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Land Use and Population: A Linking Model

Lacking an accurate census, housing land area could be used as a surrogate for estimating population density in Ilorin.

Abstract: *The census, which is the main source of data on city population, is an infrequent exercise in Nigeria. In addition, the census has been criticized for being costly and time consuming. There is the need for up-to-date information on city population for planning purposes. This paper attempts to solve the problem of non-availability of recent population figures of Nigerian cities.*

Although many of the data presently available through the census method would not be directly obtainable from aerial photographs, information regarding the total population of cities could be obtained if known relationships are in existence between population and patterns of physical phenomena measurable from aerial photographs.

We have, therefore, in this paper tried to define a mathematical model which may be used in conjunction with data on housing land area measured from aerial photographs to obtain urban population estimates for Nigerian cities. The method advocated here has the advantage of being low cost and non-time consuming in making population estimates.

Introduction

In most developed countries, population statistics are published every ten years, but in many developing countries, such as Nigeria, information on population and urban growth is difficult to obtain. The census which is the main source of population data has been criticized as being overly costly and time consuming.[1] The use of aerial photography for collecting certain types of census information and detecting some of the inadequacies of a census have been suggested as a procedure which can successfully supplement existing methods.[2] Although most data presently collected through the census method cannot be directly obtained from aerial photographs, information regarding the total population of cities can be obtained if known relationships are established between population and patterns of physical phenomena measurable from aerial photographs.

This paper attempts to overcome the problem of non-availability of up-to-date population data in Nigeria by defining mathematical models which may be used in conjunction with relevant information from aerial photographs to obtain population estimates. Specifically, the paper seeks to identify the land use types that can easily be measured from aerial photographs of Ilorin (Nigeria) and which in turn bear significant relationship to the population of the city.

The land-use method,[3] the house counting technique,[4] and the land-area method[5] are three methods commonly employed to derive population estimates from remotely sensed data. The first technique is the most appropriate in this paper because here we seek to establish a relation between indigenous, barrack/flat, flat, and uncompleted housing land-use types (Table 1) and population. If the results are successful, then several benefits could be derived from the use of this technique in generating population statistics. First, intercensal population estimates could be generated relatively easily and

Photogrammetric Engineering and Remote Sensing,
Vol. 50, No. 2, February 1984, pp. 221-227.
0099-1112/84/5002-0221$02.25/

TABLE 1. THE KEY TO THE LAND-USE ANALYSIS IN ILORIN 1950 AND 1963

Land Use	Code	Characteristics
Indigenous residential type	(A)	Rectangular or square shape with Central enclosed space.
Barrack/flat	(B)	Rectangular or square shape without enclosed space.
Flat	(C)	Self-contained detached houses with regular spacing and leading roads.
Uncompleted housing	(D)	Small regular pattern of house plans.
Bare/grass/agricultural	(E)	No vegetation/short grass is available and some heaps of soil.
Trees	(F)	Broad crowns, at times continuous.

inexpensively from land-use measurements. In addition, such estimates could be produced within a short period of time and as often as might be desired. Furthermore, it will be possible to estimate the population of communities located in remote areas where political, social, and economic conditions make field enumeration impractical but for which their aerial photographs can be obtained.

THE STUDY AREA

Ilorin, the Kwara State capital, is situated in a transition zone between the northern and southern Nigeria (Figure 1). Its population once suffered some loss, but since 1952 the population seems to have steadily increased and there has been considerable annual increases since 1967. By 1963, the population of the city was 208,546 compared to its 1952 figure of 40,994. The city's 1973 population was estimated to be about 320,000 while the population in 1980 was put at approximately 500,000[6].

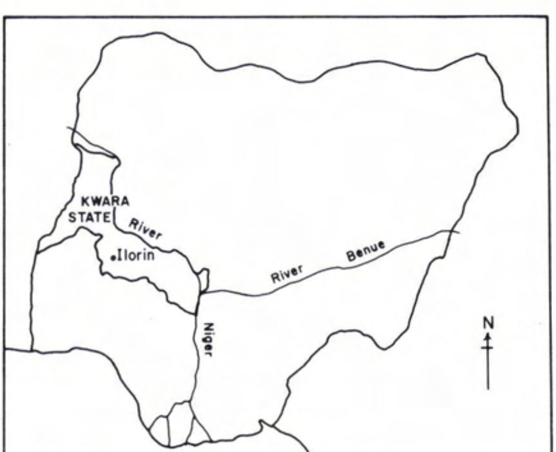


FIG. 1. Map of Nigeria showing the location of Ilorin (1:19,000,000 scale).

