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Application of GIS and Remote Sensing in Mapping and Evaluation of Urban Agricultural Lands in Relation to Food Security: A Case Study of Jos North in Plateau State, Nigeria

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Abstract: **The incessant migration of rural populace to urban areas has imposed a serious concern globally, especially in developing countries like Nigeria, due to its accompanying food security threat. Therefore, there is a need to map and evaluate Urban Agricultural land use in relation to food security challenges periodically in order to aid well-informed policy statements in tackling food security. This paper evaluates Urban Agricultural land use and food security in Jos North, Nigeria, between 1986 and 2005, with a view of analyzing the effects of urbanization on the sustainability of Urban Agriculture. Geographic Information System and Remote Sensing techniques were used in the mapping and evaluation processes in conjunction with remotely sensed data and topographic maps. Data validation was carried out using ground truthing data. Markov Chain Analysis prediction model and Cellular Automata were used for change detection analysis and to project the status of Urban Agriculture in 2020. The result shows Urban Agricultural land has reduced from 19.2% of the total area to 11.26% between 1986 and 2005. The projection shows rural-urban migration will increase more by 2020, with agricultural land reducing to 8.59% of the total area of study. Furthermore, the paper reveals Urban Agricultural practices in Jos North especially Fadama which contributes significantly to the socio-economic growth of the city through the production of vegetables and other food crops. The research work suggests some measures to enhance Urban Agriculture.**

Keywords: **Urban Agriculture, GIS, Remote Sensing, Urban Agricultural Land and Food Security.**

I. INTRODUCTION

Over the years, the movement of rural populace to urban areas has been on the increase giving rise to urbanization and a subsequent disruption of the ecosystem that heightens the demand for food security. As a result of these, humans now reside in habitat that includes large cities, towns and major urban metropolis. These urban populace are particularly vulnerable to fluctuations in food prices because food (often over 60 percent) makes up a large part of household expenses. Therefore, variations in its availability and price directly affect food security, compromising dietary quality and quantity [1]. Most urban areas have come to depend on large amounts of food being imported from other areas. As the need for food to feed cities increases, the need to develop and sustain some strategies to meet the rising need for food by policy makers ought to be considered [2]. Urban Agriculture is one of the strategies that can respond to food needs of the urban population, help set up income generating activities that could complement low income earners and further maintain the environment. According to Food and Agriculture Organization of the United Nations, FAO [3], Urban Agriculture is defined as an industry that produces, processes and markets food and fuel, largely in response to the daily demand of consumers within a town, city, or metropolis, on land and water dispersed throughout the urban and peri-urban area, applying intensive production methods, using and reusing natural resources and urban wastes to yield a diversity of crops and livestock [4]. Therefore, Urban Agriculture has an important role in contributing to the future sustainability of any cities in terms of employment and food security.

In Jos North, Plateau state in Nigeria, Urban Agriculture has been identified as one of the veritable means of tackling food security caused by rural-urban migration. The Fadama farm happens to be one of the most significant Urban Agricultural activities in Jos North. Fadama is a Hausa name for irrigable land which comprises of flood plains and low lying plains underlined with shallow aquifer found along Nigeria's river system. The basic phenomenon is the ease of accessibility of shallow ground water and or surface water for agricultural production [5]. This farming method is peculiar to Northern cities in Nigeria and is mostly done in the dry season within flood plains where there is a large span of marshy land. Its socio-economic effects and value chain to the economic growth of the states are significant. These include production of vegetable crops, vegetable fruits and cereals such as legumes, carrots, rice etc.

However, in spite of enormous contributions of Urban Agriculture to the socio-economic development of Jos North, little or no effort has been made by the government and its policy makers to know the spatial locations and distribution of Urban Agriculture in Jos North. Many questions are still open, such as: Where do Urban Agricultural activities concentrate and why? Who is involved? What is the distance to markets? How does Urban Agriculture contribute to the socio-economic development of Jos North? What infrastructure has affected Urban Agricultural land and how? Furthermore, only few data and information are available regarding the extent, importance, development and output of Urban Agricultural products in Jos North, as well as its connection to small enterprise developments. Amidst all these, only a limited experience of the application of Geographic Information System (GIS) technology in Urban Agricultural management is available. In view of these, this research work examines Urban Agriculture in Jos North, by mapping and evaluating Urban Agricultural land and relating it to food security, using GIS and Remote Sensing techniques.

A. Aims

The main aim of this research work is to use GIS, Remote Sensing, Global Position System (GPS) technologies and remotely sensed data to map, evaluate and validate the spatial dimensions of Urban Agricultural land in Jos North between 1986 and 2005. Furthermore, to relate it to the socio-economic effects in terms of food security.

