PREDICTION OF URBAN EXPANSION IN THE UPPER SHAMA AREA USING ARTIFICIAL NEURAL NETWORKS

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Presentation Outline

- Introduction
- Objectives of Project
- Relevant Information about Study Area
- Materials and Methods Used
- Results and Discussion
- Conclusions and Recommendations

Introduction

❖Urban expansion is of major concern to many disciplines in the world especially climate change activist.

❖Infrastructural expansion in cities of developing countries exposes these cities to adverse negative effects on climate, environment, and biodiversity which opposes the United Nations (UN) 2030 agenda for sustainable development;

❖with great emphasis on the goal 15 which seeks to guard, reinstate and encourage sustainable use of land-dwelling ecosystems, sustainably manage forests, fight desertification, stop and reverse degradation and stop loss of biodiversity (UN, 2015);

❖Urban expansion refers to the rise in the number of people and infrastructures inhabiting urban centres, which are towns and cities. This occurs when people move from rural areas to cities and towns, which causes an increase in the urban population and infrastructures.

Introduction Cont'd

❖According to Durlauf et al., in 2008, about 55 % of the world's population lived in urban centres and by 2050, the population of urban centres is estimated to double, and for every ten (10) people picked randomly;

❖seven of them will be living in urban centres. The swelling numbers of population has the potential of adding about 2.5 billion more dwellers in the cities on the global scale, where 90% of urban expansion will be prevalent in the peri-urban centres (Rana and Sarkar, 2021; Fenta et al., 2017);

❖According to the United Nations in 2016, the urbanization situation is crystal clear in Asia and Africa and it is expected that by 2050 these two areas will be urbanised by approximately 90% (Rana and Sarkar, 2021);

❖It is revealed by previous research that developing countries experience a more chaotic urban expansion than developed once. (Rana and Sarkar, 2021; Grimm et al., 2008; Cohen, 2006).

Introduction Cont'd

❖Urbanisation trends are more pronounced in Africa as a result of a compounding population resulting to an annual population growth rate of 3% in Africa, which is responsible for the 400 million in 2010 and the forecasted population of over 1 billion by 2040 (Rana and Sarkar, 2021; Andreasen et al., 2017);

❖Urban expansion is highly dependent on a high population growth rate in urban centres and is a major contributor of urban sprawl (Shao et al. 2021; Zhao, 2010);

❖Several researchers have indicated that an increased and uncontrolled urban population results in undue pressure on social amenities and facilities in the areas of entertainment, recreation, education, transportation, health, housing and many others which leads to urban sprawl (Rana and Sarkar, 2021; Shao et al., 2021; Ujoh et al., 2019; Tanveer et al., 2019; Fenta et al., 2017; Sumari et al., 2017).

Introduction Cont'd

❖A major factor of LCLU changes is urbanisation and this has a negative effect on biodiversity, habitat fragmentation and a danger to sustainable development (Rana and Sarkar, 2021; Pawe and Saiki, 2020; Son and Thanh, 2017; Pawe and Saikia, 2017; Souza et al., 2016; Griggs et al., 2014; Ahmed et al., 2013; Chen et al., 2006; Kalnay and Cai, 2003);

❖Developing countries are more vulnerable to a fast and uncontrolled urban due to LULC changes with a great impact on its inhabitants as a result of the limited capacity to manage the socio-economic and environmental effects of urban expansion (Rana and Sarkar, 2021; Fenta et al., 2017; Tewolde and Cabral 2011; Cohen, 2006);

❖Urban expansion itself increases economic development (Durlauf et al., 2008). When urban expansion is well monitored and managed can lead to sustainable development, which will increase productivity. However, rapid urban expansion poses many challenges

Introduction Cont'd

❖inability to provide basic services, employment challenges, and social vices rise. Poverty, unemployment, deteriorating infrastructure, and uncontrollable development of informal settlements have all followed unplanned urbanisation (Eyoh et al., 2012);

❖As cities and towns are built up, they change in their appearance and land use patterns where natural land cover is transformed into artificial structures such as housing, commercial building, transport services, etc. (Rana and Sarkar, 2021; Patra et al., 2018; Babalola and Akinsanola, 2016; Pu et al., 2006) leading to uncontrollable sprawl;

❖Cities play a vital role in tackling climate change and the greenhouse effect. Also, the rate of urbanisation is very fast in developing countries like Ghana

Introduction Cont'd

❖Land-use change modelling has become increasingly relevant for concerned urban executives, professionals, and researchers in recent years, due to the high value of land and natural resources, as well as land-use change affecting habitats and humans (Zare, 2016);

❖Therefore, monitoring and detecting urban growth have become a vital concern for urban sustainability worldwide (Zhang et al., 2019a; Shao et al., 2021);

❖Earlier studies have investigated the urban growth and land cover change scenario for densely and fast-growing urban areas (Gazi et al., 2020;Kafy et al., 2020;Rahman et al., 2020;Roy et al., 2020;Trotter et al., 2017; Ahmed et al., 2013).

❖Several studies have considered fixed land cover classes to detect land cover change (Hassan, 2017; Imran et al., 2021).

Introduction Cont'd

❖Monitoring urban expansion and different land cover features has become very easy with the use of modern geospatial techniques (Rana and Sarkar, 2021; Huang et al., 2018)

❖with Geographic Information Systems (GIS) and Remote Sensing (RS) Techniques as the commonest geospatial tools for detection of land use land cover changes (Rana and Sarkar, 2021; Jahan et al., 2021; Bhuiyan et al., 2020b; Hegazy and Kaloop, 2015).;

❖A well-known secondary source of data for change detection analysis is the Landsat satellite images (Rana and Sarkar, 2021; Nagne et al., 2018) where land cover transformations are ascertained with the aid of RS and GIS techniques using satellite images (Rana and Sarkar, 2021; Shao et al., 2021)

❖and these methods have been proven to be very accurate and effective methods for land-use/land-cover change detection (Rana and Sarkar, 2021; Shao et al., 2021; Nzunda and Midtgaard, 2019; Ligate et al., 2018; Fu et al., 2013)

Introduction Cont'd

❖and even other researchers such as Epstein et al. (2002) indicated that the use of GIS and RS techniques for quantitative analysis of urban expansion is even faster and cheaper due to the availability of quality and cheaper remote sensed satellite data.

❖Supervised and unsupervised classification are GIS and RS methods commonly used in quantifying urban expansion at various spatiotemporal scales (Rana and Sarkar, 2021; Sharma et al., 2012; Tewolde and Cabral 2011)

❖This research applied the supervised classification method under three land cover classes for analysing urban expansion and subsequently used the ANN machine leaning algorithm to predict the urbanisation scenario for 2030 for the study area;

Introduction Cont'd

❖Urban expansion results in the physical extension of the geographical footprints/features of towns sometimes as a result of an increase in population thus leading to Land Use/Land Cover changes of such area.