Although Ilorin has been a provincial headquarters for some time, its recent growth has been due to the creation of Kwara State in 1967 with Ilorin as the capital.

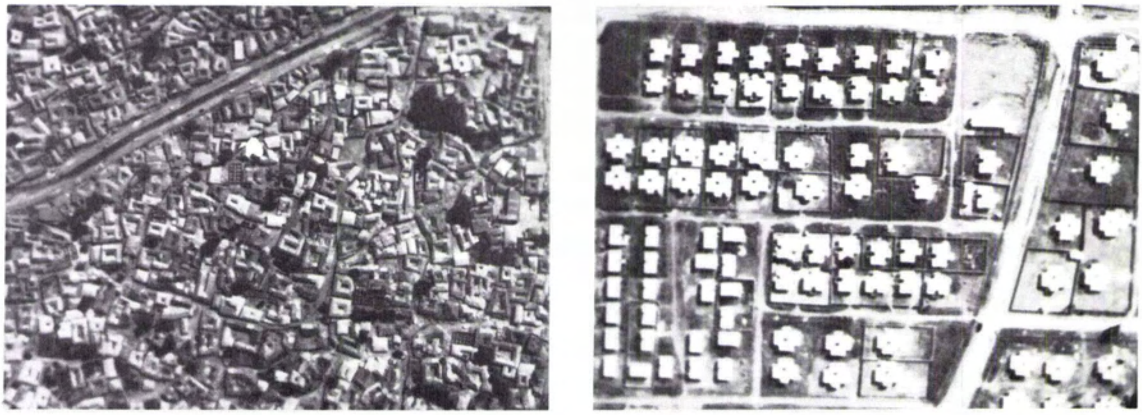
THE DATA

The data employed in this paper were obtained from two main sources. The population figures for Ilorin wards were collected from the census report for Ilorin[7] while data on land use were obtained from aerial photographs of Ilorin (Figure 2). The city was divided into 2-cm^2 cells on the 1973 (1:10,000) topographic map, out of which a total of 74 sample areas were randomly selected (approximately a 10 percent sample). These sample areas were then located and marked on the aerial photographs. The land area of each land use (Table 1) was estimated from each sample area from 1950 (1:2,400) and 1963 (1:12,000) aerial photographs of Ilorin, using the dot grid sampling technique.[8] Each of the sample areas from the 1963 aerial photographs were enlarged five times to a 10-cm^2 grid cell using the Grand Projector, while those from the 1950 aerial photographs were overlayed with a 1.8 by 1.8 cm grid cell. As a result of the size variations between the different sectors of the city (i.e., the wards), it became necessary to standardize the land-use data by expressing them as percentages of the land area in each ward.

THE ANALYSIS

THE REGRESSION OF HOUSING TYPES AND OPEN UNDEVELOPED LAND USE

Two multiple regression analyses were carried out with population and six independent variables relating to housing [(1) indigenous, (2) barrack/flat, (3) flat, and (4) uncompleted housing] and open undeveloped land [(5) bare-grass agricultural land and (6) trees]. In 1950, a coefficient of determination (r^2) 0.73 was achieved while it was 0.65 in 1963 (Table 2). Barrack/flat, uncompleted housing, bare-grass



(a) (b)

FIG. 2. Aerial photographs of part of Ilorin, Nigeria, taken January 1982 (1:8000 scale). (a) Indigenous residential type (rectangular or square shape with central enclosed space). (b) flat residential type (self-contained detached houses with regular spacing and leading roads).

agricultural land use and trees all had significant correlation with population in 1950. In 1963, however, only flat housing had a correlation—0.51, significant at the 0.5 percent level of probability. The analysis here probably points to the importance of housing land use as indicative of population in Ilorin. This may not be unexpected though because housing has a direct influence on the livelihood of the population.

