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Article

Urban Sprawl Analysis and Modeling in Asmara, Eritrea

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Abstract: The extension of urban perimeter markedly cuts available productive land. Hence, studies in urban sprawl analysis and modeling play an important role to ensure sustainable urban development. The urbanization pattern of the Greater Asmara Area (GAA), the capital of Eritrea, was studied. Satellite images and geospatial tools were employed to analyze the spatiotemporal urban landuse changes. Object-Based Image Analysis (OBIA), Landuse Cover Change (LUCC) analysis and urban sprawl analysis using Shannon Entropy were carried out. The Land Change Modeler (LCM) was used to develop a model of urban growth. The Multi-layer Perceptron Neural Network was employed to model the transition potential maps with an accuracy of 85.9% and these were used as an input for the 'actual' urban modeling with Markov chains. Model validation was assessed and a scenario of urban land use change of the GAA up to year 2020 was presented. The result of the study indicated that the built-up area has tripled in size (increased by 4,441 ha) between 1989 and 2009. Specially, after year 2000 urban sprawl in GAA caused large scale encroachment on high potential agricultural lands and plantation cover. The scenario for year 2020 shows an increase of the built-up areas by 1,484 ha (25%) which may cause further loss. The study indicated that the land allocation system in the GAA overrode the landuse plan, which caused the loss of agricultural land and plantation cover. The recommended policy options might support decision makers to resolve further loss of agricultural land and plantation cover and to achieve sustainable urban development planning in the GAA.

Keywords: landuse cover change; Object-Based Image Analysis (OBIA); urban growth model; landuse policy

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1. Introduction

For the first time in history, in 2008, the world reached an important milestone: half of the world population started to live in urban areas. Moreover, most of the urban population growth has been occurring in the developing countries [1]. The space taken up by urban areas is increasing faster than the urban population itself. Between 2000 and 2030, the world's urban population is expected to increase by 72%, while the built-up areas of cities of 100,000 people or more could increase by 175% [2]. Many urban areas are situated at the heart of rich agricultural areas or other lands rich in biodiversity. The rapid increase of urban population causes urban sprawl that is the extension of the urban perimeter which cuts further into available productive land and encroaches upon important ecosystems [3]. Urban sprawl is a rapid expansion of the built-up area into suburbs in a discontinuous low-density and uneven pattern [4,5]. It has been criticized for its inefficient use of land resources and large scale encroachment on agricultural land and natural covers [4,6].

Eritrea had the third highest urban population growth rate in Africa for the years 2000–2005, where the annual urban population growth was 6% [1]. As a result, the Greater Asmara Area (GAA) has experienced high population growth in the post two decades, particularly, after the independence of the country in 1991. As a result, intense competition of land for residential, industrial, agricultural and other developmental uses has shown; and it is growing in the absence of a clear urban growth policy and without adequate control [7]. Urban expansion has tended to ignore the topography, hydrography, natural sites as well as fertile agricultural lands [8]. It is stated in the Land Reform Proclamation [9] of Eritrean, the Government has supreme authority in formulating the country's landuse policy; and the Ministry of Land, Water and Environment, Department of Land (MoLWE-DoL) is in charge of determining the classification of land and its usage including land for urban expansion and the need to protect agricultural land loss.

Urban landuse changes have been studied for many years; however, the advent of satellite images and geospatial technologies opened a new dimension for assessing and monitoring landuse cover changes. Remote sensing techniques and the availability of free to less expensive data sources of satellite imagery and their temporal frequency has greatly enhanced the potential for monitoring urban growth [10-12], urban landuse dynamics [13], landscape pattern analysis [14], and urbanization [15].

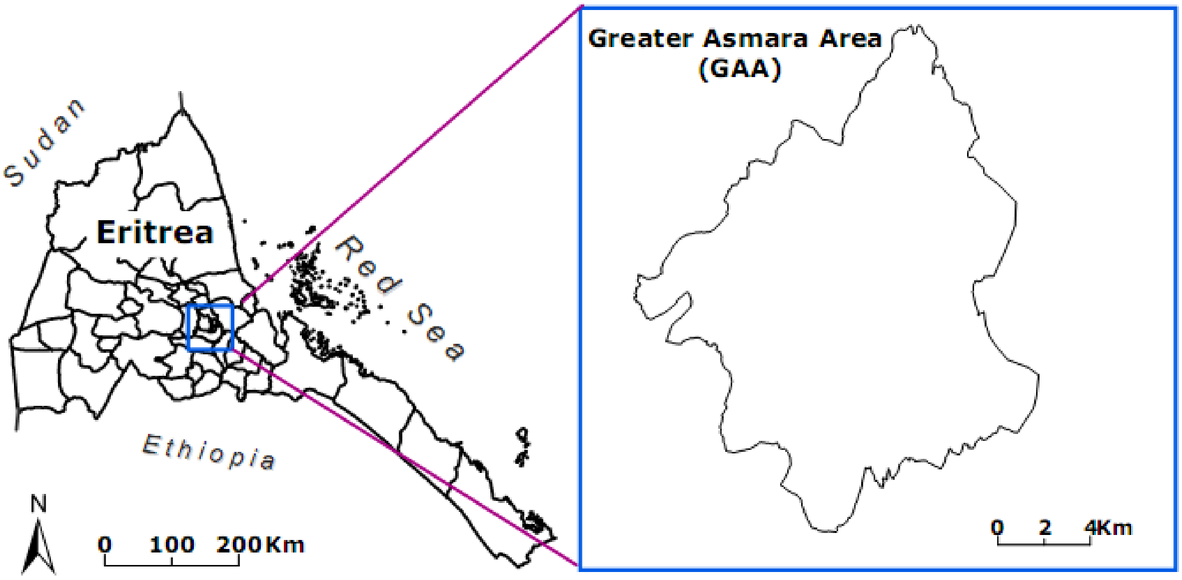
Despite the GAA is center for economic development, and its social importance, its trend of growth remains the major factor for diminishing productive land and other valuable natural resources [16]. Hence, the study analyzed how much the urban area has expanded and impacted the irrigation and rainfed agricultural areas and plantation cover during the study periods (1989 to 2009). Moreover, the study examined the effect of built-up sprawl in the coming 10 years. There will be severe loss of agricultural area and plantation cover if the land allocation system of the government does not adhere to the landuse plan of GAA prepared by MoLWE-DoL. For this purpose, remote sensing, Geographic Information Systems (GIS) and modeling tools have been applied. This study discusses the major driving forces that led to urban sprawl and to the loss of agricultural land and plantation cover. Moreover, recommendations to resolve the conflicting interests of land and policy options are presented.

