Gombe Journal of Geography and Environmental Studies (GOJGES)

Vol. 2 N0.1 Jun. 2021

e-ISSN: 2714-321X

p-ISSN: 2714-3201

http://www.gojgesjournal.com

Gombe Journal of Geography and Environmental Studies (GOJGES) Vol. 2 N0.1 Jun. 2021, e-ISSN: 2714-321X; p-ISSN: 2714-3201

ANALYSIS OF LANDFORM AND HUMAN SETTLEMENTS AND NEEDS IN GUYUK LOCAL GOVERNMENT AREA, ADAMAWA STATE, NIGERIA

John Abdullahi[1], John O. Odihi[1] and Phanuel B. Joshua[2]
[1]Department of Geography, University of Maiduguri
[2]Department of Urban and Regional Planning, University of Maiduguri

Corresponding Author: drajohn74@gmail.com Phone:+234(0)8036821438, +234(0)8026497508

Abstract

The paper examines the influence of landforms on human settlements in Guyuk Local Government Area, Adamawa State, Nigeria. The study also seeks to address the needs of the settlements. Shape files of the study area were overlaid on DEM, using the Manual Class symbology showing the highest and lowest elevation values within three classes, that is, 126 – 211m, 211.1 – 260m and 260.1 – 803m representing plains, lowland and highlands, respectively. The classified raster values were then converted to polygons in UTM projection for area/size calculation. Attribute tables of landforms and settlements were generated from the digital map. The results show that the settlement pattern in the Guyuk area is distributed in a dispersed pattern, influenced by the different types of landforms. The influencing factors include plain (126 – 211m) flat topography that implies a good accessibility, lowland (211.1 – 260m), and highlands (260.1 – 803m) for safety from natural disasters, especially floods, and soil fertility sustaining agricultural livelihoods. The settlement pattern is random. The study recommends that the plain terrain (126 – 211m) that provided good settlement site with accessibility should be provided with tarred roads by the State government to promote movement of goods and services. The lowland area (211.1 – 260m) that serves as source of domestic water supply and fertile soil for agriculture as source of their livelihood in the area should be support with boreholes and agricultural inputs by the government and NGOs to boost their agricultural activities in the area. The highlands (260.1 – 803m) area that protects the residents from natural disasters especially floods, should be provided with good drainage system by the government to facilitate easy flow of water in the area.

Keywords: Landforms, settlements, distribution, GIS, Guyuk

1. Introduction

Landform is the main object of study in geomorphology, as enshrined in its definition as the scientific study of the origin as well as the evolution of topographic and bathymetric features created by physical, chemical, or biological process acting at or near the Earth's surface. About three decades ago Van Zuidam and Cancelado (1979) and more recently Huggett (2011) suggested that the discipline of geomorphology is a science that describes landforms chronologically and the processes that are responsible for their formations as well as the intra and inter relationships between landforms and processes over space and time. The centrality of the natural environment to human behavior has long been established, for example, Sheppard, 2011). A good example for Nigeria is the study by Akpabio and Subramanian (2012) studied water supply and sanitation practices in Nigeria.

The Earth's surface landscapes have been generally categorized into simpler units based on the similarities of their nature and characteristics including general configurations such as topographic impressions as hills, mountains and undulating surfaces; attributes of the topographic expressions such as steepness and length of slopes and their shapes, whether convex or concave, differences in elevation and valley shapes; their geological and geochemical compositions and rock types and the shape of valleys such as V-shape or U-shape; and the endogenic or exogenic processes responsible for their formation (Gorum, *et al*, 2008.

Many decades ago, geomorphologists, Cooke and Dornkamp (1974), and more recently, Panizza (1996) observed that uniqueness of each landform has implications for its potential and actual use(s). This is not surprising because of the materials that compose them, their elevation, and slopes. Settlements are places in which people live. While majority of the settlements occur on land, some are on water as the case of water cities and towns such as Venice in Italy, the Kampong Ayer of Brunei of Brunei Darussalam. There are also examples of settlements on water in Nigeria including Maroko and Makoko in Lagos. Huggett and Cheesman (2002) echoed the age long question of why some places have settlements and others do not and return the answer that they are influenced by a multiplicity of factors.

Geographers in the process of the development of their discipline of Geography have seen the environment including high elevation landscapes and forests as inhibiting factors of human utilization of them for habitation and other human interests. As knowledge and technology advance and experience grown, the view of environment as inhibitors has changed to possibilities and human choice. This changing view of the environment has critical resonance with the geographic concepts of "environmental determinism" and "possibilism" which can be seen in Geoffrey J. Martin's work, *All Possible Worlds: A History of Geographical Ideas* Fourth Edition (Martin, 2005).

Pan, Dang and Shi (2020) did a comparative analysis study of traditional settlement landscapes of Leizhou Peninsula in China under the influence of topography and landform. They found that the settlements were significantly influenced by landforms. Xi, Qian, Chi, Chen, and Wang (2018) observed that terrain influences settlements' spatial distribution. The also observe that studying settlements' terrain characteristics will assist in the understanding of environmental effects on human activities. The authors used eight factors and distributive entropy assesses the extent of settlements' spatial distribution to establish their quantitative relationships in Sichuan Province in China.

In their study, Metay, Bocco, Velazquez, and Gajewski (2017) used GIS and multivariate statistical method to investigate the quantitative relationship between landforms and land uses in tropical drylands. The study was based in the geographically complex area of the tropical dry Mexican Pacific cost.

Gombe Journal of Geography and Environmental Studies (GOJGES) Vol. 2 N0.1 Jun. 2021, e-ISSN: 2714-321X; p-ISSN: 2714-3201

The study's result indicated a strong correspondence between geomorphic and land use activities.

