Geostatistical Techniques for Settlement Pattern Analysis of Adamawa and Taraba States, North East Nigeria.

[1]Ikusemoran Mayomi, [2]Luka Yohanna and [3]Eseyin E.B,

[1]Remote Sensing and GIS, Department of Geography, University of Maiduguri
[2]Department of Geography, Modibbo Adama University of Technology, Yola
[3]Mathematics Unit, Basic Science Department, Taraba State College of Agriculture, Jalingo.

Abstract

In this paper, the use of geospatial and geostatistical techniques for determination of settlement patterns in Adamawa and Taraba states were demonstrated. The actual locations of the settlements and thier attributes in both states were generated on digital maps to derive the settlement distribution pattern in the states. The analyzing pattern of the spatial statistical tool of ArcGIS 10.5 was used to calculate the average nearest neighbour of the settlements in the two States, the Getis-Ord Gi* method of hot spots was adopted to assess the clustering of settlement based on relief. The results revealed that though Taraba State is far larger in land area than Adamawa State, but Adamawa State has a total settlement of 586, with a land area of 38006.41, with 64.86 settlement density, while Taraba State with 579 settlements and 58378.51 land area has settlement density of 100.83. The nearest neighbour index which suggests the average distance among the settlements in Adamawa State is approximately 0.92 meters, while Taraba State has average of 0.88 meters. Since the index of the two states are less than one (1), the pattern exhibits clustering. The generated z-scores and the p-values in the two States are both negative and small respectively which further confirms the tendency towards clustering of the settlement pattern. About 6% of the land area in each of the two States are protected areas, that is, Gashaka-Gumti National Park. The study also revealed that the settlements in the entire Benue valley in Adamawa State are clustered, while only some areas within the Benue valley in Taraba State are clustered. In Adamawa State, an average of every 143.72 kilometers of protected land area has one settlement, while Taraba State has one settlement at every 160.27 kilometers. It was recommended that settlement pattern analysis should be seen as an important aspect of even developmental planning and hence, be integrated in regional planning processes while geospatial and geostatistical techniques which is easier to process with reliable results should be encouraged.

Keywords: Geostatistical Analysis, Hot Spot Analysis, Nearest Neighbour Index, Settlement Density, Settlement Pattern.

Introduction

Adamawa and Taraba States of today were formerly a single State called Gongola State. In 1991, Taraba State was carved out from Gongola State, leaving the remaining area as Adamawa State. Other than the location of the two States in similar climatic and vegetation zones, both States have similar terrain (high mountain ranges, floodplains and lowlands) as well as having some parts of their lands as protected areas, that is, Gumti and Gashaka sectors of the Gashaka-Gumti National Park in Adamawa and Taraba States respectively. Moreover, major parts of the two States are occupied by the floodplains of River Benue. Since Adamawa and Taraba States have similar terrain characteristics which are major determinants of location and distribution of settlement no doubt, these characteristics determine the settlement patterns in the two states.

Both Adamawa and Taraba States are located in the North Eastern geopolitical zone in Nigeria and been seriously affected by the ongoing insurgency and insecurity challenges in the country. The federal government has declared that the insurgents have been technically defeated and rehabitation and developmental programs have been put in place by the various levels of government. However, no genuine even development can be achieved if there is no proper spatial planning. Oladayo (2017) reported that, integration ofdifferentspatial actionsforstability andbalanceddevelopment inNigeria is necessary becausespatialsustainable development is the only key to even development in any country. Oladayo concluded that several yearsof developmentalplanningin isolation ofregional planning in Nigeria have its consequences, especially on rural–urban migration, poor settlement patterns and infrastructural deficit in urban and rural areas.

In Adamawa State for instance, Ilesanmi (2013) commented on the situation of regional development as follows;

> With the abundant human, natural and material resources within the large landmass of Adamawa State, it is nevertheless, one of the least developed areas in Nigeria. Using the yardsticks of the level of industrialization, urbanization, available infrastructural facilities, employment in government/industrial/non–basic establishments, productivity and the standard of living of the population, only a few settlements are developed while a substantial part of the region yet remains grossly under–developed. The country–side is highly backward, yet, natural resources like clay minerals, uranium, limestone, marble, graphite; plant and animal resources lie within the bounds of the State which, if well developed and properly harnessed, can greatly help in achieving a State–wide and high level of development.

Ilesanmi concluded that based on the (then) regional development trend in Adamawa State, regional imbalance, dualism in terms of core-periphery relationship, regional inequalities will continue to deepen.

In Geographic studies, settlements are represented on maps with dots, the point patterns of these dots are in turn used to determine the causal factors of the patterns for planning and decision making purposes. According to McGrew and Monroe (2000), the nature of the point pattern can reveal information about the process that produces the geographic results. In addition, a series of point pattern of the same variable recorded at different periods can help to determine temporal changes in the location process.

Ikusemoran (2016) discussed the characteristics of the three main point patterns as:

(i) Clustered Point Pattern: In clustered point pattern, all the settlements are very close to each other in one or more parts or region in the area, that is, the density of the points vary significantly from one part of an area to another (Fig. 1). This type of points may be sites of tertiary economic activities (retail and service functions), mining area, administrative headquaters, nodal points, among others. The Rn value of clustered pattern is 0.

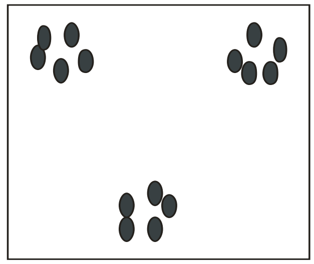


Fig. 1. Clustered Points

(ii) Random Point Pattern: The pattern suggests that there is no pattern of distribution because the settlements are randomly distributed resulting into a scattered form of settlement pattern (Fig. 2). Random pattern has an Rn value of 1.0

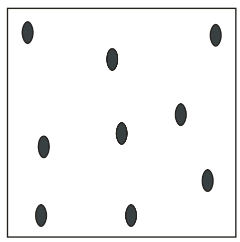


Fig. 2. Random Points

(iii) Regular Point Pattern: The pattern is perfectly uniform with equal distances between the settlements (Fig. 3). If the settlement pattern appears uniformly distributed across an area, it suggests that a systematic spatial process produced the locational pattern. Such settlement pattern can only be found in a perfectly government planned areas. The Rn value is 2.15

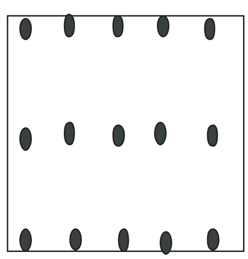


Fig. 3. Regular Points

Interpretations of point pattern are based on the Rn values:

- Clustering occur (complete clustering) when all the data are very close to themselves. In an extreme clustering case, Rn is equal to zero (Rn=0)
- Random distribution (extreme or complete random) occurs where there is no pattern at all. In this case, Rn is equal to one (Rn = 1).

♦ Regular patterns are perfectly uniform. They are rarely found in reality. Its Rn value is 2.15 or more which means that each dot is equidistant from its entire neighbors.

In most Geographic problems, a point pattern will not provide a totally clear indication that the pattern is clustered, dispersed or random, but rather shows a combination of these arrangements with tendencies from random towards either clustered or regularity as shown in Fig. 4.