2. Study Area

Asmara is the capital city of Eritrea. GAA encompasses Asmara city and the nearby 13 satellite villages. It is located on the central highlands of Eritrea (Figure 1). The geographical extent of the GAA is 15°13′30″N to 15°26′N and 38°49′E to 38°59′30E, with an elevation between 2,100 m and 2,500 m above mean sea level. It covers an area of 21,254 ha.

The geographical setting of Eritrea in general is classified as Central highland, Western and Eastern lowlands. About 65 percent of the population lives in the central highlands, this account for only 16 percent of the land area [17]. The area is characterized by diverse landcover types. The most dominant landcover types in the study area are settlement patterns (urban and sub-urban), agricultural (rainfed and irrigated), plantation, bare lands, intermittent rivers, market gardening and pasture lands.

Figure 1. Location of the study area (Data source: MoLWE, Department of Land, 2010).



3. Data

Three Landsat TM satellite images with 30m resolution, acquired in 14 December 1989; 01 October 2000; and 20 June 2009 were used. These images were obtained from the United States Geological Survey (USGS) portal [18]. Data was projected to a World Geodetic System (WGS) 1984, Universal Transverse Mercator (UTM), Zone_37N coordinate system. A 30m resolution Digital Elevation Model (DEM) was also downloaded from ASTER DEM [19].

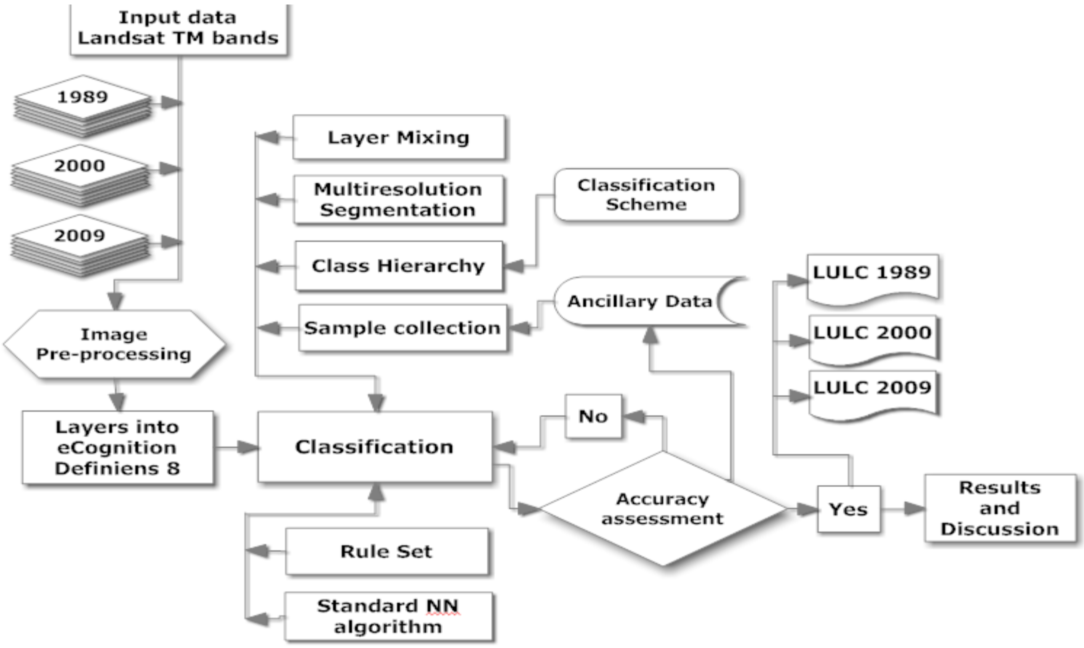
Landcover maps, main roads and main rivers data were obtained from the Ministry of Land, Water and Environment (MoLWE) Asmara, Eritrea. High resolution imageries were also obtained from the Center for Development and Environment (CDE), University of Berne, Switzerland. These are IKONOS-2, 1 meter spatial resolution acquired in 07 March 2000 and QuickBird, 0.6 meter spatial resolution acquired in 14 March 2008. Google Earth (time slide) has also been used for preliminary interpretation of the historical imageries of GAA. All these ancillary data have been used during sample collection for image classification and accuracy assessment.

4. Methods

4.1. Satellite Image Pre-Processing and Landuse Mapping

The use of satellite imagery has made urban landuse landcover (LULC) mapping and change detection more efficient and reliable [13,14,20-25]. One of the key pre-requisites for better use of land is information on existing landuse patterns and changes in landuse through time [26]. Hence, in order to monitor urban growth and urban landcover dynamics, the availability of updated surface information is required. Figure 2 shows the methodology followed for image pre-processing, classification and validation.

Figure 2. Data and methodology used for image classification and result validation.



4.1.1. Image Pre-Processing

Landsat TM satellites typically cover an area of approximate scene size of 170 km north–south by 183 km east–west with a sensor spatial resolution or pixel size of 30 m for all the spectral bands except band six (thermal band) which is 120 m. The study area covers only small portion the whole scene. It has been extracted from the scene; all bands except band six were stacked and clipped to the GAA shape for further pre-processing in ERDAS Imagine. Effective image pre-processing is critical to successful urban LULC mapping and change detection [27]. After selecting the subset imagery, it has been calibrated to ensure that the observed change in signal is attributable to “true” changes in the land surface rather than a change due to non-surface factors [27]. Moreover, the analysts made an automated image enhancement and contrast adjustments to the subset images of the study area.

