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Spatio-Temporal Analysis of Land Use Change in Uyo Urban, Akwa Ibom State, Nigeria

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ABSTRACT

The increasing population size of cities and the physical expansion of the built-up area beyond the city limits as well as rising demand for more land for various purposes induce changes in urban land-use. This study therefore evaluates the spatio-temporal changes of land uses in Uyo urban. The study utilizes Geographic Information System (GIS); where land use maps of Uyo were produced from Landsat ETM imagery of 2003, 2012 and 2021 using Erdas imagine and ArcGIS softwares. Post classification and change detection analysis for the three years was used to depict changes in identified land uses. The results indicate that in 2003 agricultural land use occupied an area of 37.307 sq.km while residential land use occupied an area of 50.494 sq.km. In 2012, agricultural land use reduced to 25.347 sq.km while residential land use increased to 62.879 sq.km. Furthermore, by 2021, agricultural lands use further indicated drastic reduction occupying an area of 6.207 sq.km while residential land use indicated remarkable increase to 73.469 sq.km. Between 2003 and 2012, residential land uses increased by 8.88 sq.km translating into 15.4 per cent within 10 years and 1.5 per cent per annum; whereas agricultural land use decreased annually by -2.5 per cent. Other land uses such as institutional, commercial and transportation land uses also increased, while forest and water bodies also decreased within the years. It is recommended that periodic monitoring of the land use should be encouraged to ascertain the pattern of changes in order to curtail negative impacts on the environment.

Key words: Spatio-temporal, Change detection, Classification, Land uses, Planning.

1. INTRODUCTION

The demand and utilization of land resource for residential, industrial, commercial and other purposes require careful analysis and planning. As the earth's population increases and national economies continue to move away from agriculture-based systems, cities grow and spread, resulting to changes in land use. The transition to an urban system arises from the transformation from peasant agricultural economy to industrial/manufacturing economy creating the enabling environment for diverse economic activities. As a consequence, the world's population is quickly becoming urbanized as people migrate to the cities. In 1950, less than 30 per cent of the world's population lived in cities. This number grew to 47 per cent in the year 2000 (2.8 billion people), 52 per cent in 2013 (7.12 billon people) and it is expected to grow to 65 per cent by the year 2030 [1]. However, urbanization is occurring rapidly in many developing countries, and it is expected that most urban growth will occur in developing countries during the next decades [2].

Although humans have been modifying land to obtain food and other essentials for thousands of years, current rates, extents and intensities of land use changes are far greater than ever before in history, driving unprecedented changes in ecosystems and environmental processes at local, regional and global scales [3]. Land is a commodity that is very much treasured by everybody as it forms the basic natural and non-renewable resource for agriculture and forestry, building, among many other uses. Therefore, the irrational use of land and inappropriate land management can be attributed to lack of knowledge of the economic, social and political pressures, increase in human population and diverse needs, which force people to use land the way they do.

The phenomenal rate at which most Nigerian cities have grown over the past few decades has had repercussions not only in the cities, but also in the adjourning rural fringes, forests, wetlands among others. While the natural population growth rate for the whole country was about 3 per cent per annum between 1963 and 1980, the growth rate of major urban areas averaged 8 per cent per annum [4]. This growth rate has since skyrocketed and has been accompanied by an unprecedented growth in the physical size of cities. The growth has resulted in the pressure on the available infrastructures and land use, necessitating the conversion of agricultural land, as well as some areas set aside for industrial zone and commercial centre to residential area.

The growth of urban population in Uyo has resulted in the rapid spatial expansion of the city. In the process, many villages which were hitherto at the periphery have been taken over by the expansion. These villages include Mbiabong/Ifa Attai, Idoro, Ediene, Nnung Oku, Osong Ama/Nsukara and many others others. Thus, urban centres, such as Uyo, are not just centres of commerce, business and industry; they are also centres of high physical and social infrastructural development for human comfort and well being. They attract high concentrations of heterogeneous people comprising the indigenous population (original settlers), and the immigrants [5]. The high influx of people into the city centres generate high population pressure on land, leading to a wide range of social and environmentally related problems such as space for housing, education, transport, sewage disposal and so on.

