MAPPING AND MODELLING OF URBAN LANDSCAPE OF OSOGBO METROPOLIS, OSUN STATE NIGERIA, USING ARTIFICIAL NEURAL NETWORK

Abstract

Continuous Geospatial studies of the transitions in Landuse and landcover are very important especially as it relates to baseline assessment as an approach for advising in policy formulations concerning the natural resources sector. This study aimed at mapping and modeling the urban landscape of Osogbo metropolis, Osun state Nigeria, using an artificial neural network with the view of providing a framework for sustainable development and as well as generating data on Landuse and landcover change transitions and maps for planning purposes. Its objectives are to; model and analyze Landuse and landcover changes in Osogbo metropolis for the last 30 years (1990 – 2020) using an artificial neural network; ascertain the trend, and characteristics of Landuse and landcover changes in Osogbo metropolis in the last 30 years; assess the urban landscape change across various terrain configurations with Osogbo Metropolis over the last 30 years, and predict the future urban landscape of Osogbo Metropolis in 2040 using artificial neural network. The methodology involved data acquisition of Landsat, Sentinel-2, and ALOS Palsar images, image preprocessing to correct the scan line error in Landsat 7 ETM+, development of classification scheme, identification of class features and image classification, trend analysis, land cover/land use transition, and prediction to 2040. The assessment of landcover/landuse change revealed significant LULC changes in the studied area. Over 30 years (1990–2020), the built-up area classes increased significantly by 111.97 km^2, while vegetation, open space, and water body decreased by 189.33km^2, 7.26km^2, and 3.46km^2 respectively. In terms of increased built-up area, this is largely seen in flat and undulating terrains between 281m and 341m. According to the prediction, by 2040, built up area is expected to grow from 35.89% to 64.48% covering an area of 201.2km^2, water body is expected to decrease from 1.11% to 1.07% with an area of 3.33km2, vegetation is expected to decrease from 60.68% to 32.42% with an area of 101.15km^2, open space is expected to decrease from 2.33% to 2.03% to an area of 6.34km^2. The study´s annual rate of change results is recommended as it reveals the annual decline vegetation within the study area, as a direct consequence can lead to an increase in urban heat islands within the study area.

Keywords: Artificial Neural Networks, Landcover/Landuse, Modelling, Osogbo, Trend

1.0 Introduction

The earth has an exceptional way of achieving or maintaining equilibrium through the use of biogeochemical cycles. Research have revealed that very few landforms or landscapes around the world still exist in their natural or pristine state. Thus, the increase in human population, industrialization, urbanization, and anthropogenic activities have increased the pressure on natural resources and become a major driving force behind the shift in landuse and landcover (Lambin, Geist and Lepers, 2003).

According to Awoniran *et al*., (2013), the International global environmental change research community considers landuse and landcover change to be a critical area of study because it provides us with a large volume of data on changes in carbon storage and sequestration by plants, as well as opening up a new frontier in understanding the human dimension of environmental change.

Landuse and landcover change research is a result of a global determination to detect, predict, analyze, and manage activities that are environmentally harmful or alter land-use.

A better understanding of the concepts underlying change dynamics can help in developing appropriate landuse and landcover management policies, reducing negative impacts while maximizing positive impacts (Aguayo *et al*, 2018).

Nonetheless, in order to understand the dynamics of landuse and landcover change, a broad evaluation of the geographic trends of transition would assist in addressing the region's present and future needs. This is essential in infrastructure planning and is particularly important when resources are limited.

The collection of remotely sensed data facilitates the synoptic assessments of Osogbo metropolis over time; with the collection of these spatial and statistical data for a different time period, it is then possible to map and model Osogbo metropolis urban landscape and foresee what the future urban landscape would look like.

The integration of remotely sensed data and artificial neural network can provide a deep insight into the spatial interaction of Osogbo metropolis's urban landscape in the past, present, and future.

With this in mind, the purpose of this study is to map and model the urban landscape of Osogbo metropolis, Osun state, Nigeria, using an artificial neural network in order to provide a framework for sustainable development.

Osogbo Metropolis and its surrounding communities have seen a high level of urban development, migration, and development activities. These anthropogenic activities have led to an increase in the rate at which land is transformed or altered, as well as a gradual development in the state of landuse and landcover.

Despite the fact that several studies in Osogbo metropolis (Aguda and Adegboyega, (2013), Ebehikhalu, Bidmus and Dawan (2016), Emmanuel, Mojooluwa, Olufemi and Awoyele, (2019), and Abiodun and Akinola, (2019) have all shown and documented the continuous change in Osogbo's landscape and the effects it has had on the environment, nnonetheless, there still exists gaps in information concerning Landuse and Landcover change in Osogbo metropolis.

Aguda and Adegboyega (2013) give insights on the changing pattern and intensity of the land surface in Osogbo, but they only centered on land use changes in Osogbo, with no attempt to deduce new findings about land transition in Osogbo.