❖As the population and infrastructure increase, they pose a lot of threats to the environment and make handling of spatial data very difficult. Therefore, the aim of this study is to monitor urban expansion and predict urban expansion for the study area for the year 2030.

❖This project sought to assess urban expansion in the Upper Shama Area using an integrated remote sensing and GIS approach and to also predict future growth using Artificial Neural Network.

Research Objectives

The objectives of this research are to:

- ❖monitor the urban expansion of the study area; and
- ❖predict urban expansion for 2030.

The Study Area

❖Ghana is one of the Sub-Saharan countries located on the Guinean Gulf. Compared to West African countries like Nigeria and Cote d'Ivoire, the country is comparatively small in area and population:

❖The Upper Shama Area (USA) is in the Shama District of the Western Region of Ghana

❖The USA is located between Latitude 4° 58' 00" N and 5° 04' 00" N and Longitudes 1° 37' 00" W and 1° 52' 30"W

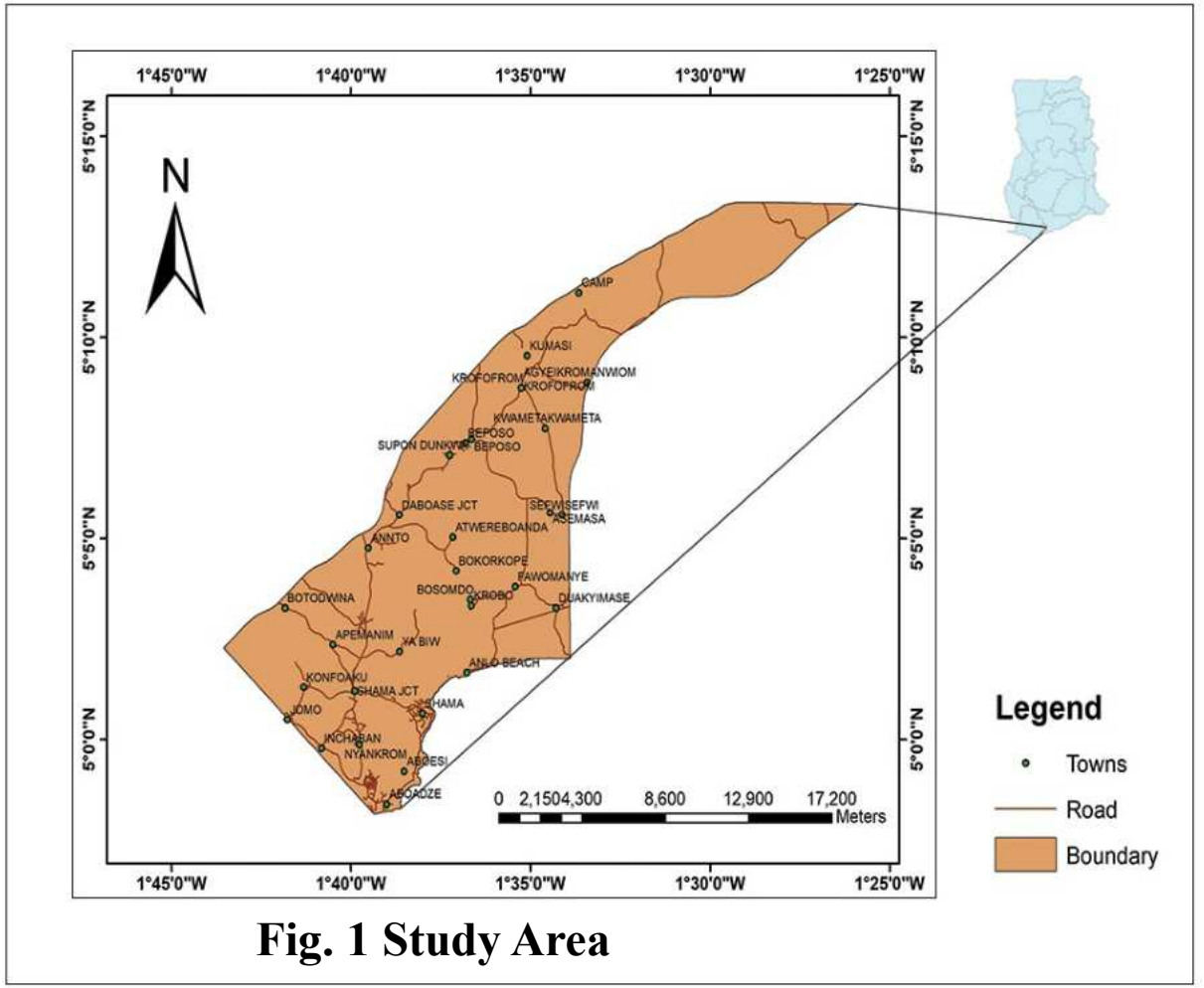

Fig. 1 Study Area

Materials Used

- Landsat Images;
- identification and classification of settlements and vegetation
- level one (1) collection, which were processed for geometric and radiometric corrections
- Bands 1, 2,3,4,5, 7, 8, & 9
- These bands were used because they represent red, green, blue, near infrared and short-wavelength infrared (for the purpose of NDVI);
- NDVI) and classification were done with the ArcGIS software;
- Table 1 provides information about the satellite images used. **DEM** & **Gh District Shape files** used

Table 1 Satellite Data

Satellite image	Sensor	Swath (Km)	Source	Resolution(m)
May 2000	TM	185 km	USGS, Landsat 5	30
January 2010	ETM	185 km	USGS, Landsat 7	30
January 2020	OLI_TRIS	185 km	USGS, Landsat 8	30

Methods Used: Urban Expansion Determination

The following methods are used:

❖**Clipping of Landsat Bands** to Boundary in ArcGIS 10 environment;

❖**Atmospheric Corrections**; scattering and absorption effects of the atmosphere and obtain the surface reflectance

❖**Lines Correction** in Landsat 7 data; Landsat toolbox image bands were added and clipped to the boundary, then Landsat 7 scanlines error was fixed in the Landsat toolbox was used to correct the line error in the 2010 image.

❖**Composite bands Creation:** various extracted reflectance bands with the atmospheric corrections were combined to produce the composite band.

Methods Used Cont'd

The following methods are used:

❖**Supervised Classification**; idea that a user can select sample pixels in an image that are representative of specific classes and then direct the image processing software to use these training sites as references for the classification of all other pixels in the image. **Settlements, Vegetation** and **Water Bodies**.

❖**maximum likelihood algorithm**

❖**Area Computation of Land use/ land cover types:** area of the land use/land cover types (bare lands/settlements and vegetation) were computed in square meters from the cell (pixel) size (length × breadth). **30m × 30m**

❖Prediction of 2030 Map using ANN

Methods Used Cont'd

❖**Accuracy Assessment of the Land Use/Land Cover Map:** This process uses three geo-processing tools: create accuracy assessment points, update accuracy assessment points and compute confusion matrix.