Closer home, Ambe's (2018) showed that natural factors including landforms influence rural settlement(s) sites in the Cross River State, Nigeria. He concluded that natural factors including landforms are important determinants of settlement patterns that include social and economic factors.

Odihi (1988) studied the settlement history of the city of Ibadan from its genesis on the mountains to the vary and related the flood problems of the city to the different terrains in its settlement history. He found that the city started on the hilltops as a calvary settlement to protect its settlers against the invading the jihadists from the north in the 19th century. This high location achieved the safety goal of establishing it and protecting the town from hydrological hazards of floods which began to be experienced as the settlement expanded downward to the plains with little regard for appropriate land use planning.

A principal concept of geomorphology states that "*Geomorphic processes leave their distinctive indelible marks or imprint upon landforms and each geomorphic process develops its own characteristic assemblage of landforms"* (Thornbury, 1958). Extending this observation, Verstappen (2014) observed that landform distribution influences settlements, especially their development, distribution patterns and density.

The general topographic configuration of an area can influence the pattern of its spatial distribution of settlements. Therefore, settlement characteristics' study may and have been used to aid the understanding of the effects of the environment on human activities. Kernel Density tool in ArcGIS, which calculates a magnitude-per-unit area from point features using a kernel function to fit a smoothly tapered surface to each point has been used for this purpose. Only the points or portions of a line that fall within the neighborhood are considered in calculating density. If no points or line sections fall within the neighborhood of a particular cell, that cell is assigned "No Data". In this analysis, natural break classification was employed in categorizing the output result of the Kernel density into five classes ranging from very low density to very high density.

Anton Bonnier and his colleagues, Erika Weiberg and Martin Finne of the University of Upsala, used a quantitative approach to survey based legacy data to further assess the spatial configuration of land use areas in the Berbati-Limnes region of Greece, demonstrating through it how GIS-based kernel density estimations linked to land use strategies. They related density surfaces to elevation and slope to produce cluster-based surfaces to produce land use (Bonnier, Weiberg and Finne, 2019). They also observed that density surfaces could be related to elevation and slope to estimate shifts in the use of a particular environment on a regional scale that permits modelling and visualizing temporal land use changes.

The kernel method is a class of algorithms for pattern analysis. A good example of the kernel method is the support vector machine (SVM). The general task of pattern analysis is finding and studying general types of relations (for example clusters (i.e., nucleation), rankings, principal components, correlations, and classifications in data sets). It is usual in several algorithms used to solve these tasks, to transform the representation of data into feature vector (i.e., a feature is a specific measurable property or characteristic of a phenomenon being observed (Bishop, 2006)) However, kernel methods require only a user-specified kernel which is a similarity function over pairs of data points in a raw representation. A similarity function, also known as similarity measure, is a real-valued function that quantifies the similarity between two objects. Choosing informative, discriminating, and independent features is a crucial step for effective algorithms in recognizing pattern, classification, and regression.

Kernel methods owe their name to the use of kernel functions, which allow them to work in a high-dimensional, hidden feature space without ever computing the coordinates of the data in that space, but rather by simply computing the inner products between the images of all pairs of data in the feature space. This operation is often computationally cheaper than the explicit computation of the coordinates. This approach is called the "kernel trick (Theodoridis, 2008). Kernel functions have been introduced for sequence data, graphs, text, images, as well as vectors.

Nearest neighbour analysis measures the spread of or distribution of something over a geographical space, providing a numerical value that describes the extent to which a set of points are random, clustered, or uniformly spaced. The nearest neigbour analysis (NNA) approach measures the distance between the two nearest neighbours in a distribution. In NNA we are concerned with whether locations of a phenomenon are randomly distributed throughout the area of interest such as a study area (i.e., are the locations a realization of Poisson process with homogenous intensity)? Otherwise, do the locations show some structure (i.e., clustering or repulsion between locations as may be the case of uniformity)? The fact that connotations and importance of Poisson process as a benchmark, it is generally referred to as "complete spatial randomness" or (CSR).

The distances between nearest neighbours provide pattern information about the points. If we define W, as the distance from a randomly chosen event to the nearest other event in a homogenous Poisson process with intensity (expected # of points per unit area) of ρ, the pdf and cdf of W are:

$$g(w)=2\rho\pi w \exp(-\rho\pi w2), \quad (1)$$

$$G(w)=1 - e{-}\rho\pi w2 \quad (2)$$

therefore, the mean and the variance of W are:

$$E\ W = 1/(2\sqrt{\rho}) \quad (3)$$

and

$$Var\ W = (4 - \pi)/(4\pi\rho). \quad (4)$$

Based on these moments, Clark and Evans (1954) proposed a test of CSR. The conditional moments, E W | ρˆ and Var W | ρˆ are calculated by substituting the observed density, ˆρ = # total number of points / total area of study region, into (3) and (4). The observed mean nearest-neighbour distance, w is computed by identifying the nearest neighbour of each point, finding the distance between nearest neighbors, then averaging. Clark and Evans (1954) proposed that the standardized mean,

$$ZCE = w - E\ W \mid \hat{\rho}\ N - 1 Var\ W \mid \hat{\rho} \qquad (5)$$

has a standard normal distribution if the process is CSR.

The ZCE statistic and the many users of it ignore two problems: non-independence of some nearest-neighbor distances and edge effects. In a completely mapped area, many of the distances between nearest neighbors are correlated. The problem is most severe with reflexive nearest neighbors. Two points, A and B, are reflexive nearest neighbors when B is the nearest neighbor of A and A is the nearest neighbor of B. Other authors have called these isolated nearest neighbors or mutual nearest neighbors. When A and B are reflexive nearest neighbors, each point has the value of W, which inflates the variance of the mean nearest-neighbor distance. This problem is not restricted to a few points. When points are CSR in 2 dimensions, approximately 62.15% of the points are reflexive nearest neighbors.