Emmanuel, Mojooluwa, Olufemi, and Awoyele (2019) explored changes in land use and land cover, as well as the associated effects on the thermal condition over the land surface of Osogbo and its environs; however, a further evaluation of the direction, trend, and annual rate of growth of landuse and landcover, as well as its effects, would have led to a better understanding of these changes and how they can be managed.

Abiodun and Akinola (2019) highlighted the impact of urban expansion on vegetation; however, the potential impact of urban growth on vegetation or the entire ecosystem was not specified; this would have shown how the growth trends over time or how these modifications will affect the environment in the near future.

Gasu, Ebehikhalu, Bidmus, and Dawan (2016) presented an analysis of Land use dynamics in Osogbo from 1986 to 2012. Nevertheless, when analyzing Landuse dynamics, they did not take into account the influencing factors of Landuse and Landcover change.

Every one of these knowledge gaps that exists can be filled through continuous research and development of new methods of acquiring innovative information on landuse and landcover transitions, future change prediction, terrain change, and subsequent it´s effects in Osogbo metropolis.

Continuous geospatial studies of transitions in landuse and landcover are very important, particularly as it provides a critical reference point for assessing changes and impact, andcreates a foundation for comparing before and after changes. As a result, improving Landuse and Landcover mapping strategies through the use of remote sensing and artificial neural networks will be useful and vital for Landuse and Landcover transition modeling in the Osogbo metropolis. The efficacy of remote sensing and artificial neural network is premised on understanding Osogbo metropolis land transition processes and impacts; with this knowledge, it is easier to present a broad assessment of the spatial trends of Landuse and landcover change that would assist in addressing Osogbo metropolis's present and future needs.

2.0 Study Area

Osogbo metropolis is the capital city of Osun State, it seats the Headquarters of both Osogbo Local Government Area and Olorunda Local Government Area. It is some 88 kilometers by road northeast of Ibadan. It is also 108 kilometers by road south of Ilorin and 108 kilometers northwest of Akure, (Akpootu and Rabiu, 2019). Osogbo shares boundaries with Ikirun, Ilesa, Ede, Egbedore, Ogbomosho and Iragbiji. The city had a population of about 499,999 people and an approximate land area of 2875 km^2 (Jiboye, 2014). It is located between latitudes 7° 42`N and 7°48`N, then longitudes 4°.34`E and 4°.36`.

Osogbo is known for the Osogbo School of Art and the Oja Oba Market building. Osogbo is the trade center for a farming region. Yams, cassava, grain, and tobacco are grown. Cotton is grown and used to weave cloth. It is also home to several hotels and a football stadium with a capacity of 10,000 and a second division professional league team. Most of the population are members of the Yoruba ethnic group. In 1988, about 27% of the population were engaged in farming as their primary occupation, 8% were traders and about 30% clerks and teachers.

3.0 Methodology

The research approach encompassed a comprehensive workflow that incorporated the collection and processing of satellite imagery from multiple sources, including Landsat, Sentinel-2, and ALOS Palsar. This multi-step methodology was executed with precision to provide a robust foundation for our study.

First and foremost, data acquisition entailed retrieving Landsat, Sentinel-2, and ALOS Palsar images, which are renowned for their high-resolution and multispectral capabilities. These images served as the primary data source for our analysis, offering a holistic view of the study area over time.

Image preprocessing was a critical phase in our methodology. We meticulously addressed issues such as the scan line error in Landsat 7 ETM+ imagery, which could introduce inaccuracies into our subsequent analyses. By rectifying these errors, we ensured the integrity of our dataset, allowing for more reliable results.

The next key step involved the development of a classification scheme. This scheme was designed to categorize various land cover and land use types within the study area. We defined a set of distinct classes that encompassed a wide range of features and characteristics present in the landscape.

Subsequently, we embarked on the task of identifying class features within the imagery. This process involved the detailed examination and extraction of distinctive patterns, shapes, and spectral signatures that characterized each land cover or land use class. By meticulously cataloging these features, we created a robust foundation for accurate image classification.The image classification phase employed advanced algorithms and techniques to assign pixels within the satellite imagery to specific land cover and land use classes. This step was pivotal in generating quantitative data on the distribution of different land cover types across the study area.

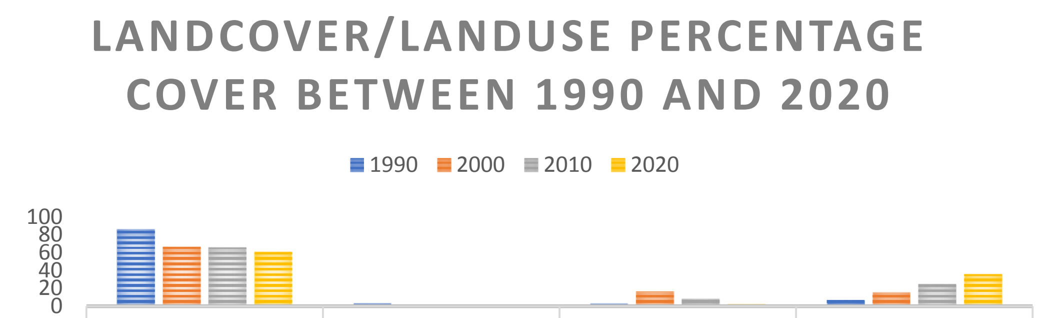
Trend analysis was another crucial aspect of our methodology. By analyzing changes in land cover and land use over time, we aimed to identify and interpret trends, providing insights into the evolving dynamics of the landscape.