❖The accuracy of the supervised classification maps was assessed by creating a set of random points from the satellite images and comparing them with the classified data in a confusion matrix.

❖**Prediction of 2030 Urban Expansion using ANN**: using QGIS software, The forecast was done using the slope, *etc.* Artificial Neural Network algorithm was used for the prediction of the year 2030. The raster and molusce options were used in QGIS.

❖It was ensured that the geometry of all the data uploaded matched. These include the slope, Euclidean distance to road, and maps of the various years. The ANN toolbox was then employed and the iterations were set to 1000. After the learning on the maps by the neurons, a map of 2030 was produced.

Methods Used Cont'd

Artificial Neural Network (ANN)

❖ANNs are heuristic algorithms in that they can learn from experience via samples and are applied to recognise new data.

❖These systems are intended in an extremely simple way to imitate the behaviour of the network of neurons in the human brain.

❖The aim of ANNs is to improve the performance of computer recognition processes by simulating the superior characteristics of the human brain (Kavzoglu and Saka, 2005).

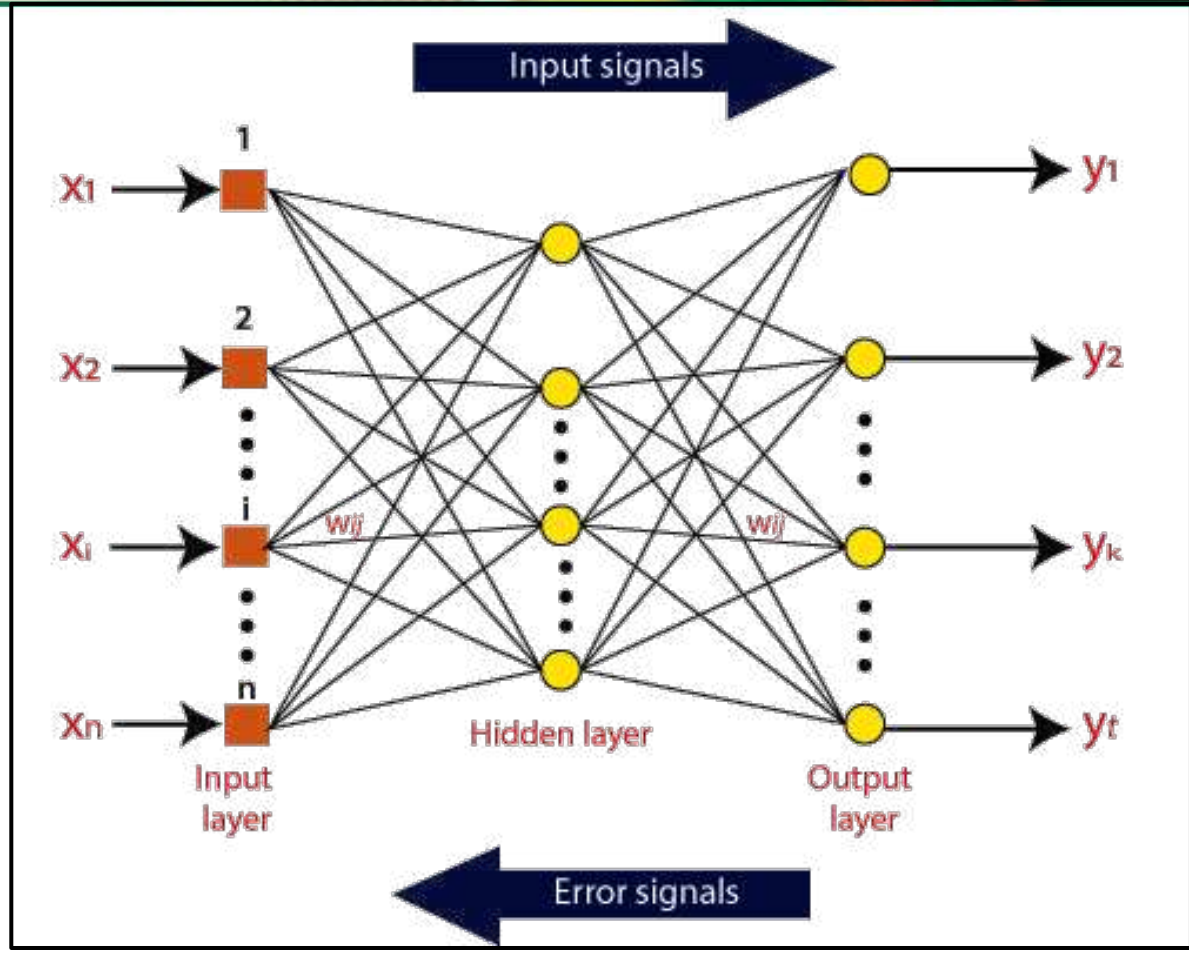

Fig. 2 Artificial Neural Network Model (Source: Anon., 2023)

Methods Used Cont'd: Artificial Neural Network (ANN)

(3.1)

(3.2)

Where $X_1, X_2, X_3, \ldots, X_n$: the input signals

Where $y_1, y_2, y_3, \ldots, y_n$: the output signals

$W_{k1}, W_{k2}, W_{k3}, \ldots, W_{kn}$: the synaptic weights of the input signals