Hence, only the four independent variables (indigenous, barrack/flat, flat, and uncompleted housing) representing the housing land-use types were further used in a series of regression analyses. This was because defined housing units could easily and quickly be recognized and identified on aerial photographs. Moreover, it seems reasonable to expect that housing more than anything else would be better related to population. In order to examine

TABLE 2. MULTIPLE LINEAR REGRESSION OF PERCENTAGE LAND-USE AREA AND POPULATION FOR ILORIN WARDS (10 PERCENT SAMPLE)

		1	2	3	4	5	6	7
Correlation Matrix 1950								
Indigenous housing	(1)	—	0.238	−0.503	0.613*	−0.796***	0.505*	0.312
Barrack/flat housing	(2)		—	−0.268	0.416	−0.578*	0.231	0.568*
Flat housing	(3)			—	−0.507*	0.582*	0.379	−0.186
Uncompleted housing	(4)				—	−0.736**	0.612*	0.659**
Bare/grass/ agricultural land	(5)					—	−0.715**	−0.657**
Trees	(6)						—	0.558*
Population	(7)							—
Coefficient of determination (r^2)						0.726**		
Correlation Matrix 1963								
Indigenous housing	(1)	—	0.625*	−0.688**	0.573*	−0.654**	0.040	0.387
Barrack/flat housing	(2)		—	−0.038*	0.013	−0.508*	0.006	0.388
Flat housing	(3)			—	−0.279	0.397	0.027	−0.506*
Uncompleted housing	(4)				—	−0.367	0.047	0.265
Bare/grass/ agricultural land	(5)					—	−0.753***	−0.174
Trees	(6)						—	0.051
Population	(7)							—
Coefficient of determination (r^2)						0.653**		

* Significant at 95% level
** Significant at 99% level
*** Significant at 99.9% level

the individual, pairwise, as well as joint pairs (sum of the variable) of indigenous, barrack/flat, and uncompleted housing on population, these variables were singly, pair wisely, and jointly regressed against population in 1950 and 1963. The results are indicated in Table 3.

The same set of analyses as above was carried out substituting population with population density as the dependent variable, the results of which are also shown in Tables 4 and 5. A coefficient of determination of 0.78 and 0.75, significant at the 99 per cent level of probability, was achieved in 1950 and 1963, respectively (Table 4). This clearly indicates an improved explanation in the variation in population density in both 1950 and 1963.

One major difference between this result and the others is the fact that in 1963 indigenous housing, barrack/flat and flat housing are now correlated with population density. This is so because in 1950, the social and economic order in Ilorin was largely preindustrial, and there was little competition for housing in Ilorin. Thus, houses emerged as the need arose. In 1963, however, as a result of the growth of Ilorin and the continued importation of 'western' ideas, competitions on site and location of land increased. In other words, it was practically possible to build a house anywhere, anytime in 1950, because most people in Ilorin were the indigenes who owned the land. But as population become heterogenous, the diffusion of western civilization increased; hence, the increased cost of land. This invariably led to crowding of people in the existing areas. This argument is further supported by the correlation coefficient 0.78 in 1963, significant at the 0.1 percent level of probability between population density and indigenous housing (Table 4).

The correlation coefficients (Table 5) indicate that the best relationship between population density and the independent variables existed with the joints pairs, triplets (sum of values of the three variables), and pair wise regression analyses. Indigenous housing was the best single variable predicting population density in 1963, while barrack/flat was the best in 1950; barrack/flat and uncompleted housing were the best pair in 1950, and indigenous and barrack/flat the best pair in 1963. Similarly, barrack/flat, flat, and uncompleted housing were the best joint triplets of variables in 1950 while indigenous, barrack/flat, and flat were the best in 1963.

The results above suggest that the joint pairs and triplets of these housing land-use types and uncompleted housing were better correlated to population density than the individual land-use categories. Considering the practical problems involved in collecting data on the other land-use types, such as interstices from aerial photographs, we concluded that the land-use types best observable from aerial photographs that are highly associated with population density are the housing land-use types (indigenous, barrack/flat, flat, and uncompleted). In consequence, housing as a land-use category, rather than differentiating between the different types, was probably the best predictor variable of population density in Ilorin. This is because, for practical

TABLE 3. LINEAR REGRESSION OF PERCENTAGE LAND-USE AREA AND POPULATION FOR ILORIN WARDS (10 PERCENT SAMPLE)