Furthermore, our study extended into forecasting, as we projected land cover and land use transitions up to the year 2040. This predictive element allowed us to anticipate how the study area might evolve in the coming years, considering factors such as urbanization, agriculture, and environmental changes.

4.0 Results and Discussion

4.1 landcover/landuse analysis of Osogbo Metropolis from 1990 to 2020

The summary of landcover/landuse analysis of Osogbo Metropolis is displayed in figure 1 and summarily discussed below.



	Vegetation	WaterBody	Open Space	Built-Up Area
1990	86.11	3.57	3.12	7.2
2000	66.25	1.65	16.38	15.71
2010	65.75	1.12	8.41	24.72
2020	60.68	1.11	2.33	35.89

Figure 1: landcover/landuse distribution of Osogbo Metropolis Between 1990 and 2020

Between 1990 and 2020, vegetation had effectively lost 25.43% of its area coverage, decreasing from 86.11% in 1990 to 66.25% in 2000, then 65.75% in 2010, to 60.68% in 2020. The highest coverage loss is seen between 1990 and 2000 with a coverage loss of 19.86%.

Waterbody also lost 2.46% of its area coverage between 1990 and 2020, with its highest loss noted between 1990 and 2000. Waterbody area percentage decreased from 3.57% in 1990 to 1.65% in 2000, then 1.12% in 2010, to 1.11% in 2020.

Open Space gained 13.26% of area coverage between 1990 and 2000, however, it lost 7.97% of its area coverage between 2000 and 2010. Between 2010 and 2010, open space also lost 6.08% of its area coverage.

Between 1990 and 2020, the built-up area had effectively gained 28.69% of its area coverage, increasing from 7.2% in 1990 to 15.71% in 2000, then 24.72% in 2010, to 35.89% in 2020. The highest coverage gain is seen between 2010 and 2020 with a coverage gain of 11.17%.

4.2 Annual Rate of Change

The results indicated that vegetation had an annual rate of change of -1.30% between 1990 and 2000, -0.04% between 2000 and 2010, -0.40% between 2010 and 2020. This signifies that vegetation was decreasing annually at the rate of 1.30%, 0.04% and 0.40% between 1990 and 2000, 2000 and 2010, and 2010 and 2020 respectively.

Waterbody had an annual rate of change of -3.67% between 1990 and 2000, -1.90% between 2000 and 2010, -0.07% between 2010 and 2020. This signifies that open space was decreasing annually at the rate of 3.67%, 1.90% and 0.07% between 1990 and 2000, 2000 and 2010, and 2010 and 2020 respectively. The annual decline of waterbody is similar with that of vegetation as they both had the highest decline rate between 1990 and 2000.

Open space had an annual rate of change of 6.80% between 1990 and 2000, -3.22% between 2000 and 2010, -5.66% between 2010 and 2020. This signifies that open space was increased annually at the rate of 3.67% between 1990 and 2000. However, a decline in open space started at the rates of 3.22% and 5.66% between 2000 and 2010, and 2010 and 2020 respectively.

Built-Up area had an annual rate of change of 3.71% between 1990 and 2000, 2.23% between 2000 and 2010, 1.84% between 2010 and 2020. This signifies that built-up area was increased annually at the rate of 3.71%, 2.23% and 1.84% between 1990 and 2000, 2000 and 2010, and 2010 and 2020 respectively. the highest rate of increase was seen in the period between 1990 and 2000, the rate of increase slowed down between 2000 and 2020, see figure 2.