Edge effects arise because the distribution of W (2) assumes an unbounded area, but the observed nn distances are calculated from points in a defined study area. When a point is near the edge of the study area, it is possible that the true nearest neighbor is a point just outside the study area, not a more distant point that happens to be in the study area. Edge effects lead to overestimation (positive bias) of the mean nearest neigbour distance. Edge effects can be practically important; neglecting them can alter conclusions about the spatial pattern.

The problem of edge effects can be reduced through the inclusion of a buffer area that surrounds the primary study area. Nearest neighbour distances are only calculated for points in the primary study area, but locations in the buffer area are available as potential nearest neighbours. With a sufficiently large buffer area, this approach can eliminate edge effects, but it is wasteful since an appropriately large buffer area may contain many locations.

Ma, Guo, Tian, Wang, and Chen (2017) analyzed the temporal-spatial differentiation of rural settlement patterns in Shandan County of Hexi Corridor in China and studied the spatial association between rural settlements and water-land resources. Results show the dynamics of rural settlements over time. They found that the spatial distribution of rural settlements, cultivated land and the hydrographic network in Shandan County is closely related. Their study results provide a theoretical basis for the reasonable utilization of water and land resources elsewhere as it did in Shandan County to, in the long run provide a balance between population and water and land resources and regional sustainable development.

The pattern of settlement distribution may reflect the degree of spatial interaction of human beings and their physical environment as observed by (Metay 2017). This implies that human beings have underlining reasons in selecting a specific site for settlement. These reasons are influenced by the general topographical configuration as well as the suitability and potentiality of landforms in meeting the needs for settlement since every landform is unique in terms of the resources that are associated with it that could support the existence and development of human settlement (Goudie, 2016).

Lowland areas are generally characterized by well-developed soils due to the depositions and decompositions of eroded materials, rich in nutrients suitable for agricultural production. The lowlands usually found between river channels are in the form of alluvial plains, characterized by alluvial soils with higher moisture content compared with soil sat the upstream riverbanks (Verstappen, 2014). Thus, significant proportions of lowlands are used for agricultural activities, while the plain and highlands are used for settlement.

2. Statement of the Research Problem

Scholars believe that landforms, as integral parts of the physical environment through their characteristics, control the spatial distribution of environmental resources and geomorphological hazards. Therefore, they influence human decisions in land use choices, including settlement locations. Using examples of settlements in antiquity to more modern times, Brenner (2018) demonstrated the significance of landforms in all people's lives. The author noted that landforms affect where people choose to live, the foods they can grow, a region's cultural history, societal development, architectural choices, and building development. They even influence where military sites work best to defend an area, as Odihi (1988) observed for choosing the settlement of Ibadan, Nigeria, as a calvary settlement.

What lies beneath the ground also plays a vital role in human development as what lies above it. A related question is whether settlement locations in the study area are needs-driven as environmental endowments afford settlers to meet their biological and socioeconomic needs in line with Ambe (2018) and Agabi, Abang and Animashaun (2010) have observed. The critical q uestion is whether the settlements in the Guyuk Local Government Area and landforms have this association. If this is the case, settlements will manifest some affinity with types of landforms. To what extent are settlements in the study area attracted to natural resources such as water and fertile soils, among others in accordance with Emielu’s (2008) observation that relief, soil, and sources of water are physical conditions influencing locations and patterns of settlements. This observation has been echoed in a recent study of factors of rural settlements in China by Zhang, He, Deng, Ma, Chen, Zhang and Li (2018) who concluded that “the influence of elevation and slopes remained the biggest factor.” (p.12).

The finding of landofrms influencing rural settlements in the study area of Guyuk, LGA, Adamawa State is not a novel one. Many erstwhile studies have made similar conclusions. For example, Ebong and Animashaun (1992) observed concerning the influence of natural conditions on settlements locations and patterns that different relief units are associated with a particular settlement pattern. Plain landform units for instance, is said to favor the concentration of nuclear settlements pattern due to the availability of arable land in one location, thus permits uniform exploitation. On the other hand, undulating and rugged relief is associated with dispersed settlements pattern because arable land occurs in small patches of unequal sizes which discourage nucleated settlement pattern. However, the relationship between landforms and settlement pattern cannot be causal, empirical evidence/observations confirm that specific landforms have peculiar settlement patterns. In view of the foregoing, this study is sets out to analyze the landforms and settlement patterns in Guyuk Local Government Area, Adamawa State, Nigeria.

3. Aim and Objectives of the Study

The aim of the study is to examine the influence of landforms on human settlements in Guyuk Local Government Area, Adamawa State, Nigeria. The study also seeks to address the needs of the settlements. This is to understand what and how the settlements use their locations' physical environment and its endowments. The specific objectives of the study are to: identify landforms of the area and examine the settlement distribution patterns in relation to them. A related objective is to understand how each landform type influences humans' use of the environment.

4. Methodology

Field trips to the study area from 2014-2020 in which the researchers stayed in the area and carried out both physical and human surveys revealed the interesting natural and human geographical features of the study area, Guyuk Local Government Area, Adamawa State, Nigeria. The increasing familiarity with both the natural and human features of the place sparked the curiosity that led to this study.