Variable	*Correlation Matrix*	1950 (r)	1963 (r)
Indigenous housing	(1)	0.312	0.387
Barrack/flat housing	(2)	0.568*	0.388
Flat housing	(3)	−0.186	−0.506*
Uncompleted housing	(4)	0.659**	0.265
	1 and 2	0.577*	0.430
	1 and 3	0.315	0.509*
	1 and 4	0.669**	0.390
	2 and 3	0.569*	0.549*
	2 and 4	0.734**	0.467
	3 and 4	0.681**	0.522*
	1 + 2	0.411	0.419
	1 + 3	0.312	0.367
	1 + 4	0.412	0.390
	2 + 3	0.565*	0.274
	2 + 4	0.729**	0.463
	3 + 4	0.653*	0.005
	1 + 2 + 3	0.411	0.399
	1 + 2 + 4	0.486	0.420
	1 + 3 + 4	0.413	0.372
	2 + 3 + 4	0.734**	0.375

* Significant at 95% level
** Significant at 99% level
*** Significant at 99.9% level

TABLE 4. MULTIPLE LINEAR REGRESSION OF PERCENTAGE LAND-USE AREA AND POPULATION DENSITY FOR ILORIN WARDS (10 PERCENT SAMPLE)

Correlation Matrix 1950

Variable		1	2	3	4	5	6	7
Indigenous housing	(1)	—	0.382	−0.503*	0.613*	−0.796***	0.505*	0.496
Barrack/flat housing	(2)		—	−0.268	0.416	−0.578*	0.231	0.598*
Flat housing	(3)			—	−0.507*	0.582*	−0.379	−0.479
Uncompleted housing	(4)				—	−0.736**	0.612*	0.560*
Bare/grass/ agricultural land	(5)					—	−0.715**	−0.765***
Trees	(6)						—	0.297
Population	(7)							—
Co-efficient of determination (r^2)				0.779***				

Correlation Matrix 1963

Variable		1	2	3	4	5	6	7
Indigenous housing	(1)	—	0.625*	−0.688**	0.573*	−0.654**	0.040	0.784***
Barrack/flat housing	(2)		—	−0.381	0.013	−0.508*	0.006	0.717*
Flat housing	(3)			—	−0.279	0.397	0.027	−0.568*
Uncompleted housing	(4)				—	−0.367	0.047	0.319
Bare/grass/ agricultural land	(5)					—	−0.753***	−0.466
Trees	(6)						—	−0.131
Population density	(7)							—
Co-efficient of determination (r^2)			0.745**					

* Significant at 95% level
** Significant at 99% level
*** Significant at 99.9% level

TABLE 5. LINEAR REGRESSION OF PERCENTAGE LAND-USE AREA AND POPULATION DENSITY FOR ILORIN WARDS (10 PERCENT SAMPLE)

Correlation Matrix

Variable		1950 (r)	1963 (r)
Indigenous housing	(1)	0.496	0.784***
Barrack/flat housing	(2)	0.593*	0.717**
Flat housing	(3)	−0.479	−0.685*
Uncompleted housing	(4)	0.560*	0.319
	1 and 2	0.660**	0.836***
	1 and 3	0.563*	0.745**
	1 and 4	0.593*	0.799**
	2 and 3	0.680**	0.745**
	2 and 4	0.686**	0.781***
	3 and 4	0.604*	0.592*
	1 + 2	0.580*	0.824***
	1 + 3	0.492	0.780***
	1 + 4	0.546*	0.762***
	2 + 3	0.572*	0.607*
	2 + 4	0.685**	0.700***
	3 + 4	0.547*	0.016
	1 + 2 + 3	0.577*	0.822***
	1 + 2 + 4	0.611*	0.812***
	1 + 3 + 4	0.543*	0.757***
	2 + 3 + 4	0.679*	0.706**

* Significant at 95% level
** Significant at 99% level
*** Significant at 99.9% level

purposes of identification and classification from aerial photographs, it was difficult to differentiate between barrack/flat and flat types of housing in Ilorin. This was due in the main to the fact that flat (single story, self-contained) houses which were originally limited to the European quarters have diffused to virtually all other parts of the city in recent years.

Moreover, housing structures could easily be recognized from aerial photographs, hence minimizing the difficulty of photointerpretation. This is essential to enable one to make rapid estimates of housing land area that could be used for intercensal population estimation.