4.1.2. Object-Based Image Analysis (OBIA) using eCognition Developer

eCognition Definiens 8 was used for image classification due to the advantage of classifying image at image object level instead of pixel level. The real world is not made of pixels; rather it is arranged in objects [28]. Object-oriented classification avoids mixed pixel problems which usually occur in urban area image classification. For example, at pixel level classification, bare sand soil and the impervious parts of urban areas usual create a mixed pixel problem. The advantage of object-based classification is that each image object represents a definite spatially connected region of the image. The pixels of the associated region are linked to the image object. In addition to the multispectral bands, the object-based approach takes advantage of all dimensions of remote sensing including spatial (area, length, width and direction), the morphological (shape parameters, texture), contextual (relationship to neighbors, proximity analysis) and temporal (time series) [29]. The resulting object-based features can then be incorporated into the classification process.

Classification Scheme

This study followed the classification scheme proposed by Afri-Cover [30] and adopted by the MoLWE-DoL. The detail land classes nomenclature is simplified (Table 1), as the main focus of the study is in urban / built-up areas.

Table 1. Landcover classes/Landcover nomenclature.

No	LULC Classes	Simplified description based on the MoLWE-DoL
1	Built-up	Industrial, commercial and public built-ups; transportation and other continuous and non continuous urban fabrics and related built-up areas
2	Water body	Dams and other water bodies (swamp area)
3	Irrigation	Flowering and fruit irrigation, high potential urban agricultural areas, nursery
4	Grazing land	Bare soil, barren lands and grazing areas
5	Plantation	Seasonal wet lands, artificial trees and natural bushes
6	Rainfed	Any kind of rainfed agriculture, other than irrigation

Image Segmentation

Image segmentation algorithm ran with different parameters was used to find regions of minimum heterogeneity (or maximum homogeneity) [31]. In this analysis, the ‘‘multiresolution’’ algorithm was used; this algorithm locally minimized the average heterogeneity of image objects for a given resolution [32]. In order to accomplish segmentation, the analysts developed a rule set based on the following methods, algorithm and parameters: The *Edit Image Layer Mixing* tool to find out the best band mix that shows the expected classes. Hence, histogram equalizing and six layers mixing gave best outcome. As a result all the TM bands except band 6 have been applied. Multiresolution segmentation algorithm with scale (5), shape (0.01) and compactness (0.5) parameters has been applied. A lower shape value (0.01) resulted in objects more optimized for spectral heterogeneity. The quality of segmentation is decisive for the outcome of subsequent classification [33].

Training Sites and Classification Algorithm

After completing the classification scheme and segmentation, the image analysts selected training sites. In the first step, for all the classes a classifier standard Nearest Neighbor (NN) algorithm [32] was applied and classification has been executed. Based on the information on the window views of 'image object information' and 'feature view' further refinement and merging of classified image objects have also been done.

4.1.3. Accuracy Assessment

Accuracy assessment is an important process in the classification procedure. eCognition Developer 8 uses accuracy assessment methods to produce statistical outputs which can be used to check the quality of the classification results. These are based on an error matrix which compares on class-by-class based on the training samples and classification results. Producer's, User's and Overall accuracies; and Kappa Index of Agreement (KIA), available in eCognition, were computed for the three classified images (Table 2) [34].

4.2. Urban Landuse Cover Change (LUCC) Detection and Urban Sprawl Analysis

A considerable number of studies in urban landuse change detection and sprawl measurement with the application of geospatial tools have been done; and remote sensing can be used to acquire spatiotemporal series of geographical data and to perform LUCC analysis [24,35-37]. The acquired data of the study area were processed and analyzed using GIS and Remote sensing techniques to obtain information for environmental and urban growth monitoring [4,11-13,23]. In this study, in order to detect, quantify and analyze the changes, post classification change analyses with ArcMap and 'Land Change Modeler' in IDRISI Andes have been employed. Shannon's Entropy (an urban sprawl index) has been used to measure the urban sprawl in the GAA.

4.2.1. LUCC Detection Using Post-Classification Method and Land Change Modeler (LCM)

Post-classification comparison is one of the available change detection methods [38]. Two multi-temporal images are classified separately and labeled with proper attributes. Then, after establishing the classification result, the area of change is extracted through direct comparison [38,39]. In other words, it involves an initial, independent classification of each image, followed by a thematic overlay of the classifications. Such a method results in a complete from-to change matrix of the conversion between each class on the two dates. Post-classification change detection is the method applied in this research. As mentioned in the literature above, the images for the year 1989, 2000 and 2009 were classified independently. The classification rules developed for each of the three images were the same and the samples collected were also similar to minimize inconsistency problems.

4.2.2. Urban Sprawl Measurement with Shannon's Entropy

Quantifying the urban growth is not difficult from remote sensing data. However, quantifying the sprawl is challenging [40,41]. The most efficient and commonly used approach in urban sprawl studies is to integrate Shannon's Entropy with GIS tools [42-44]. In this study, in order to examine the spatial expansion of the built-up areas during the three time periods, the LULC maps were reclassified into built-up and non-built-up area. Shannon's entropy along with GIS tools was applied to measure the sprawl during the study periods. Shannon's entropy measures the degree of spatial concentration and dispersion on the surface of area of study [42,45]. The entropy value varies from 0 to 1. If the distribution of the built-up is maximally concentrated in one region the value of entropy is 0. The value is 1; if the built-up is unevenly dispersed distribution across space. The dispersion of built-up areas from a city center or road network leads to an increase in the entropy value. This gives a clear idea as to whether the urban expansion is more dispersed or compact. The Shannon entropy (E_n) is computed by:

$$E_n = \sum_{i}^{n} p_i \ \log(1/p_i)/\log(n) \tag{1}$$

Equation (1): Shannon Entropy. Where, $p_i = x_i/\sum_i^n x_i$ and xi is the density of land development, that is equals to the amount of built-up land divided by the total amount of land in the i^{th} of n total zones. The number of zones refers the number of buffers from the city center.