: the output of the summing junction $\sum$

(.):the activation function and is bias

Results and Discussion: **Maps**

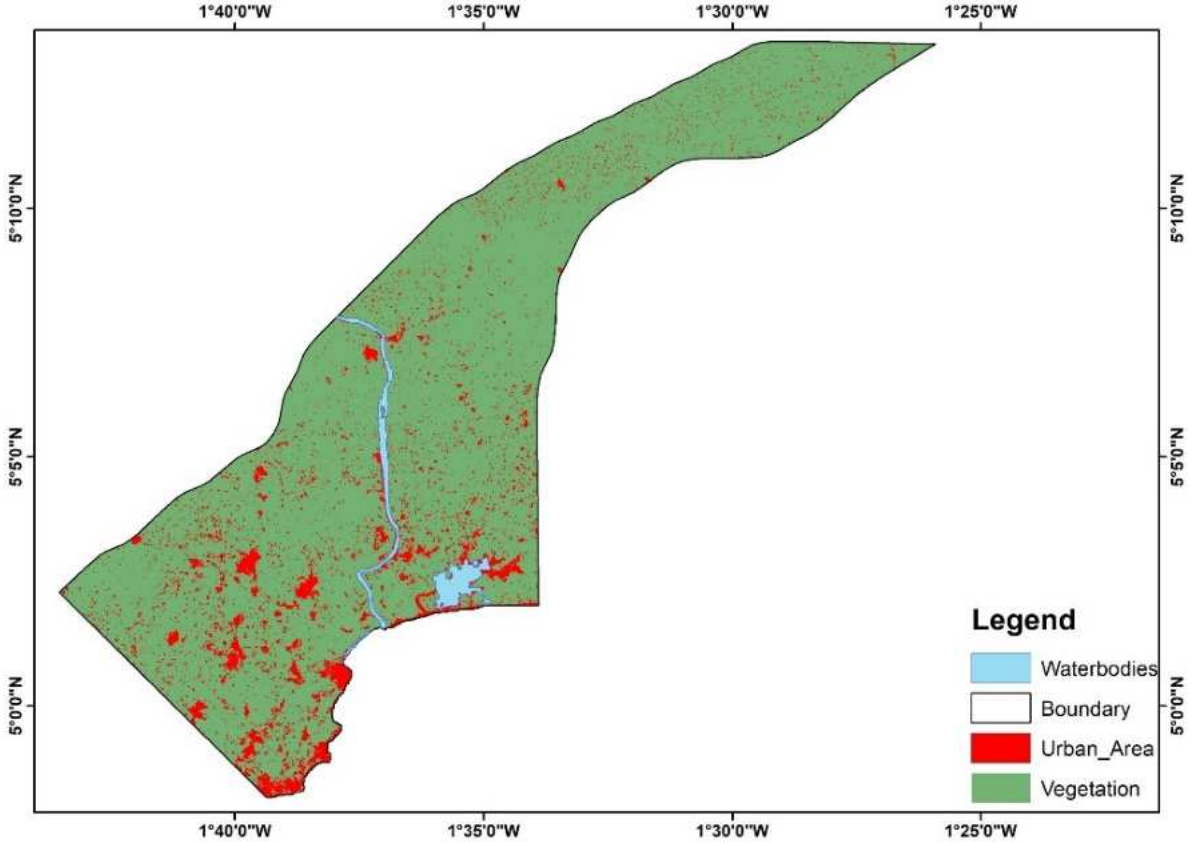

Fig. 3a Expansion in 2000

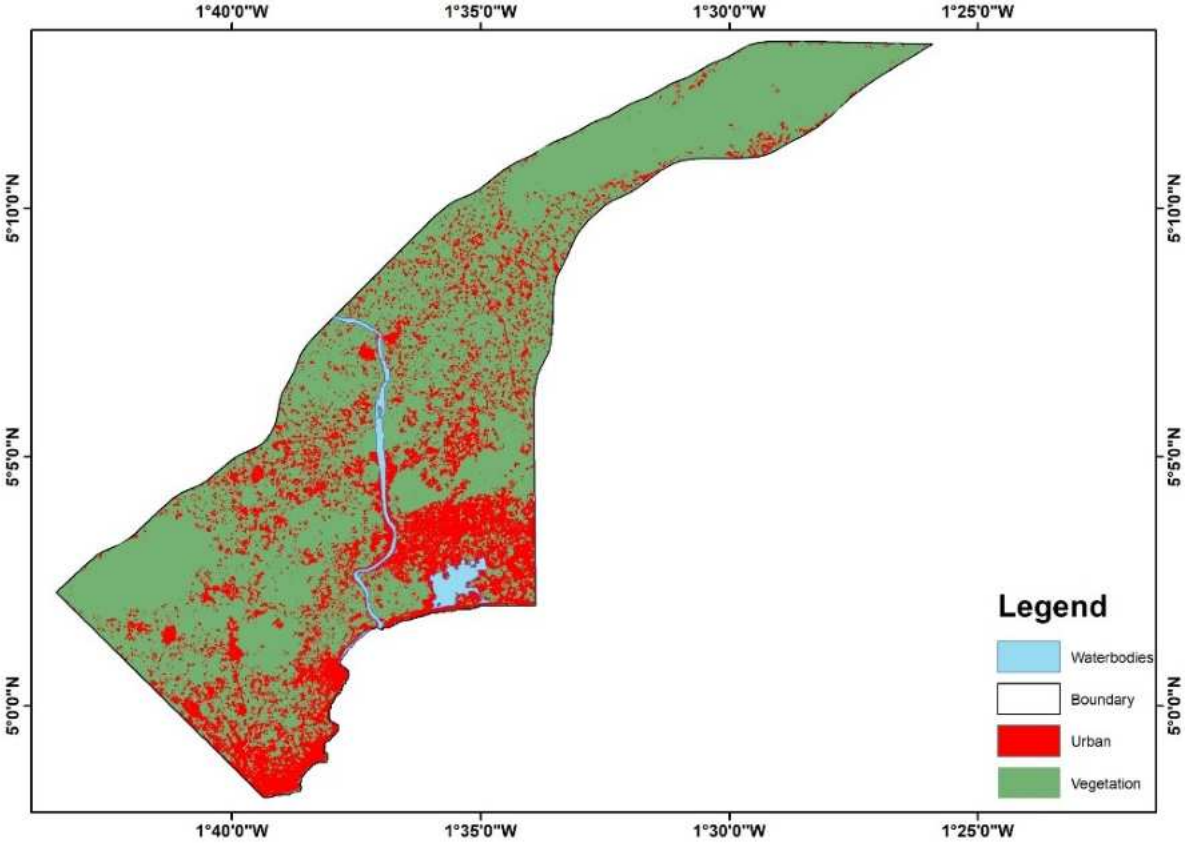

Fig. 3b Expansion in 2010

Results Cont'd and Discussion: **Maps**

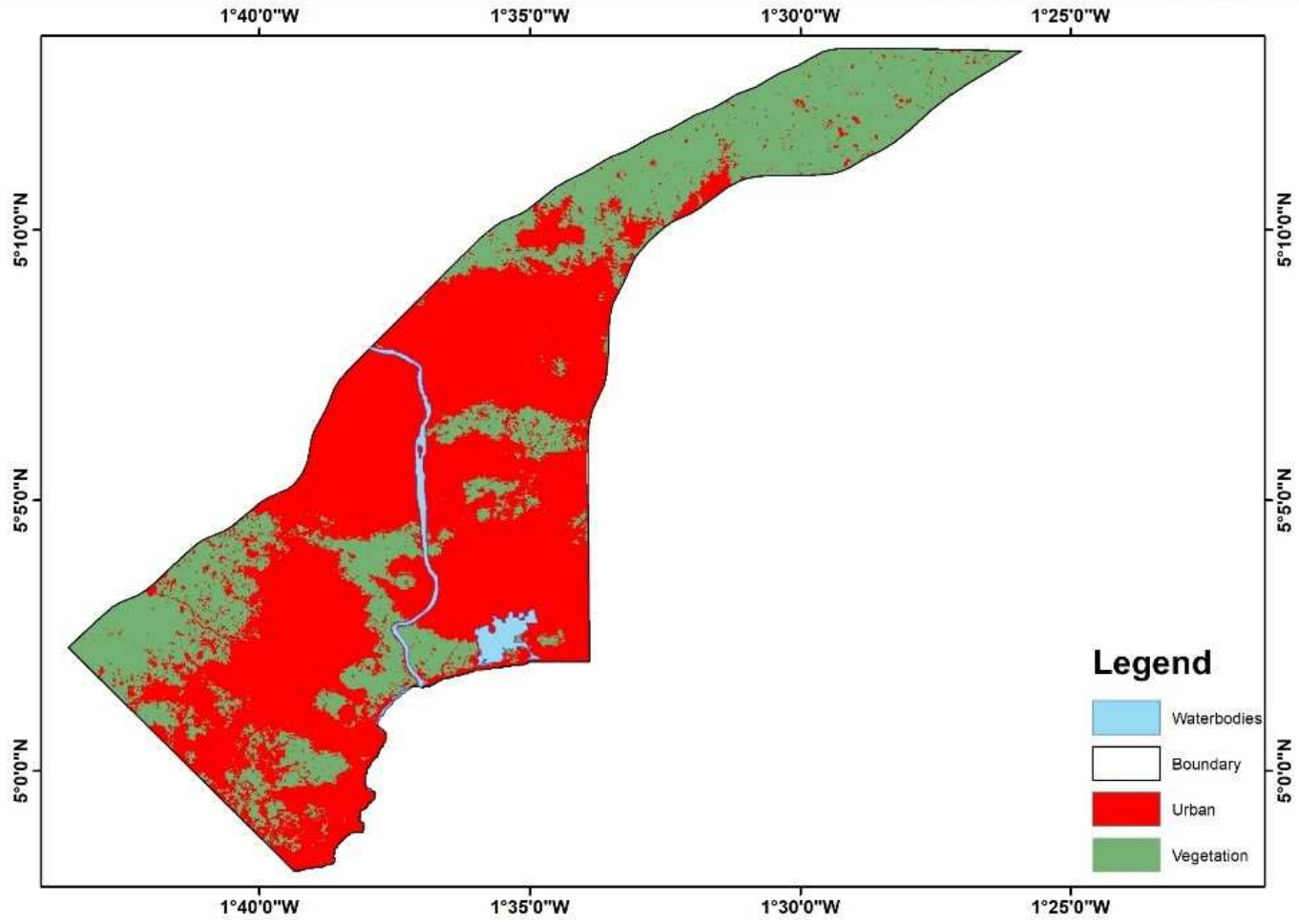

Fig. 4 Expansion in 2020

Results and DiscussionCont'd:

Urban Expansion

Table 2 Urban Expansion from 2000 to 2020

	Urban Areas (km sq)	Vegetation (km sq)	Urban Areas %
2000	24.3009	223.4997	9.8066