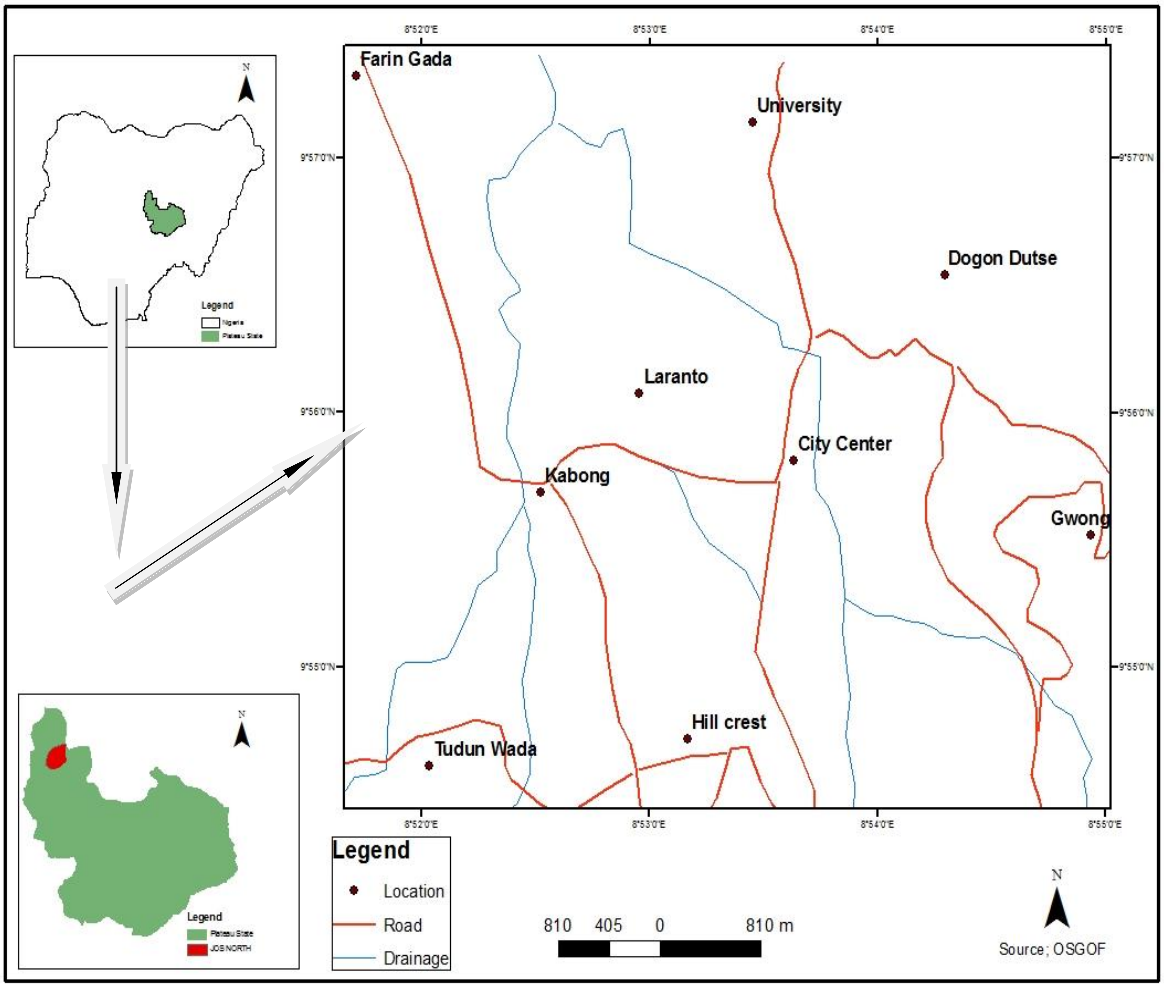
B. Objective

The following objectives were carried out in order to achieve the above aims:

- Identify, map and evaluate Urban Agricultural land in Jos North between 1986 and 2005.
- Carry out change detection analysis and prediction of Urban Agriculture in 2020.
- Examine the functional relationship between Urban Agriculture and socio-economic development of Jos North.

C. Study Area

The area of study is Jos North. Jos North, the administrative capital of Plateau state is a city in the middle belt, currently the North Central geopolitical zone of Nigeria in West Africa. The state acquired its name from the physical terrain (Jos-Plateau), where Jos North and its environs are located. It lies between latitudes 9° 55′ N and 9° 57′N and longitude 8° 52′E and 8° 55′E with an altitude of about 4,062 feet (1,217 m) above sea level. It enjoys a more temperate climate than most of the rest of Nigerian states (average monthly temperature ranges from 70°F to 77°F or 21° to 25°C), from mid-November to late January. Night time temperatures may drop as low as 8°C resulting to chilly nights. The city receives about 1,400 mm (55.1 inch) of rainfall annually, coming from both conventional and orographic sources due to its location on the Jos-plateau [6].



Source: Author

Fig. 1. Map showing the geographic location of the study area.

The study area lies on the Guinea Savannah belt of Nigeria, characterized by grassland with shrubs and scattered trees, except in places where vegetation is heavy [7]. Because of the rocky nature of the terrain, there is an abundance of wild cacti growing in Jos North and its environs. The land cover of Jos North is characterized by bare rocks, with grasses reaching up to 1m-1.5m tall and scattered trees. The Jos plateau is a source of many rivers and streams, thus its drainage pattern spreads away from the city [8]. Jos North is an urban area with extensive development with surrounding areas used for both rainy and dry season farming (Fadama farm) by the locals. The region's climatic conditions together with its suitable Fadama soils and available irrigation water favor the production of fruits and vegetables of the Mediterranean type such as apples, berries, avocado, carrots, lettuce, cabbage and cauliflower [9].

II. METHODOLOGY

The research work relies on primary and secondary data for mapping, evaluation, validation and prediction exercises. The primary data include those spatial and geospatial data that were gathered during ground truthing/field validation exercise and data generated from satellite imageries. On the other hand, the secondary data are the topographic maps, administrative map of Jos North and reviewed literatures. The steps involve feature pre-processing and post processing using IDRISSI software. Feature extraction from topographic/administrative maps and remotely sensed data were done using ESRI ArcGIS software. Collection of field data for feature validation was carried out with hand held GPS. Spatial and Geospatial data standardization, integration and analysis was carried out in the ArcGIS environment. The flowchart of the research methodology is illustrated in Fig. 2.

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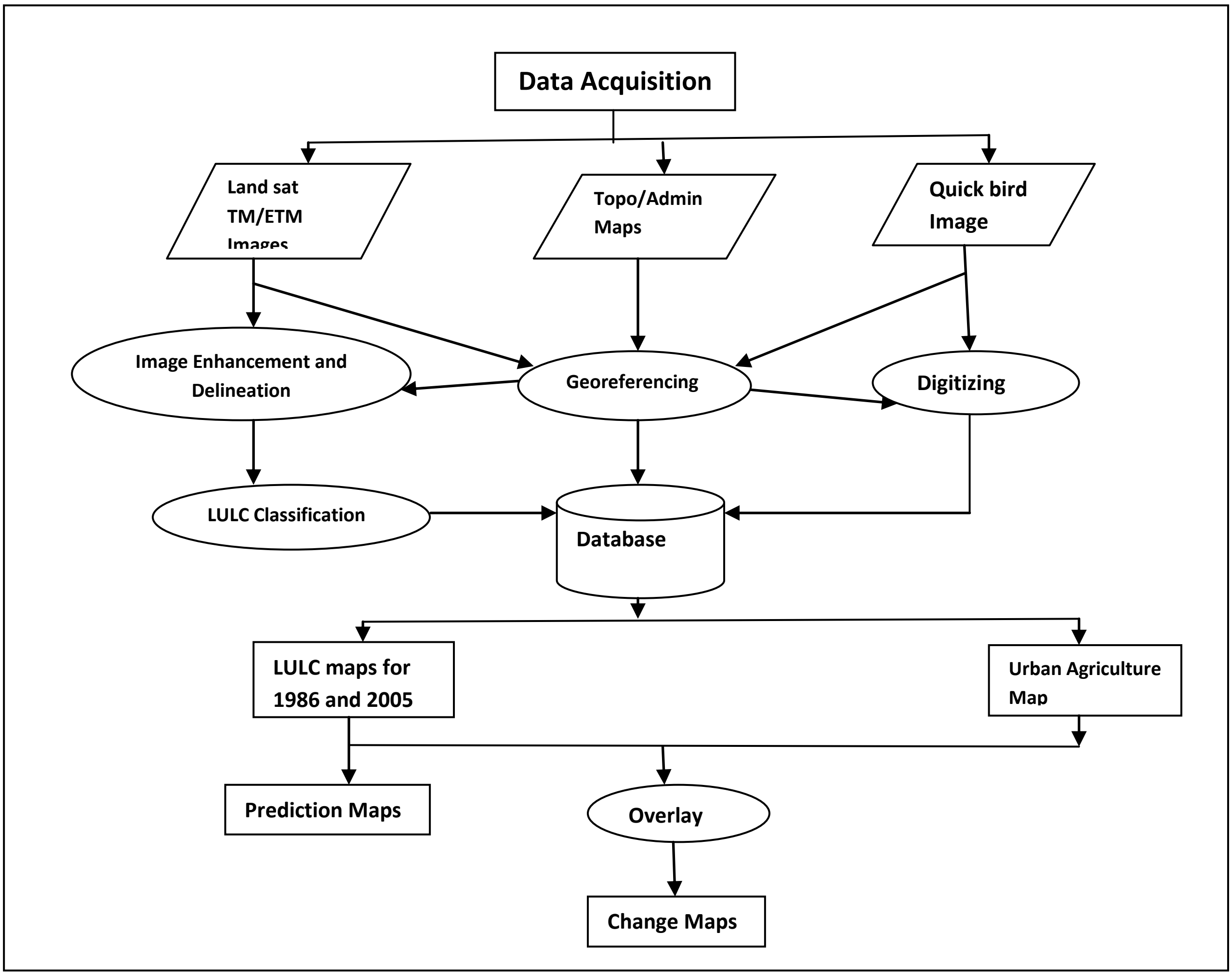

Fig. 2. Flowchart of the research methodology

A. Sources of Data Used and their Characteristics

The following data were used for the research work: Landsat TM/ETM+ imagery covering Jos North and its environs were obtained for two (2) epochs, 1986 and 2005 from Global Land Cover Facility (GLCF), Quick Bird satellite imagery, topographic and administrative maps covering the study area and GPS data which was obtained during the field validation. TABLE I shows the data used, sources and their characteristics.