4.3. Urban Growth Model

Models dealing with quantity of urban expansion in space and time are essential in providing policy makers and scientists with statistical support for their decisions toward an environmentally sustainable future [46,47] .

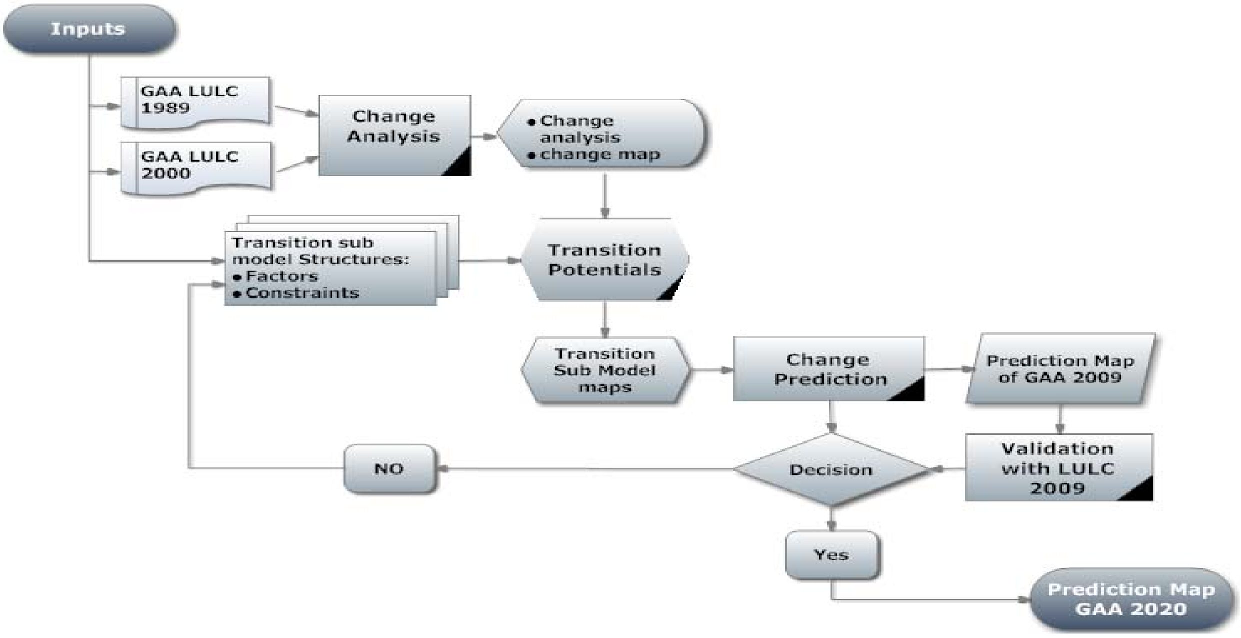
4.3.1. Urban Landuse Modeling using LCM

Among several available landuse modeling tools and techniques, some of the most commonly used models are embedded in IDRISI, such as, LCM, Markov Chain, CA_Markov, GEOMOD, and STCHOICE [48]. In this study, LCM was used and the steps followed are indicated in Figure 3. Modeling using LCM requires mainly two time categorical maps. The LUCC maps of 1989 (time-1) and 2000 (time-2) has been used as inputs for the Change Analysis Tab of IDRISI, which enabled the analysts to understand the gains and losses and the transition of areas among the LULC classes; and to quantify the changes occurred from time-1 to time-2.

Results of the quantified and analyzed data can be presented in a graphical and/or map outputs. Hence, the landcover of 1989 and 2000 were analyzed and major driving forces were identified in the Change Analysis Tab where eight transitions were considered. Explanatory static and dynamic variables were developed based on the assumption that the suitability of a cell to change its class depends on the neighboring cells. New built-ups tend to be near existing built-ups or road networks [48]. The second tab is Transition Potential Tab, where the analysts confirmed the necessary transitions to be modeled. Then, factors and constraints were created and incorporated into the model.

The MLP neural network algorithm has been employed to run the model to yield transition potential maps [48,49]. The transition potential maps with Markov Chain modeler [47] and transition probability grid has been used to predict year time-t (2009). The accuracy of the simulated map of time-t (2009) was examined against the LULC map of 2009. Finally, a scenario for the year 2020 has been carried out.

Figure 3. Methodology applied to calibrate, simulate and validate the model.



4.3.2. Model Validation

Comparing the result of the simulation with a reference map of the same year is one method to evaluate the predictive power of the model. However, there is no consensus on the way to assess the performance of landuse change model [50]. IDRISI provides VALIDATE module in the validation process. It involves a comparative analysis of the simulated map and a reference images. In this study validation has been done by comparing the predicted 2009 with the 'real' or 'actual' map of 2009 based on the Kappa variations [50] which are given by: Kno (shows the proportion classified correctly relative to the expected proportion classified correctly by a simulation without the ability to indicate accurately quantity or location); Klocation (is defined as the success due to a simulation's ability to indicate location divided by the maximum possible success due to a simulation's ability to specify location perfectly); and Kquantity (is a measure of validation of the simulations to predict quantity accurately). The predictive power of the model is considered strong when around 80% accuracy is achieved [48].

5. Results and Discussion

5.1. Landcover Classification and Accuracy Assessment

Result of the classified images of the three study time periods are shown in Figure 4. The accuracy results calculated in eCognition software based on the training samples for the classified images are shown in (Table 2). The results indicated that the overall accuracy and KIA for the three classified images were above the minimum acceptable level of accuracy (85%) to be used for efficient LUCC analysis and modeling [51]. KIA takes in to account the effect of chance agreement in the error matrix [52]. It expresses the proportionate reduction in error generated by a classification process compared with the error of a completely random classification [34].

Figure 4. Landuse landcover (LULC) maps obtained from image classification of the three study periods.