Shape files of the study area were overlaid on the digital elevation model (DEM) using the Manual Class symbology showing the highest and lowest elevation values within 3 classes i.e., 126 – 211m, 211.1 – 260m and 260.1 – 803m is representing plains, lowlands, and highlands, respectively. The classified raster values were then converted into polygons in UTM projection for area/size calculations. Natural break classification was employed to categorize the output result of the Kernel density into five classes ranging from very low density to very high density. The number of settlements within each of the classification was then counted to derive their corresponding percentages.

5. Results and Discussion

5.1 Classification and Description of Landforms of the Area

The findings of the study show that out of the total land area of 107930.2km^2, 53.24% is plains **(**126 – 211m asl**),** 34.42% is lowlands (211.1 – 260m asl) and12.34% highlands (260.1 – 803m) respectively as shown in Figure 1 and Table 1. The results also show that majority of the settlements are located on plain lands, followed by lowland and with insignificant number sited on highlands. The study showed that the terrain varies within the study area and influence the distribution patterns of settlements in the area. According to the results on Figure 1, there are several types of

settlement density in the study area: very low (1.01%), low (19.19%), medium (34.34%), high (32.32%), and very high (13.13%). The results showed that medium elevations are the likeliest choice of settlement locations in the area, accounting for 34.34% while very low elevations are the least favored, accounting for only 1.01%. The results also showed that the general settlement pattern in the area is cluster as shown on Figure 1.

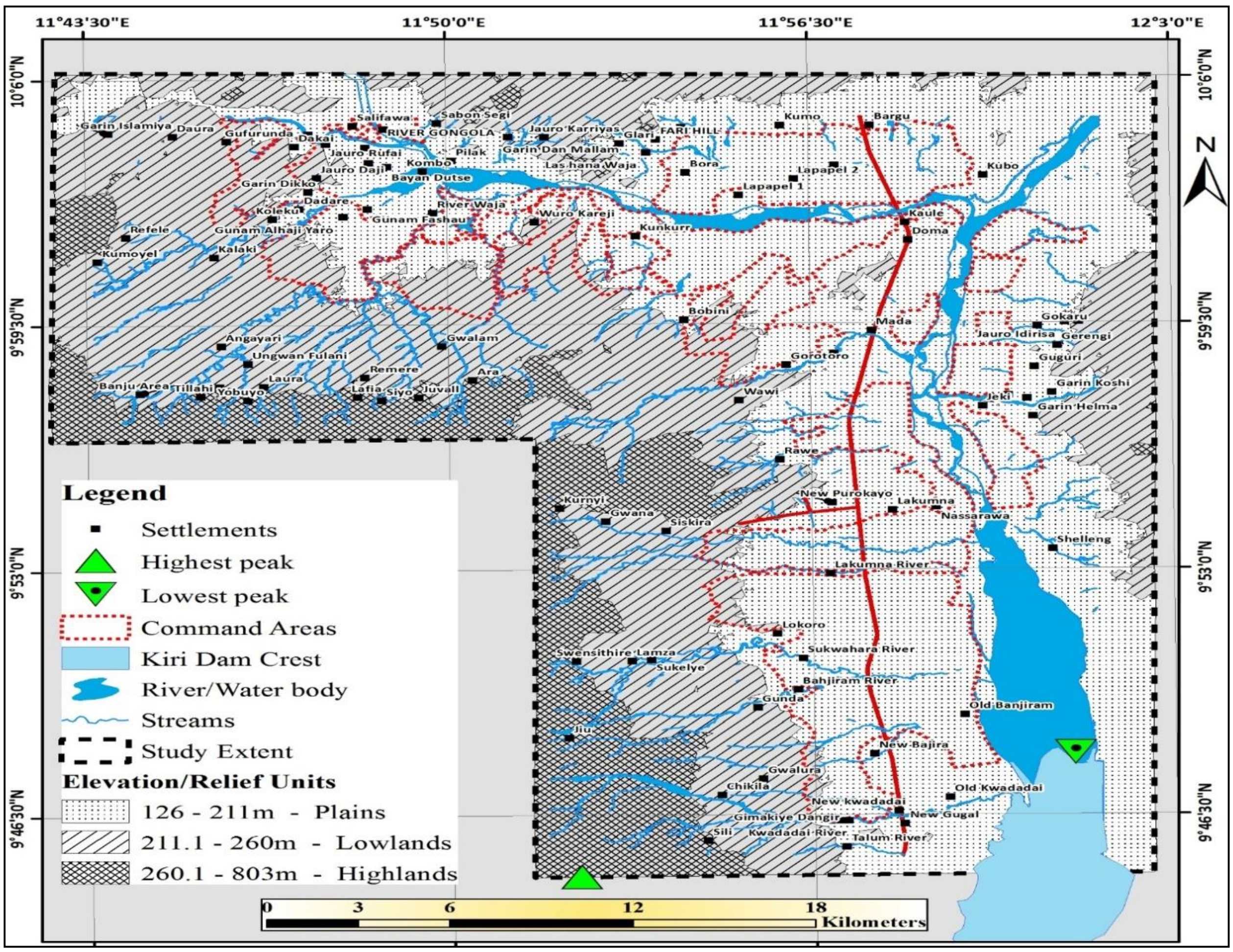

Figure 1: Landform and Relief Units

Source: GIS Analysis, Department of Geography, University of Maiduguri (2021)

Table 1: Landform Classification (Relief Units)

Landforms/Relief units			
Landforms	**Relief range (m asl)**	**Area ha.**	**%**
Plains	126 - 211m	57460.57	53.24

Lowlands	211.1 – 260m	37152.21	34.42
Highlands	260.1 – 803m	13317.43	12.34
		107930.2	**100**

Source: GIS Analysis, 2021

5.2 Description of Settlement Pattern in the Study Area

Based on the results of the Nearest Neighbor Analysis (NNA) carried out, shows that given the z-score of -3.18, there is less than 1% likelihood that this clustered distribution of settlement pattern in the study area could not be attributed to random chance, but was influenced and controlled by the landforms in the area.