Table I: Data Sources and Their Characteristics

S/No	Data	Source	Characteristics
1	Satellite imagery. (Landsat TM & ETM. For 1986 & 2005)	Global Land Cover Facility (GCLF)	Spatial resolution of 30m
2	Quick Bird Satellite Image for 2007	NCRS	Spatial resolution of 0.6m
3	Topographic Maps	Plateau State Ministry of Lands & Survey.	Naraguta sheet No 166 at scale of 1: 50000.
4	Administrative Map of Plateau State	Office of the Surveyor-General of the Federation.	1:50000.
5	GPS data	Field survey and ground truthing	Coordinates and attribute data

B. Software used for the research work

The software packages used for the study include:

1. IDRISSI: This was used for the following operations:

a. Data pre-processing, post processing and development of land use land cover classes.

b. Change detection analysis of the study area.

c. Modelling the predicted change over time.

2. ESRI ArcGIS: This software was used for data standardization, georeferencing, feature extraction, data manipulation and analysis. It also aids in cartographic enhancement and visualization.

C. Data Preparation, Processing and Analysis

The primary and secondary data that was in several formats were standardized to ensure spatial and geospatial data integration. Using the Landsat TM/ETM+ imagery, the following digital image pre-processing and post processing steps were adopted for the land-use change analysis:

a. Image Resampling: The Landsat images were already georeferenced. Due to differences in pixel sizes, the images were resampled using IDRISSI software to 30m pixel size. This was necessary for final map scaling.

b. Colour Composite: The images were displayed in False Colour Composite (FCC) for visualization and feature identification. The colour combination for bands that were used for the Landsat TM of 1986 and ETM+ of 2005 was 432. This band enables identification of urban areas and vegetation.

c. Delineation of the study area: The area of interest was extracted from the satellite scene using topographic and administrative maps as base maps. This was updated with the satellite data for each of the study years. Also, coordinates and attributes data acquired from the field survey were used as a check.

d. Classification Scheme: An effective land use management planning is represented by a classification scheme as a necessary component. However, there is no internationally agreed classification of land use and land cover [10]. Corine land cover and the FAO classification seem to be the most commonly used classifications. But for the purpose of this study, a simple scheme was developed and used based on the objectives of the research.

D. Feature Classification

Feature classification refers to the process of pattern recognition of the pattern associated with each pixel position in an image in terms of the characteristics of the objects or materials present at the corresponding point of the Earth's surface [11]. Based on prior knowledge of the study area, the data type needed and the field surveys done, the feature classification was selected. TABLE II shows the classes used for the classification of the Land sat imagery. Supervised classification was adopted based on knowledge of the study area. The training data for supervised classification was gathered using pixel reflectance of each identified land use class. Supervised Classification was done using Maximum Likelihood algorithm. This classification method assumes that statistics for each land use and land cover class is normally distributed and thus groups pixels into a specific class that has maximum probability [12]. Sample sets and Domain names were created using the map list created with the sub maps for each year. Training sites were picked based on field verification and colour representation. The classification was done for each of the study years, and the maps were produced and analysed. The prediction model was done to forecast the changes that will likely occur by 2020 in the study area based on GIS and remote sensing methods.

Table II: Land Use Classes on The Land-Sat Imagery

Code	Land use Classes
1	Agricultural/cultivable land
2	Bare surface
3	Built up
4	Rocky Outcrop

E. Digitization

This is said to be the process of extracting information and details in a vector format from raster data (satellite images). Such information could be polygon, polyline and point features such as settlements, roads and power lines. The quick bird high resolution image was digitized to extract the details used for the study. This process was done in an ArcGIS environment. Feature classes that matched the features extracted from the image were created. The classes are summarized in TABLE III.

Table III: Summary of The Feature Classes

Code	Feature Class
1	Agriculture land
2	Recreational areas
3	Bridge
4	Cemetery
5	Drainage
6	Major roads
7	Public/commercial buildings
8	Residential buildings
9	Rocky Outcrop
10	Railway
11	GPS points

F. Reconnaissance/ Ground Truthing

Ground truthing was carried out to view major farmlands identified on the imagery for result validation. The coordinates and attributes data of these areas that was visited were taken. These areas were categorized based on the type and season of farming practiced. Two major categories were identified namely: Fadama farming (irrigation farming) and rainy season farming. The geospatial locations of these Urban Agricultural lands are widely distributed over the study area, this helps in giving an overview of the farming type practiced in the area and the crop types cultivated. TABLE IV shows Urban Agricultural lands visited, farming season, type of crops being produced and their geographic locations.

Table IV: Field Validation Result Of Urban Farmlands And Their Type Of Crops

Code	Coordinates (WGS-84)	Farming season	Crop type
1	8 °21’25.45’’E 9°53’48.75’’N	Rainy season	Maize
2	8°21’32.7’’E 9°52’45.62’’N	Rainy season	Maize and sweet potatoes
3	8°21’54.17’’E 9°53’22.17’’N	Rainy season	Beans and groundnut
4	8°22’10.68’’E 9°53’50.54’’N	Fadama	Tomatoes and small pepper
5	8°22’8.93’’E 9°52’23.13’’N	Fadama	Tomato and small pepper
6	8°22’26.50’’E 9°53’42.55’’N	Fadama	Tomato, pepper, onions and garlic
7	8°22’43.2’’E 9°53’30.96’’N	Fadama	Mango, avocado, Spinach and tomatoes
8	8°22’9.98’’E 9°53’3.54’’N	Fadama	Carrots and cabbage
9	8°22’16.66’’E 9°52’46.68’’N	Fadama	Cabbage, carrots and lettuce
10	8°23’36.79’’E	Rainy season	Cocoyam and potatoes

	9°53'28.15''N		
11	8°24'15.80''E 9°52'45.62''N	Rainy season	Maize and groundnut
12	8°24'29.86''E 9°51'30.08''N	Fadama	Cabbage, garden egg, lettuce and carrots
13	8°23'45.22''E 9°50'59.84''	Fadama	Onions, garlic, tomatoes and green beans

The reconnaissance/ground truthing data was plotted and used for validation of the feature classifications as shown in Fig. 3.