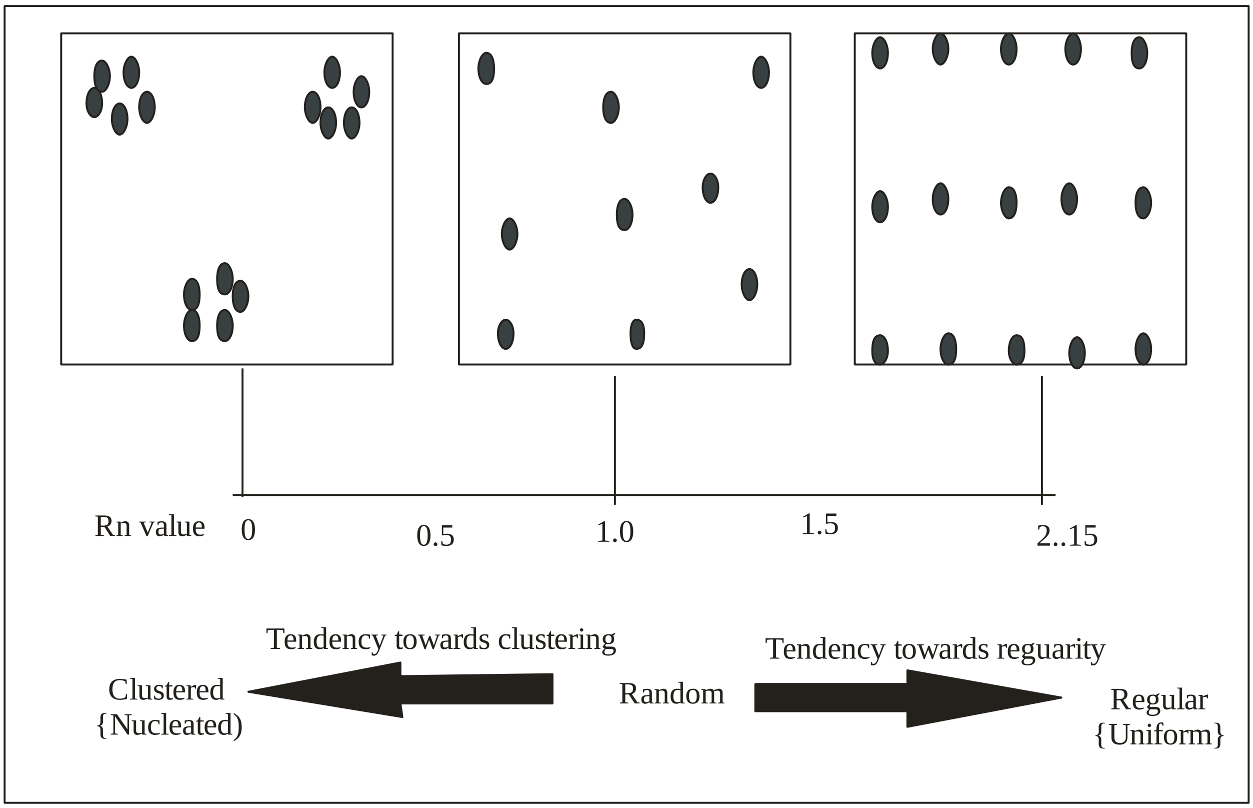


Fig. 4. Point Pattern Analysis

Many studies have been carried out to investigate point pattern analysis especially settlement patterns based on the traditional technique commonly referred to as Nearest Neighbour Analysis which is a common procedure for analyzing the spatial arrangements or the determination of settlement patterns. This method entails complex manual procedures such as the determination of settlement locations, nearest neighbour of each of the settlements, calculation of the distances between the nearest neighbours, calculations and computations of Rn values. Moreover, Waugh (1995) also noted that the reliability of the result of Nearest Neighbour depends on several factors such as the size of the area, the numbers of the settlenments, the terrain factor, determination of the center of each settlements and finally the expertise and experience of the analyst. All these challenges make the results of the technique to be inaccurate in some cases. Recently, the use of geostatistical technique has been appreciated in Nigeria, while Isah and Abdullahi (2015) applied geostatistics to analyze water quality parameters in some rivers and streams in Niger State, Ikusemoran, Bayo and Elijah (2018) used the technique to analyze rainfall pattern and prediction in Taraba State. Therefore, in this study, geospatial and geostatistical techniques which have the capability of spatial and statistical analysis, and also automatic determinations of all the activities that are difficult to carry out in manual methods such as measurement of distances, determination of areas and center points among others, were used to analyze the settlement patterns of Adamawa and Taraba States which may be useful for regional developmental planning.

The main objectives of this study are:

(i) To map the locations of settlements in Adamawa and Taraba States using geospatial techniques.
(ii) To analyze the patterns of the Avearge Nearest Neighbour of the settlements in the two States with geospatial statistical tools.
(iii) To assess the effect of the topography on settlement patterns through Hot Spot Analysis of the relief and the settlement locations in the States.
(iv) To carry out comparative analysis of the settlement patterns between the two States

Description of Study Area

Adamawa and Taraba States which were formerly Gongola State comprise the study area. Adamawa State which occupies a land area of 38050.05km^2 is bounded in the East by Republic of Cameroon, North by Borno and Gombe States and to the South and West by Taraba State (Fig. 5). Taraba State occupies a land area of 57139.28km^2, which means that in terms of area landmass, Taraba State is larger than Adamawa State. Taraba State is bounded in the North by Bauchi and Plateau States, and in the West by Nassarawa and Benue States. It is bordered by Republic of Cameroon to the South and Eastern parts of the State (Fig. 5). Adamawa State has twenty-one (21) Local Government Areas, while Taraba State has sixteen (16) LGAs. The 2006 Population and Housing Census of Nigeria (NPC 2007) put the population of Adamawa State as 3,178,950 and that of Taraba State as 2,294,800. This means that the population of Adamawa State was almost a million more than that of Taraba State.

In terms of relief, the two States are endowed with numerous highlands and mountains. For instance, in Adamawa State, the Mandara Mountains in the Mubi region, Atlantika, Shebsi (with larger portion in Taraba State) and Vogel peaks are found, while Shebsi, Wonka, Fali, Chappal Hendu, Chappal Wade, Gotel and Wanga Mountains are located in Taraba State (Fig. 5). The highest peak in Adamawa State with an elevation of 1738m above sea level is at Vogel hills in Ganye LGA, while Chapal Wadi hill near Cameroon with elevation of 2398m (highest plateau in Nigeria and West Africa) is the highest peak in Taraba State. Both States are located within the floodplains of River Benue. While Rivers Gongola, Lokko/Kilange, Mayo Belwa and Mayo Inne are major tributaries to River Benue in Adamawa State, Rivers Shemanker, Wase, Donga and Taraba are main tributaries to the Benue in Taraba State (Fig. 5). The combinations of the Benue and the numerous tributaries created large floodplains within the two States.

Gashaka Gumti National Park is located in the two States. It is the largest park in Nigeria (GGNP 2011) with a land coverage of about 5784.09km^2. The land area of Adamawa State section is 2162.92km^2 which is about 5.69% of the entire State. The park in Taraba State covers about 3621.17km^2, that is, 6.20% of the State (Fig. 5). Gashaka park comprises two sectors, the first is the Southern Gashaka sector which is mainly mountainous. The second sector is the Northern

Gumti sector which comprises mainly of woodland and grasslands. The park derived its name from two of the most popular settlements within the park, that is, Gashaka in the South and Gumti in the North.