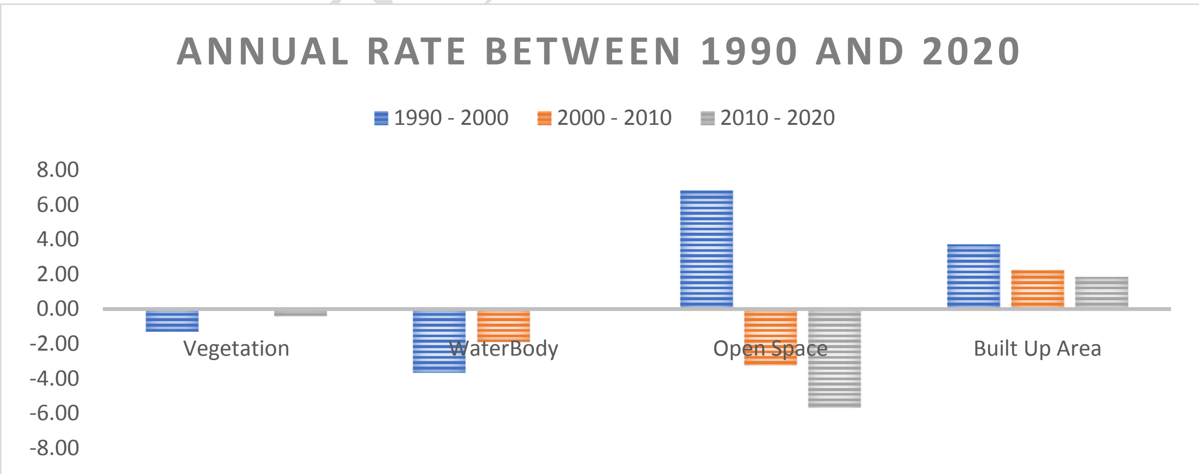


Figure 2: Annual Rate of Change of landcover/landuse of Osogbo Metropolis Between 1990 and 2020

4.3 Urban Landscape Development Assessment Across Various Terrain Configurations

The study area has four terrain configurations namely flat, undulating, rolling and hilly terrains. To determine the rate of development across the various terrain configurations, the acquired DEM was reclassified into reflect these four terrain types. The elevation ranges for these terrain configurations are (see figure 3):

1. Flat: 281m – 319m
2. Undulating: 319m – 341m
3. Rolling: 341m – 365m
4. Hilly: 365m -424m

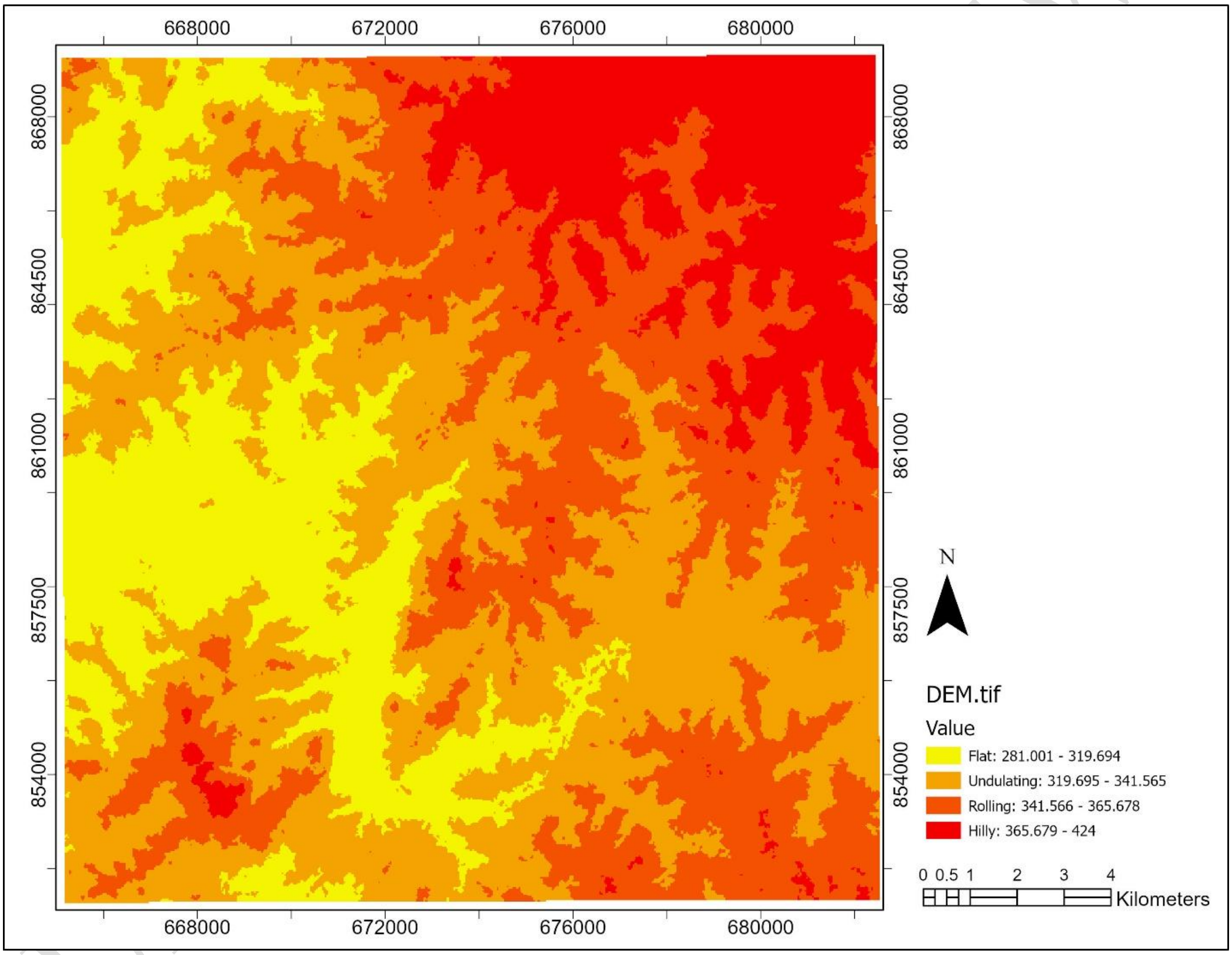


Figure 3: Terrain Configuration of Osogbo Metropolis

In 1990, flat terrain had the highest percentage of built-up areas with a coverage and area of 3.21% and 10.01km^2 respectively. This was followed by undulating terrain with a cover percentage and area of 2.70% and 8.4km^2 respectively. Rolling and hilly terrains had the least coverage with percentage cover and area of 0.98% and 3.05km^2 and 0.31% and 0.98km^2 respectively.

