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Application of GIS in land-use studies in the Osse-Ossiomo River basin, Nigeria

CATHERINE I. IKHILE[1] & LEKAN OYEBANDE[2]

1 *Department of Geography and Regional Planning, University of Benin, PMB 1154, Benin City, Nigeria*
ikhilek@yahoo.com

2 *Hydrology Laboratory, Department of Geography, University of Lagos, Akoka-Yaba, Lagos, 101017, Nigeria*

Abstract The Osse-Ossiomo River basin of Edo State, Nigeria, was investigated in terms of land-use changes from 1970 to 2000 using Geographic Information System (GIS) technology. The topographic map of 1965 and Landsat ETM images of 1987 and 2000 were used to investigate these changes. AutoCAD 2000, Arcview GIS 3.2 and Erdas Imagine 7.1 software were used. The results showed that land use in the Osse-Ossiomo River basin changed between 1970 and 2000. The built-up area is principally Benin City. As of 1965, the areal extent was about 25 km^2 or 2500 ha, which increased to 645 km^2 or 64 500 ha in 1987, and 804 km^2 or 80 400 ha by 2000. The other settlements, which included many villages of different sizes (ranging from 5 to 10 km), have merged with the Benin City metropolitan area. The number of roads has increased and the original tropical rainforest vegetation is now a more open type of guinea savanna vegetation. The many rubber plantations that existed in the 1970s have been converted to built-up areas and farmlands. These changes are accompanied by the rapid rate of population growth in the metropolitan area. Appropriate land-use laws are recommended to check the eventual destruction of the natural ecosystem and the dynamic modification of the basin hydrology.

Key words GIS; land use; Osse-Ossiomo River basin

INTRODUCTION

Geographic Information Systems (GIS) are a technology designed to solve geospatial problems. The concept has been universally defined and accepted as a set of computerized tools and methods for the efficient acquisition, processing, storage, management manipulation, and dissemination of geospatial data for decision making and planning (Kufoniyi, 2000). In the Bargi Command Area in Jawai, GIS was used as the best tool to study soil type and land-use/landcover in order to develop a land capability map (Seth *et al.*, 2001). Also Omamoo-Otchere (1998) investigated the urban land-use of Ibadan City using GIS. Many other studies have employed GIS in land-use investigations (Dunne *et al.*, 1995; Rookee *et al.*, 2001). From this work it is observed that the versatility of GIS was brought about through advances in computer technology (hardware and software), satellite technology and geosciences. All these have enabled spatial study of the human environment, such that it is now possible to provide answers to complex land-related problems in near real-time (Kufoniyi, 2000). The application of GIS to study the land-use of the Osse-Ossiomo River basin between 1970 and 2000 has enabled change analysis to be effectively performed between these times.

THE STUDY AREA

The drainage basin lies between latitudes 5°00′N and 6°30′N and longitudes 5°30″E and 6°00″E (Fig. 1). It covers Benin City and its environs up to a radius of 15 km. It is bounded in the west by Ondo State, in the east by the River Niger, in the north by Kogi State, and in the south by Delta State. It covers a total area of 112 km^2. It lies properly within the Edo State of Nigeria. It is part of the Benin-Owena River Basin Development Authority, which is one of the 10 established by *Act no. 25 of 1976: River Basin Development Authorities* on the basis of drainage basin boundaries.