Many infrastructural facilities and institutions have experienced tremendous expansion beyond their statutory limits. Urban growth has spilled beyond the city boundary. From preliminary findings, some social factors such as increase in income of people have increased the capacity of people over the years to acquire more land and also increase the frequency of land development. The wealthier group of the population own many plots and some even build mini estates such as Apico, Edet Akpan, Udoh Ibuot, Anietie estate; others with families seek to own their own houses. Thus, the rate of land acquisition is increasing and is expected to bring many undesirable changes (like slums, unregulated buildings, plan less areas, poor infrastructural planning) in the land use pattern within the city as well as its surrounding areas. However, not enough is known about the magnitude of these land use changes. For instance, before Uyo became the capital city of Akwa Ibom State in 1987, residential land use was about 18.82sq.km but by 2002 it had increased to about 59.97sq.km, while agricultural land use which was 47.55sq.km had reduced to about 33.34sq.km [6].

2. AIM OF STUDY

This study is aimed at evaluating the spatio-temporal changes of the land uses in Uyo urban, Akwa Ibom State, from 2003 to 2021.

3. LITERATURE REVIEW

3.1. Spatio-temporal changes in land use

Land use is the term that is used to describe human uses of land, or immediate actions modifying or converting land cover [7]. On the other hand, land cover refers to the natural vegetative cover types that characterise a particular area. Land-use change is the proximate cause of land-cover change. Land use is the intended employment of land management strategy placed on the land cover by human agents, or land managers to exploit the land cover and reflects human activities such as industrial zones, residential zones, agricultural fields, grazing, logging, and mining among many others [8-9]. However, land cover is defined by the attributes of the earth's land surface captured in the distribution of vegetation, water, desert and ice and the immediate subsurface, including biota, soil, topography, surface and groundwater, and it also includes those structures created solely by human activities such as mine exposures and settlement [9-11]. Land use change is defined to be any physical, biological or chemical change attributable to management, which may include conversion of grazing to cropping, change in fertilizer use, drainage improvements, installation and use of irrigation, plantations, building farm dams, pollution and land degradation, vegetation removal, changed fire regime, spread of weeds and exotic species, and conversion to non-agricultural uses ([12]. Furthermore, "Land use deals essentially with the spatial aspects of all man's activities on land and the way in which the land surface is adapted, or could be adapted, to serve human needs."[13].

3.2. Change Detection Analysis

Land use changes are studied employing the protocols of change detection. Change detection according to [14-15], is identifying contrasts or discrepancies in the state of an object or phenomenon by observing it at different times. This involves the ability to quantify temporal alteration and transformation using multi-temporal data sets. In general, change detection involves the application of multi-temporal data sets to quantitatively analyse the temporal effects of the phenomenon. Author [16] provide a different definition, arguing that change detection comprises of processes that are used to determine the changes associated with land use/land cover characteristics based on geo-registered remote sensing data. According to [17], change detection in images identifies the set of pixels that are significantly different between two consecutive images of the same scene. Moreover, [18] reports that digital change detection technique is based on multi-temporal and multi-spectral remotely sensed data, which have great potential as tools for understanding landscape dynamics, including detection, identification, mapping and monitoring differences in land use/land cover change over time, irrespective of causal factors. However, change detection is useful in such diverse applications as land-use analysis, habitat fragmentation, urban sprawl, assessment of deforestation as well as other environmental changes [19].

4. THE STUDY AREA

4.1. Location

Uyo urban is situated between latitudes $4^0$59' and $5^0$05' North and longitudes $7^0$54' and $8^0$00' East. Its location relative to some urban centres in the State shows that it is 51 kilometres from Ikot Ekpene, 70 kilometres from Eket, 16 Kilometres from Abak and 90 kilometres from Calabar, Cross River State. It is relatively at the centre of the State and easily accessible to any of the south Eastern and South South States. It is bounded on the West by Abak LGA, East by Uruan LGA, North by Ikono LGA, Ibiono Ibom and Itu, on the South by Etinan, Ibesikpo/Asutan and Nsit Ibom Local Government Areas [6].

Uyo urban has, a total land area of 187,467 square kilometres and is made up of three residential clans namely, Oku (9 villages), Etoi (17 villages) and Offot (19 village) [6].