2010	68.3621	178.0416	27.7439
2020	154.8432	92.1348	62.6951

Results Cont'd and Discussion: Urban Expansion

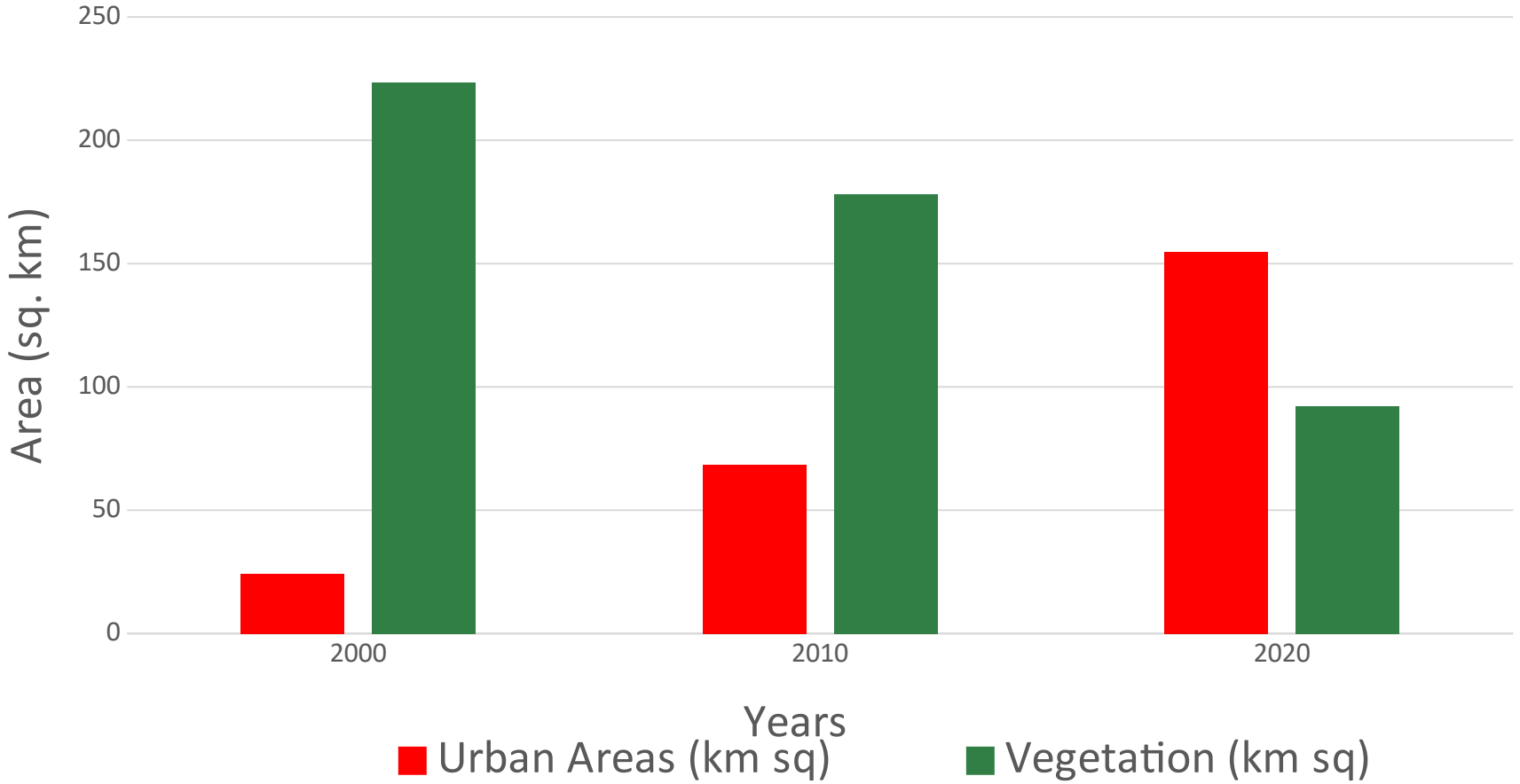

Fig. 5 Urban Expansion from 2000 to 2020

Results and Discussion Cont'd: Tables

Table 3 Area Change between 2010 to 2020

		2010-2020					
	Class color	2010	2020	Δ	2010%	2020%	Δ %
1	Urban	76033800.00 sq. metre	154641600.00 sq. metre	78607800.00 sq. metre	30.82980874	62.70331	31.874
170	Vegetation	170590500.00 sq. metre	91982700.00 sq. metre	-78607800.00 sq. metre	69.17019126	37.29669	-31.87