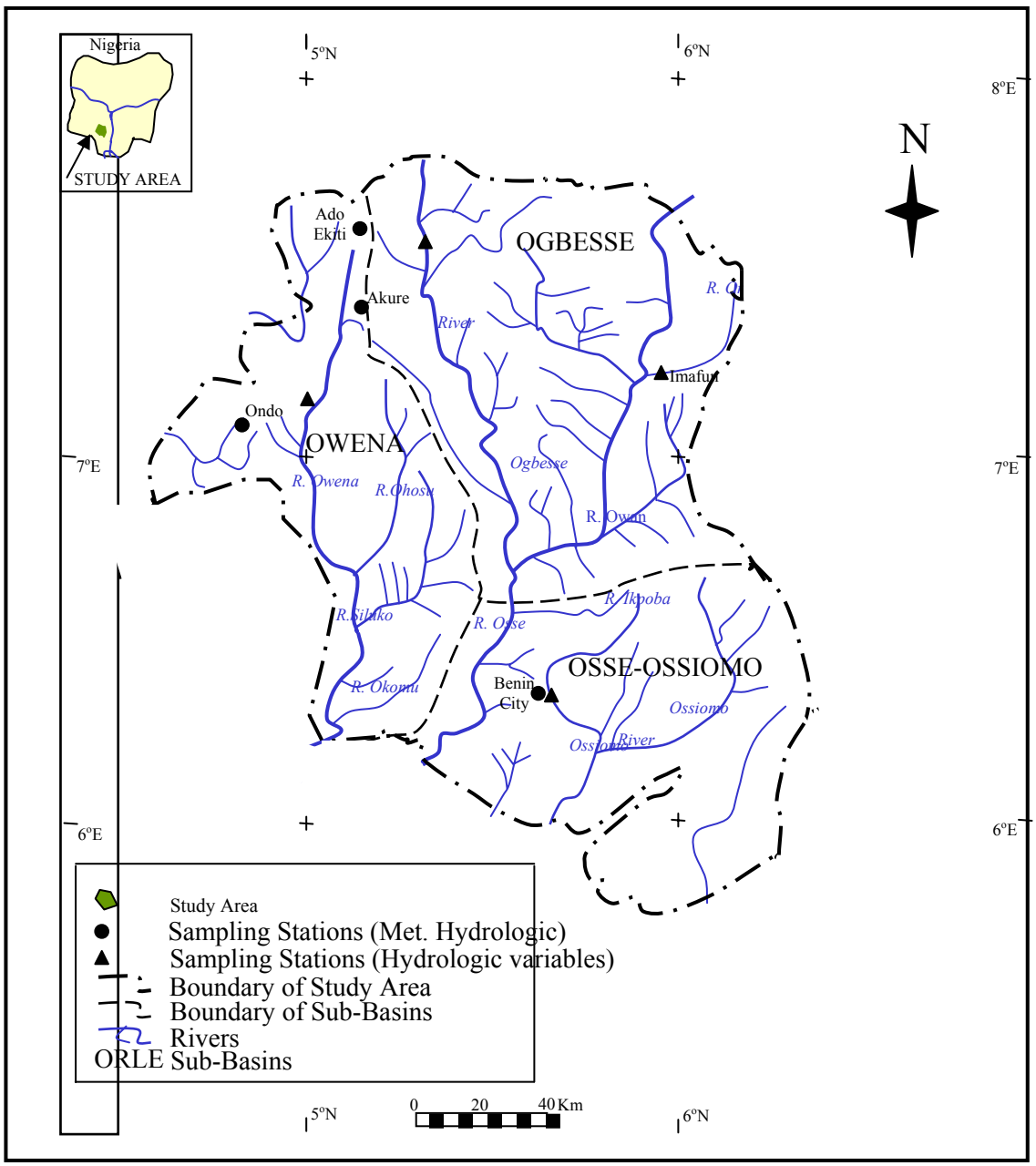

Fig. 1 Benin-Owena River Basin.

Geologically, the basin lies completely within the younger sedimentary formation. This formation consists mainly of the Cretaceous sedimentary rocks of the Upper Senonian group. They occur mainly around Benin City. The sediments are friable, some very fine, and others granular to moderately sorted. The climate is the subhumid equatorial type. This is generally characterized by two distinct seasons, wet and dry. These correspond to the periods of dominance of the wet tropical maritime and the dry tropical continental air masses. The seasonal distribution of rainfall follows the direction of the ITD (wind) and varies almost proportionately with the distance from the coast. The wet season occurs within seven months, from April to October, with an August break, while the dry season lasts from November to March. The mean annual rainfall of Benin City ranges from 1500 to 2780 mm. About 90% of the rain occurs during the March/April to October period. The mean annual temperature ranges from 24 to 30°C. The mean number of hours of sunshine is 5–7, depending on the season. The rate of evaporation is high due to continental effects. The annual mean relative humidity varies from 60 to 80%, depending on the season. The mean atmospheric pressure is about 1031 mb. The vegetation is predominantly tropical high forest. Much of the original forest has been cut down to give room to the open savannah of the guinea type. The vegetation and land-use are dependent upon climate, soils and the influence of human activities.

METHODS OF STUDY

The process of data analysis started with the selection of cloud-free multispectral satellite imagery Landsat ETM (1987) and Landsat ETM (2000) of the Osse-Ossiomo River Basin. Topographic map sheet 298 of 1965 of Benin City was used. The topographic map was scanned and converted to digital form, while the satellite images used were obtained in digital format. The map had co-ordinates while the satellite images were subjected to geo-referencing, classification, digitization and overlay. AutoCAD 2000, Arcview GIS 3.2 and Erdas Imagine 7.1 software were used. The classes identified include built-up areas, other settlements, roads, vegetation and agriculture.