4.2. Land use utilization pattern

The uses of land in Uyo urban depend on the prevailing social, economic, and physical environment. According to [20] man's relation to the land, patterns of land-holding, and land use are shaped by "the interaction of a complex of forces". In the study area, these forces produce

characteristics of land use activities and can be classified into residential, commercial, institutional, transportation, industrial, agricultural, secondary forest, recreational and degraded area.

5. TYPE AND SOURCE OF DATA

Data on distribution and land use changes were obtained through satellite imageries from the National Airspace Research and Development Agency (NASRDA) and Aerial photographs of Uyo for 2003, 20012 and 2021. This showed land use changes that existed over the study period.

6. DATA COLLECTION METHOD

6.1 Data Set

The data set include othorectified LANDSAT Thematic mapper (TM) imageries of 2003, 2012 and enhanced thematic mapper (ETM) imageries of 2021 with 30m resolution and 3 color bands resolution were used.

Software

Erdas Imagine software version 10.0 and ArcGIS Version 10.1 were used. Erdas were used for land use classification from the identified land use classes, while ArcGIS is suitable for calculation of area coverage of land uses. The map of Uyo urban as the study area were geo-referenced in ArcGIS 10.1, the study area shape files were re-projected to World Geodetic System (WGS) 1984, Universal Transverse Mercator (UTM) Zone 32 North coordinate system to march with the orthorectified LANDSAT image. This allowed extraction of area of interest from the image.

Image processing

Layer combination and stacking were done in order to view the satellite image as a three band color composite. Erdas imagine 10.0 were used for inlayer stacking, mosaicking, subseting of the three imageries. After which the imageries were enhanced using Principal Component Analysis (PCA).

Creation of Area of Interest (AOI)/Reprojection

Sub-setting of a portion of the imagery by super imposing the Uyo LGA map and Coordinates on the imagery. The Uyo Local Government map was overlaid on the imageries to create the areal coverage of Uyo urban (the study area) to ease data analysis.

6.2 Ground Truthing.

A high end Global Positioning System (GPS-Gamin Etrex 30) was used in the field to track the different land uses, to note their distribution and their appearance on the imagery. This enabled easy identification of the land uses as they appear on the imagery for classification and analysis.

6.3 Classification

Supervised classification which involves ground verification of the land use/ land cover was carried out in which coordinates of different land uses were acquired. The data acquired from ground truthing were interpolated on the imageries to ease identification of features. Thus, the images were processed using the supervised image processing technique. This was done through the classifier menu by training the signature first according to land use categories developed and then were classified using the trained signature. The advantage of supervised classification is that the classification analysis is based on the band data and the training sample data follow normal distribution, which enable the detailed analysis with the reality on ground. While in the unsupervised classification the band data are clustered. Besides, during the analysis, once the training samples are created, the Interactive Supervised Classification tool allows you to perform a supervised classification without explicitly creating a signature file. Also, this tool accelerates the speed of the classification. Internally, it calls the Maximum Likelihood Classification tool with default parameters. During the classification, it makes use of all the bands available in the selected image layer. Based on the prior knowledge of the study area for over 15 years, a brief reconnaissance survey was carried out, and a classification scheme was developed for the study area after [21-22]. The modification of the classes was done keeping in view the area under investigation for detailed analysis. Ten (10) classes of land use emerged from the analyses. The land use categories include residential, recreational, agricultural, institutional, degraded area, secondary forest, industrial, commercial, transportation and water body (Table 1).

Table 1: Land use classification scheme and their sub-categories in Uyo urban

S/No	Level I	Level II
1	Residential	a) Detached houses b) Semi-detached houses c) Single storey houses d) Blocking of flat
2	Recreational	a) Parks b) Hotels
3	Commercial	a) Super markets b) Open markets c) Shops (retail and wholesale) d) Filling Stations
4	Industrial	a) Factories b) Petrol storage tank c) Power stations
5	Transportation	a) MotorParks b) Roads c) Airport
6	Agricultural	a) Farm land b) Poultry farm c) Orchards d) Plantations e) Gardens f) Fallow land
7	Institutional	a) Educational b) Religious facility c) Military facility d) Government offices e) Public establishment
8	Degraded area	a) Ravine b) Eroded lands c) Beaches

9	Forest	a) Tropical forest b) Secondary forest c) Riparian forest
10	Water body	a) Stream and canals b) Lakes and ponds c) Estuaries d) Open marine waters

Source: Adapted and modified from Effiong-Fuller, (1988) and Anderson,Hardy, Roach, and Richard, (2001).