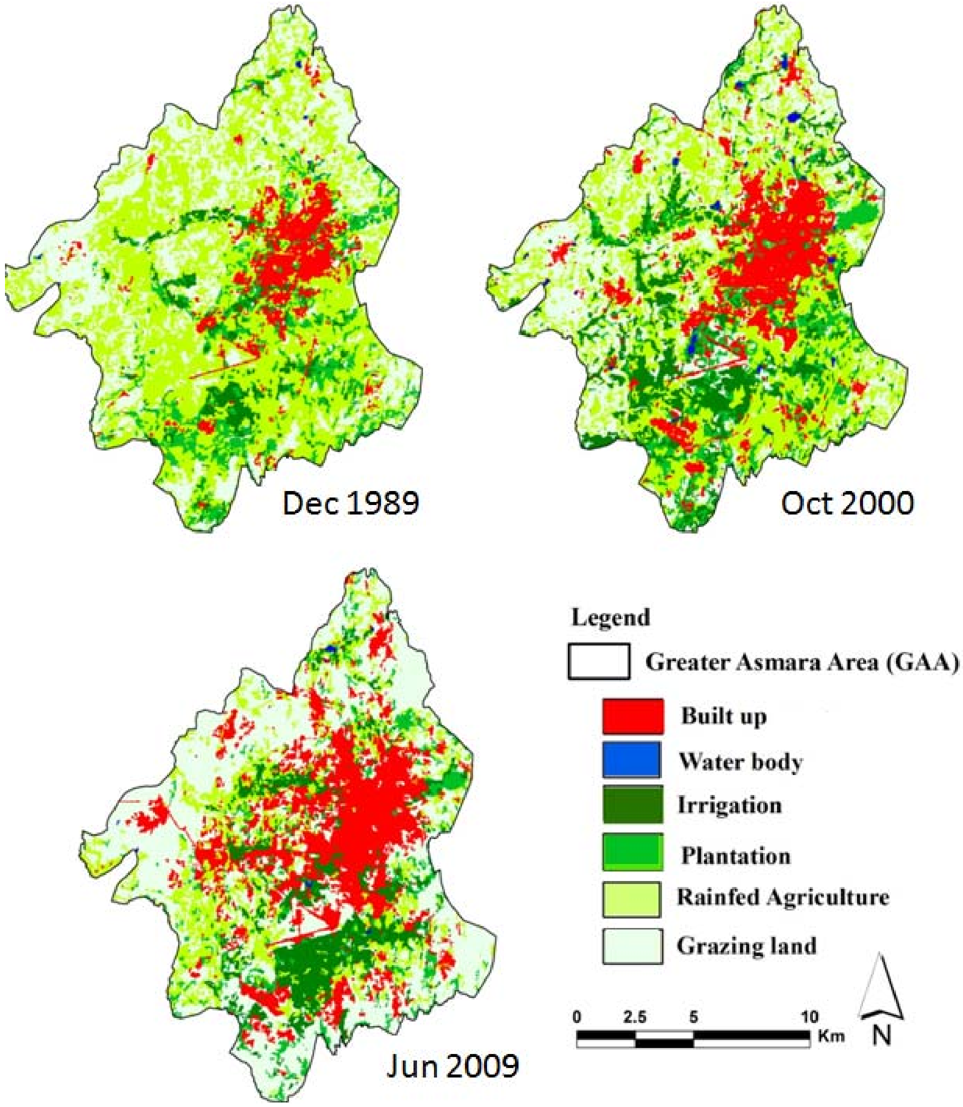


Table 2. Summary of error matrixes for the classified images of 1989, 2000 and 2009.

Land Class	Producer's			User's			KIA per Class		
	1989	2000	2009	1989	2000	2009	1989	2000	2009
Built-up	1	1	0.98	1	1	1	1	1	0.97
Irrigation	1	1	1	0.71	1	0.68	1	1	1
Rainfed	0.95	0.8	0.9	0.95	1	0.66	0.93	0.74	0.9
Plantation	0.88	1	0.85	1	0.8	1	0.87	1	0.85
Water body	1	1	1	1	1	1	1	1	1
Grazing land	0.88	1	0.91	1	1	1	0.87	1	0.85
LULC Map of:	1989			2000			2009		
Overall accuracy	0.952			0.946			0.945		
KIA	0.937			0.934			0.918		

5.2. LUCC Detection, Quantification and Analysis

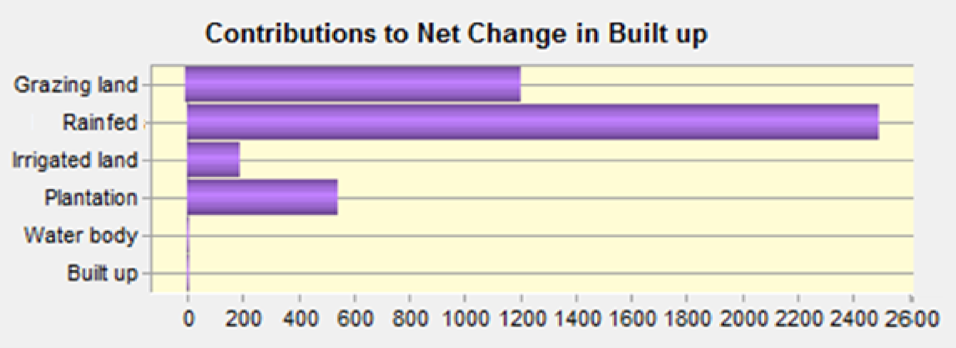
The classified images were quantified and the results are presented in Table 3. The change in hectares and in percentage of individual class area is also presented. Based on the quantified result, it can be inferred that the study area has experienced a considerable change among the land classes.

Table 3. LULC in hectare and percentage during the three study periods.