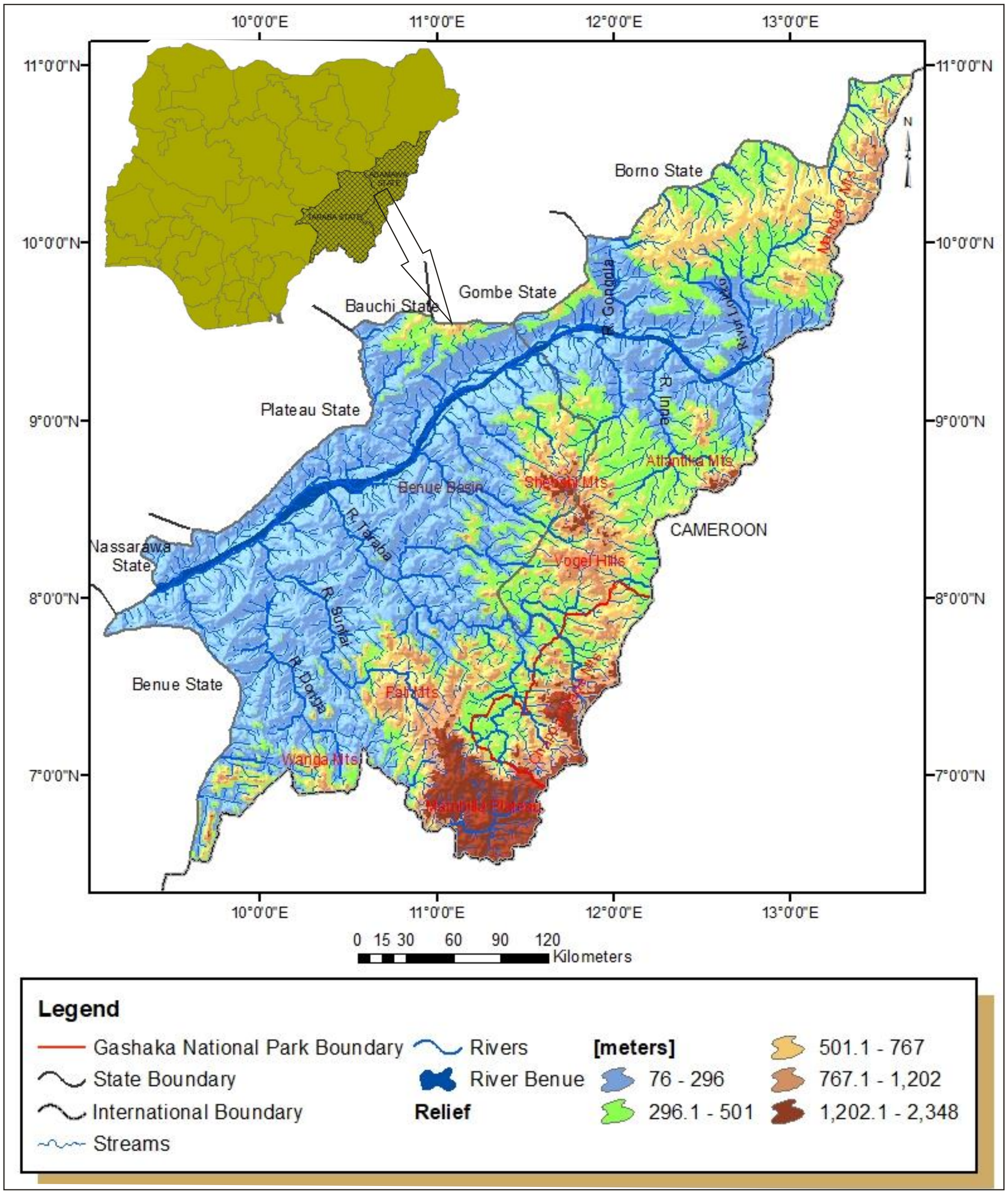


Fig.5. the Study Area

Materials and Methods

Mapping of settlement patterns in Adamawa and Taraba States

Geographical Information System (GIS) was used to generate and calculate the spatial patterns of settlements in the study area. The steps include:

(i) The base maps of the two States were obtained, georeferenced and digitized in ArcGIS 10.5 environment.

(ii) The coordinates of the actual locations of each of the settlements in the two States were acquired using GPS or obtained from World Atlas (2009), Google Earth Pro (2019), existing data among others (where many settlements are clustered together with less than 1km distance, only one of them was chosen for the study in order to avoid selection of too many settlements in a compacted area. All the coordinates were converted into decimal degrees and inputed into excel, converted into text file and exported to the digitized map in ArcGIS software.

(iii) The exported points automatically appear on their exact locations with their attribute information such as names of settlements and their serial numbers.

(iv) The Terrain of the two States were generated using the ASTADigital Elevation Models (DEM) Data (ASTAGDEM2), the positions of Gashaka Gumti National Park in each of the two States were also mapped and overlain on the terrain.

(v) Finally, the settlements were added to the terrain map so that the locations of each of the settlements and their corresponding terrian are easily assessed as seen in Fig. 9.

(vi) The area calculation module of ArcGIS software was also used to calculate the land area of each of the States and the landcover of the entire Gashaka Gumti National Park area. Other activities such as extraction of terrain features and protected areas and the settlements within each portion were carried out in ArcGIS environment using appropriate modules such as extraction by mask and clipping.

Determination of Average nearest Neighbour

The analyzing pattern of the spatial statistical tool of ArcGIS 10.5 software was used to calculate the average nearest neighbour of the settlements in the two States as displayed in Figures 10a and 10b. The ArcGIS 10.5 software and geostatistical module was developed by ESRI (2016). In the module, it was stated that Average Nearest Neighbour calculates a nearest neighbor index based on the average distance from each feature to its nearest neighboring feature. The Average Nearest Neighbour tool returns five values: Observed Mean Distance, Expected Mean Distance, Nearest Neighbor Index, Z-Score, and P-Value (Table 1). The Nearest Neighbor Index is expressed as the ratio of the Observed Mean Distance to the Expected Mean Distance. The expected distance is the average distance between neighbors in a hypothetical random distribution.

The interpretation of Average Nearest Neighbour is based on the fact that if the average distance is less than the average for a hypothetical random distribution, the distribution of the features being analyzed is considered clustered. If the average distance is greater than a hypothetical random distribution, the features are considered dispersed which can be summarised as:

(i) If the index (average nearest neighbor ratio) is less than 1, the pattern exhibits clustering.

(ii) If the index is greater than 1, the trend is toward dispersion.

Hypothesis

For the Average Nearest Neighbor statistic, the null hypothesis states that features are randomly distributed (ESRI 2016). The z-scores and p-values returned by the pattern analysis tools indicates whether the null hypothesis can be rejected or not. When the p-value is very small, it means it is very unlikely (small probability) that the observed spatial pattern is the result of random processes, so the null hypothesis will be rejected (ESRI 2016).

Mapping of Hot Spots based on Settlements and Relief

The Getis-Ord Gi* method of hot spots was adopted in this study. According to ESRI (2016), the Hot Spot Analysis tool calculates the Getis-Ord Gi* statistic (pronounced G-i-star) for each feature in a dataset. The resultant z-scores and p-values shows where features with either high or low values cluster spatially. To be a statistically significant hot spot, a feature will have a high value and be surrounded by other features with high values as well.The High/Low Clustering (Getis-Ord General G) tool is an inferential statistic, which means that the results of the analysis are interpreted within the context of the null hypothesis.

The null hypothesis for the High/Low Clustering (General G) statistic states that there is no spatial clustering of feature values. When the p-value returned by this tool is small and statistically significant, the null hypothesis can be rejected. If the null hypothesis is rejected, then the sign of the z-score becomes important. If the z-score value is positive, the observed General G index is larger than the expected General G index, indicating high values for the attribute are clustered in the study area. If the z-score value is negative, the observed General G index is smaller than the expected index, indicating that low values are clustered in the study area. ESRI (2016) summarized the interpretation of the Getis-Ord Gi* method of hot spots as follows:

(i) If the p-value isnot statistically significant: the null hypothesis cannot be rejected. This means that it is quite possible that the spatial distribution of feature attribute values is the result of random spatial processes.

(ii) If the p-valueisstatistically significant, and the z-score is positive. The null hypothesis is rejected. That is, the spatial distribution of highvalues in the dataset is more spatially clustered than would be expected if underlying spatial processes were truly random

(iii) If the p-value is statistically significant, and the z-score is negative. The null hypothesis is rejected. The spatial distribution oflowvalues in the dataset is more spatially clustered than would be expected if underlying spatial processes were truly random

In this study, hot spots of the settlement pattern based on the relief was examined to determine how clustered are the patterns on high and low relief. To achieve this, the location of each of the settlements in each State were compared to the relief so as to determine the hot spots and cold spots based on the terrain as shown in Figs 11 and 12.

Comparative Analysis of Settlement Patterns between the two States

Comparative analysis of the settlement patterns between the two States were based on: (i) the number of settlements, (ii) Nearest neighbour index (Rn values) (iii) settlement densities based on the terrain and (iv) settlement densities in the protected areas.