6.4 Interpolation

Interpolation was carried out by calculating the annual change between the successive years of 2003, 2012 and 2021 [23].

$$\text{Annual Change} = \left[\frac{\text{Final Value} - \text{Initial Value}}{\text{Initial Value}}\right] \times 100$$

$$\frac{}{n-1}$$

Where n = number of year

6.5 Map Overlay and Land Use Change Analysis

In order to detect the changes that have occurred between 2003 and 2012 and that between 2012 and 2021, the different themes containing the land use maps of the respective periods were overlaid in Erdas 10.0 for classification and for calculation and interpretation. Through this method, the rates, extent and direction of land use change were determined.

6.6 Change Detection Technique

For this study change detection approach was used in detecting the differences in land use types from the multi-temporal data set obtained. The approach is suitable because it applies pixel by pixel analysis. This shows the differences that existed within the years (2003-2012 and 2012-2021). The land use maps were produced through digitization of the different land use classes.

7. RESULTS AND DISCUSSION

Changes have been noted among the different land uses in the three epochs. In 2003, commercial land use occupied an area of 0.928 sq.km (0.8 per cent of the total area); In 2012, commercial land use expanded to 1.172 sq.km (1.0 per cent); while in 2021, it expanded to more than sixth times of the what was obtainable in 2009 with a new area of 8.129 sq.km translating to 6.8 per cent of the total area. The change in industrial land use indicated that in 2003, it occupied an area of 1.553 sq.km (1.3%); which later expanded to 2.265 sq.km (1.9%) and later in 2021 Industrial land use reduced to 2.013 sq.km (1.7%).

Transportation land use also show significant changes occupying an area of 0.796 sq.km (0.7 per cent of the total area) in 2003; in 2012, occupied an area of 0.506 sq.km translating to 0.4 per cent). In 2021, transportation land use increased to 4.218 sq.km (3.5 per cent of the total area). In a similar study on the central highlands of Vietnam, [24] used a spatial model combining village survey with the identified imagery interpretation. In their work, technological and rural development policy, variables were the determinants of past land cover change in the area.

Agricultural land use occupied an area of 37.307 sq.km (which was 31.2 per cent of the total area) in 2003. A decrease was observed in 2012, occupying an area of 25.347 sq.km (which was 21.2 per cent of the total area); a severe decrease was noticed in agricultural land use in 2021 occupying an area of 6.207 sq.km (which is 5.2 per cent of the total area). As noticed by [10] land use decisions are motivated by socio-economic drivers which build a vital feedback loop of the interaction of human societies and the natural environment.

Residential land use is the most prominent land use in the area. It increased from 50.494 sq.km (42.2 per cent of the total area) in 2003. Residential land use increased to 62.879 sq.km (52.5 per cent of the total area) and to 73.469 sq.km (which was 61.4 per cent of the total area) in 2021.

Thus in 2003 the areal extent of other land uses include institutional land use occupied an area of 10.521 sq.km (8.8 per cent of the total area); secondary forest land use occupied an area of 16.028 sq.km (which is 13.4 per cent of the total area); degraded area occupied an area of 0.783 sq.km (which is 0.7 per cent of the total area) recreational land use occupied an area of 0.448 sq.km (which is 0.4 per cent of the total area); water bodies occupied 1.115 sq.km (which is 0.9 per cent of the total area); (Table 2). Figure 1, shows the land use map of 2003 showing the different use classes.

In 2012, institutional land use occupied an area of 13.905 sq.km (which is 11.6 per cent of the total area); secondary forest land use occupied an area of 10.948 sq.km (which is 9.1 per cent of the total area); degraded area occupied an area of 0.829 sq.km (which is 0.7 per cent of the total area) recreational land use occupied an area of 0.472 sq.km (which is 0.4 per cent of the total area);water bodies occupied 1.070 sq.km (which is 0.9 per cent of the total area); (Figure 2).

