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ASSESSMENT OF URBAN SPRAWL USING GEOSPATIAL TECHNOLOGY: A CASE STUDY OF DEBRE BERHAN TOWN, ETHIOPIA

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Abstract

The fast rate of increase in urban population is mainly due to large scale migration of people from rural and smaller towns to bigger cities in search of better employment opportunities and good life style. This rapid population pressure has resulted in unplanned growth in the urban areas to accommodate these migrant people which in turn leads to urban sprawl. Urban sprawl has resulted in loss of productive agricultural lands, open green spaces, loss of surface water bodies and depletion of groundwater. Therefore, there is a need to study, understand and quantify the urban sprawl. Understanding urban growth spatiotemporally is important for landscape and urban development planning. Urban sprawl has been one of the burgeoning issues of study in the present development situation where increasing population and migration for better livelihood opportunities have paved way for rapid expansion of the urban centres. Remote Sensing and GIS based study is carried out to comprehend the process of sprawl. Topographic map, Landsat satellite image and Sentinel satellite image are used to study the phenomena for the years 1986, 2000, 2009 and 2018 respectively. It is observed that 65.53% area is expanded in time duration of 1986 to 2018.

Introduction

Urban sprawl is the expansion of a city and its suburbs to exurbs, to low-density and often auto dependent development on rural land [1]. This is caused by the increase in population in an area. Rapid urbanization leads the change in land use/cover pattern. The changes in land use/cover may have adverse impacts on ecology of the area, especially the greenness [2] [3] [4].

Urban sprawl is termed for an uncontrolled haphazard growth in the fringe of urban area due to the rapid population growth [5] [6]. This growth is resulted in a dispersed development along highways, or around the city in the countryside. Because of sheer numbers, the civic bodies have already been wavering; they could not manage the fast growth of the population and therefore, urban centres are expanding in an unplanned way. Urban sprawl is a complex phenomenon, through which environment and society is affecting [7]. Due to its complexity, there is no specific, measurable, and generally accepted definition of urban sprawl [8]. Urban sprawl has resulted in the loss of productive agricultural land, open green spaces, loss of surface water bodies and depletion of ground water, besides causing water, air, noise, and solid waste pollution. The transformation of rural land into urban land uses leads to increase in impermeable surfaces. The major impact of urban sprawl is felt on the productive agricultural lands, surface water bodies, changing urban hydrology and creating new hydrological environment [9] [10] [11] [12]. Mapping urban sprawl helps to identify areas where environmental and natural resources are critically threatened and to suggest likely future directions and patterns of sprawling growth [13].

The physical expressions and patterns of sprawl on landscapes can be detected, mapped, and analysed using remote sensing and geographical information system (GIS) technologies in conjunction with the secondary and ground truth data [7]. Urban sprawl mapping and monitoring is one of the operational applications of satellite remote sensing data, irrespective of its spatial and spectral resolution of the satellite-borne sensors. The conventional surveying and mapping techniques are expensive and time consuming for the estimation of urban sprawl and such information is not available for most of the urban centres, especially in developing countries. As a result, increased research interest is being directed to the mapping and monitoring of urban sprawl/growth using GIS and remote sensing techniques [14]. Remote sensing is cost effective technologically sound, so is increasingly used for the analysis of urban sprawl [15] [16] [17] [18].

Objective

The main objective of the study is to quantify urban sprawl in Debre Berhan town, Ethiopia. The urban boundary is increased rigorously since 1986. Therefore, urban boundary is delineated using satellite images to assess urban sprawl. This study is carried out to investigate the urban sprawl in between 32 years (1986 to 2018) by using the Remote Sensing and GIS techniques.

Study Area

Debre Berhan is located in $9^0$38’00” N to $9^0$42’00” N latitude and $39^0$30’00 E to $39^0$33’00” E longitude (Figure 1). It is situated at about 130 km road distance from Addis Ababa (the national capital) and at about 696 km from Bahir Dar (the

Amhara National Regional State Capital) on the main highway to north-central part of Ethiopia. The town is bounded by weredas of North Shewa Zone of Amhara Region which is an indication of good potential. Currently, it is classified with 9 kebeles under municipal status and wereda level and serves as a centre for North Shewa Zone and Basonna Wereda too. The town is based on an average elevation of 2750 meter above sea level (masl). Debre Berhan is classified under Dega agro-climatic zone. With an average maximum temperature of 20.1 ^{0}C and average minimum temperature of 6.5 ^{0}C, the town has got mean annual temperature of 13.3 ^{0}C (2008 to 2013 G.C). The mean annual rainfall of the town is 965.25mm (2008-2013 G.C).

