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ANALYSIS OF SPATIAL PATTERN OF SETTLEMENTS IN THE FEDERAL CAPITAL TERRITORY OF NIGERIA USING VECTOR-BASED GIS DATA

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Abstracts

Human settlements are important, seemingly static but dynamic, features of the cultural landscape that have attracted several studies due to the important role they play in human life. This paper examined the spatial distribution of settlements in the Federal Capital Territory (FCT) of Nigeria. The analysis uses vector based GIS data derived from the 1989 political map of the FCT. Map composition was done with ArcView 3.2a software and the nearest neighbour statistics was computed using the pattern analysis function of Ilwis 3.0 software. The result of the quadrat count analysis yielded a variance mean ratio of 1.34 to show that the settlements of the FCT were clustered in space as opposed to the subjective findings of some authors, which suggested that the settlements were evenly spread. Analysis of the degree of clustering reveals that 51 per cent of all settlement pair has a separation of less than four kilometres, 63 per cent has a separation of less than five kilometres, 79 per cent has less than six kilometres while 97 per cent has a separation of less then nine kilometres. It was thus found out that, for 80 per cent of all settlements in the point map, one nearest neighbour can be found within a radius of 2 kilometres. Also, for 68 per cent of the settlements, three nearest neighbours can be found while for 60 per cent of the settlements, six nearest neighbours can be found within a radius of 2 kilometres. Analysis of the distance at which neighbours could be found revealed that the probability of finding six neighbours becomes 1 at a distance of one kilometre. This indicates that, we are 100 per cent sure of finding 6 nearest neighbours within a distance of one kilometre radius on the map.

Introduction

Settlements are a concrete expression of human occupation of the earth's surface and they form an essential element of the landscape (Hagerstrand, 1957). These settlements are noted to exhibit certain distribution pattern over space. Several evolution and distribution models advanced by Bylund (1960), Morrill (1962), Chisholm (1962), Hudson (1969) and Christaller (1933) have explained how settlements evolved over time and space as well as the principles behind their distribution pattern. The theoretical advancement of these models, coupled with the empirical findings of authors like Dacey (1962) and Rayner and Golledge (1972), help establish three major settlement distribution patterns in the literature - regular, random and clustered.

The emergence of a given spatial pattern of settlements is ascribed to both physical and human factors. The physical factors have to do with the terrain and the distribution of natural resources – soil, water and mineral wealth that attract and influence settlement location. On the other hand, the human factors include cultural dictates and warfare, which influence cluster or disperse living as well as the rise, fall and migration of settlements respectively.

Whatever the factors of location and pattern, analysis of spatial distribution of settlements is of great importance to both the geographers and planners. This is because the exercise gives an insight into the spatial character of settlements as important landscape elements and provides ample data for their planning and management. This

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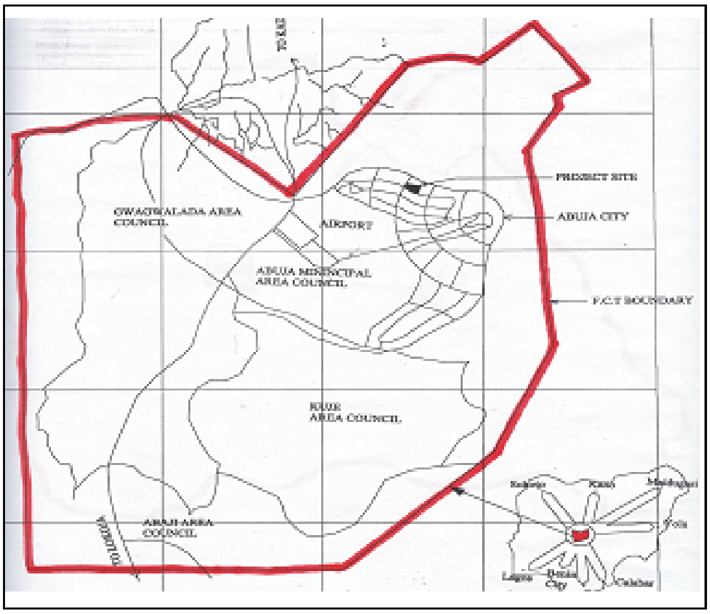
paper examines the spatial distribution of settlements at the Federal Capital Territory (FCT) of Nigeria with a view to understanding the pattern they exhibit and degree of clustering or dispersion. It considers the processes of settlement development and dynamics as a background to the understanding of the existing pattern and concludes with the discussion of research findings.