In 2021, institutional land use occupied an area of 16.003 sq.km (which is 13.4 per cent of the total area); secondary forest land use occupied an area of 4.609 sq.km (which is 3.9 per cent of the total area); degraded area occupied an area of 0.257 sq.km (which is 0.2 per cent of the total area) recreational land use occupied an area of 4.142 sq.km (which is 3.5 per cent of the total area); water bodies occupied 0.630 sq.km (which is 0.5 per cent of the total area); (Figure 3).

Author [25] have presented a land-use transition model that depicts a sequence of land-use stages beginning with 100 per cent of the landscape covered by pre-settlement natural ecosystems, followed by frontier clearing, subsistence agriculture, and small-scale farming, intensifying farmland production, and lastly, the intensive stage. The latter is characterized by expanded urban areas, intensive agriculture and expanded, protected and recreational lands, leaving small proportions of the landscape covered by either natural ecosystems or subsistence/small-scale agriculture. In this

conceptualization of land use changes, small-scale farming systems in developing countries will most likely be situated at subsistence and intensifying stages as the key point is that urban land use change and other dynamics are intricately related to both economic development and the ecological characteristics of the landscape. [26, 27, 28], the model is based on classical land intensification theory and it envisages a unidirectional process of intensification in response to locally driven demands for land-based products and services. Land use and land cover change (LULC) is a good indicator that reflects the interface of human - environment interaction [29]. Author [30] in his work entitled "*Implication of human activities on land use land cover dynamics in Kagera catchment, East Africa*" analysed land use change over a 28 year period and observed that the most dynamic land use land cover (LULC) change was agriculture followed by woodland savanna.

Table 2
Land use areas of Uyo urban from 2003 to 2021

	2003		2012		2021	
Land Use	Area (sq. km)	% of the total area	Area (sq.km)	% of the total area	Area (sq.km)	% of the total area
Commercial	0.928	0.8	1.172	1.0	8.129	6.8
Industrial	1.553	1.3	2.265	1.9	2.013	1.7
Transportation	0.506	0.4	0.796	0.7	4.218	3.5
Institutional	10.521	8.8	13.905	11.6	16.003	13.4
Agricultural	37.307	31.2	25.347	21.2	6.207	5.2
Secondary Forest	16.028	13.4	10.948	9.1	4.609	3.9
Degraded area	0.783	0.7	0.829	0.7	0.257	0.2
Recreational	0.448	0.4	0.472	0.4	4.142	3.5
Residential	50.494	42.2	62.879	52.5	73.469	61.4
Water body	1.115	0.9	1.070	0.9	0.630	0.5
Total	119.682	100.0	119.682	100.0	119.682	100.0