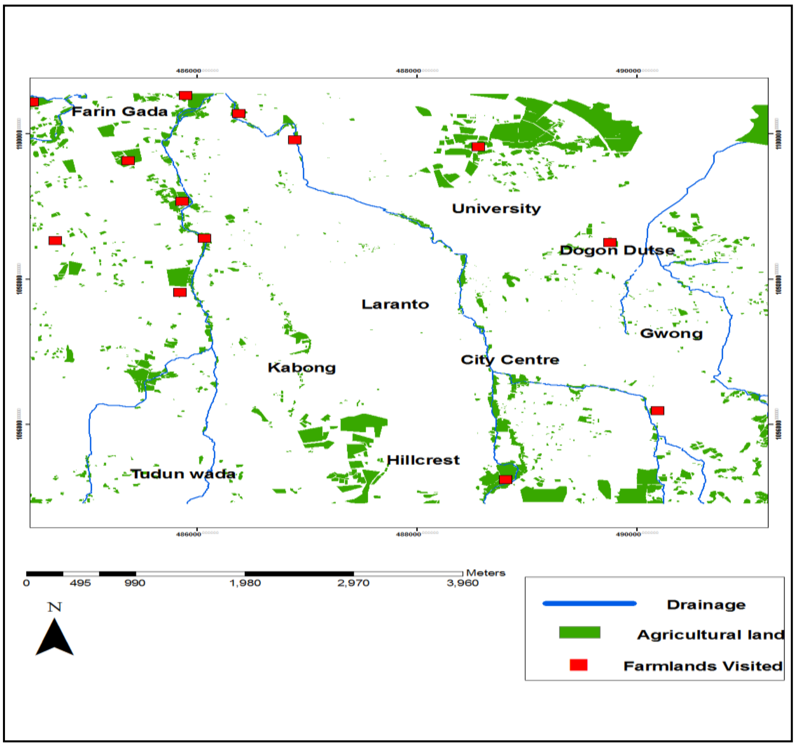

Fig. 3. Major Farmlands visited in Jos North

G. Prediction

The information generated from the maps produced in the two time epochs were used in IDRISSI software to predict the likely changes that will occur in Jos North by 2020. Markov Chain analysis method of projection was used in tandem with cellular automata.

Markov method, also known as Markov chain is a mathematical system that undergoes transitions from one state to another, between a finite or countable number of possible states [13], [14]. The process is represented by the mathematical expression:

$$\Pr(X_{n+1} = x | X_1 = x_1, X_2 = x_2, \ldots, X_n = x_n) = \Pr(X_{n+1} = x | X_n = x_n). \quad (1)$$

Where: X1, X2….Xn. are random variables and Pr the probability function.

Markov Chain Analysis is one of the convenient tools for modelling land use change when changes and processes in the landscape are difficult to describe. A Markovian process is one in which the future state of a system can be modelled purely on the basis of the immediately preceding state. Markovian chain analysis will describe land use change from one period to another and use this as the basis to project future changes. This is achieved by developing a transition probability matrix of land use change from time one to time two, which shows the nature of change while still serving as the basis for projecting to a later time period .The transition probability may be accurate on a per category basis, but there is no knowledge of the spatial distribution of occurrences within each land use category. Hence, Cellular Automata (CA) was used to add spatial character to the model.

According to [15], [16] Cellular automata is a cellular entity that independently varies its state based on its previous state and that of its neighbours according to some specific rules, it's a spaced dynamic system where variable time and space are discrete. This method of prediction and modelling was applied in an IDRISSI software environment to model and predict the changes.

H. Data Analysis

The following methods were used for data analysis:

1. Overlay method

An overlay method identifies the location and magnitude of change. This process combines the features of two or more layers to create a new layer that contains their attributes. To investigate the change over the study period, the land use map for each of the years were overlaid in an IDRISSI environment in a process called CROSSTAB. This results to the statistical production of information about the magnitude and rate of change over time in the study area.

2. Area Calculation (hectares)

This was done by calculating the areas, in hectares, of the resultant land use/land cover types for each study year and subsequently comparing and analysing its resultant effect on Urban Agriculture. To achieve this, the areas in hectares was generated using ArcGIS and the percentage change for each year were determined and matched against each land use/land cover type. Thus,

$$PC = \frac{OC}{SC} * 100 \qquad (2)$$

Where:

PC = Percentage change

OC = observed changes

SC = sum of changes

3. Percentage Growth Rate

The growth rate of the various land use/ cover types over the study time periods was measured thus [17], [18]:

$$PGR = \frac{A2 - A1}{A1} * 100 \qquad (3)$$

Where:

PGR = Percentage Growth Rate

A1 = Area in the first time epoch

A2 = Area in the second time epoch

4. Annual Percentage Growth Rate

The annual percentage growth rate of each of the land use classes were calculated thus:

$$APGR = \frac{PGR}{D2 - D1} \qquad (4)$$

Where:

APGR = Annual Percentage Growth Rate

PGR = Percentage Growth Rate

D1 = Date of first Image

D2 = Date of second image

III. RESULTS, ANALYSIS AND DISCUSSIONS

This section presents the results, analysis and discussions based on the results. The aims and objectives of this research work forms the basis of analysis. The results are presented in maps, tables and charts. Appendix 1 shows land use classification in 1986 while Appendix 2 presents land use classification in 2005. The map showing overlay of the 1986 and 2005 classification is presented in Appendix 3 while map showing Urban Agricultural lands in relation with other land uses as at 2005 is presented in Appendix 4. Projected land use of Jos North by 2020 is presented in Appendix 5. The percentage change, percentage growth rate and the annual percentage growth rate were computed using equation 2, 3 and 4 respectively.

Fig. 4 shows the percentage land use cover in 1986 while percentage land use cover in the year 2005 is presented in Fig. 5. Fig. 6 shows land use percentage change between 1986 and 2005 while the percentage growth rate and the annual percentage growth rate are presented in TABLE V. The transitional matrix, which shows the probability of any category of land use changing to another land use category is presented in TABLE VI, and TABLE VII shows projection of land area and percentage cover by 2020 . In addition, a graph with values of commission and omission or gain and loss which indicates the percentage of the study area lost or gained by each of the land use class during conversions is presented in Fig. 7.

A. Land Use Distribution Analysis

From the results obtained, data were generated for the analysis. The analysis of land use classes identified in the study area for 1986 and 2005 are presented. Fig. 4 reveals that in 1986, built up area occupies about 25% of the total study area (3908.520 hectares) and are concentrated at the center of the city having an outward spread as shown in appendix 1.

The Urban Agricultural land areas were mostly peri-urban which are mostly located at the edges and fringes of the city and covers about 19% of the total area. Comparing Fig. 4 and Fig. 5 results gives rise to Fig. 6 which shows that between 1986 and 2005, Urban Agricultural land decreases from 19.2% to 11.26% giving rise to a percentage change of -13%. While built up area increases from 25.92% to 45.09% which amounts to 31% percentage change. In addition, the bare surface records a decrease from 41.48% to 18.34% between the two epochs, which amounts to -37% change. The rocky outcrop records unusual increase from 13.4% to 25.31% amounting to 19% change in area. Further validations and analysis reveals that the 1986 and 2005 imageries of the study area may have been captured during the winter and summer seasons respectively. As a result, most of the rock surfaces were covered with vegetation at the time of image capture in the first epoch, and as such with reduction of the vegetation cover on the rocky surfaces during the summer, the rocky outcrops were more exposed and thus the resultant increase in area.