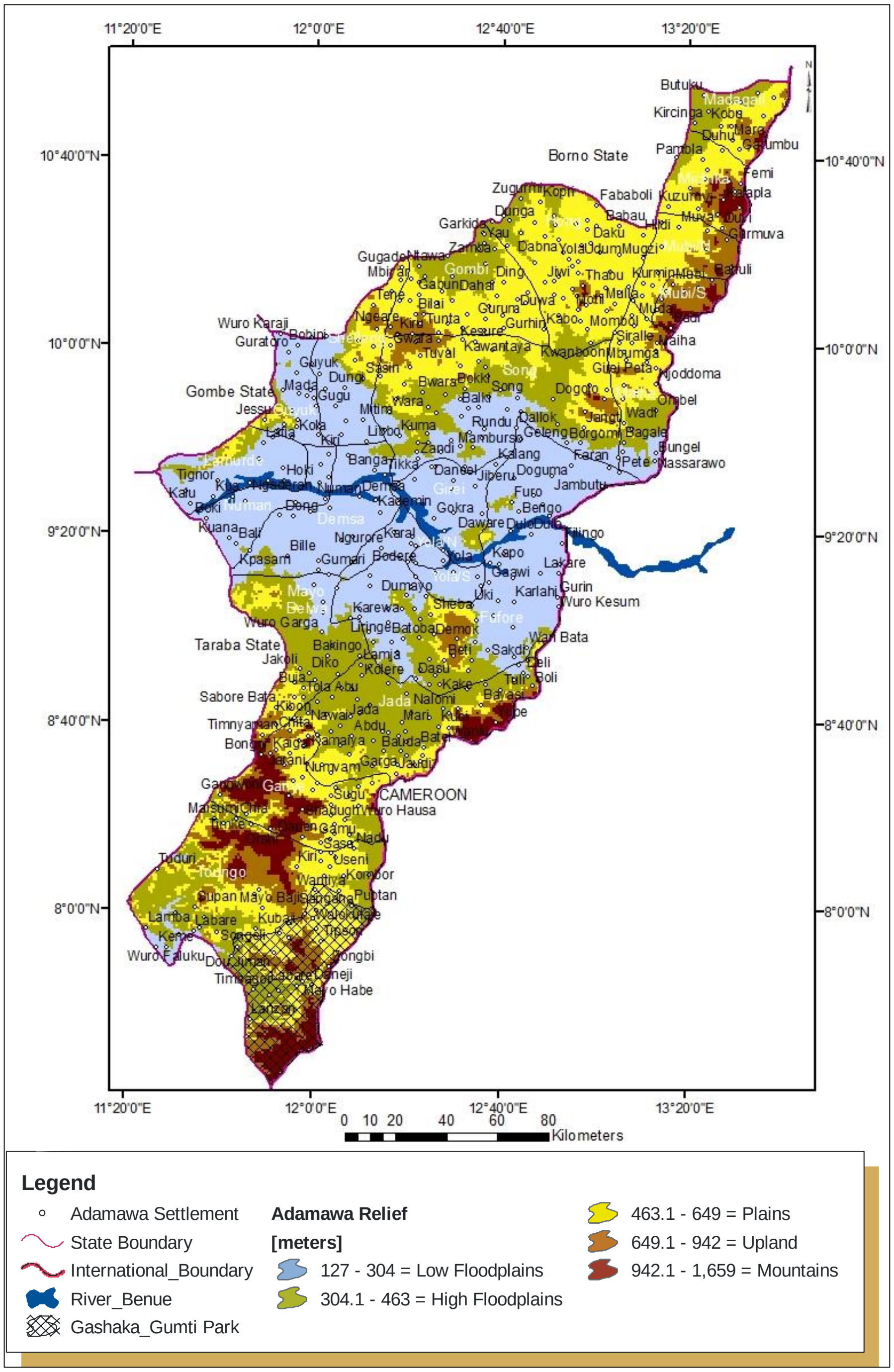


Fig. 6. Settlements distribution on the terrain in Adamawa State

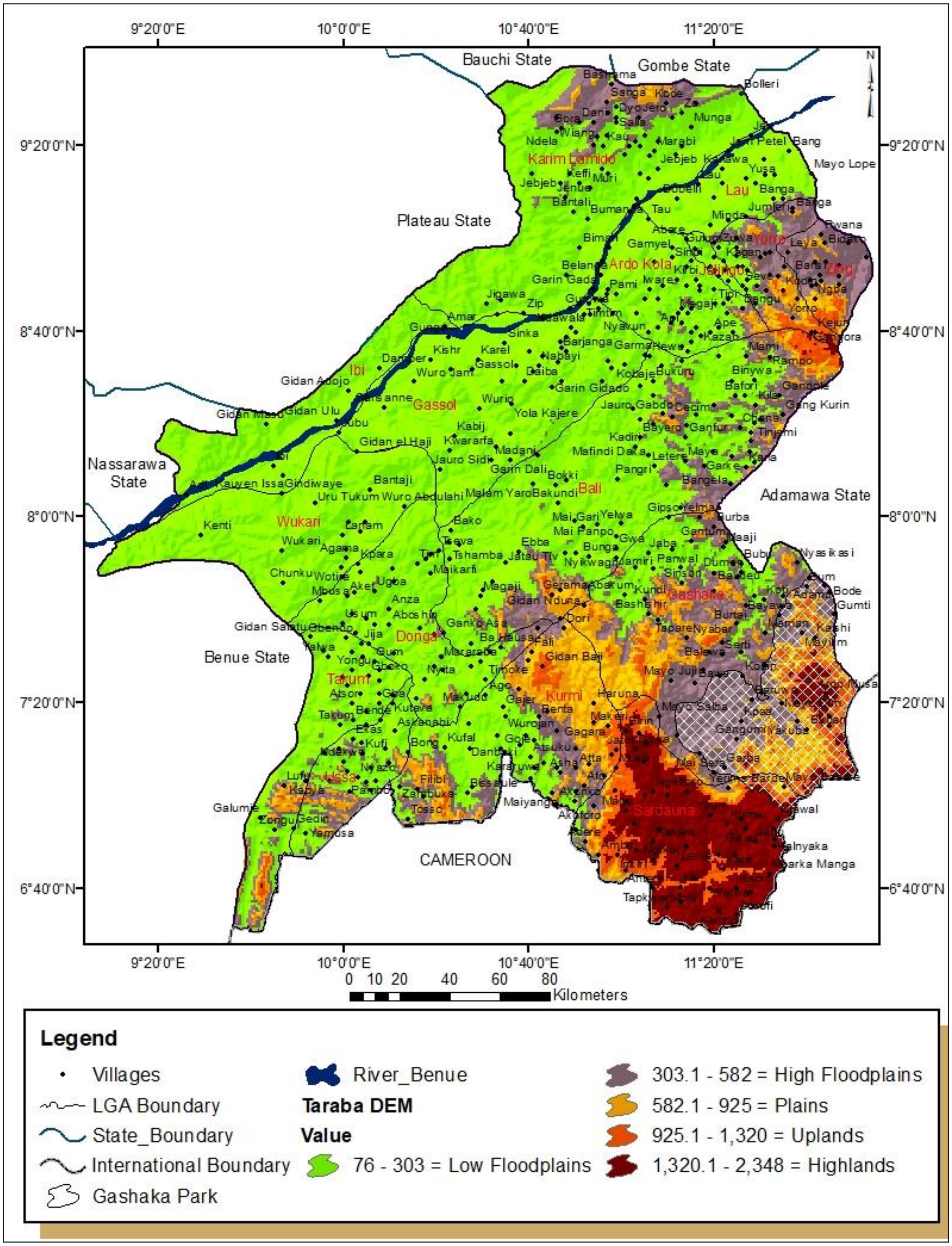


Fig. 7. Settlements distribution on the terrain in Taraba State

Result of the Findings

The analysis of the settlement pattern was categorized into the following:

Settlement Distribution in Adamawa and Taraba State

Adamawa State has a total of 586 settlements as against Taraba State with 579, (only one settlement among all those within less than 1km distance from each other were sampled for this study). It was observed that though Taraba State is far larger in land area size than Adamawa State with 38006.41km^2 and 58378.51km^2 respectively, the two States have similar numbers of settlements. The settlement distribution of the two States are shown in Figs. 8 and 9.