This finding implies that natural conditions such as landforms, soil fertility, and water availability are significant determinants of the location of settlement and settlement patterns in the study area. This finding is like that of Agabi *et al.* (2010). They observed that since the rural community depends absolutely on farming for their livelihoods, the community is settling on any form of landform unit and seeks units with fertile soils, adequate water supply, and accessibility. Safety from natural disasters, especially floods, could be an essential location criterion for a rural community.

The settlement pattern in the study area conforms to the findings of a similar research work carried out by Emielu (2008) also supported that dispersal settlement pattern is mostly the reflection of the influence of rugged and mountainous terrain that did not support the nucleation of settlement. For instance, in the eastern part of the study area (see Figure 1), mountainous areas are usually devoid of settlement, while the plains and lowlands are usually nucleated with settlements.

5.3 Description of Settlement Density in the Area

The variables of settlement density are divided into four categories, namely very high density, high density, medium density, and low density as shown in Figure 2, Table 2 and the Appendix 1 and 2. The very-high and high-density settlements were easily identified through imagery because they are close together as shown in Figure 2. Medium density determined from the sparse distance between houses; between one building and another while low density is the settlement location far from each other due to the existence of separators such as farmlands, rivers and hills or mountains.

5.4 Analysis of Settlement Density using Kernel Density tool

The findings on Figure 2 and Table 2 show the settlement density, the level and percentage of settlement density in each village in the area. Out of the total 99 settlement in the area as shown in Table 2, 1, is very low density (1.01%), 19 is low density (19.19%), 34 is medium density (34.34%), 32 is high density (32.23%) and 13 is very high density (13.13%) respectively

Gombe Journal of Geography and Environmental Studies (GOJGES) Vol. 2 N0.1 Jun. 2021, e-ISSN: 2714-321X; p-ISSN: 2714-3201

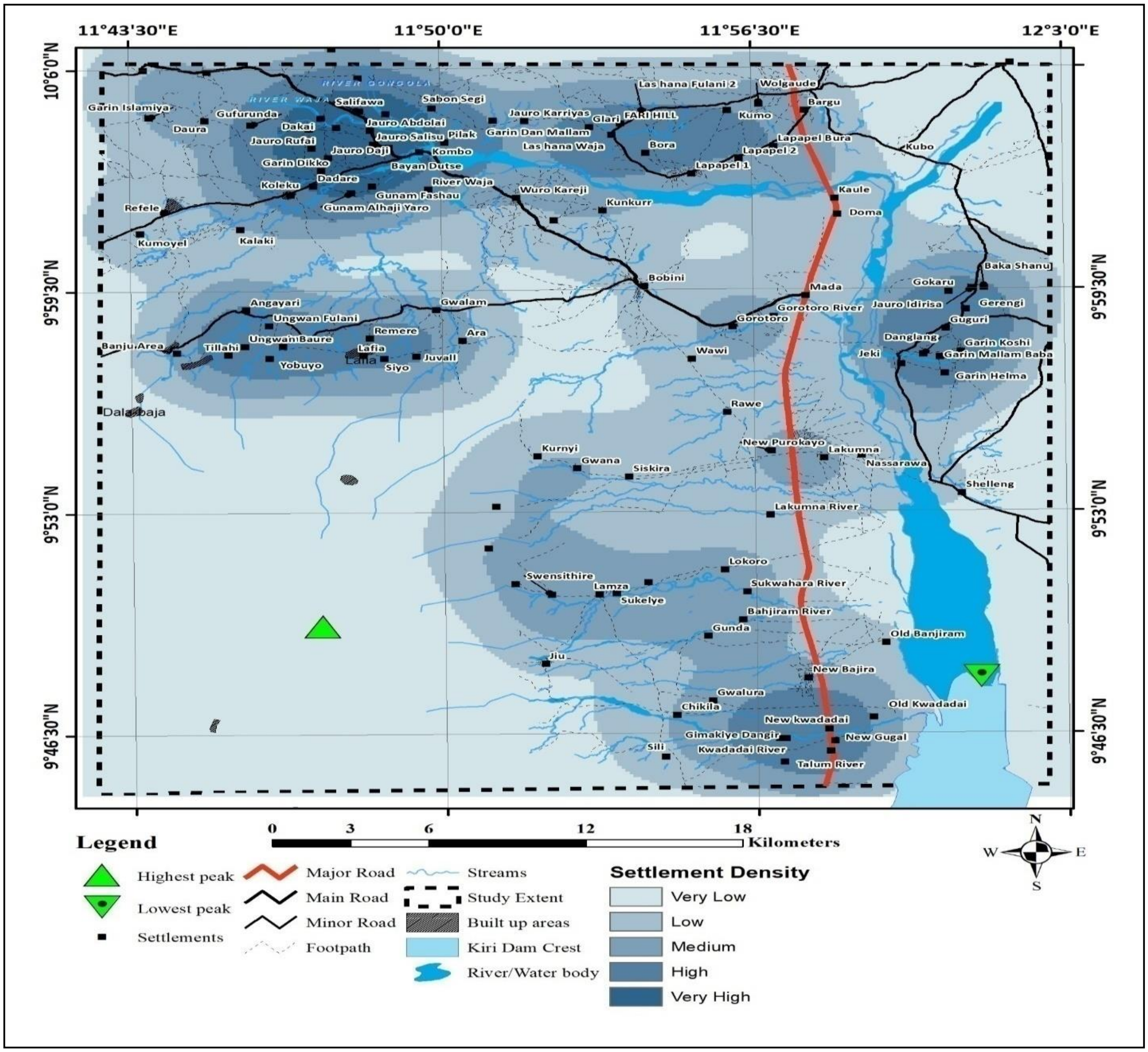

Figure 2: Settlement Density in Guyuk Local Government Area
Source: GIS Analysis, Department of Geography, University of Maiduguri (2021)