In a larger study of land use and population, Olorunfemi[9] observed a relatively higher degree of relationship between population and housing land-use types at the 10 percent level than at the five percent, which suggests an improved correlation between the dependent variables and the independent variables as the sampling fraction increases. Consequently, we decided to take a 100 percent sample of housing from aerial photographs. Table 6 shows the results of this exercise. Basically, the same process adopted in the earlier samples was employed, which involved the use of the dot grid sampling device.

The estimated proportion of land area devoted to housing was then used in a regression analysis with population and population density. Table 7 indicates the results. It shows the highly significant correlation of housing and population in 1950, with about 68 percent of the variation being accounted for. There is a low correlation between population and housing land area in 1963. This is perhaps strange. However, population density, rather than population *per se*, which is a measure of concentration of people in a unit area of land, would be better predicted by housing land area in Ilorin during this period. This is because Ilorin consisted mainly of the indigenes who live in the crowded indigenous residential land-use type.[10] Indeed, when population density was the dependent variable, a strong correlation existed between population density and housing in both 1950 and 1963. Table 7 indicates that about 93 and 92 percent of the variation in population density was explained by housing in 1950 and 1963, respectively, with a probability of being a wrong relationship in once out of 100 times.

Table 6. Percentage Housing Land Area Distribution in Ilorin 1950 and 1963 (100% Sample)

Ward	1950	1963
Ajikobi	23.22	30.97
Ogidi	11.01	18.46
Ojuekun	22.04	26.30
Ojoje	8.09	9.50
Zarumi	11.61	13.09
Alanamu	17.81	33.49
Adewole	9.03	10.43
Ubandawaki	8.70	14.50
Fulani	23.08	33.74
Okaka	10.91	18.12
Okeogun	17.97	37.88
Gambari	21.89	28.57
Ibagun	7.37	12.00
Zango	13.39	24.00
Are	28.00	41.39
Sabon Gari	3.76	3.16
Badari	3.67	5.22
Emirs'	22.26	33.61

Source: Aerial photo analysis.

Table 7. Linear Regression of Percentage Housing Area and Population/Population Density for Ilorin Wards (100 Samples)

	Coefficient of Determination			
	Population		Population Density	
	1950	1963	1950	1963
Housing	0.679**	0.278	0.934***	0.918***

** Significant at 99% level
*** Significant at 99.9% level

Conclusion

This paper has established a fundamental relationship between population and land use types. It started by enumerating the different ways by which the population of a city could be estimated. The correlation and regression model, the main analytical technique employed in this paper, was used to exploit the potential connections that exist between population density, and the different land-use types (Table 1).

The bare-grass-agricultural and tree land-use types did not show consistent association with population, even though they tend to decrease as population increases. An increase in bare-grass-agricultural land was indeed associated with an increase in flat type of housing. This can be associated with the fact that flat type of housing was originally constructed for the Europeans in the new town of the city. They are characterized usually with large open fields and gardens, hence the increase in grass land area with an increase in flat housing in Ilorin. The importance of the creation of parks as recreational and relaxation centers is only a recent development in Ilorin. Besides, grass land and tree land areas may not be good surrogates of population, especially in a city where the land consumption rate of open undeveloped land is hardly known. Furthermore, there is the fact that no particular and constant relationship exists between open space and population. As a result of the unconfirmed direction of relationship, both the bare-grass-agricultural and tree land-use types were dropped from further consideration.

After a series of regression analyses, it was found that population density was better related to all the housing land use types when jointly regressed than when singly regressed. A 100 percent sampling process was therefore undertaken for housing land-use alone, and this showed a remarkable improvement on the previous results.

Table 7 indicates that about 92 percent of the variation in population density could be explained by housing as a category of land use in Ilorin in 1950 and 1963 (with a probability of being wrong once in 100 times). This in essence means that housing land area could be used as a surrogate for estimating population density in Ilorin. This method has the advantage of being low cost and non-time consuming in making population estimates. It should be stressed, however, that, for this method to be useful in generating nationwide data, there is the need for further research aimed at testing the applicability of this model in cities with similar and/or different characteristics. If this were so, intercensal population estimates could be quickly generated for places where the housing land area are known. Finally, this approach lends itself to use in communities located in areas for which data on population are very scanty because of remoteness, political obfuscation, or insufficient resources to conduct frequent census enumeration.

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(Received 11 July 1981; revised and accepted 12 October 1983)

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