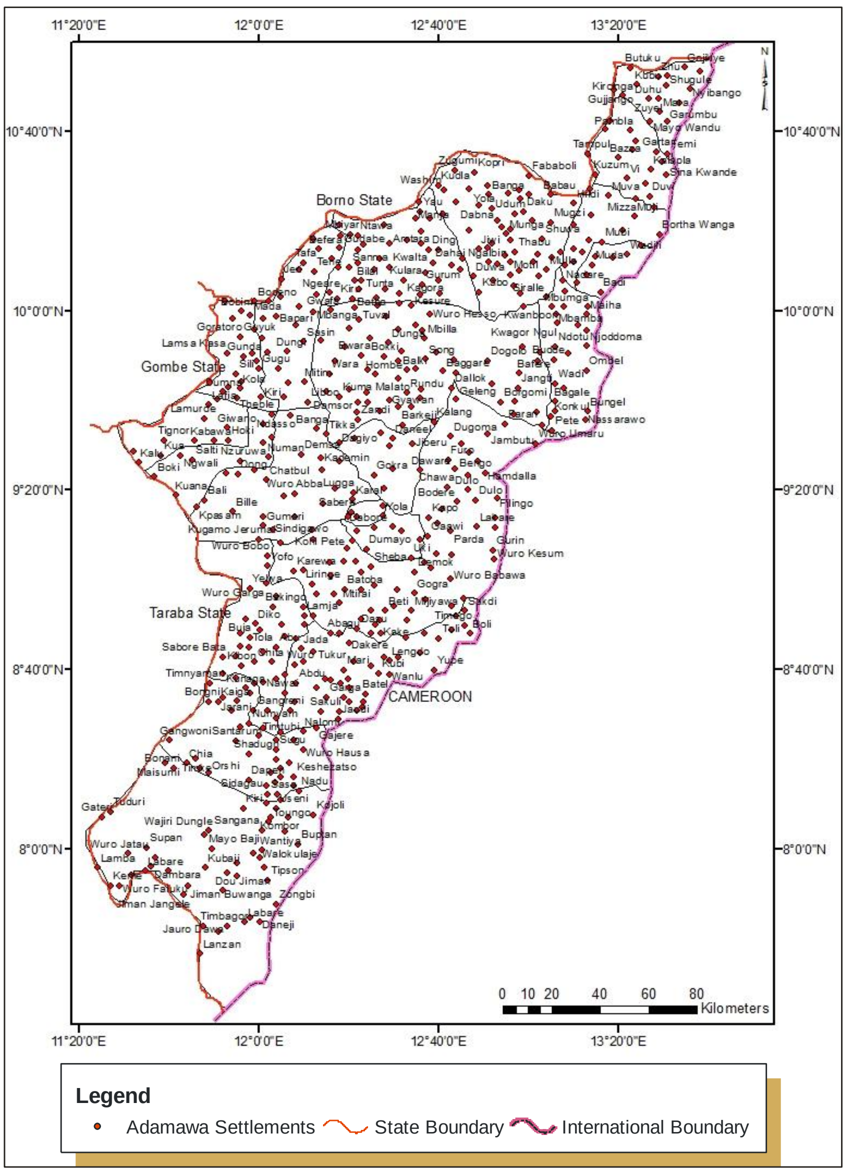


Fig. 8. Settlements distribution in Adamawa State

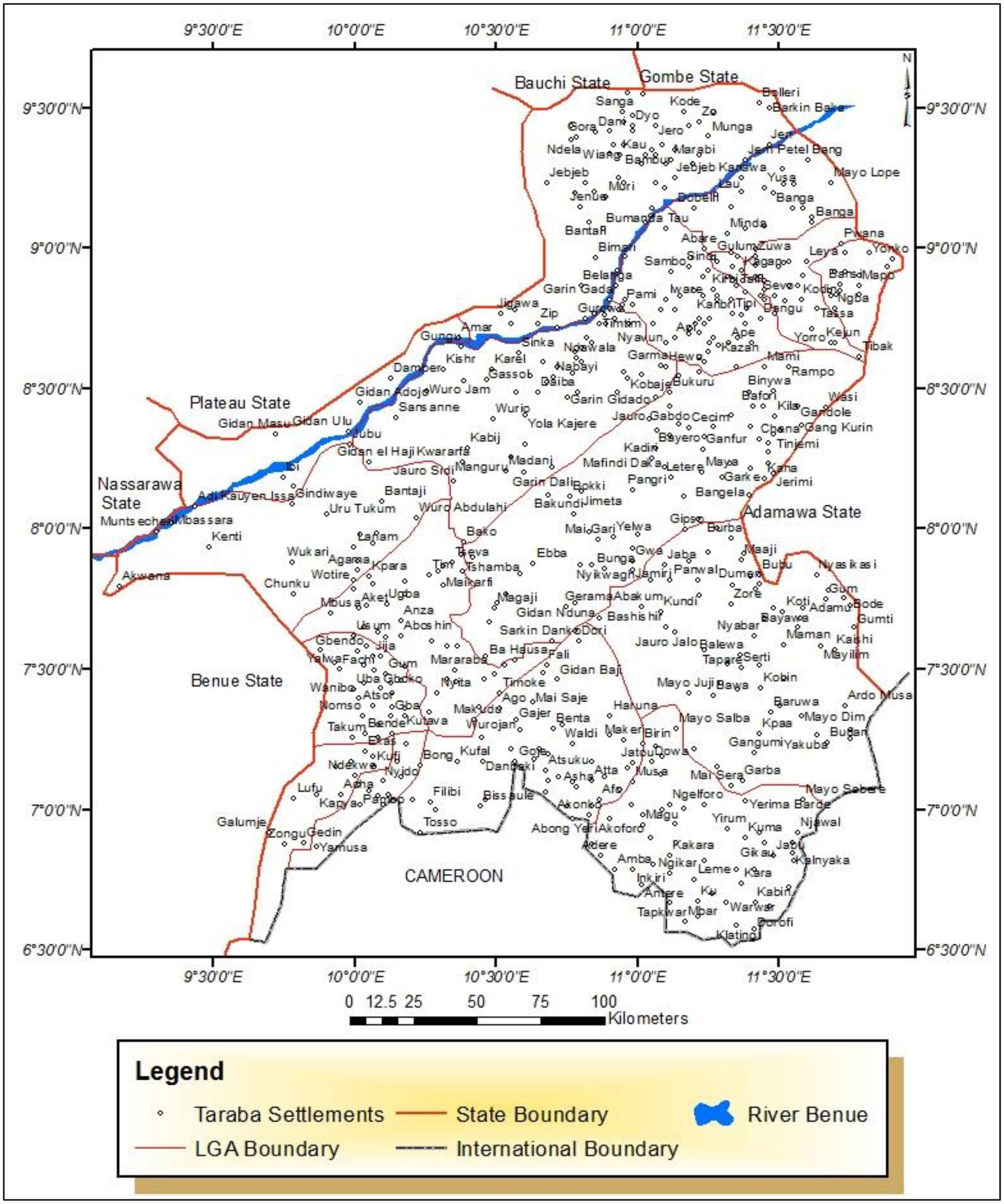


Fig. 9. Settlements distribution in Taraba State

Average Nearest Neighbour of the settlement patterns in the two States

The Average Nearest Neighbor tool returns five values: Observed Mean Distance, Expected Mean Distance, Nearest Neighbor Index, z-score and p-value (Table 1).