Table 2: Settlement Density (Very Low, Low, Medium, High and Very High)

Density	No. of Settlements	Percentage %

Very Low	1	1.01
Low	19	19.19
Medium	34	34.34
High	32	32.32
Very High	13	13.13
Total:	99	100.00

Source: Analysis, 2021

5.5 Needs of the Settlements in the Different Landform Units

The nature and characteristics of the landform units in which settlements in the study area are found both confer certain benefits and impose some problems. For example, settlements in the hilly and mountainous areas afford protection from natural disasters and external aggression but have water supply and soil fertility problems that make agricultural production and expansion a challenge, especially at the slopes. Settlements in the plains are endowed with ample water supply sources and fertile soils but suffer from poor drainage and floods and now trespass from external aggressors.

5.6 Conclusion

On the basis of the findings of this study, it can be concluded that the settlement pattern in the Guyuk is the direct reflection of the influencing factors in residential site selection which include plain (126 – 211m) flat topography that implies a good accessibility, lowland (211.1 – 260m), and highlands (260.1 – 803m) for safety from natural disasters especially floods and soil fertility and abundant water supply that defines land carrying capacity in sustaining their agricultural livelihood in the study area.

5.7 Recommendations

From the results of the study, the following recommendations were made:

i. The lowland area (211.1 – 260m) provides the people with source of domestic water supply and fertile soil for agriculture as source of their livelihoods in the area. Thus, the government and other nongovernmental organizations (NGOs) should support the residents with farm inputs to boost their agricultural activities in the area.

ii. The highlands (260.1 – 803m) surrounding the settlements that protect the residents from natural disasters especially floods, should be provided with good drainage system by the government to facilitate easy flow of water in the area.

References

Agabi, J. A.; Abang, S. O., and Animashaun, I. A. (2010). Nigerian Environment. Lagos: Macmillan & NCF.

Akpabio, M.E. (2012).The reality and tough choices about water and sanitation in Nigeria's coastal settlements: a preliminary discussion. *Nordic Journal of African Studies***21**(4): 164-182.

Ambe, B.A., Imoke, M.J. and Oba, D. (2018). Determinants of Rural Settlement Patterns and Impacts on the Environments of Some Settlements of Cross River State, Nigeria. *Journal of Environmental and Tourism Education (JETE)*1(1): 1-14.

Bishop, C. (2006). *Pattern Recognition and Machine Learning.* Berlin: Springer

Bonnier, A., Weiberg, E. and Finne, M. (2019). Examing Land-Use through GIS-Based Kernel Density Estimation:A Reexamination of Legacy Data from the Berbati-Limnes Survey. *Journal of Field Archeology* (**44**): 70-83. Doi: 10.1080/00934690.2019.1570481.

Brenner, L. (2018). How Do Landforms Affect Humans? https://sciencing.com/do- landforms- affect-humans-8611414.html. Accessed 11 February 2021.

Clark, P.J. and Evans, F.C. (1954).Distance to Nearest Neighbor as a Measure of Spatial Relationships in Populations. *Ecology* (**35**): 445-453.

Cox, T. F. (1981, Reflexive Nearest Nghbours. Biometrics (**37**): 367-369.

Cooke, R.U. and Doornkamp, J.C. (1974). *Geomorphology in Environmental Management.* London: Clarendom Press.

Ebong, M. O. and Animashaun, I. A. (1992). A planning perspective in rural settlements. Uyo: K. W. Publications.

Emielu, S.A. (2008). Senior Secondary Geography:Geographical Bureau Ilorin

Goudie, A. (2016). Quantification of rock control in geomorphology. Earth-Science Review, 159: 374-387.

Gorum, T., Gonencgil B., Gokceoglu, C., and Nefeslioglu, H.A. (2008). Implementation of Reconstructed Geomorphologic Units in Landslide Susceptibility Mapping: The Melen Gorge (NW Turkey). *Natural Hazards, 46, 323–351.*

Hugget, R.J. and Cheesman, J. (2002). *Topography and the Environment.*New York:Pearson Education.

Huggett, R.J. (2011). *Fundamentals of Geomorphology*, Third Edition. New York: Routledge, Taylor and Francis Group.

James, O.O. and Olatubosun, O., Olatunde, A.,Anyakora, C. and Christopher, K. (2014). Occurrence of Selected Veterinary Pharmaceuticals in Water from a Fish pond Settlement in Ogun State, Nigeria. *International Journal of Environmental Monitoring and Analysis* **2**(4): 226-230. Doi: 10.11648/j.ijema.201402204.16

Matay, L., Guo, X. Tian, Y., Wang, Y., and Chen, M. (2017). Micro-Study of the Evolution of Rural Settlement Patterns and Their Association with Water and Land Resources: A Case Study of Shandan County, China. *Sustainability* (**9**):1-18.Doi:10.3390/su9122277

Martin, G.J. (2005). *All Possible Worlds: A History of Geographical Ideas* Fourth Edition. Cambridge: Oxford University Press.

