	Zone_1	Zone_2	Zone_3	Zone_4	Zone_5	Zone_6	Zone_7	Zone_8	Zone_9
Goodness	1.93	-0.81	1.68	2.10	0.92	0.65	0.32	-0.65	0



Fig. 10. Sprawled zone of the study area.



Fig. 11. Zone of bad urban built-up growth.

between 30-35 km circular distances.

3.2. Discussion

Addis Ababa and the surrounding Oromia special zone city region LULC change analysis manifest the presence of a strong tradeoff between the LULC types, and the dynamic LULC change index depicted built-up as the most dynamic land cover type. When the annual urban expansion intensity index computed for built-up, it was more intense in the southern direction up to 15 km circular distance in the period of 1984–1994 that was around Akaki area. However, in the time dimension 1994 to 2005, the urban dynamism shifted towards the eastern and southwest direction, which was along Taffo and Sebeta routs, respectively. In fact, this period also distinguished by the lowest intensity level of the annual urban expansion speed, since it was the period of the current urban development policy was launched, and most of the surrounding towns gained their municipal status. During the period 2005 to 2015, the dynamism was again getting intense in the entire City region, and the high-speed expansion also extended more distance. Such high-speed urban growth needs strong monitoring scheme for the sustainability of overall urban development (Zhao-ling et al., 2007).

To measure the urban sprawl and degree of urban growth goodness, Bhatta (2012), Nigatu et al. (2014) and Dadras et al. (2015) applied similar methods. The sprawling pattern computation of this study, As a result, depicted that a sprawled urban built-up condition, with the entropy value around 3. This value is lower than the output of the Dadras et al. (2015) for Bandar Abbas city of Iran and higher than the result of Nigatu et al., 2014 for Hawassa town, Ethiopia. The degree of goodness of urban growth measure revealed that it was in a bad condition, while the index value was lower than the studies stated above. The result also showed a relative decline in the year between 1994 and 2005, however, it increased again in the year 2005 to 2015. As Dadras et al. (2015) discussed, although the declining trend of sprawling is expected, researches have depicted a reversal pattern in several developing countries' urban growth.

Specifically, widespread sprawling prevailed in the N, NE and NW directions due to the topography of the area preventing the continuous denser built-up expansion. Another serious sprawl pattern was taken by the eastern part showing the recent trend of suburbanization in Addis Ababa, especially, in Ayat, Meri-CMC to Taffo. It also further extends in the W, SW, S and SE direction within the Addis Ababa area. At the same time, the Oromia special zone also showed the same sprawling pattern. For instance, in the W along the Burayu road, In the SW along Alemgena road to Sebeta, in the S around the new express highway were the remarkable areas and another hotspot was the industrialized area of Dukem, Gelan.

Likewise, the bad urban growth conditions were also portrayed in the E, SE, S, and SW direction from the center up to 20 km. In the E the areas encompass the Ayat, Meri CMC, extends up to Taffo and it leaped to Sendafa. In the SE it is around Bole Bulbula and jumped to Dukem-Gelan area. On the S and SW side again the urban growth badness was observed around Lebu and Haile-garment area that extends up to Alemgena.

In view of that, an output of the LULC change, the sprawling pattern and the degree of urban growth goodness quantification can increase the understanding of the spatial and temporal pattern of the urban dynamism. Indeed, the methods showed the way to connect the scientific research result to the practical application on the urban growth monitoring schemes for planners and managers of developing counties in general and the study area in particular.

4. Conclusion

Measuring the urban built-up dynamics and quantification of the sprawling and the degree of urban growth goodness as the main aim of the study requires a mix of different geospatial techniques. The results of the satellite imageries classification help to create the LULC map of Addis Ababa and the surrounding Oromia special zone. The study made the LULC change detection and identification of the major contributor of built-up. It also measured the built-up dynamics, sprawling and the degree of urban growth goodness. As a result, the study finds out the prevalence of strong urban built-up dynamism in the region, particularly in the latter period of investigation. It also discovered that this strong dynamism was not mainly driven by the demographic forces rather it is pulled out by the strong demand of suburbanization or sprawling. Therefore, the study measured the magnitude of sprawling and proof that the region is found in highly sprawled built-up and bad urban growth condition. The urban built-up growth quantification also revealed that widespread sprawling pattern, and the bad urban built-up growth.

Such a built-up dynamics have a complex and wide range of impact that required to assess the study region's overall landscape and demographic characteristics. Therefore, the built-up dynamics, the degree of sprawling and urban growth goodness quantification and mapping give enough knowledge about the region. Certainly, it is also helpful to make a correct decision on monitoring the built-up growth and to face the related urban planning and management challenge. The methods of this research also could be one of an important instrument for sustainable plan led urbanization and rural-urban synergy. The study, finally, revealed the need of an integrated approach to harness the different part of the problem and the multiple stakeholders.

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Competing interests

The authors declare that they have no competing interests.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jum.2018.11.002.

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