# GIS Approach in Assessing Seasonal Rainfall Variability in Guinea Savanna Part of Nigeria

**Ayansina Ayanlade and Odeyemi T. Odekunle, Nigeria**

**Key words**: rainfall spatiotemporal variation, GIS technique

## SUMMARY

This study aimed at using Geographical Information systems (GIS) Kriging interpolation technique to examine and map the spatiotemporal variation in rainfall in Guinea Savanna of Nigeria. Rainfall data, for the periods between 1970 and 2000, were collected from the archives of the Nigerian Meteorological Services, Oshodi Lagos. In this study, rainfall is considered as the primary and input for crop yield. It was observed that the most important climatic element is rainfall; particularly inter-annual variation and the spatiotemporal distribution of rainfall. Three spatial interpolation methods were chosen for this research work: Inverse Distance Weighting (IDW) method and the Spline (completely regularized) as the determinist methods; and Ordinary Kriging as the stochastic methods. In order to analyze the interpolation quality, an evaluation by cross validation has been carried out. Ordinary Kriging method was discovered suitable for this study because it allows the sharpest interpolation rainfall data and is the most representative. Therefore, it was found out that rainfall varies both in time and space. These anomalies (such as decline in annual rainfall, change in the peak and retreat of rainfall and false start of rainfall) are detrimental to crop germination and yield, resulting in little or no harvest at the end of the season.

# GIS Approach in Assessing Seasonal Rainfall Variability in Guinea Savanna Part of Nigeria

**Ayansina Ayanlade and Odeyemi T. Odekunle, Nigeria**

## 1. INTRODUCTION

Intra-annual rainfall variability refers to the distribution of rainfall within a year (Obasi, 2003). In the last decade, inter-annual rainfall variations are causes of great stress to the farming activities, crop production and crop yield in the Guinea Savanna of Nigeria (Adejuwon, 2004). Previous studies have examined inter-annual rainfall variability in Nigeria and other part of West Africa (Awosika et al, 1994; FAO, 2001; Obasi, 2003; Adejuwon, 2004). It affects the various aspects of plant growth and yields; consequently, alter crop productivity. As observed by Awosika et al (1994), the aggregate impact of drought on the economy of Nigeria in 1992 was between 4% and 6% of the GDP. From an analysis of recent rainfall conditions in West Africa, FAO (2001) concluded that a long-term change in rainfall has occurred in the semi-arid and sub-humid zones of West Africa. Although, it may appear that little or nothing could be done to improve variability in rainfall since most of its causes are natural. Thus, there is need for in-depth study and understanding of spatiotemporal rainfall variability. Surprisingly, little systematic research has focused on the distribution patterns of the impacts of rainfall variability in terms of mapping its spatiotemporal impact using the modern GIS techniques such as Kriging interpolation technique. There is need however for an integrated this type of GIS modeling system, to allow agricultural producer as well as policy makers to know the impact of spatial-temporal variation in rainfall on crop yield for better management, productivity and profitability. Therefore, this study aimed at using GIS Kriging interpolation technique to examine and map the spatiotemporal variation in rainfall.

## 2. MATERIALS AND METHODS

The study area lies approximately between longitudes $3^0$ and $14^0$E and latitudes $7^0$ and $10^0$N (see Figure 1). The region is sometimes referred to as the middle belt of Nigeria and has a land extent of about 323,569 square kilometers and a west-east breadth of about 800 km (Buchanan and Pugh, 1955). The climate of the study area is characterized with relatively high temperatures throughout the year. The average annual maximum varies from 35ºC and 31ºC throughout the year while the average annual minimum is between 23ºC and 20ºC.

### 2.1 Data acquisition and Analysis

Rainfall data for 1970 to 2000 were collected from the archives of the Nigerian Meteorological Services, Oshodi Lagos. The rainfall data used in this study consist of monthly and annual rainfall total for the period 1970 to 2000. Several Kriging interpolation methods have been tested for the production of maps in this study:

Cokriging; Universal Kriging; Residual Kriging and ordinary Kriging but, after many attempts and qualitative and quantitative verifications, the last of theses- Ordinary Kriging- was chosen for the map productions. Ordinary Kriging estimates for a rainfall and crop yield distributed variable at any unmonitored location are computed as a weighted average of the known values from a surrounding set of sampled points. Kriging weights are derived from a statistical model of spatial correlation expressed as semivariograms that characterize the spatial dependency and structure in the data. A major strength of the method is that measured spatial dependence in the weather parameter of interest. This process has been carried out on each rain station. For each interpolation test on the three methods, the rainfall observed values Z(x) have been considered, the estimated values of Ž(x), and the errors e(x) = Z(x)–Ž(x). ( e.g Tveito et al, 2000; Tveito and Sch-oner, 2002; Daly et al, 2004; Zbigniew and Danuta, 2005).