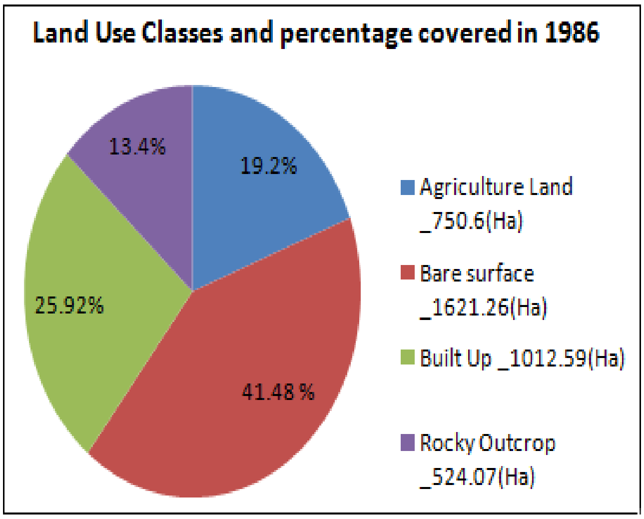

Fig. 4. Land use area and percentage coverage in 1986

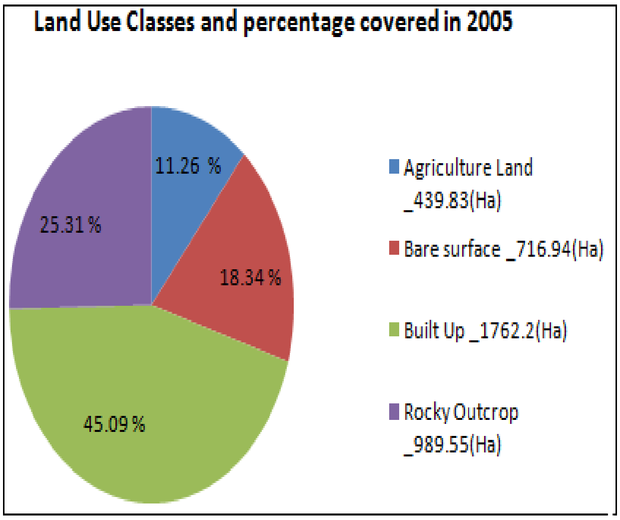

Fig. 5. Land use area and percentage coverage in 2005

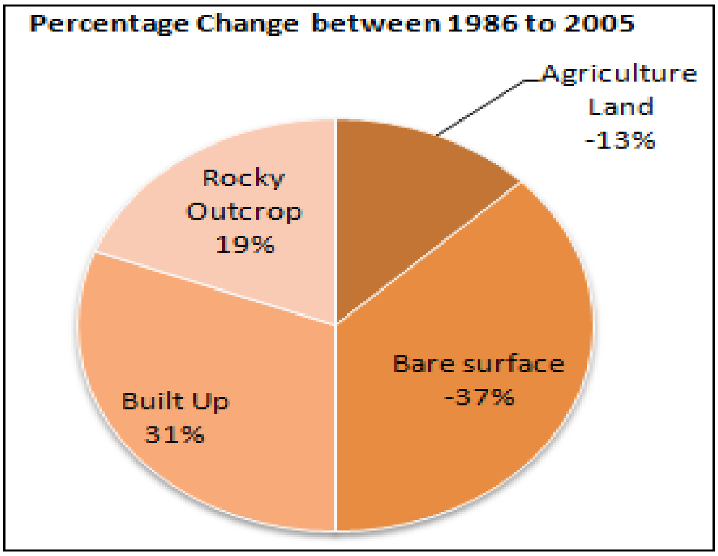

Fig. 6. Land use area and percentage change between 1986 to 2005

TABLE V shows that, from 1986 to 2005 percentage, growth rate for Urban Agricultural land and bare surface was on a decrease to about -41.4% and -55.77% respectively. These amount to a decrease in annual percentage growth rate by -2.18% and -2.93% respectively. Furthermore, the built up area and rocky outcrop have a percentage growth rate of 74.02% and 88.82% respectively. These resulted to an annual percentage growth rate of about 3.89% and 4.67% respectively.

Table V: Annual Growth Rate And Land Use Change From 1986-2005

Classes	PGR (%)	Change (ha)	APGR (%)
Agriculture Land	-41.40	-310.77	-2.18
Bare surface	-55.77	-904.32	-2.93
Built Up	74.02	749.61	3.89
Rocky Outcrop	88.82	465.48	4.67

The transition probability matrix which records the probability that a category will change to another category within a specified time difference was computed. This matrix is calculated by multiplication of each column in the transition probability matrix by the number of cells of corresponding land use in the later image. From TABLE VI, it shows that built up area has the highest probability of remaining built up and a null (zero) probability to transform to agricultural land. Moreover, it reveals that each of the other classes has various degrees of probability of not changing to another class type.

Table VI: Transition Table (Matrix) For 1986-2005

	2005	Built up	Bare surface	Agriculture land	Rocky outcrop
1986	Built up	19061	411	72	36
	Bare surface	1601	3672	554	2139
	Agriculture land	0	452	2613	1822
	Rocky outcrop	3155	1139	477	6224
Total		19580	7966	4887	10995

Fig. 7 shows built up area having the highest percentage gain of about 24% while Urban Agricultural land and bare surface having 18% and 14% loss respectively within the study period.

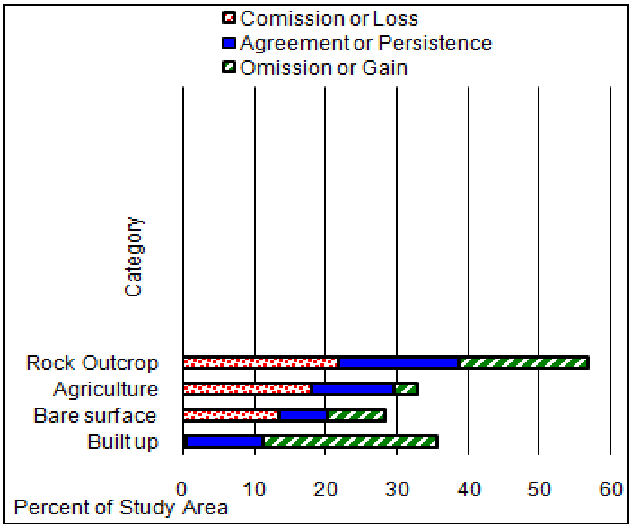

Fig. 7. Gain and Loss graph between 1986 to 2005

B. Land Use Prediction Analysis

From the projected map of land use in Jos North by 2020 which is based on the land use categories mapped using 1986 and 2005 satellite imageries, it shows that, there will be an increase in the built up areas coverage with a resultant decrease in Urban Agriculture area. TABLE VII shows that by 2020 the built up area will cover about 54.86% of the total area (3908.520 hectares) of Jos North which amounts to about 2144.25 hectares. The bare surface area will cover about 13% of the city which is about 509 hectares while agricultural land will occupy about 335.88 hectares which amounts to 8.59% of the total area of Jos North. The area covered by rocky outcrop will be 919.3 hectares amounting to about 23.5% of the total area.