RESULTS AND DISCUSSION

From the 1965 index map (sheet 298) of the river basin, it was observed that many natural and human activities make up the land-use types. These are discussed below.

Built up area

The built-up area is principally Benin City. As at 1965, the areal extent was about 2500 ha (Fig. 2). According to Ikhuoria (1994) by 1979 the total built-up area had grown to 3000 ha, excluding vacant plots. According to him, changes in the city's radius gave rise to geometric increase in its area. By 1987, the areal extent had grown to 64 500 ha, while by the year 2000 it was 80 400 ha (Fig. 3).

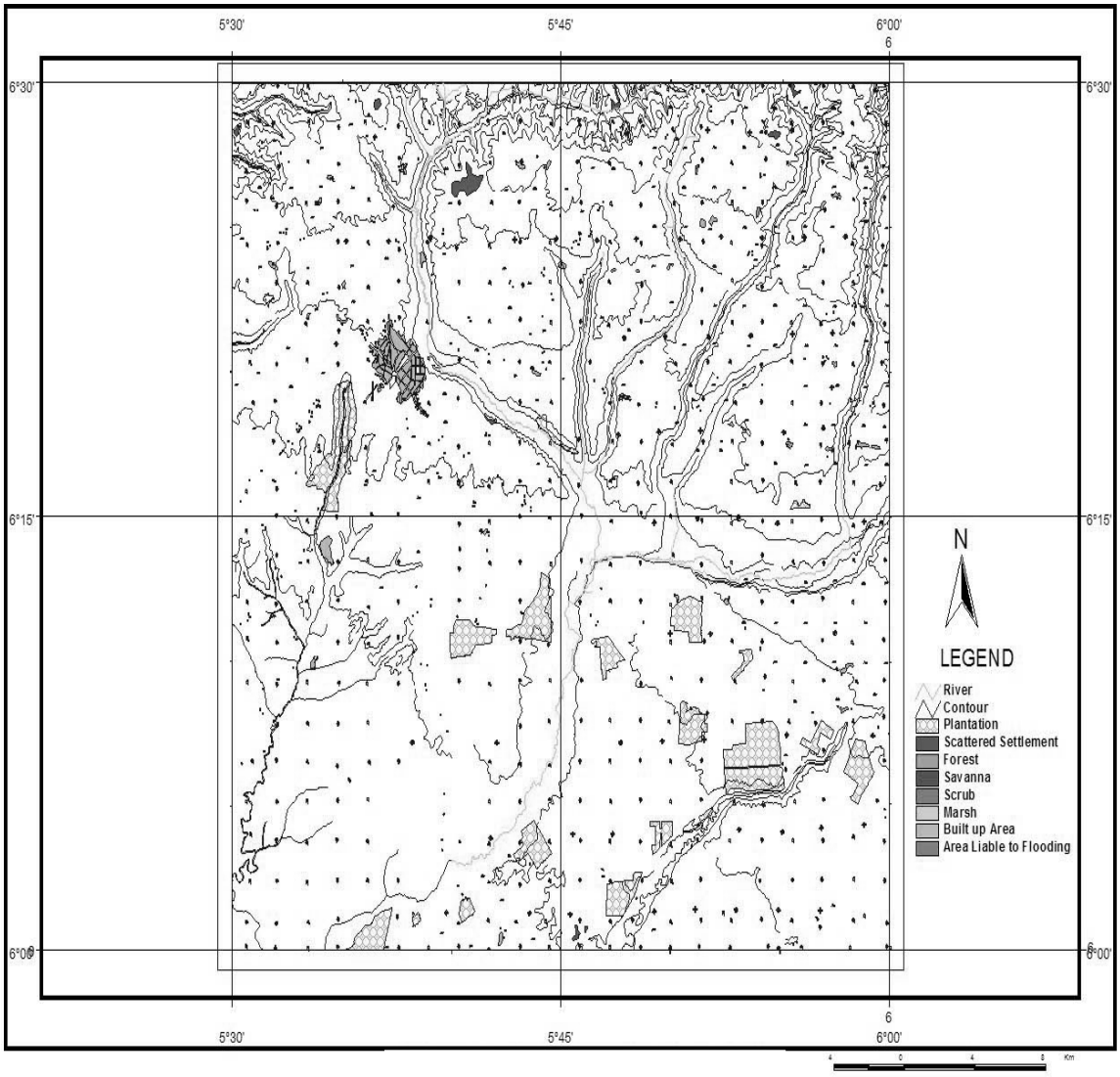

Fig. 2 Land-use of Osse-Ossiomo River basin.