Source: Author's GIS Analysis, 2022

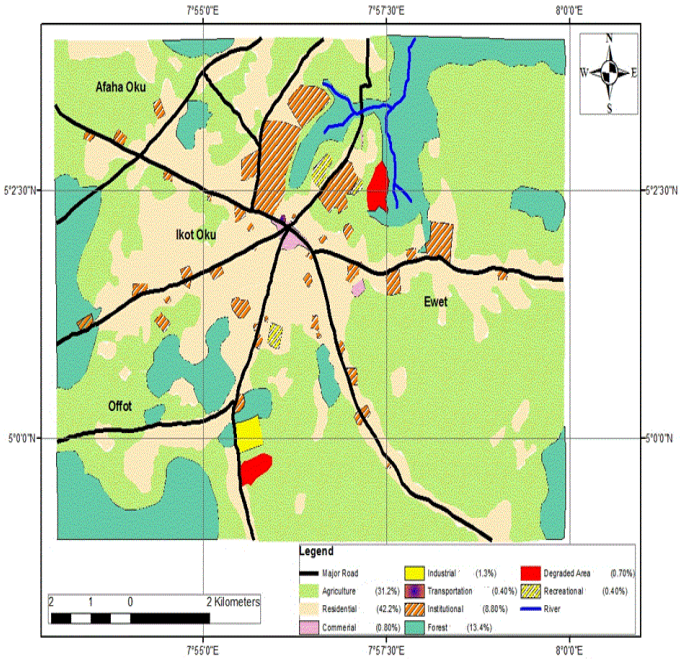

Figure 1: Land use Map of Uyo Urban, 2003.
Source: Author's GIS Analysis, 2022

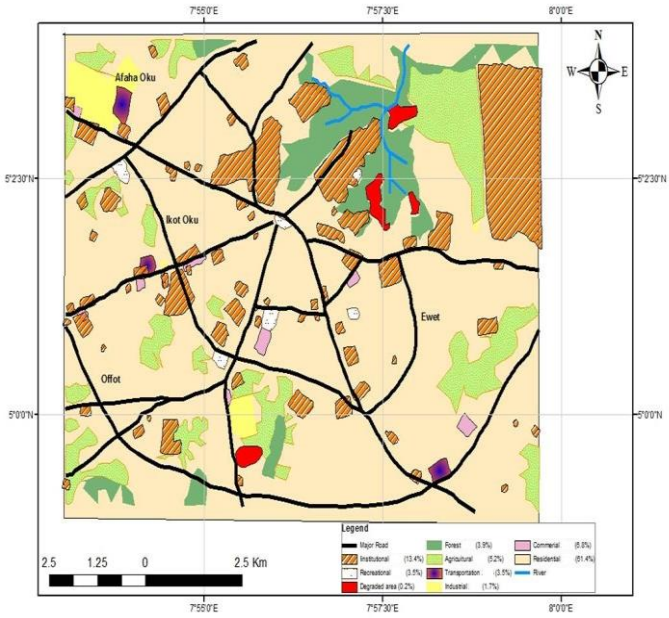

Figure 2: Land use Map of Uyo Urban, 2012
Source: Author's GIS Analysis, 2022

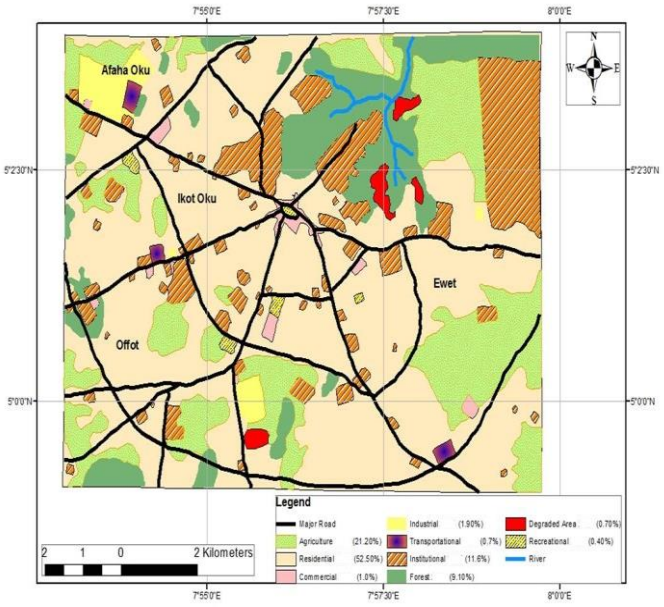

Figure 3: Land use Map of Uyo Urban, 2021
Source: Author's GIS Analysis, 2022

8. CONCLUSION AND RECOMMENDATIONS

There is increasing trend for land uses relating to development of critical infrastructures such as housing, commercial activities, industrial and so on, which displaces other uses such as home gardening, small–scale urban farming.

The establishment of small scale industries and businesses further contribute to land use changes. Attention has been focused on development of infrastructures which reduces the other land uses. The long term loss of forest, green areas and agricultural area has reduced green areas and their functions. Green areas for instance are necessary for recreation which on other hand is essential for climate moderation, provide shade and reduces heat especially along the sidewalks, provide parks and entertainment spots. Agricultural land use is important for home gardening and small-scale urban farming that provide part of the food needs of the urban population. This also helps to moderate local weather regime by providing ambient air. Green areas also add to the aesthetics of the urban centre.

Changes in the environment should be monitored. Changes in land use sometimes result in changes of the scenery. This also results in negative impacts on the environment such as erosion, waste and flood among others. Periodic monitoring of the land use especially in urban settlement pattern and vegetation cover should be encouraged to ascertain the pattern of changes in order to curtail negative impacts on the environment.

Planning laws should be implemented. Some settlement within Uyo were found to develop into slum, some were also without approval. Planning laws that restrict urban sprawl and other forms of anti-planning regulations such as building codes, development control edicts that limits control within the approved plans should be put in place by government. Only building and facilities in line with the regulations shall be approved.

Statements and Declarations

The authors have no competing interests to declare that are relevant to the content of this article.

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