Table 1. Nearest Neighbour returns in Adamawa and Taraba states

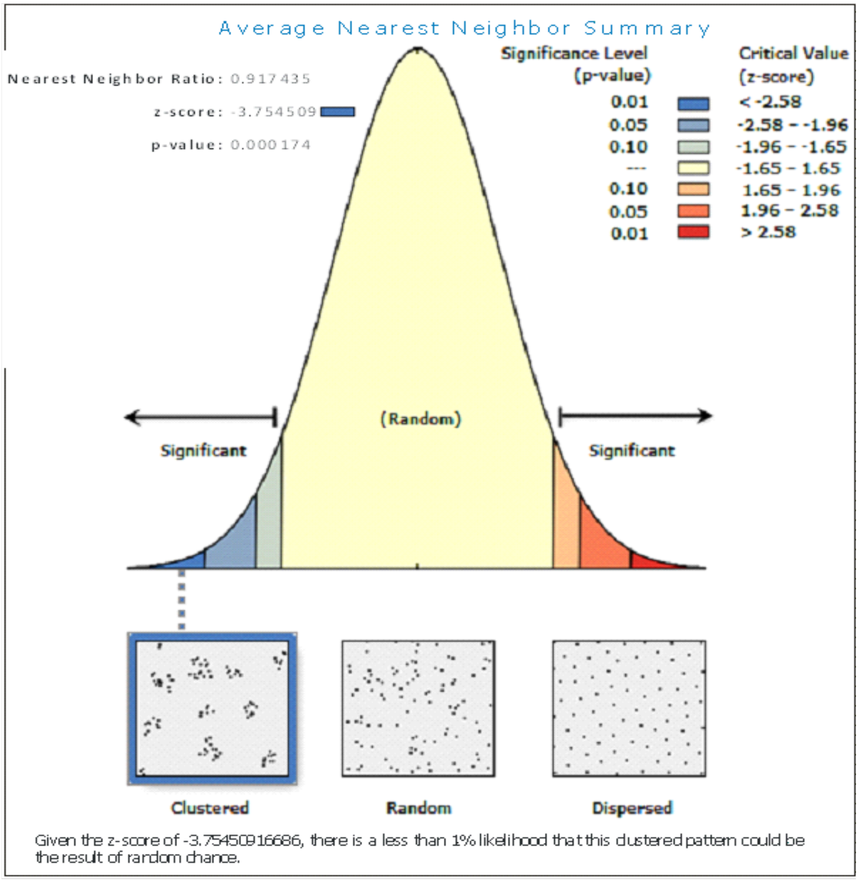
Values	Adamawa State	Taraba State
Observed Mean Distance	4918.8866 (meters)	5364.4438 (meters)
Expected Mean Distance	5361.5664 (meters)	6100.0918 (meters)
Nearest Neighbour Index	0.917435	0.879404
Z-Scores	-3.754509	-5.512932
P-Values	0.000174	0.000000

Source: Generated from ArcGIS 10.5 spatial statistics module

The Nearest Neighbor Index is expressed as the ratio of the Observed Mean Distance to the Expected Mean Distance. The nearest neighbour index means the average distance between the settlements in each of the State. For Adamawa State for instance, the average distance among the settlements is approximately 0.92 meters, while Taraba State has average of 0.88 meters. These findings suggest that if the settlements distribution of each of the two States are well spread, the average distances between the settlements in each of the two States are not up to a kilometer.

The Average Nearest Neighbour index in the States as well as their corresponding z-values are presented in Figures 10a and 10b. Average Nearest Neighbour calculates a nearest neighbor index based on the average distance from each settlement to its nearest neighbour. The nearest neighbour index (average nearest neighbor ratio) which is akin to Rn values in point pattern analysis for the settlement pattern in Adamawa State was calculated as 0.92, while that of Taraba State was 0.88. Settlements pattern seem to be similar in some parts of Nigeria. For instance, Abdullahi (2009) in his work on the settlement pattern in Kwajaffa districts, Biu plateau in Borno State, arrived at 0.90 Rn value, while Ahmed (2009) in his analysis of settlement pattern in a LGA in Kwara State arrived at 1.12, both of which are more of random pattern.

Using the nearest neighbour index interpretation format and since the nearest neighbour index are 0.92 and 0.88 in Adamawa and Taraba States respectively, the settlement patterns in both States can therefore be said to exhibit clustering pattern since the index (average nearest neighbor ratio) is less than one (1) in both States. Therefore, since it has been established that the two States have clustering pattern, the factors that cause the clustering can be identified and analyzed.



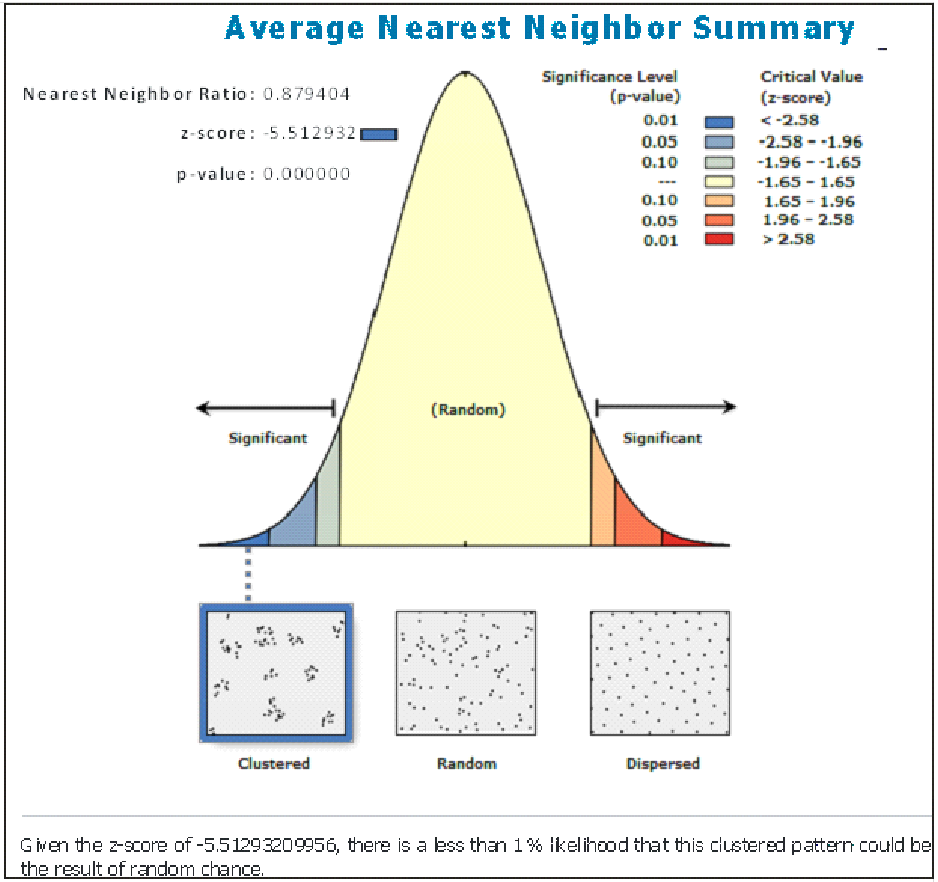


Fig. 10a. Average Neighbour Summary in Adamawa State.Fig. 10b. Average neighbour summary in Taraba State

Hop Spot Analysis

According to ESRI (2016), in the Average Nearest Neighbor statistic, the null hypothesis states that features are randomly distributed. The z-scores and p-values returned by the pattern analysis tools helps to decide whether the null hypothesis can be rejected or not. In Figures 10a and 10b, and Table 1, the returned p-values are small (0.000174 for Adamawa and 0.000000 for Taraba) and the z-scores are both negative (-3.75 in Adamawa State and -5.51 in Taraba State). Using the rule of hot spot analysis the result falls in the third category, that is, the p-value is statistically significant because the p-value is very small which means it is very unlikely (small probability) that the observed spatial pattern is a result of random processes, so the null hypothesis is rejected in the two States and conclusions are made that the settlements are not randomly distributed but some existing factors results into the clustering pattern of the settlements. The z-scores are also negative, hence the null hypothesis is rejected. The existence of clustering in an area is an evidence of some underlying spatial processes at work, that is, some factors must have led to the clustering of such settlements.

The statistical significant interpretation of Hot Spot, is that forstatistically significant positive z-scores, the larger the z-score is, the more intense the clustering of high values (hot spot). For statistically significant negative z-scores, the smaller the z-score is, the more intense the clustering of low values (cold spot). Hence, looking at the the z-scores values of the two States, both are negative which means there are more intense of low values, that is more clustered settlement in the low terrain in the two States. This means that settlements are more concentrated in the plains than the mountanous areas in the two States. However, since the z-score of Adamawa State (-3.75) is less than that of Taraba State with -5.52, and since the smaller the z-score is, the more intense the clustering of low values (cold spot), it can be concluded that Adamawa State has more clustered settlements in the low terrain than that of Taraba State as evidenced in Table 2 where 547 out of the 586 settlements (93.34%) in the State are located within the plains, that is, either low flood plains, high floodplains or the plains as against Taraba State where 523 out of the 579 settlements (90.33%) are located in the plains (low flood plains, high flood plains and plains).