Other settlements

By 1965, other settlements in the river basin included very many villages of different sizes (Fig. 2). By 1987, most of these villages, which formerly ranged between 5 and 10 km distance, had merged with the Benin metropolitan area (Fig. 3). Examples of such settlements include Aduwawa, Ekosodin, Isihor, Ugbekun, and Oliha.

Transportation network

By 1965, there were few major roads built, but by 1987 most of the minor roads had become major roads and the footpaths had been converted to secondary roads (Figs 2 and 3). By 2000, dual carriage roads had emerged, connecting Benin City to Sapele/Warri, Benin City to Ore and Benin City to Agbor (Fig. 4). By 1987 the Benin

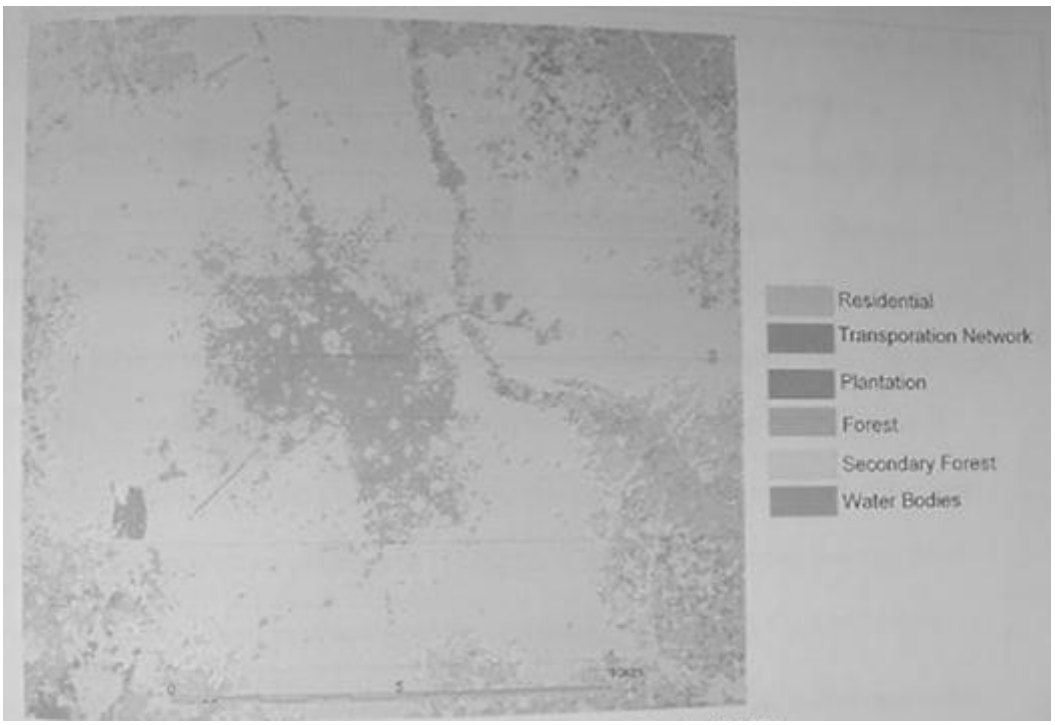

Fig. 3 Classification map of Osse-Ossiomo sub-basin (1887).