Research Setting and Scope

The research is focused on the Federal Capital Territory (FCT), which covers an area of 800km^2 (Abuja Master Plan, 1979). The FCT is located at the heart of Nigeria, approximately between latitudes 7^0 25" - 9^0 20" north of the Equator and longitudes 6^0 45" - 7^0 39" east of the Greenwich meridian. It lies just above the hot humid lowlands of the Niger - Benue trough and it is bounded on the north by Kaduna State, on the west by Niger State, on the east and southeast by Plateau State and on the southwest by Kogi state (Figure 1).

Figure 1: The Federal Capital Territory, Nigeria



Source: Excelarc Partners, 2006

The study covers all settlements within the boundaries of the FCT's six Area Councils, including Abuja Municipal, Bwari, Abaji, Kuje, Gwagwalada and Kwali Area Councils. The entire FCT is taken into consideration in the analysis of the spatial distribution of settlements

Settlement Development Process and Dynamics in the FCT

The settlements of the FCT have undergone several development processes in form of disintegration, migration, amalgamation, displacement and relocation. At one time or the other, each of these development processes brought about settlement dynamism in form of birth, death, locational change as well as the reorganization of the entire space economy. Historical facts on settlement development processes in the FCT presented by Balogun (2001) revealed that the process of settlement disintegration started in the pre-colonial period, which witnessed rampant inter-tribal wars and the Fulani Jihad operations. As a result, some of the war-affected settlements were ruined and deserted while others

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relocated to defensible areas. The subsequent relative peace brought about by colonial administration and missionary activities resulted in down hill migration of settlements. Generally, development at this period witnessed the movement of settlements away from barriers, hilly and inaccessible locations to areas of favorable economic conditions.

Settlement disintegration and migration also occur in form of the breaking and moving away of 'daughter' settlements from their 'mothers'. Nadel (1951) has empirically established the mother-daughter development process in the middle belt of Nigeria when he observed that, as in the Yoruba land, large settlements in the Nupeland had a number of daughter-settlements called tunga. In the FCT, the migration processes which give rise to daughter settlements were confirmed by Doxiadis and Associates (1983) who observed that settlement migration occurred both on plains with abundant farmlands and in hilly areas with limited farmlands. As it were, daughter settlement development process in the FCT began when few populations migrated afield for the purpose of farming. In the process, farm centres were created to reduce daily commuting to settlement of origin.

Such farmsteads were later transformed into hamlets and small permanent villages, which normally bear the name of the mother settlement or with the addition of the prefix *sabo* (new) or *Tunga* (area). Examples of such daughter settlements that have migrated from their mothers in the FCT include Kabusa, Durumi Jetere, Mailauni, Gaba, Pyakasa, Sabon Karmo, Sabon Lugbe, Tungan Ladan, Tungan Samu amongst others. Figures 2.1 and 2.2 illustrate examples of daughter settlements migration in the FCT. Figure 2.1 shows the case of Durumi where three daughter settlements migrated to the northwest and southwest with restrictions to the east due to hilly barriers while figure 2.2 shows the migration of five daughter settlements from mother Kabusa to the northwest, north and southeast directions without any barrier. The two examples show the nature of space colonization process in the FCT and they approximate the four models of Bylund's colonization theory.