Table VII: Projection Of Land Area And Percentage Cover By 2020

Classes	Area (ha)	%
Agriculture Land	335.880	8.59
Bare Surface	509.040	13.02
Built Up	2144.250	54.86
Rocky Outcrop	919.350	23.52
Total	3908.520	100.00

C. Discussions

In this study, a total of 4 land use and feature classes were identified and used for the mapping and evaluation exercise. Difference spectral signatures were assigned to these land areas which resulted to changes from one class to another. Urban Agriculture was identified as a major farming system that enhances food security in the area. Two major farming seasons were identified and categorized as rainy season and Fadama (use of irrigation during the dry season) with their geographic locations and type of crops produced as presented in TABLE IV. Urbanization and poor management system which is due to population growth and poor policy (Land tenure system and agricultural policies) were identified as serious challenges to Urban Agriculture in Jos North.

The study area covers about 3908.52 hectares with Urban Agricultural land and bare surface covering about 750.6 hectares (19.2%) and 1621.26 hectares (41.5%) in 1986 respectively. By 2005, Urban Agriculture and bare surface decreased to about 439.83 hectares (11.3%) and 716.94 hectares (18.3%) respectively with built up area increasing from about 1012.59 hectares (25.9%) to 1762.2 hectares (45.1%) within the study period. This is because of urbanization and infrastructural development as a result of population growth within the period. The annual percentage growth rate of about -2.2% and -2.9% of Urban Agricultural land and bare surface respectively, which were on decrease, present a possible threat in food security in the study area. The strength of each land use classes being converted to another class indicates that built up area has the highest probable value of 19061 of remaining built up area with zero [null] probability of changing to Urban Agricultural land. The other land use classes have varying degree of probabilities with Urban

Agricultural land and bare surface being most vulnerable to changes. Furthermore, the gain and loss graph in Fig. 7 presents built up area having 24% gain and 0% loss while Urban Agricultural land, bare surface and rocky outcrop had about 8%, 3% and 18% gain and 14%, 18% and 22% loss respectively. This is due to population growth and may likely cause food insecurity, compromising dietary quality and quantity within Jos North if alternative measures are not put into place. The 2020 projection in TABLE VII put built up area increasing to 2144.250 hectares [54.86%] while Urban Agriculture will be decreasing to 335.880 hectares [8.59%] of the total area. From the forgoing discussions, it is apparent that the food security of Jos North will be threatened by 2020 except alternative sources of supply are made or drastic measures taken to discourage rural-urban migration in Jos North. Also, deployment of high technologically driven Urban Agricultural practices backed with good agricultural policies may ameliorate food insecurity in the area.

1. What Government is not doing well, and what should be done

It might be true that Government and some donor agencies like the UN have been making frantic effort to sustain human livelihood in forms of agricultural loans and agricultural policies in Jos North, yet there is enough room for improvement. For example, the government should embark on Geographic Information System (GIS) and Information Technology (IT) driven management system by deploying an intelligent geodatabase. This will prompt spatial and geospatial information gathering such as the legal policies on Urban Agricultural land and implementation strategies, population census, annual crop yield, storage and or processing mechanism, unemployment rate etc. Currently, the government are planning and budgeting without proper knowledge of the population being budgeted for and the current agricultural products output. The government should deploy the services of professionals such as scientist, research institutes with adequate knowledge to research and proffer mitigating measures to rural-urban migration in Jos North. This will reduce population explosion in the area. The Fadama faming practice should be mechanized and adequate storage and or processing facilities put in place. This is because in some years where the farmers have bounty harvest there is usually accompanying wastage of food crops due to lack of storage or processing facilities since most of these food crops are perishable crops. Since part of the achievement of food security is accessibility of the food, efforts should be made by the government to make all the roads leading to the Urban Agricultural lands motorable regardless of the season of the year.

IV. CONCLUSIONS AND RECOMMENDATIONS

This study has mapped and evaluates Urban Agricultural land in Jos North using GIS, Remote Sensing, GPS technology and spatial data from ground truthing. It identifies two major types of Urban Agriculture being practiced in Jos North which was categorized as rainy season farming and Fadama farming (farming along the marshy area using irrigation). The Urban Agricultural land use was found to be decreasing annually by -2.18% while built up area was on annual percentage growth rate of 3.9%. This was attributed to urbanization as a result of population increase and infrastructural developments to meet this population growth. This situation likely points to food insecurity, accompanying unemployment and malnutrition if adequate measures are not taken in Jos North. The 2020 projection saw Urban Agricultural land decreasing further to 335.880 hectares [8.59%] with built up area increasing to 2144.250 hectares [54.86%] of the total area of 3908.520 hectares. Going by this development, it is obvious that the socio-economic activities of Jos North will be adversely affected negatively because of possible inadequate food security. Moreover, currently government approach to planning and budgeting lacks GIS and IT driven platform hence lacks well informed decisions.

A. Recommendations

The following recommendations are made:

1. Government should include GIS, IT and Urban Agriculture in their policy statements. These will encourage allocation of funds for the management of any IT driven management platform and proper management of the land tenure system.
2. Design and implementation of intelligent geodatabase to aid effective and efficient decision making in planning for the populace.
3. Periodic mapping and evaluation of Urban Agricultural land in relation to population growth should be encouraged by government and research institutes.

4. Government and other stakeholders should provide basic infrastructure such as constant power and good water in the rural area to discourage rural- urban migration.
5. Provision of adequate storage and processing facilities to preserve crops during bounty harvest show be encouraged.
6. Farming groups in the urban areas should form a formidable cooperative societies to source for funds from Fadama development projects in Jos North and other cities to enhance their productivity.
7. Land tenure system should be properly addressed so that inhabitants in the city of Jos North will have access to arable land for cultivation.