The significant levels of the clustering nature of the settlements based on the elevation of each of the two States at the three popular level of significant of 0.10 (95%), 0.05 (95%) and 0.01 (90%) are presented in Figures 11 and 12.

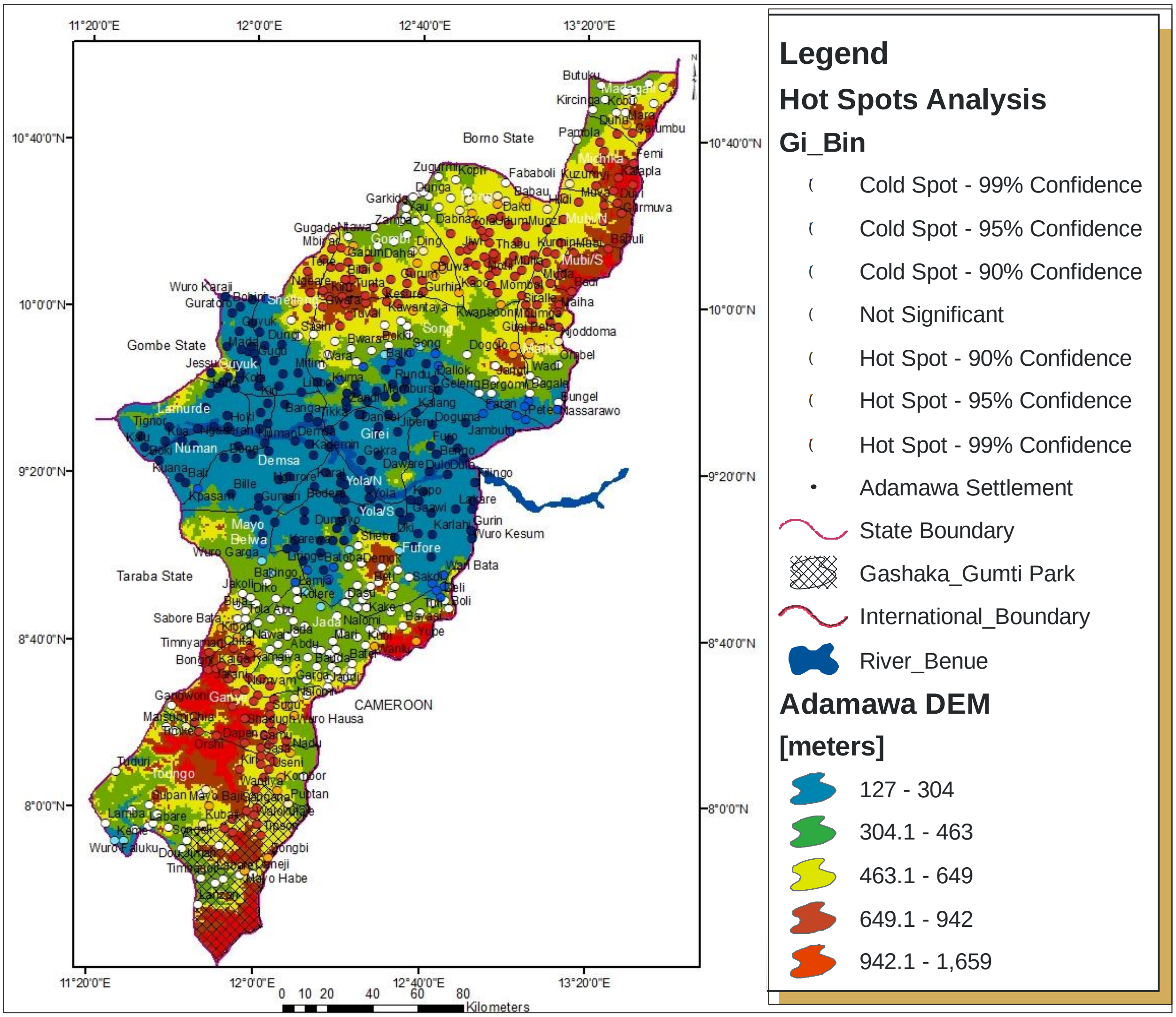


Fig. 11. Hot Spots of settlements on relief in Adamawa State

In Adamawa State, hot spots clustering (clustering of settlements on high elevation) at 99% confidence level were found mainly on elevation from 463.1m above the sea level (Fig. 11). They are conspicous on the Vogel hills in Ganye and Tungo LGAs, the Mandara Mountains in the Mubi region comprising; Mubi North and South, Michika, Maiha and Madagali LGAs and some parts of Hong, Gombi and Song LGAs. Those at 90% confidence level, were mainly on plains with elevation ranging from 304.1m to 463m above sea level. Clustering of settlements at the low relief was more conspicious in Adamawa State because at 99% confidence level, the entire Benue valley of the State returned 99% confidence level of cold spots, that is clustering of settlements on low terrain as revealed in Fig. 12.