The process of population displacement and relocation within the FCT has also brought about the death of some settlements and the creation of new ones. In line with the recommendations of the Abuja Master Plan, statistics given by the MFCT (1992) shows that the Federal Capital Development Authority (FCDA) has displaced and relocated over 10, 000 people both within and outside the FCT. For instance, the construction of Abuja city has led to the demise of settlements like Garki, Maitama Tsoho, Maitama sabo, Durumi, Wuse, Asokoro, Kukuwaba and Jabi in which about 2,442 persons were displaced (FCDA, 1989). Likewise, the construction of the Lower Usman Dam led to the displacement of 1,200 persons from old Ushafa, Payi Jigo and Kwabara. The early population displacement and relocation exercises in the FCT culminated into massive evacuation of squatter settlements by the development control department of the Abuja Metropolitan Management Agency (AMMA) between July 2003 and 2006. Within this period, over 16 squatter settlements including Idu – Karmo, Jabi, Mabushi, Durumi, Wuye, Kado, Kuchingoro, Aleyita, Piwoyi, Karomajiji and Lugbe were demolished and their population relocated under the Abuja Master Plan Restoration Programme (see the Department of Development Control's Progress Report, AMMA, 2006).

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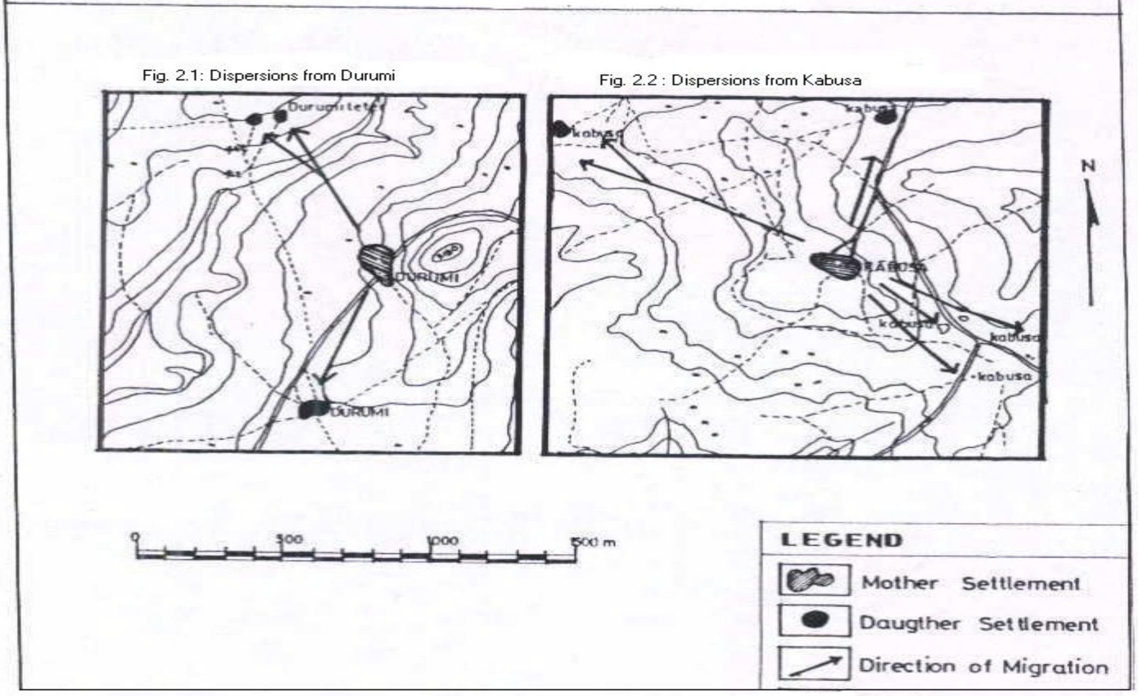
FIGURE 2 : SETTLEMENT MIGRATION IN THE FEDERAL CAPITAL TERRITORY



Source: FCT Regional Development Plan, 2000 and Federal Department of Survey, Abuja

The resettlement exercises, which followed series of displacements during the construction of Abuja city, saw to the birth of settlements like Kubwa, Ushafa, Dutse, Usuma town, Gosa and Giri within the FCT. New resettlement sites such as Pegi, Yangoji, Kuchiko and Gidan Mangoro were also established to accommodate the populations of the squatter settlements displaced between 2003 and 2006.