However, in 2000, undulating terrain had the highest coverage of built-up areas with a percentage cover and area of 6.36% and 19.83km^2 respectively. This was followed by flat terrain with a cover percentage and area of 6.23% and 19.44km^2 respectively. Rolling and hilly terrains had the least coverage with percentage cover and area of 2.71% and 8.45km^2 and 0.39% and 1.23km^2 respectively.

Similarly, in 2010, undulating terrain also had the highest coverage of built-up areas with a percentage cover and area of 10.28% and 32.09km^2 respectively. This was followed by flat terrain with a cover percentage and area of 8.97% and 27.98km^2 respectively. Rolling and hilly terrains had the least coverage with percentage cover and area of 4.62% and 14.41km^2 and 0.85% and 2.66km^2 respectively.

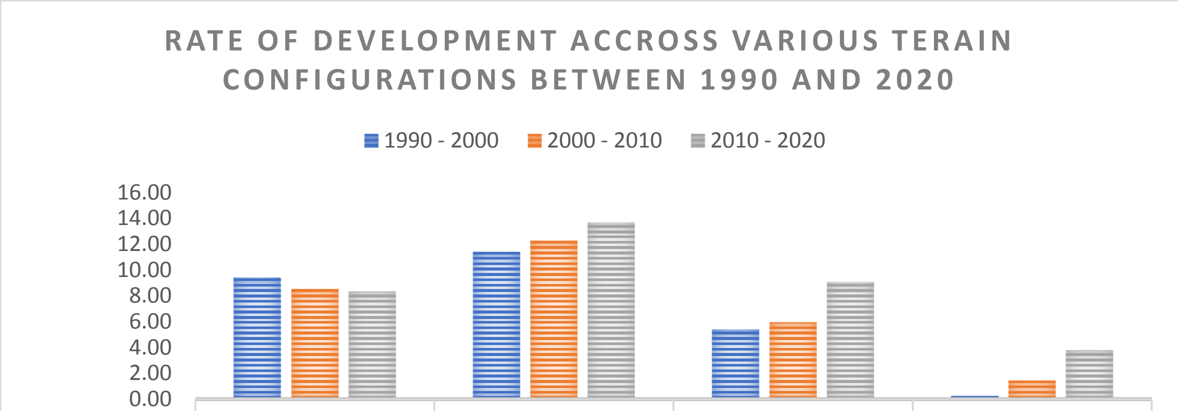
Lastly, in 2020, undulating terrain also had the highest coverage of built-up areas with a percentage cover and area of 14.66% and 45.75km^2 respectively. This was followed by flat terrain with a cover percentage and area of 11.64% and 36.31km^2 respectively. Rolling and hilly terrains had the least coverage with percentage cover and area of 7.52% and 23.45km^2 and 2.07% and 6.45km^2 respectively.

Analysing the change across terrain configuration indicated that undulating terrain experienced the highest growth in built-up areas with a rate of 11.39%, 12.26% and 13.66% between 1990 and 2000, 2000 and 2010, and 2010 and 2020 respectively. The highest development in undulating areas is seen between 2010 and 2020.

While flat terrain experienced the second highest growth in built-up areas with a rate of 9.43%, 8.54% and 8.33% between 1990 and 2000, 2000 and 2010, and 2010 and 2020 respectively. The highest development in flat areas is seen between 1990 and 2000.

Rolling terrain came third with a development rate of 5.40%, 5.96% and 9.04% between 1990 and 2000, 2000 and 2010, and 2010 and 2020 respectively. likewise, the highest development in rolly terrain is seen between 2010 and 2020.

Hilly terrain had the least rate of development rate, given the values of 0.25%, 1.43% and 3.79% between 1990 and 2000, 2000 and 2010, and 2010 and 2020 respectively, see figure 4.



	Flat	Undulating	Rolling	Hilly
1990 - 2000	9.43	11.39	5.40	0.25
2000 - 2010	8.54	12.26	5.96	1.43
2010 - 2020	8.33	13.66	9.04	3.79

Figure 4: Rate of Development Across Various Terrain Configurations in Osogbo Metropolis

The results (figure 4), suggests that urbanization and development have been more concentrated in undulating and flat terrains, which may have implications for land use planning, environmental conservation, and infrastructure development.