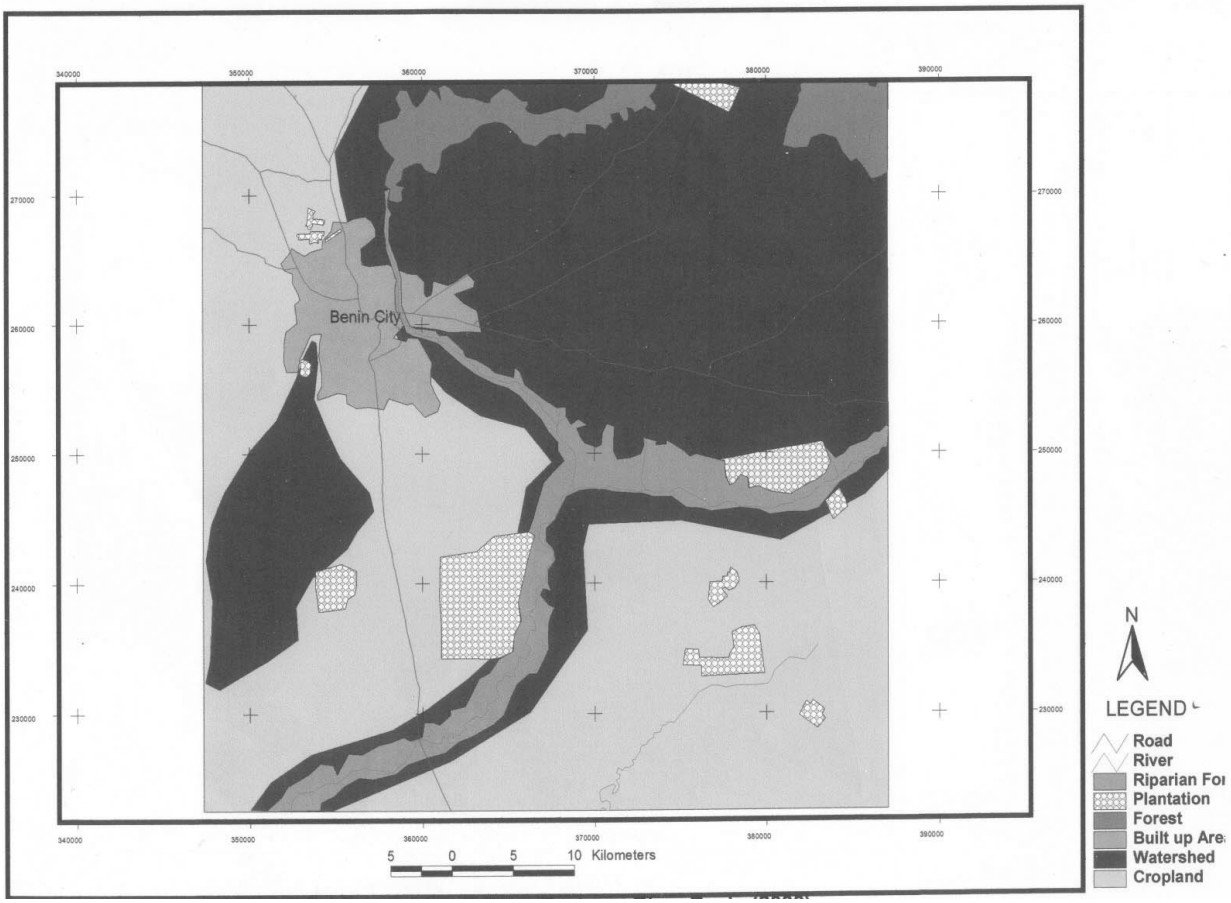

Fig. 4 Land-use of Osse-Ossiomo River basin.

by-pass was constructed (along the oil pipe line) linking the Benin-Ore Road to Benin-Auchi Road, Benin-Agbor road and Benin-Sapele road, as shown in Fig. 4. By 2000, the by-pass had been fully developed. This major transport diverter was commissioned in the year 2003.

Vegetation

The major vegetation types in 1965 were the original tropical rainforest and secondary forests (Fig. 2). By 1987, the forest has been reduced in many places to secondary forest, especially around Benin City metropolis (Fig. 3). By the year 2000, much of the forest in the basin had been greatly reduced to nearly secondary vegetation of the open guinea savanna type (Fig. 4).

Agriculture

Agriculture in Osse-Ossiomo River Basin can be grouped into agro-forestry and arable crops. In 1965, there were many rubber plantations in the river basin (Fig. 2). In fact Sanyu & Sumiko (1994) hold that about 85% of Nigerian rubber in 1968 was produced in this area. These plantations were to be found in the southern part of the basin. This is where the Rubber Research Institute of Nigeria (RRIN), about 20 km along Benin-Sapele road, is located. These plantations vary in size. There were also palm oil plantations. By 1987, many of the plantations had been cut down for the purposes of building houses and schools, farming activities, road construction and industrial developments (Fig. 3). The rubber plantation that was close to the Domestic Airport in Benin City has been reduced to half its original size. Many of the smaller ones have been totally destroyed as the areas were more intensively cultivated. By the year 2000, the rubber plantation near the airport had been almost completely removed for construction of houses, express roads and by-pass and farming activities. In 1965, the basin was mainly cultivated for arable crops such as cassava, yams, maize, melon and okra. In 1987, the area under cultivation was taken, especially around Benin City metropolis, for building purposes (Fig. 3). However, the rubber and palm plantations were destroyed so as to increase the areas under arable farming. By the year 2000, cultivation activities increased due to increasing population and urban development thereby increasing the cultivated areas. Even small vacant plots around the fast developing urban fringes were being cultivated (Fig. 4).

CONCLUSIONS

The importance of investigating or assessing changes in the land-use of a river basin using Geographic Information Systems cannot be over emphasized. A proper mix of land-use types and effective control of the land is necessary for the future survival of the ecosystem, good ecological preservation, and an undestroyed environment for the individual, the family and community as a whole, and for national development.

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