Generally, displacement and resettlement exercise in the territory brought about migration and amalgamation of settlements. With respect to migration, the report of the Ministerial Committee on Physical Planning and Development Issues in the FCT noted, in 1999, that a total of 6,958 households were evacuated from the FCT and resettled at New Bwari, New Wuse and Gawun Babangida in Niger State as well as in New Karu, New Karshi, New Ukya, New Gwargwada and New Gudun Karya in Nasarawa State. Also, several other small, isolated settlements have amalgamated and transformed into larger ones. For instance, Payi, Jigo and Kwabara villages were brought together to form the Usuman resettlement town while Garki, Durumi, Maitama Tsoho, Maitama Sabo, Kukuwaba, Jabi I and Jabi II villages were brought under the Kubwa resettlement scheme (FCDA, 1989 and MFCT, 1999).

Analysis of Spatial Distribution of Settlement

The spatial pattern exhibited by the entire settlements was examined using the GIS data derived from the 1989 settlement and infrastructure map of the FCT produced by Omonogun Cartographic Services. In order to appreciate the spatial distribution of the settlements at a glance, the map was registered into the decimal degrees coordinate system and digitized with 0.049 error limit. The settlements were digitized as point features and saved in Arc\View with their corresponding attributes (names) entered into the theme table. A map (figure 3) showing the spatial distribution of settlements in the FCT was

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composed in Arc\View. The figure reveals that the FCT has a dense population of settlements, which are spread all over the six Area Councils. The greatest number of settlements is found in the northeast, around the Federal Capital City (FCC) and in the southwest corner of the territory, with heavy concentrations in the Municipal and Abaji Area Councils.

A casual inspection of the spatial distribution of settlements in the FCT suggests a fairly even spread. The quadrat count statistical analysis was computed to determine the pattern of settlement distribution in the area. The number of settlements per unit area was determined by imposing $16km^2$ size quadrats on the settlement map of FCT (figure 3). The variance (σ) and the variance mean ratio (VMR) were calculated for the data (see table 1). The result yields a VMR value of 1.34. Since the calculated value is greater than 1.0, this shows that the distribution pattern is clustered in space.

Table 1: Calculation of Variance and Variance Mean Ratio

Settlement Per Quadrat (χ)	No. of Quadrat(f)	χf	Variance (σ) for No. of Settlement per Quadrat
0	214	0	$(0 - 0.9)^2 \times 214 = 173.3$
1	159	159	$(1 - 0.9)^2 \times 159 = 1.6$
2	75	150	$(2 - 0.9)^2 \times 75 = 90.8$
3	21	63	$(3 - 0.9)^2 \times 21 = 92.6$
4	15	60	$(4 - 0.9)^2 \times 15 = 144.2$
5	3	15	$(5 - 0.9)^2 \times 3 = 50.4$
6	0	0	$(6 - 0.9)^2 \times 0 = 0$
7	1	7	$(7 - 0.9)^2 \times 1 = 37.2$
Total	488	454	$\Sigma(\chi - 0)^2 \times n = 590.1$