The higher growth rate in undulating and flat terrains indicated that these areas are more desirable for development due to factors such as accessibility, availability of resources, and topography. The lower growth rate in rolling and hilly terrains indicated that these areas are less suitable for development, which could have implications for managing urban sprawl and protecting natural habitats.

The result will be useful for policymakers, urban planners, and researchers who are interested in understanding the patterns and trends of urbanization and development across different terrain configurations. It may also help in identifying areas that require more attention in terms of infrastructure development, environmental management, and disaster risk reduction.

4.4 Urban Landscape Prediction to 2040

Urban landscape prediction was done based on historical change from 1990 to 2020, using influencing factors like distance to roads, elevation and distance to built up areas. The change assessed between 1990 and 2020 are identified and trained as transitions from one landcover/landuse state to another using an artificial neural network model (see figure 5).

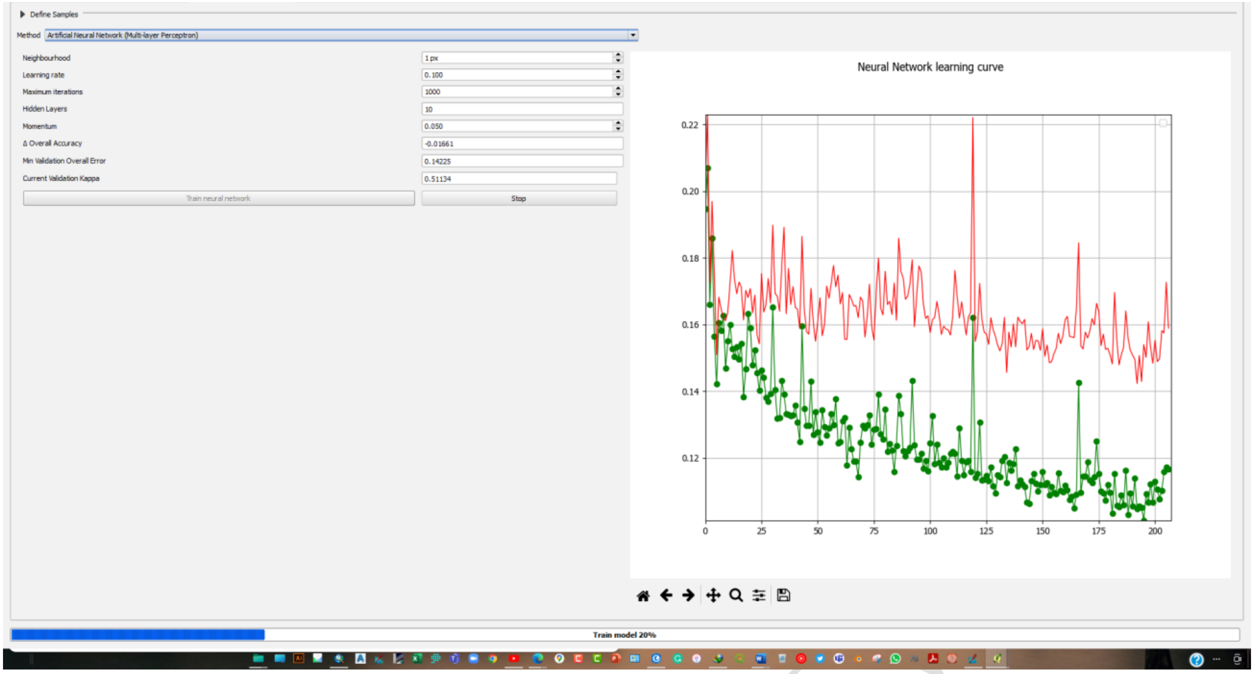


Figure 5: Artificial Neural Network Model Training

After the training, the model was used to predict the change to 2021, and was validated using a landcover/landuse data produced from 2021 Landsat 8 OLI image, see figure 6. the validation exercise gave an overall percentage of correctness of 73.23%, this signifies a good predictive result. Following the validation results, a prediction was made to 2040, see figure 7 for results.