Odihi, J.O. (1988). Ibadan Urban Floods: Nature Pleads, "Not Guilty" .(Award- wining Paper, Willard Miller Award, Department of Geography, (Graduate Category), the Pennylvania State, Univerity, University Park, PA, USA)

Pan, Y, Dang, J. and Shi, Y. (2020). Comparative Analysis of Traditional Settlement Landscape of Leizhou Peninsula Under the Difference of topography and Landform. *IOP Conference Series Earth and Environmental Science* (580) 012083

Panizza, M. (1986). *Environmental Geomorphology*. Amsterdam: Elsevier.

Sheppard, E. (2011). Geography, Nature and the Question of Development. *Dialogue in Human Geography* **1**:46-75.

Thornbury, W.D. (1958). *Principles of Geomorphology*. New York: John Wiley and Sons.

Verstappen, H.Th. and van Zuidam, R.A. (2014). *ITC System of Geomorphological Survey*. Enchede, the Netherlands: ITC Texbook of Photo Interpretation,Vol. II.

Van Zuidam, R.A. and Cancelado, F.I. (1979). *Terrain Analysis and Classification Using Aerial Photographs, ITC Textbook of Photo-Interpretation, Vol. VII,* Enschede, and the Netherlands: International Institute for Aerial Survey and Earth Science (ITC).

Van Zuidam, R.A. and Cancelado, F.I. (1979). *Terrain Analysis and Classification Using Aerial Photographs, ITC Textbook of Photo-Interpretation, Vol. VII,* Enschede, and the Netherlands: International Institute for Aerial Survey and Earth Science (ITC).

Xi, C-B., Qian, T-L., Chi, Y., Chen, J. and Wang, J-C. (2018). Relationship Between Settlements and Topographical Factors: An Example from Sichuan Province, China. *Journal of Mountain Science* (**15**), 2043-254.

Zhang, X., He, J., Deng, Z., Ma, J., Cheng, G., Zhang, M. and Li, D. (2018).Comparative Changes of Influence Factors of Rural Residential Areas Based on Spatial Econometric Regression Model: A Case Study of Lisham Township, Hubei Province, China. *Sustainability* 2018, 10, 3403. Doi: 10.3390/su10103403, Pp.1-14.

Appendix 1

Table 3: Distribution of Settlement Pattern using Nearest Neighbor Analysis

FID	from	To	NEAR_DIST(meters)	NEAR_ANGLE (degree)
1	Kalaki	Koleku	1006.82	30.22
2	Koleku	Dadare	890.36	70.35
3	GarinIslamiya	Daura	1792.71	-7.63
4	Daura	Gufurunda	1792.71	172.37
5	Gufurunda	Daura	1792.71	-7.63
6	JauroAbdolai	JauroSalisu	624.32	-15.19
7	JauroSalisu	Bayan Dutse	624.32	164.81
8	Bayan Dutse	JauroSalisu	624.32	-15.19
9	Kombo	Pilak	1078.04	-151.30
10	Pilak	Kombo	1078.04	28.70
11	Garin Dan Mallam	JauroKarriyas	1207.86	179.05
12	JauroKarriyas	Garin Dan Mallam	1207.86	-0.95
13	Glari	Las hanaWaja	697.45	63.17
14	Kumo	Wolgaude	1241.59	-163.67
15	Wolgaude	Kumo	1241.59	16.33
16	Bargu	Wolgaude	1241.59	-163.67
17	Kubo	Bargu	1775.99	169.25
18	Kaule	Doma	870.71	96.45
19	Doma	Kaule	870.71	-83.55
20	Lapapel 2	Lapapel Bura	1493.57	-153.46
21	Lapapel Bura	Lapapel 2	1493.57	26.54
22	Lapapel 1	Lapapel 2	1493.57	26.54
23	Gora	Las hanaWaja	697.45	63.17
24	Kunkurr	HawaUku	1881.68	140.19
25	WuroKareji	Hawa Uku	1881.68	140.19
26	GunamFashau	Gunam Alhaji Yaro	889.34	25.09
27	Gunam Alhaji Yaro	GunamFashau	889.34	-154.91

28	Dadare	GarinDikko	733.79	67.94
29	GarinDikko	JauroDaji	733.79	-112.06
30	JauroDaji	GarinDikko	733.79	67.94
31	Refele	Kumoyel	1499.97	51.93
32	Kumoyel	Refele	1499.97	-128.07
33	Angayari	Ungwan Fulani	1215.53	136.07
34	Lafia	Siyo	821.01	168.40
35	Bobini	Gorotoro	1670.98	19.88
36	Gorotoro	Gorotoro River	1666.39	42.76
37	Ara	Gwalam	1936.85	-58.40
38	Remere	Lafia	821.01	-11.60
39	Siyo	Lafia	821.01	-11.60
40	Juvall	Siyo	821.01	168.40
41	Laura	Yobuyo	838.67	51.67
42	UngwanBaure	Tillahi	775.55	35.79
43	Tillahi	UngwanBaure	775.55	-144.21
44	Yobuyo	Laura	838.67	-128.33
45	Banju Area	Tillahi	775.55	35.79
46	Ungwan Fulani	Angayari	1215.53	-43.93
47	Shelleng	Nassarawa	1439.61	-173.57
48	Nassarawa	Lakumna	1439.61	6.43
49	Lakumna	Nassarawa	1439.61	-173.57
50	New Purokayo	Lakumna	1439.61	6.43
51	Rawe	New Purokayo	2033.09	-10.64
52	Sukelye	Lamza	651.62	5.60
53	Lamza	Sukelye	651.62	-174.40
54	Swensithire	Walu	1515.30	-22.57
55	Gunda	Banjiram River	1522.37	83.97
56	Banjiram River	Sukwahara River	1466.94	125.06
57	New Bajira	New kwadadai	673.12	-71.46
58	New kwadadai	New Gugu	562.84	-106.55
59	New Gugu	Gugu	562.84	73.45
60	GimakiyeDangir	Kwadadai River	242.56	-1.40
61	Old Kwadadai	New kwadadai	673.12	-71.46
62	Sili	Chikila	1578.38	29.69
63	Gwalura	Chikila	1578.38	29.69
64	Chikila	Gwalura	1578.38	-150.31
65	Jiu	Swensithire	1515.30	157.43
66	Old Banjiram	New Bajira	2875.64	-73.93
67	Siskira	Gwana	1651.92	157.21
68	Gwana	Kurnyi	1651.92	-22.79