Source: Author's Analysis, 2005

Mean density (0) $= \Sigma\chi f / \Sigma f = 454 \div 488 = 0.9$

Variance (σ) $= \Sigma(\chi - 0)^2 \times f / n - 1 = 590.1 \div 488 - 1 = 1.21$

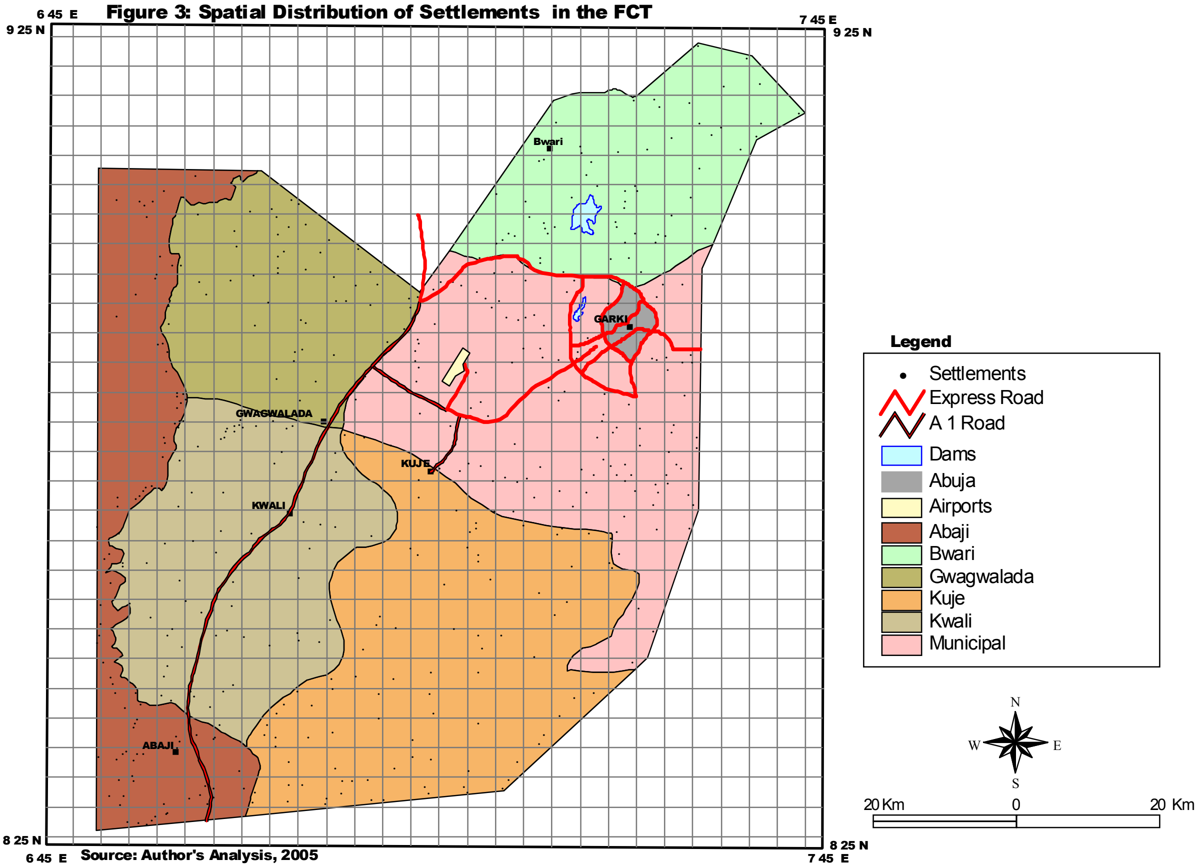
Variance Mean Ratio (VMR) $= \sigma/0 = 1.21 \div 0.9 = 1.34$ Approximately

Quadrat Count Analysis Decision Rule

(i) If VMR is < 1.0, the distribution pattern is regular

(ii) If VMR is = 1.0, the distribution pattern is random

(iii) If VMR is > 1.0, the distribution pattern is clustered



Although the spatial pattern of settlements in the FCT is generally clustered, settlement densities per square kilometer vary slightly over space with Kuje Area Council having the least settlement density (table 2). However, the goodness-of-fit test (Chi-Square analysis) performed for the observed and expected settlement point distribution in the Area Councils yielded a calculated X^2 value of 20.5 which is lower than the table value of 37.70 under 15 degree of freedom and 0.1 alpha level. This shows that the difference in the level of clustering across the Area Councils is not significant.