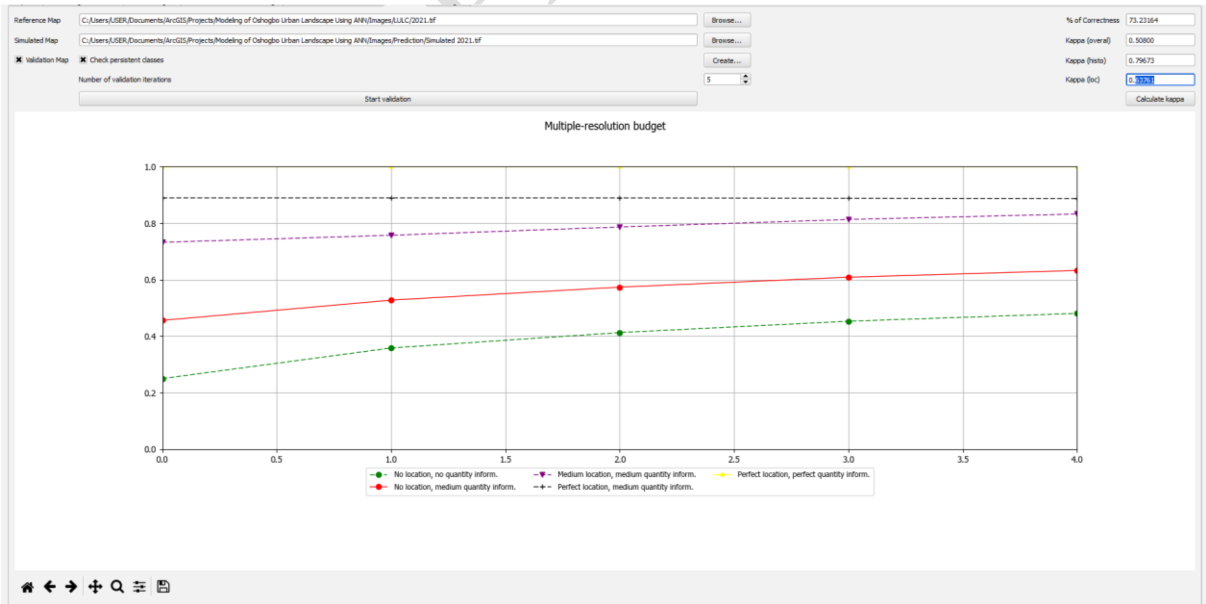


Figure 6: Landcover/Landuse Prediction to 2021

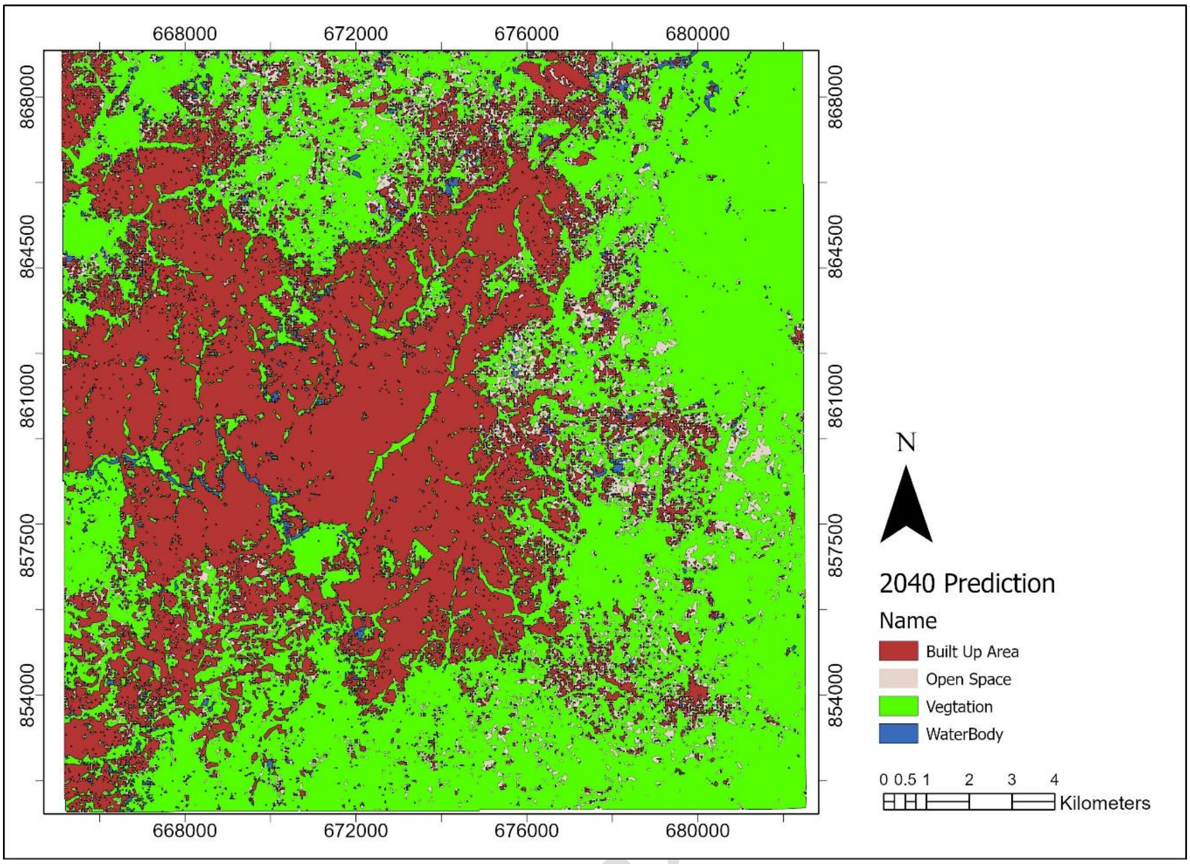


Figure 7: 2040 Osogbo Metropolis Prediction

Table 1: Predicted Landcover/Landuse distribution for 2040

S/N	*Class Name*	*Area*	*Percentage*
1	Vegetation	101.15	32.42
2	Waterbody	3.33	1.07
3	Open Space	6.34	2.03
4	Built-Up Area	201.2	64.48
5	Total	312.02	100

The results (Table 1) shows that the built-up areas are expected to increase from 35.89% to 64.48%, covering an area of 201.2km^2, which suggests a significant expansion of urbanization and development within the metropolis.