## Results and Discussion

Figures 1, 2, 3, and 4 show variation in rainfall for different decade between 1970 and 2000, in Guinea Savanna part of Nigeria. The interpolation silhouette graduated from the Southern to Northern Guinea Savanna and the pattern is typical to all the figures. The decadal interpolation values vary from 550mm to 2987mm. Highest interpolation silhouette was shown during the third decade i.e 1990-1999 (Figure 1) with six interpolation silhouettes while the least was observed during the second decade i.e 1980-1989 (Figure 2) with four interpolation silhouettes The 10-year mean rainfall was highest in the period 1970- 1979 (Figure 1) and least in 1980-1999 (Figure 4). More so, the variation is very significant in Makurdi, Ilorin, and Yola with lower rainfall values for the period of 1980 to 1989 (Figure 2). Generally, rainfall value was increased in 1990s (Figure 3) for all the stations, which signified the peak. In Shaki, Lokoga, Ogoja and Minna rainfall total is observed to be very low within the period of 1980s (Figure 2), and early 1990s (Especially in 1991, 1992 and 1993. The figure also shows abnormal low rainfall in 1980s with amount less than 900mm in almost all the stations. Further more, there is increase in Mokurdi within the period of late 1990s (especially 1996 to2000), which reveals an increase with amount ranging between 1200 and 2200 mm p.a., except in 1980s, which has less than 900mm p.a. In Mokwa, Shaki, Ogoja and Minna, Figure. 3 also show that between 1980 and1989 there is low rainfall of below 700mm p.a while from 1990 to 2000 (Figure 6) rainfall value is as high as 1800mm p.a. The evidence of rainfall variability is observed as a result of the impacts of climate change and variability.