Table 2: Settlement Densities by Area Councils

S\No.	Area Council	Area in Km^2	No. of Settlements	Density\Km^2
1	Municipal	1,600.33	108	0.07
2	Bwari	913.91	60	0.07
3	Abaji	935.01	85	0.09
4	Gwagwalada	835.16	54	0.07
5	Kuje	1,625.07	88	0.05
6	Kwali	1, 271.89	93	0.08
	Total	7, 181.37	488	0.43

Source: Author's Analysis, 2005

The quadrat count analysis performed enables us to statistically establish that the settlements in the FCT are clustered in space. However, the analysis did not provide information on the degree of closeness or dispersion amongst the settlements. This shows

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the limitation of the quadrat count method in pattern analysis. The Nearest Neighbour Analysis is a powerful measure of dispersion. In order to ascertain the degree of closeness and\or dispersion, the Nearest Neighbour Analysis (Rn statistics) was performed using figure 3 as the input point map. The point map data were imported from Arc\View to Ilwis 3.0 Academic software. Using the pattern analysis function of Ilwis, the Rn statistics was run to determine the probability of finding a given number of settlements within a given distance radius.

The result of the analysis is contained in the eight-column output table (see appendix 1) in which the mean distances between reflexive nearest neighbours (RNN) were tested against the expected distances in a simulated complete spatial randomness (CSR). The first column of the table contains distance values from any point in the input point map. The Prob1pnt – Prob6pnt columns list the probabilities that, within certain distance of any settlement, at last one – six other settlements will be found. The probAllpnt values are the probabilities that, a randomly selected settlement pair from the point map has a separation of less than the corresponding distance in the distance column and it is determined by the addition of all probabilities (Prob1pnt + Prob2pnt +...+ Probn –1pnt) divided by (n – 1).

The distances in the output table are measured in meters and the values are multiplied by the map scale of 1:10,000 to get the ground distance. As shown in the output table, 51 per cent of all settlement pair has a separation of less than four kilometres, 63 per cent has a separation of less than five kilometres, 79 per cent has less than six kilometres while 97 per cent has a separation of less then nine kilometres. Also, for 100 per cent of the settlements in the point map, one to six nearest neighbours can be found within a radius of one kilometre. Considering the mean values calculated for the eight columns (table 3) it is found that, for 80 per cent of all settlements in the point map, one nearest neighbour can be found within a radius of 2 kilometres. Also, for 68 per cent of the settlements, three nearest neighbours can be found while for 60 per cent of the settlements, six nearest neighbours can be found within a radius of 2 kilometres. The value in the probability of all points (ProbAllpnt) column (0.2390) indicates that, 23 per cent of all settlement pair has a separation of less than 2 kilometres. The calculated standard deviation values of between 0.3473 (1σ) – 0.4598 (2σ) establish 68 – 95 % confidence limit for the Nearest Neighbour statistics performed.

Table 3: Summary Statistics Calculated for the Nearest Neighbour Analysis

	Distance	ProbAllpnt	Prob1pnt	Prob2pnt	Prob3pnt	Prob4pnt	Prob5pnt	Prob6pnt
Min	0.0	0.0000	0.0211	0.0000	0.0000	0.0000	0.0000	0.0000
Max	1.3	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Avg	0.2	0.2390	0.8041	0.7269	0.6831	0.6501	0.6240	0.6044
StD	0.3	0.3473	0.3183	0.3932	0.4219	0.4391	0.4513	0.4598
Sum	14.6	14.0996	47.4444	42.8844	40.3011	38.3538	36.8146	35.6569

Source: Author's Analysis, 2005.

The distance at which the probability of finding neighbours becomes 1 (i.e. 100% probability) is determined by preparing a graph of the distance against the probability columns. As shown in figure 4 the probability of finding six neighbours becomes 1 at a distance of one kilometre. This indicates that, we are 100 per cent sure of finding 6 nearest neighbours within a distance of one kilometre radius on the map. For the ProbAllpnt, the probability becomes 1 at 11 kilometres (figure 5). This means, we are 100 per cent sure that a randomly selected settlement pair in the area will have a separation of less than 11 kilometres.