Land Class	1989		2000		2009	
	area (ha)	area (%)	area (ha)	area (%)	area (ha)	area (%)
Built-up	1,464.4	6.9	3,172.6	14.9	5,905.0	27.8
Grazing land	6,857.3	32.3	6,252.9	29.4	8,767.0	41.2
Irrigation	1,042.3	4.9	3,150.9	14.8	2,143.0	10.1
Plantation	2,067.0	9.7	1,661.4	7.8	1,156.0	5.4
Rainfed	9,799.4	46.1	6,916.7	32.5	3,257.0	15.3
Water body	23.9	0.1	99.8	0.5	26.0	0.1
Total	**21,254.3**		**21,254.3**		**21,254.0**	

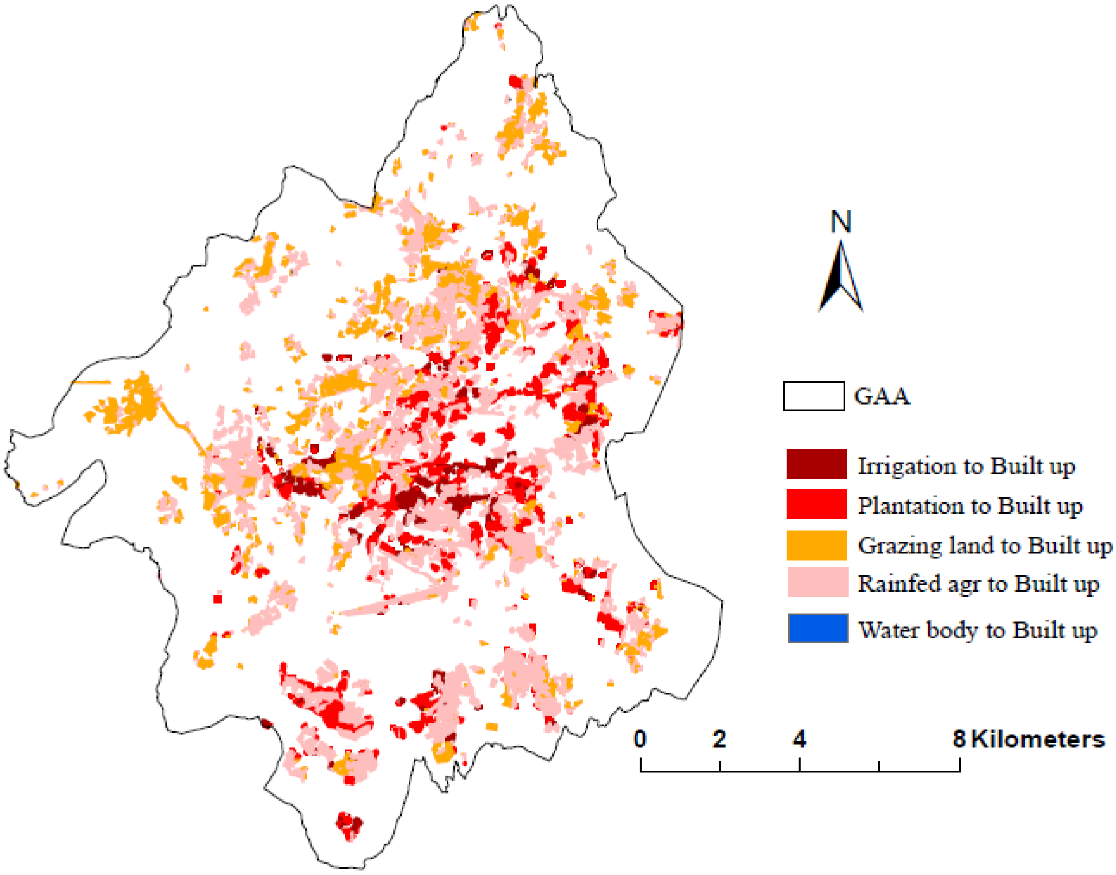
In the first decade, from 1989 to 2000, the built-up area has increased by about 1,700 ha, that is more that hundred percent. In contrary to built-up, the rainfed agricultural area has decreased tremendously, that is by about 2,800 ha. The grazing land and plantation has also decreased while the water body and irrigation increases. The tripling of water body has led for the doubling of irrigation. This is due to the construction and rehabilitation of dams. As it is stated in [53], after the independence of Eritrea, in 1991 about 50 dams have been built in *Zoba Maekel* to promote irrigation and water for domestic use. During the second decade, year 2000 to 2009, the built-up area kept the pace of increase and gained more than 2,700 ha. Water body and irrigation decreased by about 70% and 30%, respectively. The dramatic decrease of water bodies (mainly dams) was due to severe siltation [53,54]. Irrigation lands which are the high potential areas for urban agriculture are shrunk due to the expansion of built-up. In the process of urbanization, agricultural land and plantation were continuously pushed and converted to built-up area. The overall gain of built-up from all other classes in the last 20 years is presented in Figure 5 in graphical form.

Figure 5. Contribution of other land classes to built-up (in ha), from 1989 to 2009, computed in Land Change Modeler (LCM).



Map Transition Option in LCM is a mapping tool to visualize the change that occurred from all the other land classes to the built-up class. The computed transition map is shown in Figure 6. The rate of urban encroachment on other land uses is shown.

Figure 6. Transition from all land classes to built-up (from year 1989 to 2009).



5.3. Urban Sprawl Measurement

In order to visualize and examine the spatial expansion of the built-up areas during the three time periods, the LULC maps were reclassified into built-up and non-built-up area (Figure 7). The built-up areas proportion was only 6.89% until 1989. This proportion has grown to 27.8% in 2009 (Table 4).

The entropy of the urban areas in 1989, 2000 and 2009 was, respectively, 0.39, 0.42, and 0.97. Sprawl was lower in the first decade and it increased significantly from 2000 to 2009 corresponding to a substantial variation in the patterns of urban growth. Urban sprawl increased because of the fragmented type of growth. It is found that fragmentation of landuse caused loss of farmland and environmentally fragile areas as well as infrastructural cost of urban growth [55-57].

Figure 7. Reclassified images (maps) showing the spatio-temporal change of urban areas.