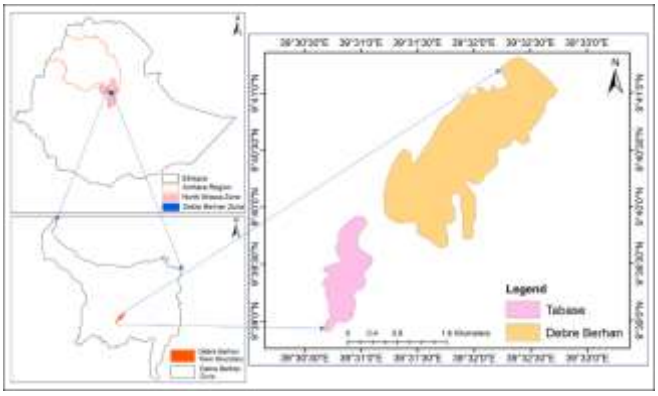

Figure 1. Location map of the study area

Materials and Methods

Understanding the dynamic phenomenon of urban sprawl/growth requires the identification of urban sprawl patterns, the computation of landscape criteria, and the analysis of built-up area change. The identification of built-up area change is a fundamental input in urban planning, management, and environmental analysis. For this study, topographic map (Ethiopian Mapping Agency, 1986, Sheet No. 0939 B3) of Debre Berhan was used to prepare base map. Landsat7 satellite images were used to delineate town boundary for two time points i.e., 2000 (acquired date 09/04/2000) and 2009 (acquired date 06/12/2009) (http://earthexplorer.usgs.gov; p168r053). Thematic mapper images were acquired with a spatial resolution of 30m. Sentinel-2 satellite data was acquired for year 2018 (acquired date 24/01/2018) having 10m spatial resolution (http://earthexplorer.usgs.gov). Topographic map and satellite data were processed in ArcGIS 10.2 software to delineate town boundary.

Results and Discussion

By using remote sensing and GIS techniques, urban sprawl of Debre Berhan is identified. In topographic map, town boundary was depicted that was delineated as GIS layer. It was found that town was divided into two parts, one was Debre Berhan and the other was Tabase (Table 1). In 1986, total boundary area of the town was 4.41 km^2 (Figure 2). In 2000, the town boundary was increased by 25.14% from 1986 (Figure 3). Total boundary area was 5.89 km^2 in 2000. The boundary was increased 31.48% from 2000 as area increased to 8.59 km^2 in 2009 (Figure 4). In 2018, the area increased to 12.79 km^2 (Figure 5). Therefore, it was found that 65.53% boundary area was expanded from 1986 to 2018. A positive correlation (r^2 = 0.9545) was observed (Figure 6; Table 1).