The reduction in water bodies from 1.11% to 1.07%, covering an area of 3.33km^2, may have implications for the availability of water resources in the area, which could affect the local ecology and the livelihoods of people who rely on these resources.

The decrease in vegetation from 60.68% to 32.42%, covering an area of 101.15km^2, may have significant environmental impacts, such as loss of biodiversity, reduction in ecosystem services, and increased carbon emissions. This could also lead to challenges such as increased air pollution, heat island effects, and reduced quality of life for the inhabitants of the metropolis.

The reduction in open space from 2.33% to 2.03%, covering an area of 6.34km^2, may have implications for the availability of recreational spaces, social and community gathering areas, and the overall quality of life of the inhabitants. It may also result in increased air pollution, reduced biodiversity, and an overall loss of natural spaces.

It is important to understand the land cover changes and trends in an area over time. This information can be used to develop land use plans, environmental management strategies, disaster risk reduction plans, and infrastructure development plans. It can also be used to monitor and assess the impacts of human activities on the environment and support decision-making processes for sustainable development.

5.0 Conclusion

The comprehensive analysis of land cover and land use changes spanning three decades, from 1990 to 2020, reveals several significant trends. Notably, vegetation has experienced a substantial decline, losing 25.43% of its coverage, with the most significant loss occurring between 1990 and 2000. Water bodies have also decreased by 2.46% over this period. Open spaces exhibited fluctuations, gaining ground initially but later seeing a significant decline. In contrast, the built-up area expanded significantly, particularly between 2010 and 2020.

Annual rate of change results indicate that vegetation and water bodies have been consistently decreasing annually, while open spaces showed fluctuations and the built-up area continued to expand, albeit at a slower rate.

Additionally, the analysis of terrain configurations reveals that undulating terrain experienced the highest growth in built-up areas, followed by flat and rolling terrain, with hilly terrain showing the least development.

Looking to the future, our predictions for 2040 indicate that the built-up area is expected to continue its expansion, water bodies will decrease slightly, vegetation cover will decline, and open spaces will shrink. These findings have the following implications for environmental conservation, urban planning, and sustainable development in the study area.

a. The significant decline in vegetation underscores the urgent need for environmental conservation and measures to counter deforestation and land degradation.

b. The decrease in water bodies calls for improved water resource management and conservation efforts to ensure water availability for the future.

c. Fluctuations in open spaces highlight the importance of adaptable land use policies to preserve green areas within urban environments.

d. The projected expansion of built-up areas emphasizes the necessity of sustainable urban planning to accommodate growth while maintaining quality of life for residents.

e. Terrain-specific growth patterns should inform local land use planning and development strategies to maximize the benefits of different terrain types.

In conclusion, the findings of this study offer crucial insights into the changing landscape and provide a foundation for informed decision-making to address the observed trends and plan for the future in the study area.

References

1. Abiodun, B. J., & Akinola, O. J. (2019). Impact of urban expansion on vegetation in Osogbo Metropolis, Nigeria. *Journal of Environmental Management and Safety, 10*(3), 40-53.
2. Aguayo, M., et al. (2018). Land use and land cover change impacts on urban sprawl and climate change in Osogbo Metropolis, Nigeria. *Journal of Remote Sensing & GIS, 7*(1), 2-11.
3. Aguda, L. A., & Adegboyega, S. A. (2013). Assessment of land use and land cover changes in Osogbo, Osun State, Nigeria. *Ethiopian Journal of Environmental Studies and Management, 6*(1), 40-48.
4. Awoniran, A. O., et al. (2013). Land use/land cover change and its implications for carbon storage in rural landscapes. *International Journal of Environmental Research and Public Health, 10*(11), 4881-4901.
5. Ebehikhalu, O. I., Bidmus, M. A., & Dawan, D. E. (2016). Land use/land cover dynamics in Osogbo, Osun State, Nigeria, from 1986 to 2012. *Journal of Geography and Geology, 8*(3), 75-85.
6. Emmanuel, I., Mojooluwa, L., Olufemi, F., & Awoyele, K. (2019). Analysis of land use and land cover dynamics and its impact on thermal conditions over Osogbo and environs. *International Journal of Remote Sensing & Geoscience, 8*(2), 1-14.
7. Gasu, S. B., Ebehikhalu, N. L., Bidmus, M. A., & Dawan, D. E. (2016). Analysis of land use dynamics in Osogbo, Nigeria, from 1986 to 2012 using remote sensing and GIS. *Ethiopian Journal of Environmental Studies and Management, 9*(4), 467-478.
8. Lambin, E. F., Geist, H. J., & Lepers, E. (2003). Dynamics of land-use and land-cover change in tropical regions. *Annual Review of Environment and Resources, 28*, 205-241.