Table 4 Artificial Neural Network Accuracy Assessment

	Current Validation Kappa	Overall Error
Predicted	0.50372	0.17797
Acceptable	0.4 - 1.0	0.0 - 0.2

Results and Discussion Cont'd:

Neural Network Curve

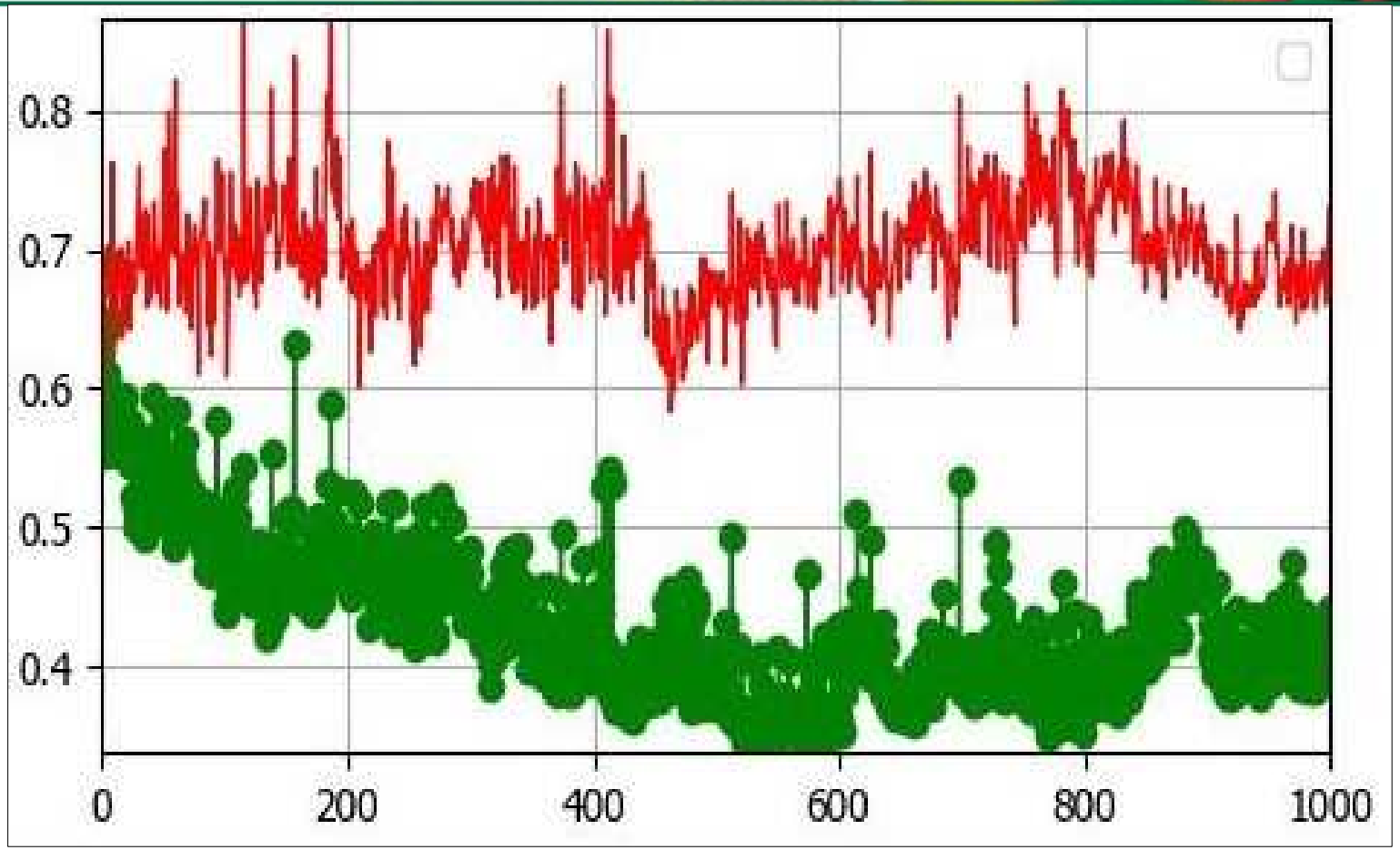

Fig. 6 Neural Network Curve Showing accuracy of ANN Prediction

Results Cont'd and Discussion: ANN Accuracy Assessment

Table 5 Artificial Neural Network Accuracy Assessment

	Current Validation Kappa	Overall Error
Predicted	0.50372	0.17797
Acceptable	0.4 - 1.0	0.0 - 0.2

Results and Discussion Cont'd:

Predicted Urban Expansion using ANN

Table 6 Area of the Classification and Accuracy

	Urban Areas (km sq)	Vegetation (km sq)	Overall Classification Accuracy (%)
2000	24.3009	223.4997	86.00
2010	68.3621	178.0416	82.00
2020	154.8432	92.1348	85.00
2030	226.4616	20.5164	82.22

Results Cont'd and Discussion: Maps Showing Predicted Urban Expansion

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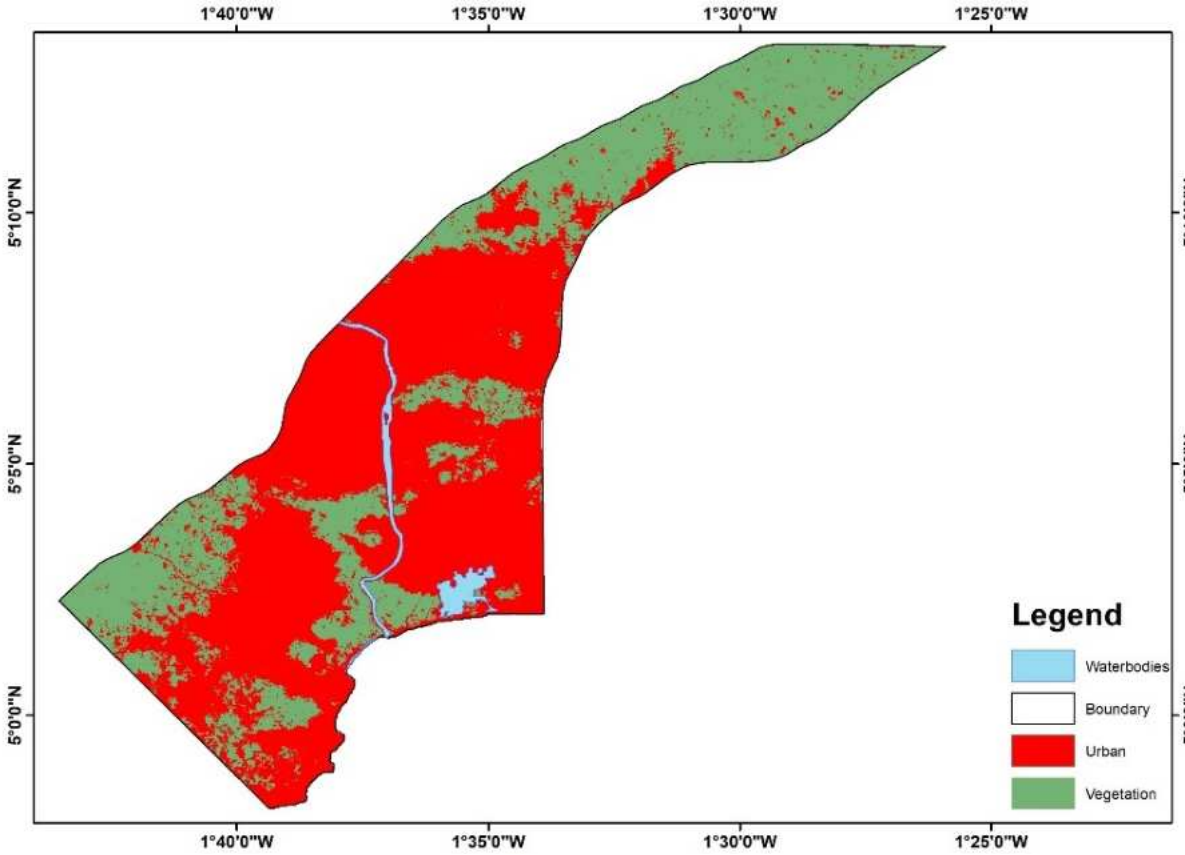