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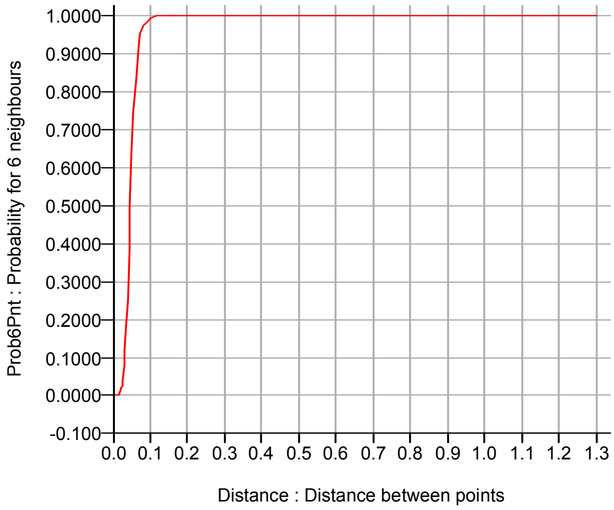

Figure 4: Probability and Distance of Finding Six Neighbours

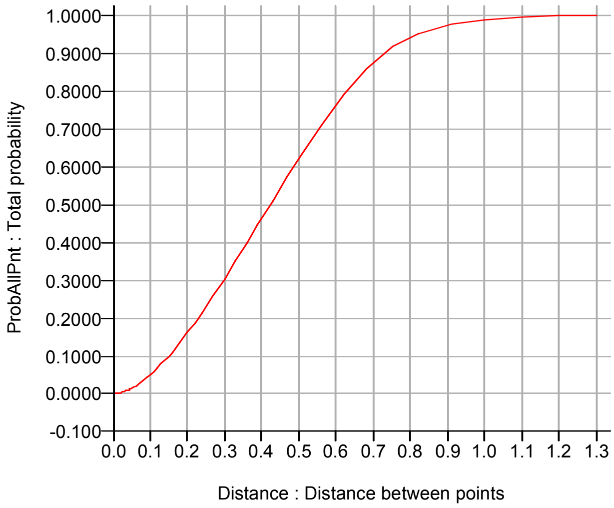

Figure 5: Probability and Distance of Finding Neighbours.

Discussion of Findings

The elements of human landscape are affirmed to be in a constant flux of continuous change due to natural processes and human activities. Some of the findings of this research confirm this global assertion. At the onset, the study presents the accounts of various authors, which help establish that the settlements in the FCT had undergone dynamic development processes of disintegration, migration, amalgamation, displacement and relocation. These historic processes are observed to give context to the spatial distribution of settlements that we see today.

The study established that the distribution pattern of settlements in the FCT is clustered. The results of the quadrat count and nearest neighbour analyses carried out thus give empirical statistical validity to the subjective assertions of some authors like Doxiadis and Associates (1983) and disprove others like Gaza (1990) and MFCT (1999) who opined that the settlements are evenly spread, suggesting a regular pattern. Generally, the study demonstrated the usefulness of the GIS method in spatial analysis and the findings are important contributions to knowledge that could guide settlement development policy in the FCT.

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The observed spatial pattern of settlements in the FCT has implications for facility planning and distribution in the area. For instance, the nearest neighbour analysis reveals that for 100% of the settlements, one to six nearest neighbours can be found within a radius of one kilometre. This is an indication that facilities such as schools, hospitals, post offices and recreation parks could be planned and provided on a shared basis for groups of villages with close proximity. A settlement planning and development policy, which will focus on village grouping or the model village approach, is therefore recommended for the FCT.