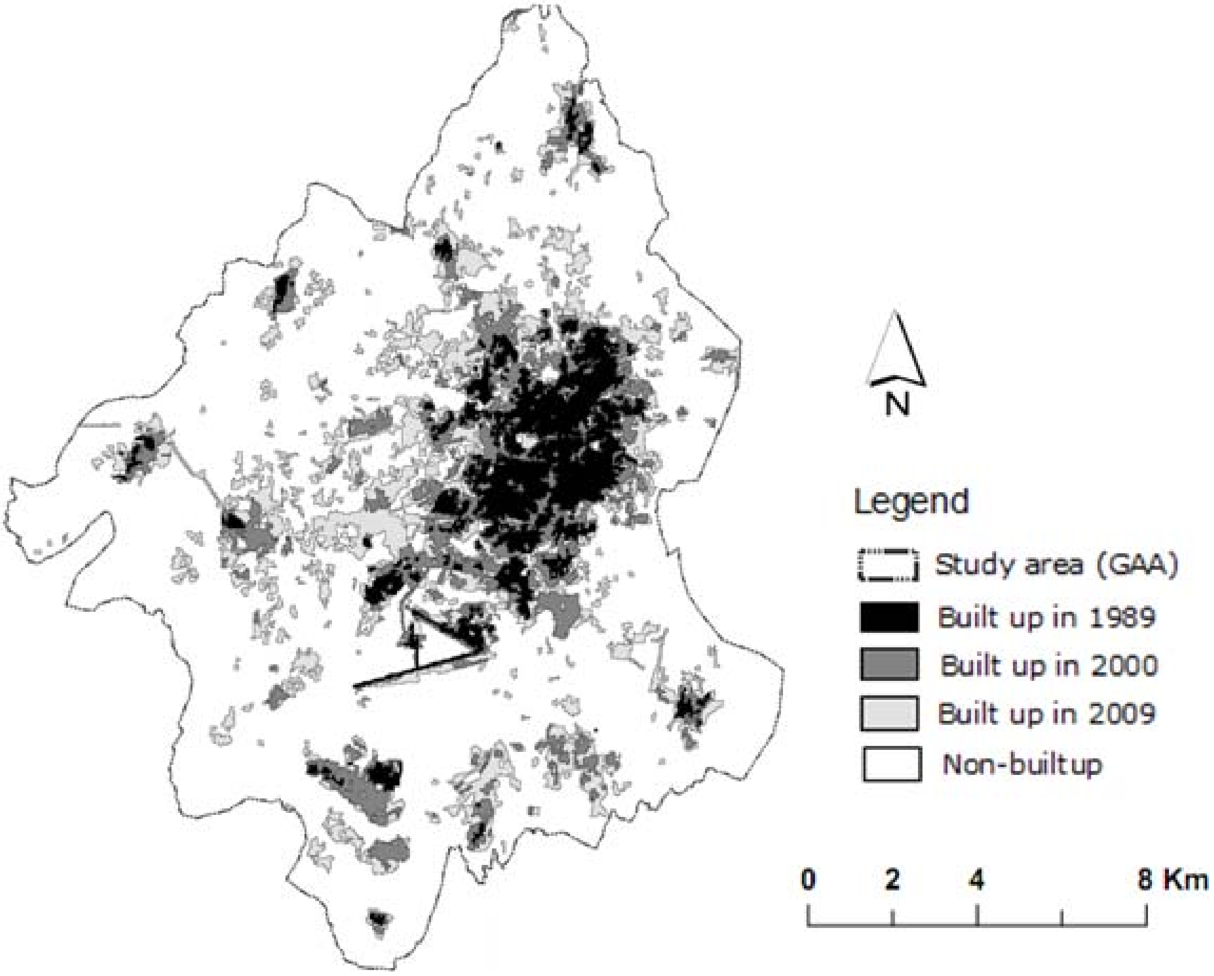


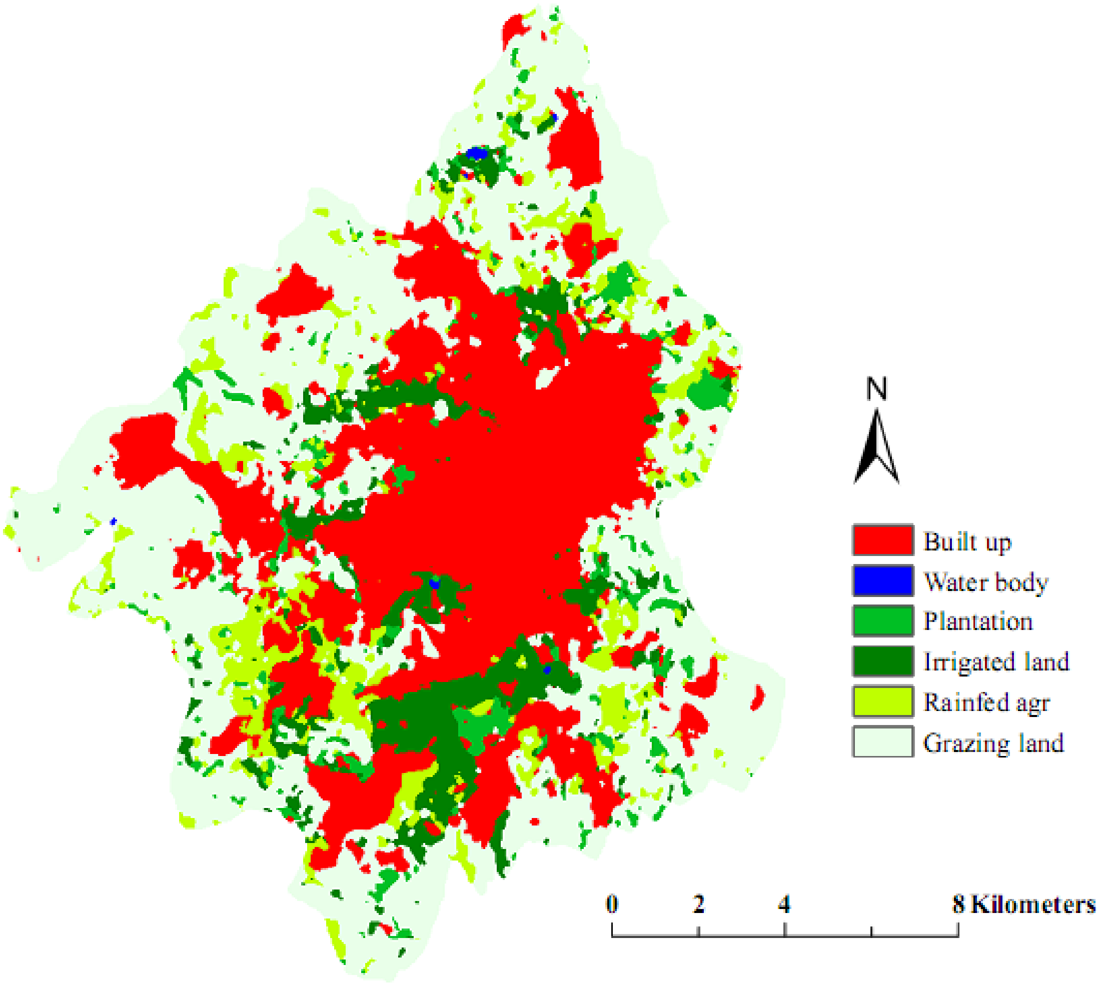
Table 4. Proportion of built-up areas in the Greater Asmara Area (GAA) in 1989, 2000 and 2009.