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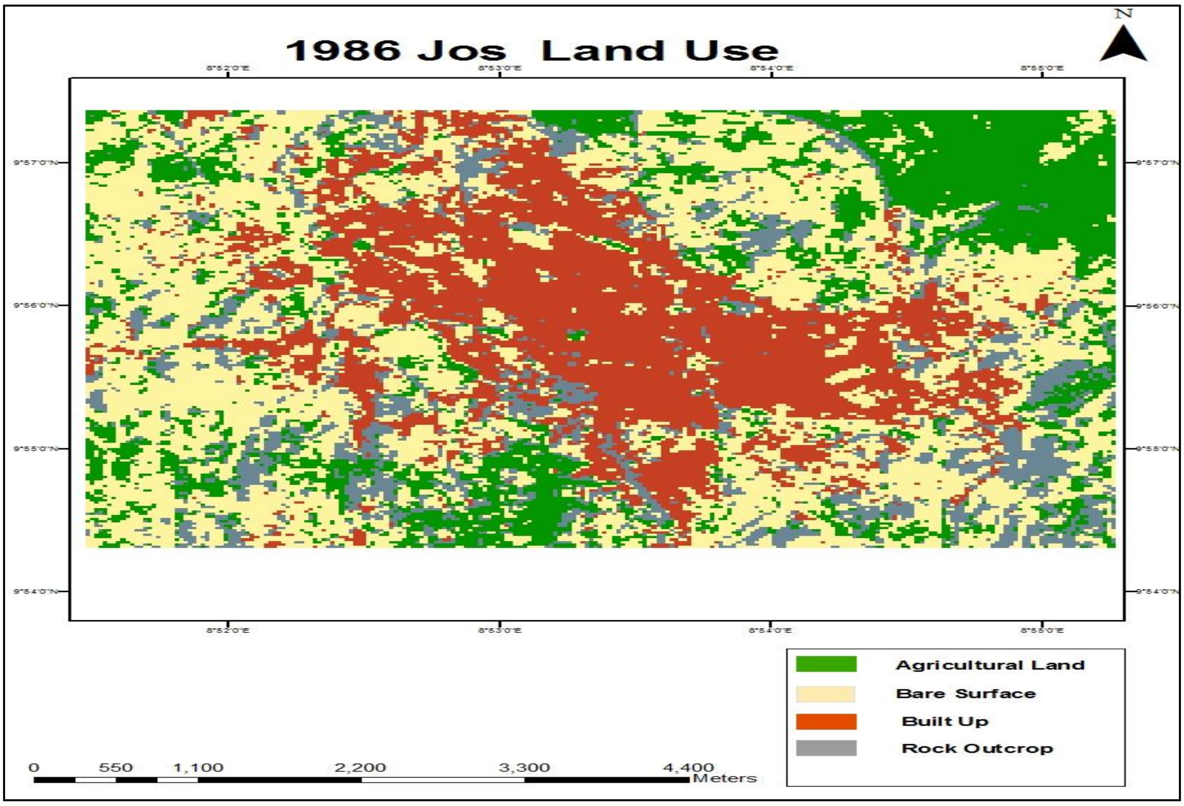
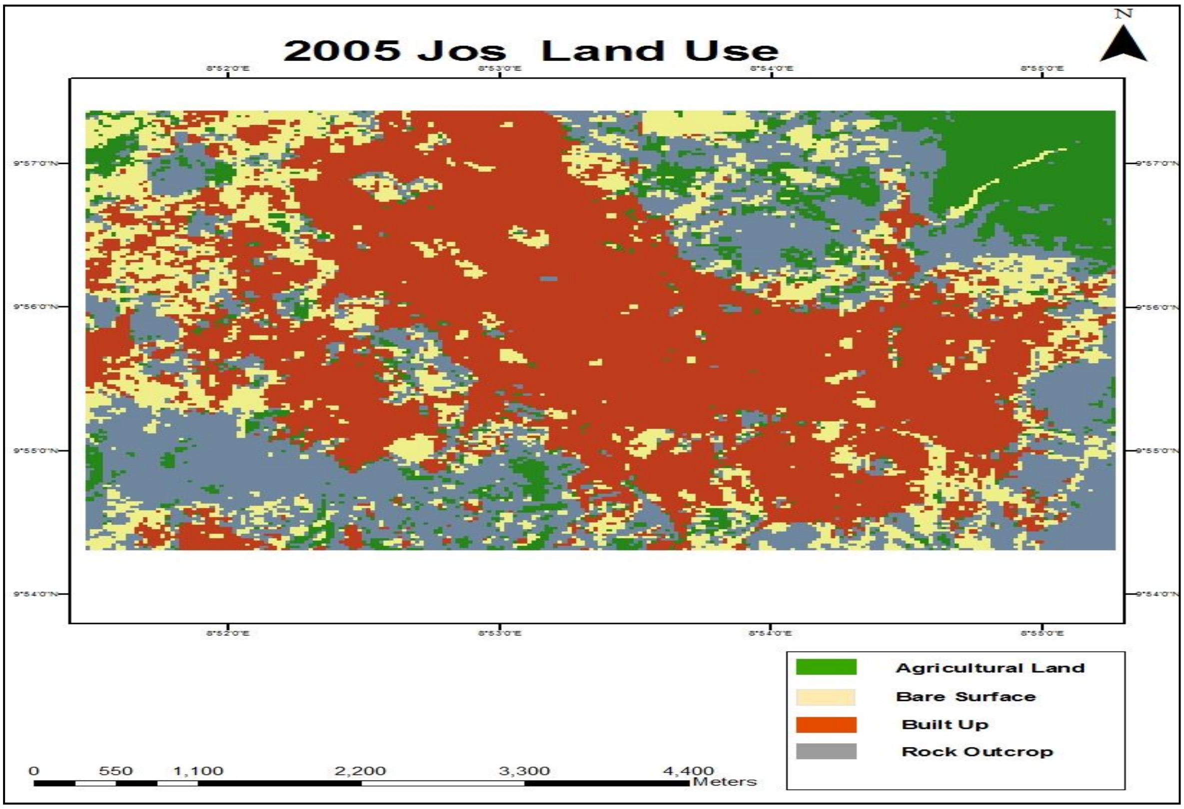
APPENDIX - A

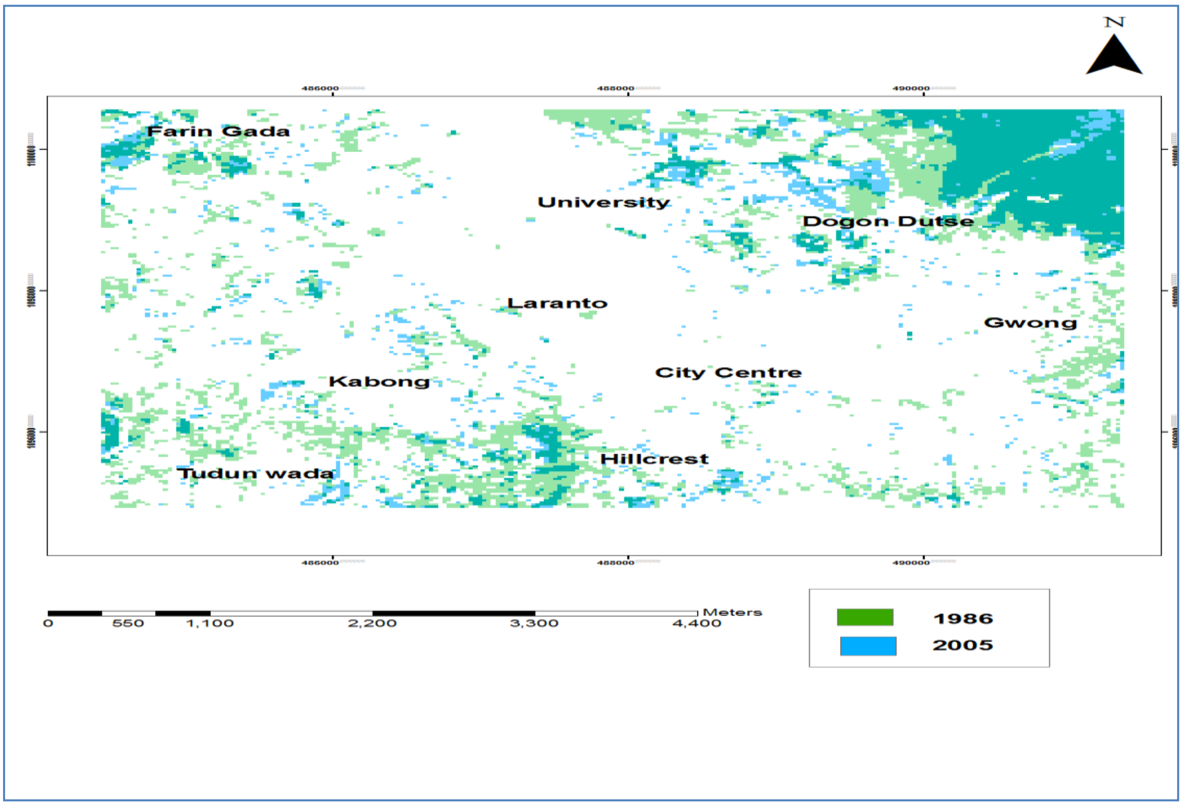
A. 1. Map showing land use classification in 1986.