69	Kurnyi	Gwana	1651.92	157.21
70	Sukwahara River	Lokoro	1466.94	-54.94
71	Wawi	Gorotoro	1670.98	19.88
72	Jeki	Danglang	648.63	-12.84
73	Danglang	Garin Mallam Baba	648.63	167.16
74	Garin Mallam Baba	Danglang	648.63	-12.84
75	GarinKoshi	Garin Mallam Baba	648.63	167.16
76	Guguri	Kerengi	1152.10	124.55
77	Kerengi	Gokaru	915.16	12.60
78	Gokaru	JauroIdirisa	462.36	2.47
79	Baka Shanu	JauroIdirisa	462.36	2.47
80	JauroIdirisa	Baka Shanu	462.36	-177.53
81	Gwalam	Ara	1936.85	121.60
82	GarinHelma	Garin Mallam Baba	648.63	167.16
83	HawaUku	WuroKareji	1881.68	-39.81
84	Sabon Sara	Kurkude	1775.20	-88.13
85	Kurkude	Salifawa	1015.88	-8.42
86	JauroGotel	Bashere	2437.38	-2.29
87	Bashere	JauroGotel	2437.38	177.71
88	Balarabe	Falu	2179.00	-62.00
89	Falu	Walu	1515.30	-22.57
90	Walu	Swensithire	1515.30	157.43
91	Kawa	Sukelye	651.62	-174.40
92	Gugu	New Gugu	562.84	-106.55

Source: Fieldwork, 2021

Appendix 2

Table 4: Very Low (1) and Low Settlement Density (14)

Object ID	Settlements	Density

1	Kubo	Very Low
2	Balarabe	Low
3	Bashere	Low
4	Bobini	Low
5	Doma	Low
6	HawaUku	Low
7	Jiu	Low
8	Kaule	Low
9	Kumoyel	Low
10	Kurnyi	Low
11	Mada	Low
12	Nassarawa	Low
13	Old Banjiram	Low
14	Rawe	Low
15	Refele	Low
16	Shelleng	Low
17	Sili	Low
18	Siskira	Low
19	Wawi	Low

Source: Fieldwork, 2021

Appendix 3

Table 5: Medium Settlement Density (34)

Object ID	Settlements	Density
1	Ara	Medium
2	Banju Area	Medium
3	Bargu	Medium
4	Chikila	Medium
5	Daura	Medium
6	Falu	Medium
7	Garin Dan Mallam	Medium
8	GarinIslamiya	Medium
9	Gorotoro	Medium
10	Gunda	Medium
11	Gwalam	Medium
12	Gwalura	Medium
13	Gwana	Medium
14	JauroGotel	Medium
15	JauroKarriyas	Medium
16	Kalaki	Medium
17	Kawa	Medium
18	Kumo	Medium
19	Kunkurr	Medium
20	Lakumna	Medium
21	Lamza	Medium
22	Lapapel 1	Medium
23	Lapapel 2	Medium
24	Lapapel Bura	Medium
25	Lokoro	Medium
26	New Bajira	Medium
27	New Purokayo	Medium
28	Old Kwadadai	Medium
29	Sabon Sara	Medium
30	Sukelye	Medium
31	Swensithire	Medium

32	Walu	Medium
33	Wolgaude	Medium
34	WuroKareji	Medium

Source: Fieldwork, 2021

Appendix 4

Table 6: High Settlement Density (33)

Object ID	Settlements	Density
1	Angayari	High
2	Baka Shanu	High
3	Danglang	High
4	GarinHelma	High
5	GarinKoshi	High
6	Garin Mallam Baba	High
7	GimakiyeDangir	High
8	Glari	High
9	Gokaru	High
10	Gora	High
11	Gufurunda	High
12	Gugu	High
13	Guguri	High
14	JauroIdirisa	High
15	Jeki	High
16	Juvall	High
17	Kerengi	High
18	Koleku	High
19	Kurkude	High
20	Lafia	High
21	Las hana Fulani 2	High
22	Las hanaWaja	High
23	Laura	High
24	New Gugu	High
25	New kwadadai	High
26	Pilak	High
27	Remere	High
28	Sabon Fegi	High
29	Siyo	High
30	Tillahi	High
31	UngwanBaure	High
32	Ungwan Fulani	High
33	Yobuyo	High

Source: Fieldwork, 2021

Appendix 5

Table 7: Very High Settlement Density (13)

Object ID	Settlements	Density
1	Bayan Dutse	Very High
2	Dadare	Very High

3	Guyuk	Very High
4	Dakai	Very High
5	GarinDikko	Very High
6	Gunam Alhaji Yaro	Very High
7	GunamFashau	Very High
8	JauroAbdolai	Very High
9	JauroDaji	Very High
10	Jauro Rufai	Very High
11	JauroSalisu	Very High
12	Kombo	Very High
13	Salifawa	Very High

Source: Fieldwork, 2021