Fig. 7a Expansion in 2020

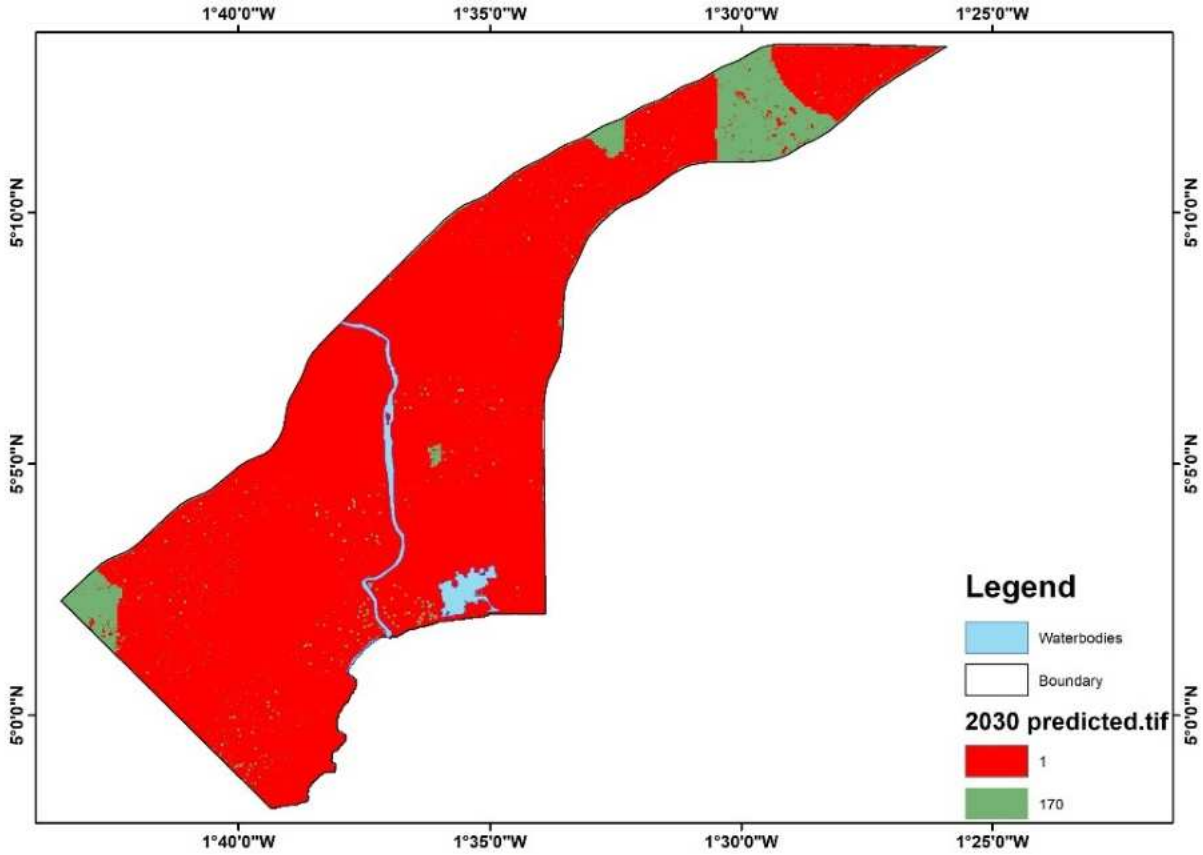

Fig. 7b Predicted Expansion in 2030

Results and DiscussionnCont'd:

Map Showing T rend of Urban Expansion

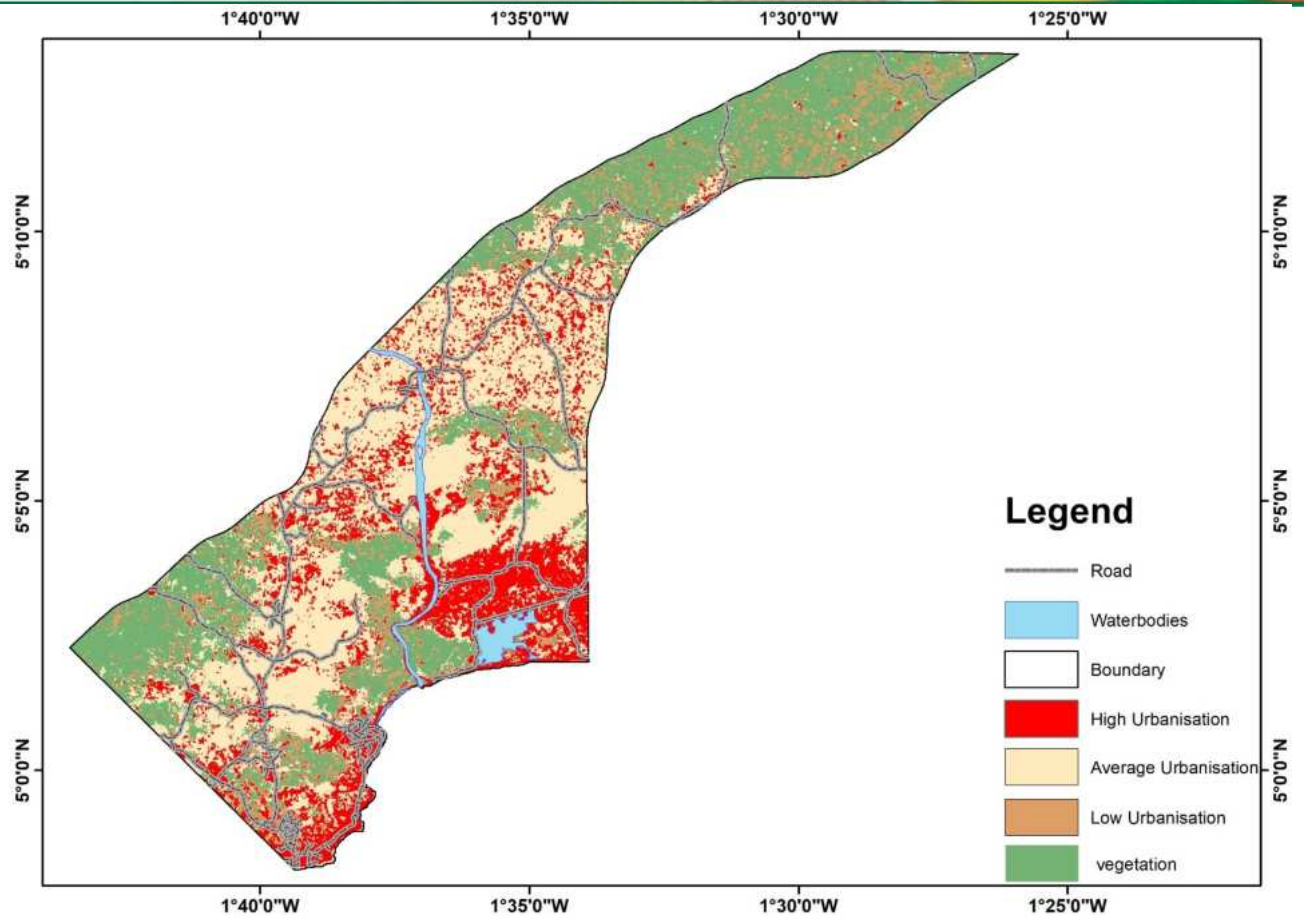

Fig. 8 Map Showing Trend of Urban Expansion

Results and Discussion Cont'd:

Graph Showing T rend of Urban Expansion

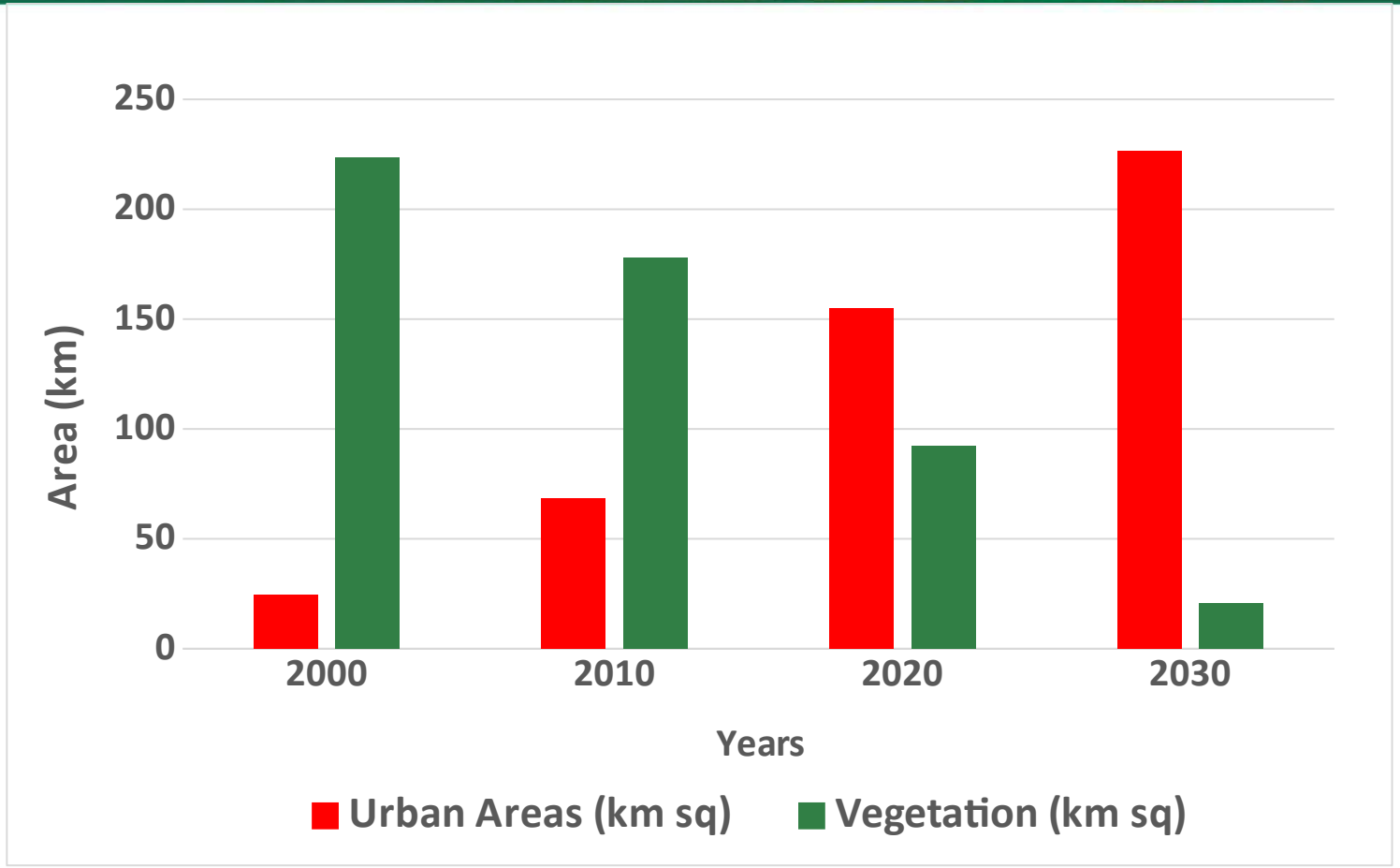

Fig. 9 Graph Showing Trend of Urban Expansion

Conclusions

It can be concluded that:

❖the study used the integration of RS and GIS techniques to analyse and to determine urban expansion in the Upper Shama Area between the years 2000 and 2020 and in 2000, 9.8 % of the study area was urbanized, in 2010, 27.7% of the study area was urbanized, and in 2020, 62.7 % of the study area was urbanized.

❖in the year 2030, 91% of the USA will be urbanised based on the results obtained from the ANN algorithm used for forecasting urban expansion for the year 2030

Recommendation

It recommended that:

❖It is therefore recommended that shorter interval time-series satellite data be used for future research for a greater accuracy and for the prediction of urban expansion and ther Parameters such as population be integrated into prediction model in order to monitor the effects of urban growth on urban expansion.

❖It is further recommended that research be conducted to study the impacts of urban expansion on climate change and to offer remediating solutions to the recent crisis resulting from climate change on the global scale.

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