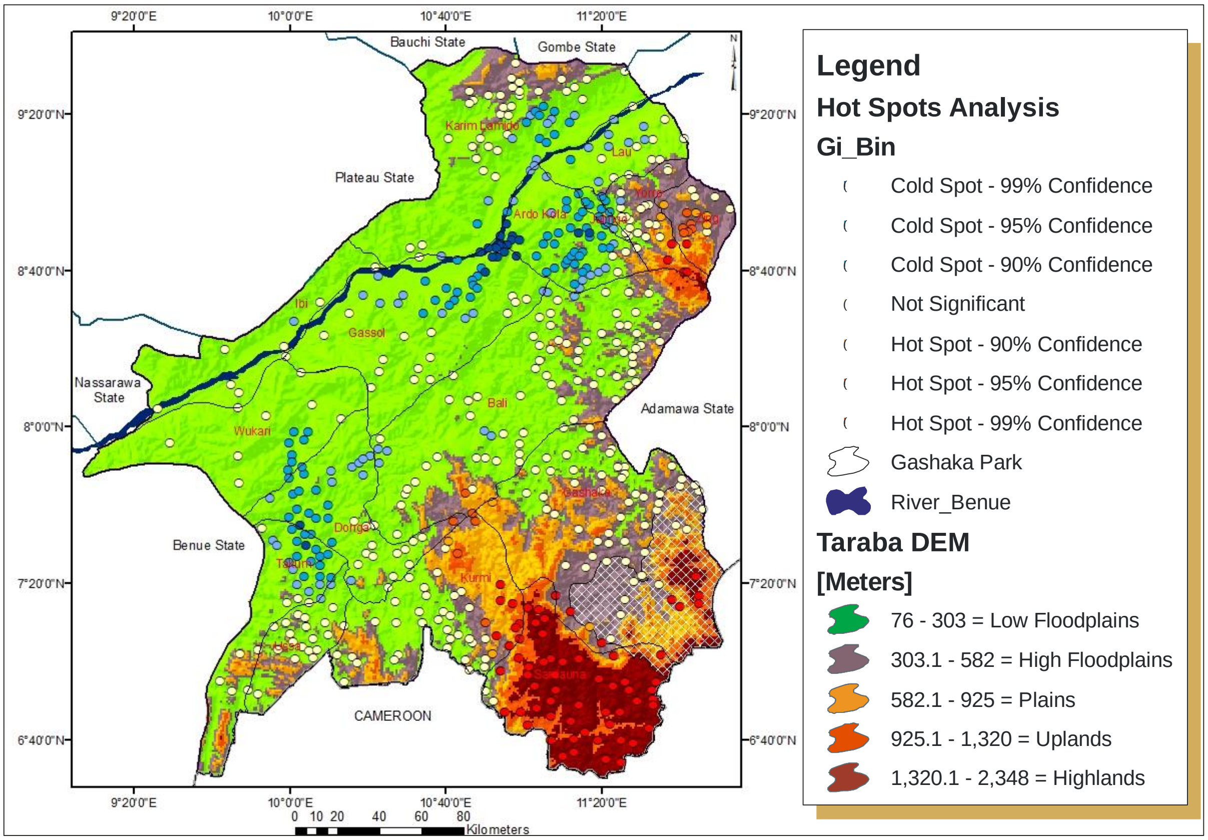


Fig. 12. Hot Spots of settlements on relief in Taraba State

In Taraba State, hot spots and cold spots clustering are highly conspicous as hot spots clustering at 99% cofidence level were found mainly on the Mambilla plateau in Sardauna and Gashaka LGAs as well as the mountain areas in Zing and Yorro LGAs of the State. Unlike in Adamawa State where the entire Benue valley was significant at 99% confidence level, the Benue valley revealed 99% confidence level of cold spots clustering within the boundary of Gassol and Ardo Kola LGAs along River Benue (Fig. 12). At 95%, settlements in Taraba State clusters in some parts of Ardo Kola, Donga, Gassol, Karim Lamido, Takum and Wukari LGAs. Settlements distribution at the remaining parts of the low floodplains in Taraba State were found not to be significant (Fig.12). This further confirms that Adamawa State has more clustered settlements in the low terrain than that of Taraba State since the z-score of Adamawa State (-3.75) is less than that of Taraba State with -5.52 and since the smaller the z-score is, the more intense the clustering of low values (cold spot).

Comparative analysis of settlement patterns between the two states

Comparative analysis of the settlement patterns between the two States were based on: (i) the number of settlements, (ii) States' settlement density (iii) Nearest neighbour index (Rn values) (iv) Settlement densities based on the terrain and (vi) Settlement densities in the protected areas. The results were presented in Table 2.

In Table 2, it was revealed that while Adamawa State has a total settlements of 586, with a land area of 38006.41. The settlement density of the State was calculated as 64.86, while Taraba State with 579 settlements and 58378.51 land area has settlement density of 100.83. This means that Adamawa State has an average of one settlement at every 64.86 kilometers, while Taraba State has an average settlement at every 100.83 kilometers. Therefore, Taraba State which is larger in size than Adamawa State can be said to have fewer settlements and larger settlement density than Adamawa State. The average nearest neighbour of Adamawa State was also calculated as 0.92, while that of Taraba State was 0.88 both suggesting clustering nature of the settlement patterns in the two States

Table. 2. Comparisons of settlement distribution on the terrain of Adamawa and Taraba State

Adamawa State					**Taraba State**			
Number of settlements				586				579
Avearge Nearest Neigbour Index				0.92				0.88
Terrain	**Area (km^2)**	**% of State**	**No of Settlements**	**Density**	**Area (km^2)**	**% of State**	**No of Settlements**	**Density**
Mountains	1548.71	4.07	10 (1.71%)	154.87	3524.90	6.04	39	90.38
Uplands	3247.21	8.54	29(4.95%)	111.97	2642.25	4.53	17	155.43
Plains	11209.43	29.49	210 (35.84%)	53.37	5471.17	9.37	23	237.88
High Floodplains	9640.11	25.36	152 (25.94%)	63.42	9453.75	16.19	102	92.68
Low Floodplains	12360.95	32.52	185	66.82	37286.44	63.87	398	93.68
TOTAL	**38006.41**	**100**	**586**	**64.86**	**58378.51**	**100**	**579**	**100.83**
Protected Areas	2162.92	5.69	21	135.18	3621.17	6.20	21	172.44

Source: Derived from settlement and Digital Elevation Model (DEM) analysis
Number of settlements, settlement densities and average nearest neighbour index

Settlement densities on terrain types

Settlement density based on the terrain was presented in Table 2. The terrain of the two States were classified into five: the low floodplains, high floodplains, plains, uplands and mountain areas. For Adamawa State, the density is higher on the plains, high floodplains and the low floodplains. The terrain with the highest settlement density in the State is the plains with an average of a settlement at every 53.37 kilometers, while the mountains has the least with a settlement at every 154.87 kilometers. In Taraba State, settlement density is more on the mountains than other terrain types with a settlement at every 90.38 kilometers, closely followed by high and low floodplains with a settlement at every 92.68 and 93.68 kilometers respectively. Contrary to Adamawa State which has the highest settlement density in the plain, the plain of Taraba State has the least settlement density of an average of one settlement at every 237.88 kilometers, while the plain of Adamawa covers about 11,209.43 square kilometers, Taraba State has only 5,471.17 square kilometers as plain. The summary of this finding is that settlements are more clusterd in the plains of Adamawa State while the high and low floodplains are more compacted with settlements in Taraba State with the plains of the State having more scattered settlements.

Settlement densities in the protected areas

About 6% of the land area in each of the two States are protected areas, that is, Gashaka-Gumti National Park (Figures 6 and 7). The Gashaka Gumti Nationl Park which is supposed to be free from permanent habitation was discovered to house some settlements in the two States. In Adamawa State, an average of every 143.72 kilometers of protected land area has one settlement. The case is better in Taraba State with one settlement at every 160.27 kilometers. The existence of settlements within the park was based on mutual agreement between the inhabitants and the federal goverment as reported by GGNP (2011). Akinsoji, Adeonipekun, Adeniyi, Oyebanji and Eluwole (2016), Oruonye, Ahmed, Garba and Danjuma (2017) have also reported that enclaves and other settlements exist within the camp for local pastoralist and farming communities. Among the enclaves are Gumti, Tipsun, Nyumti, Selbe, Mayo Sabere, Filinga, Hendu among others. Oruonye, et al (2017), stated that the major occupations of the enclave communities in the park are farming, livestock husbandry, vocational jobs, civil service with few hunters and fishermen. They engage in subsistence farming and crops cultivated include maize, groundnut, millet, guinea corn, beans soya beans, rice, yams, sugar cane, and cassava.

Conclusion

In this study, the location, distribution and pattern of settlements in Adamawa and Taraba States were generated and analyzed using geospatial and geostatistical techniques. The need for even developemnt calls for settlement pattern assessment through which spatial pattern analysis can be used for regional planning and development. The use of manual determination of settlement pattern such as the popular nearest neighbour analysis has been considered obsolete since modern technology especially in the field of GIS has the capability of automatic generation of most of the determinants of point patterns such as, accurate positional accuracy of settlement locations, automatic generation of z-scores, p-values and hypothesis rejection/acceptance and most importantly nearest neighbour index commonly referred to as Rn values in manual methods, among others.

The settlement patterns in both States also exhibit clustering patternbecause the index (average nearest neighbor ratio) is less than one (1) in both States. The average nearest neighbour index of Adamawa State was calculated as 0.92, while that of Taraba State was 0.88 both suggesting clustering nature of the settlement patterns in the two States. Therefore, since it has been established that the two States have clustering pattern, the existence of clustering settlement patterns in the two State is an evidence of some underlying spatial processes at work, that is, some factors must have led to the clustering nature of the settlement patterns. Clustering of settlements at the low relief was more conspicious in Adamawa State because the entire Benue valley of the State returned 99% confidence level of cold spots, that is clustering of settlements on low terrain. In Taraba State, only some patches of land area within the Benue valley were clustered and not the entire valley. However, settlements were more clustered on the Mambilla plateau in Taraba State than the highlands of Adamawa State where only some few ones were clustered. Investigation of the factors that cause the clustering of settlements in some parts in both States is suggested for further studies, while the use of geospatial and geostistaical techniques for the determination of settlement pattern analysis should be encouraged for accurate results. Regional planners should also integrate settlement patterns analysis with other factors for even developemntal planning since the patterns exposes clustered areas which are usually more populated and moreover, may suggest the likely factors that make such areas to be clustered.

Recommendations

Based on the findings of the study, the following recommendations are proferred.

(i) Settlement pattern analysis should be seen as an important aspect of even developmental planning and hence, be integrated in regional planning processes.
(ii) The use of manual methods of determination of settlement patterns should be discouraged because of inaccuracies that are commonly associated, while geospatial techniques which is easier to process with reliable results should be encouraged.
(iii) Investigation of the possible factors resulting into the clustering of settlements in specific places should be carried out so as to find out how such factors can lead to the development of other areas.

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