Figure 2. Boundary given in Topographic map 1986

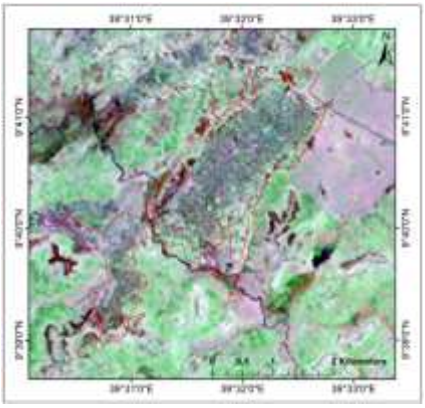

Figure 3. Boundary delineated on satellite data 2000

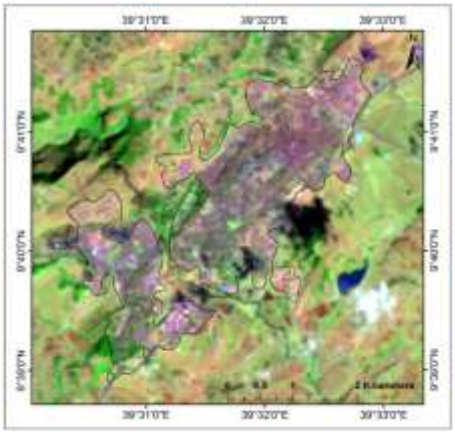

Figure 4. Boundary delineated on satellite data 2009

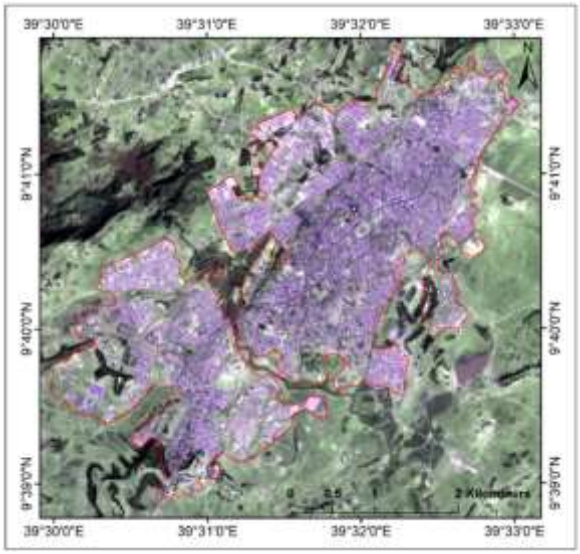

Figure 5. Boundary delineated on satellite data 2018

Table 1. Increasing sprawl in Debre Berhan and Tabase area

Year	Debre Berhan Area (km2)	Tabase Area (km2)	Total Area (km2)	Increase in %	From 1986 to 2018 total % increased
1986	3.62	0.79	4.41		
2000	4.51	1.38	5.89	25.14	
2009	5.98	2.61	8.59	31.48	65.53
2018	8.22	4.57	12.79	32.81	

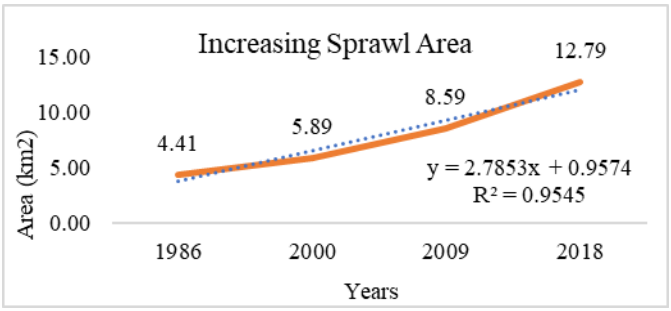

Figure 6. Graph showing increasing sprawl area

According to Central Statistical Agency, Ethiopia (CSA), the population of Debre Berhan town is growing continuously. The latest estimation of Debre Berhan population reached that of 83,479 (CSA, 2013). As per CSA, the total population of the town was 25635, 38717, 65231 in 1984, 1994 and 2007 respectively (Table 2). It is revealing an alarmingly population growth and increasing of population size continuous without any doubt. The reason behind such increment might be its high natural growth and immigration to the town since the area is becoming economically active and very much convenient for investment as compared to the area around it. In population growth, a positive correlation coefficient (r^2 = 0.9851) was observed (Figure 7).

Table 2. Population of whole Debre Berhan town

Central Statistical Agency, Ethiopia	
Year	Population
1984	25635
1994	38717
2007	65231
2013	83479

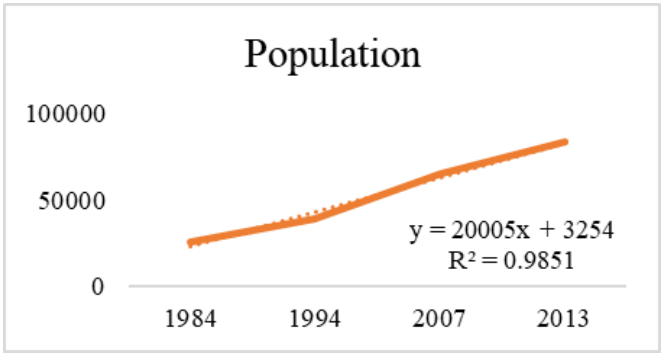

Figure 7. Population growth of Debre Berhan Town

Conclusion

The urban sprawl is seen as one of the potential challenge to sustainable development where urban planning with effective resource utilization, allocation of natural resources and infrastructure initiatives are key concerns. The study was aimed to analyse the urban growth of Debre Berhan town by Remote Sensing and GIS technique. The analysis was carried out by town boundary delineation over topographic map (1986) and satellite images (2000, 2009, 2018). It was observed that 65.53% area is expanded in time duration of 1986 to 2018. Remote sensing technology is essential for dealing dynamic phenomenon, like urban sprawl. Without remote sensing data and GIS analysis, one may not be able to monitor and estimate the urban sprawl effectively over a time period, especially for elapsed time period.

Acknowledgement

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