Land class	**1989**		**2000**		**2009**	
	Area (ha)	**Area (%)**	**Area (ha)**	**Area (%)**	**Area (ha)**	**Area (%)**
Built up	1,464.4	6.9	3,172.6	14.9	5,905.0	27.8
Non built up	19,789.9	93.1	18,081.7	85.1	15,349.0	72.2
Total (ha)	21,254.3	100.0	21,254.3	100.0	21,254.0	100.0

5.4. LUCC Modeling and Validation

Model validation was done by comparing the simulated map of 2009 with the 'actual' landuse map of 2009 based and Kappa variations. Obtained values had an acceptable level of accuracy, that are: K_{no} = 84%, $K_{location}$ = 83% and $K_{quantity}$ = 81% [50]. Finally, to examine the pattern and tendency of change in the long run, urban LUCC future projection (Figure 8) for the year 2020 has been done.

Figure 8. Future projection landuse map of GAA for year 2020.



In general, as shown in Table 5, the growth trend of built-up for year 2020 is likely to keep an alarming tendency.

Table 5. Comparison of the LULC map of year 2009 and expected LUCC of GAA 2020.

Land class	2009	2020	'Expected' change in 2020	
			in hectares	in%
Built-up	5,905.00	7,388.83	1,483.83	25.13
Grazing land	8,767.00	9,225.99	458.99	5.24
Irrigation	2,143.00	1,738.28	−404.72	−18.89
Plantation	1,156.00	910.92	−245.08	−21.20
Rainfed	3,257.00	1,964.28	−1,292.72	−39.69
Water body	26.00	25.70	-0.30	−1.15
Sum	21,254.00	21,254.00		

6. Conclusion

This study shows the application of geospatial tools to analyze urban LUCC and to examine the implementation of urban landuse plan based on land capability in the GAA which is under intense land conflict and competition. Conversion of agricultural land and plantation cover to human settlements, urban fragmented growth, challenges in urban planning; and proper land resource allocation concerns were addressed in this study.

The results of the study indicates that, in the last two decades (from 1989 to 2009), GAA experienced a rapid horizontal urban growth which resulted in loss of valuable land for urban agriculture, decline in plantation cover and uncoordinated outward sprawling. The growth trend of built-up areas in the coming ten years is also likely to keep expanding at an alarming rate. If the sprawling cannot be regulated by strict policy instrument, in the future the urban environment of GAA might reach in a stage where the situation is critical and irredeemable. Based on the field observation and discussions with concerned bodies the major driving forces behind the landuse change and urban sprawl can be attributed to: (i) Population growth, particularly during the post-independence period (1991); and returnees and deportees from the neighboring countries after the year 2000. This created high demand of land for residential and industrial purposes. As a consequence it increased the pressure on the government and on the land administration body. (ii) Absence of clear urban development policy. (iii) Limitation of technology and human expertise in the MoLWE-DoL which has the responsibility for land use planning. (iv) Allocation of land for less compacted residential purposes, like *Tessa* (land for housing, to village land that is allotted to an Eritrean whose origin is in the village), *Bond* (special form of lease land) and *villas* (less compact single large residential houses). (v) Conflicting interests of land by various sectors and the override of the landuse plan produced by the MoLWE-DoL. Another factor could be (vi) government's independence of decision especially in the absence of a clear landuse policy which ultimately resulted in uncoordinated and uncontrolled growth [5]. In Eritrea, all land is owned by government and the Land Reform Proclamations [9,58] state: land allocation system, land administration decision and land related guidelines implementation is the mandate of the MoLWE-DoL. The DoL has prepared the land capability map of GAA which indicates the areas protected for agricultural land (high and medium potential agricultural land), plantation land and other uses. However, the result of this study shows a significant proportion of land for irrigation, rainfed and plantation within the GAA is being pushed and shrunk by uneven and discontinuous urbanization patterns. This is in opposition to the landuse plan produced by the DoL based on the land capability. The finding of this study indicated incongruence between the landuse plan and the land allocation system in the GAA. Hence, the researchers suggest the following recommendations that may contribute to the strengthening of the landuse plan and its implementation; and eventually to the urban development policy. "Smart growth", which is a policy oriented urban development strategy to minimize impacts of urban sprawl and it advocates implementation of higher residential densities and consideration of preserving agricultural land [5]. It is important that planners and decision makers consider vertical urban development for optimal use of land. To strengthen the institution that is responsible for landuse planning with modern technology and professional capacity. The Department of infrastructure Asmara, MoLWE-DoL, Ministry of Agriculture and other related governmental sectors should consider the application of geospatial tools that enable to establish cross-sectoral communication and integration. This would avoid conflicting interests of land and move towards a sound decision making process for policy formulation. Consistency between land allocation and landuse plan and its goals are also recommended. The land allocation system should adhere to the land capability classification of the GAA to achieve a sustainable urban development.

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