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Appendix 1: Nearest Neighbour Statistics Output Table

Distance	ProbAllPnt	Prob1Pnt	Prob2Pnt	Prob3Pnt	Prob4Pnt	Prob5Pnt	Prob6Pnt
0.0	0.0000	0.0211	0.0000	0.0000	0.0000	0.0000	0.0000
0.0	0.0001	0.0379	0.0000	0.0000	0.0000	0.0000	0.0000
0.0	0.0002	0.0779	0.0021	0.0000	0.0000	0.0000	0.0000
0.0	0.0003	0.1158	0.0147	0.0000	0.0000	0.0000	0.0000
0.0	0.0004	0.1495	0.0253	0.0021	0.0000	0.0000	0.0000
0.0	0.0005	0.1811	0.0379	0.0042	0.0000	0.0000	0.0000
0.0	0.0006	0.2337	0.0442	0.0126	0.0000	0.0000	0.0000
0.0	0.0007	0.2737	0.0568	0.0168	0.0021	0.0000	0.0000
0.0	0.0009	0.3305	0.0716	0.0274	0.0084	0.0000	0.0000
0.0	0.0011	0.3747	0.0947	0.0274	0.0168	0.0000	0.0000
0.0	0.0013	0.4379	0.1158	0.0421	0.0232	0.0063	0.0021
0.0	0.0017	0.5011	0.1874	0.0653	0.0274	0.0126	0.0021
0.0	0.0018	0.5263	0.2084	0.0821	0.0316	0.0147	0.0042
0.0	0.0022	0.6084	0.2632	0.1074	0.0463	0.0211	0.0063
0.0	0.0027	0.6589	0.3453	0.1537	0.0674	0.0358	0.0147
0.0	0.0032	0.7032	0.4063	0.2189	0.1032	0.0400	0.0189
0.0	0.0037	0.7411	0.4926	0.2779	0.1242	0.0568	0.0232
0.0	0.0045	0.8189	0.5874	0.3621	0.2042	0.0884	0.0400
0.0	0.0055	0.8716	0.6842	0.4632	0.2779	0.1537	0.0800
0.0	0.0065	0.9179	0.7537	0.5663	0.3537	0.2295	0.1200
0.0	0.0075	0.9495	0.8232	0.6463	0.4505	0.2905	0.1853
0.0	0.0086	0.9621	0.8716	0.7284	0.5537	0.3895	0.2505
0.0	0.0103	0.9768	0.9116	0.8063	0.6758	0.4989	0.3853
0.0	0.0121	0.9832	0.9432	0.8611	0.7642	0.6295	0.4947
0.1	0.0141	0.9958	0.9684	0.9179	0.8379	0.7389	0.6274
0.1	0.0166	0.9958	0.9811	0.9516	0.8968	0.8211	0.7453
0.1	0.0202	1.0000	0.9937	0.9726	0.9453	0.8968	0.8463
0.1	0.0243	1.0000	1.0000	0.9937	0.9726	0.9389	0.9053
0.1	0.0291	1.0000	1.0000	0.9979	0.9853	0.9768	0.9537
0.1	0.0344	1.0000	1.0000	0.9979	0.9895	0.9874	0.9768
0.1	0.0416	1.0000	1.0000	0.9979	0.9979	0.9937	0.9832
0.1	0.0488	1.0000	1.0000	1.0000	0.9979	0.9958	0.9937
0.1	0.0580	1.0000	1.0000	1.0000	1.0000	0.9979	0.9979
0.1	0.0674	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.1	0.0779	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.1	0.0990	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.2	0.1109	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.2	0.1349	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.2	0.1601	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.2	0.1875	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.2	0.2149	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.3	0.2597	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.3	0.3035	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.3	0.3512	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.4	0.3991	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.4	0.4467	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.4	0.5101	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.5	0.5749	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.5	0.6376	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

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0.6	0.7103	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.6	0.7917	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.7	0.8601	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.8	0.9183	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.8	0.9536	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.9	0.9781	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1.0	0.9912	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1.1	0.9976	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1.2	0.9998	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1.3	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000