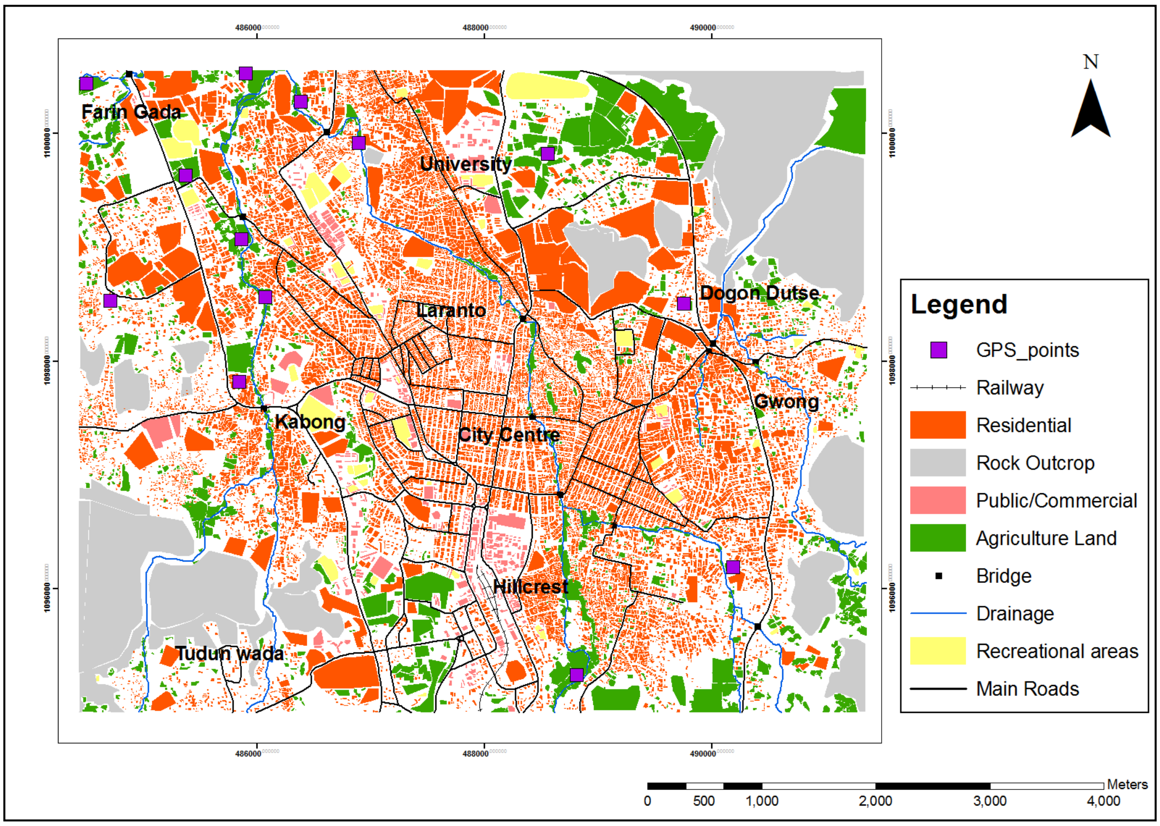
A. 2. Map showing land use classification in 2005



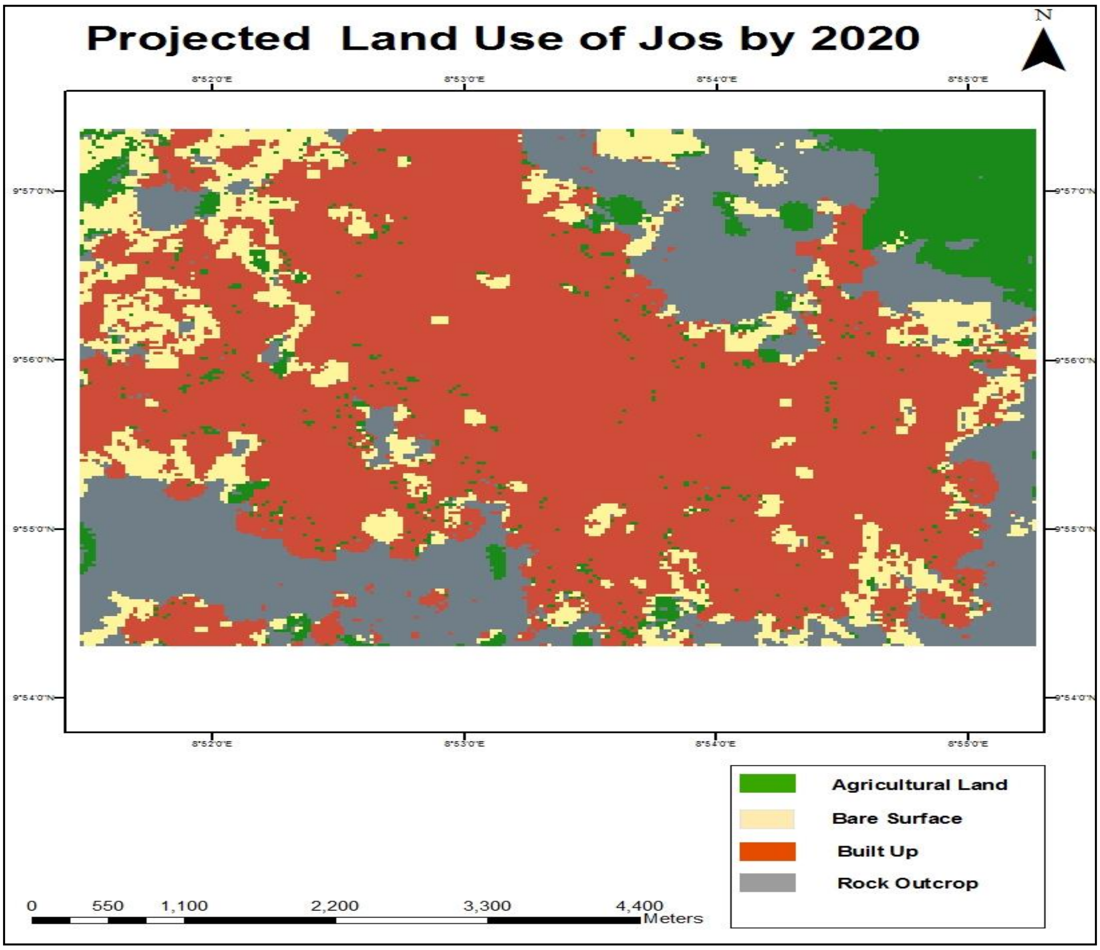
A. 3. Overlay map of 1986 and 2005 agricultural areas



A. 4. Map of Jos North showing urban agriculture land and adjoining land use in 2005



A. 5. Map showing projected land use change in 2020



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