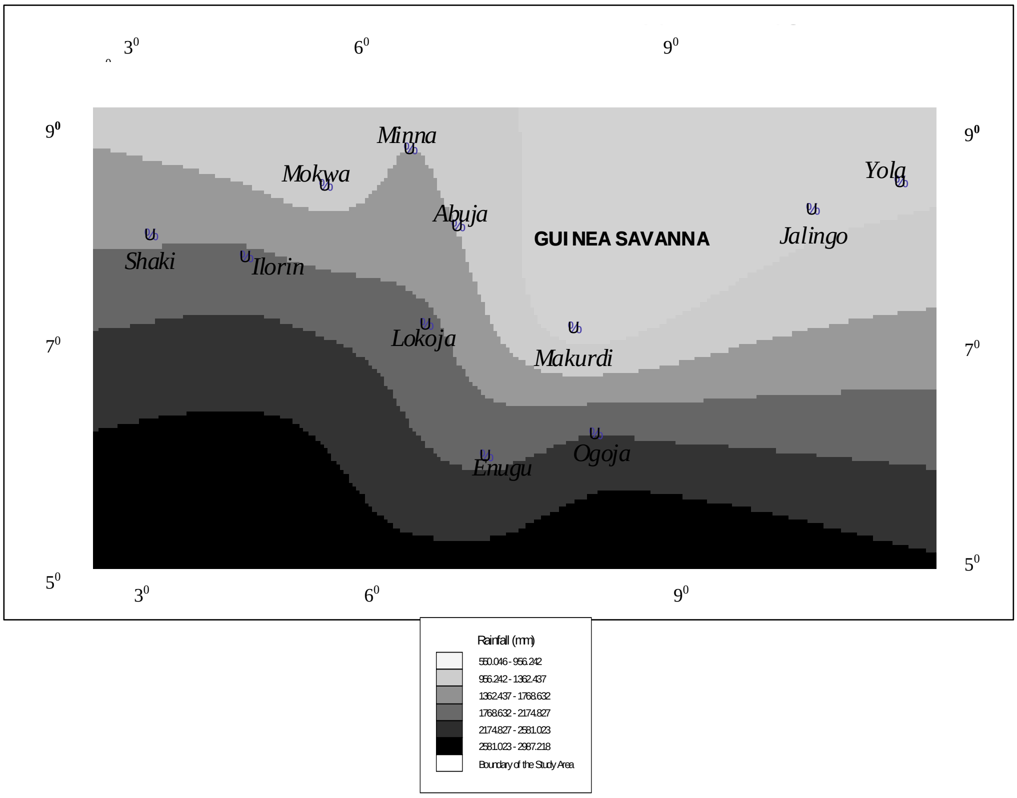


**Figure 1: Rainfall Variability in Guinea Savanna of Nigeria during the first decade (1970-1979)**

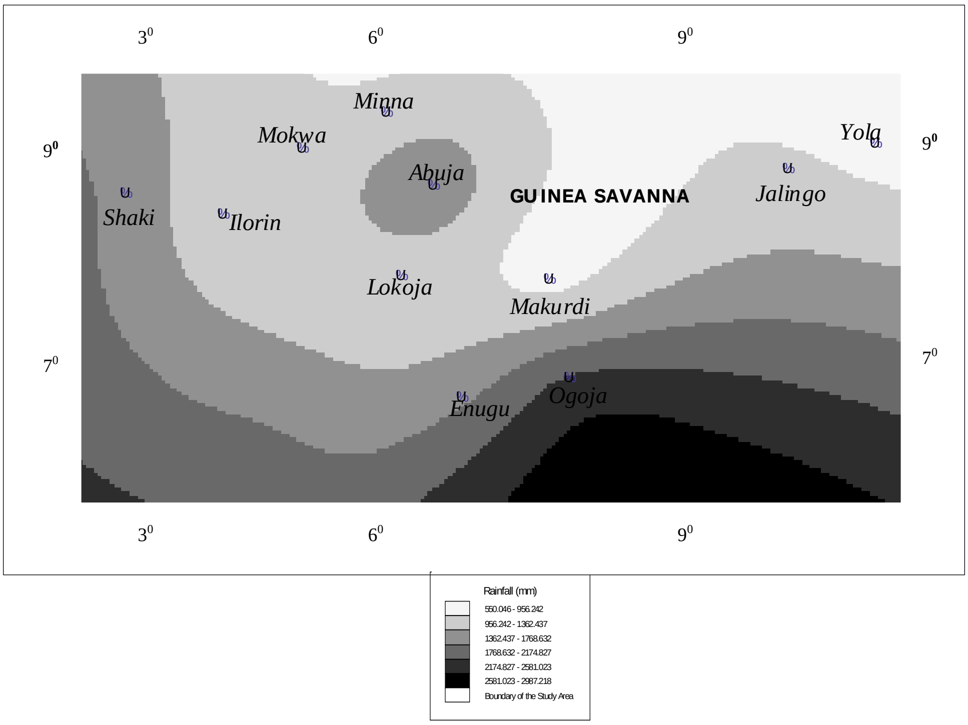


**Figure 2: Rainfall Variability in Guinea Savanna of Nigeria during the second decade (1980-1989)**

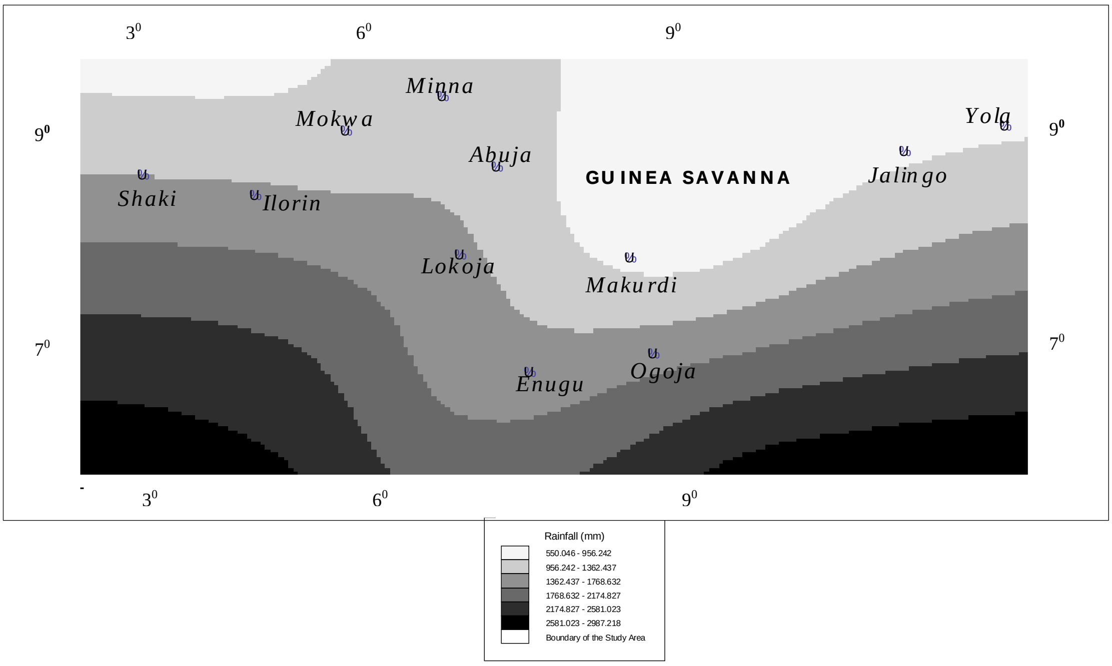


**Figure 3: Rainfall Variability in Guinea Savanna of Nigeria during the third decade (1990-2000)**

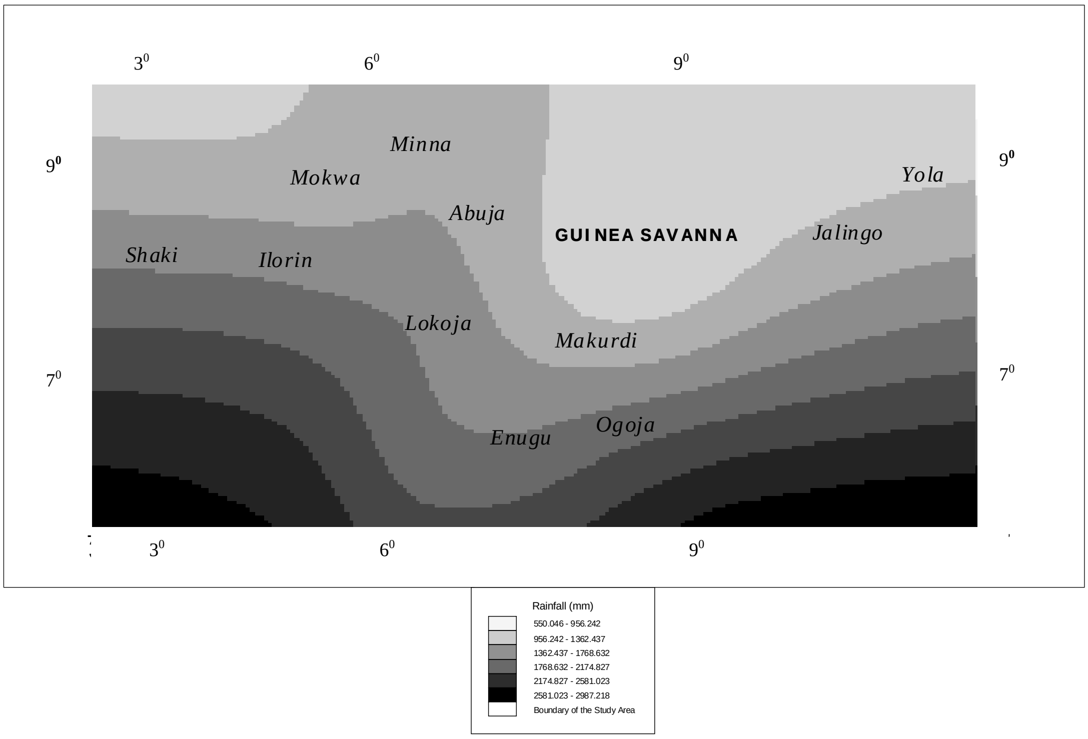


**Figure 4: Mean Variation in Rainfall in Guinea Savanna of Nigeria (1970-2000)**

Observation shows that rainfall variability continues to be on the increase following the increase in climate change and variability as revealed in the analysis. The total rain and distribution of rains at any location determine the frequency and intensity of drought and flooding as well as the length of growing season in that location (Anuforom, 2004). The evidence of droughts and floods are observed as a result of the impacts of climate variability. The impacts of its variability are very significant on crop yield especially in Guinean Savanna Ecological zone of Nigeria where evaporation potential is very high throughout the year.

This study also established that the rainfall variability generally increases with decreasing total rainfall (Ojo and Oni, 2001). It should be noted that rainfall varies inversely with the mean rainfall or that rain become less reliable as one moves toward thee northern Guinean Savanna of Nigeria. Although, both southern and northern Guinean Savanna are similar in that they experience alternate wet and dry seasons of varying intensity at times of high and low sun respectively, it is not very satisfactory from an agricultural point of view to lump them all together. Apart from local differences due to altitude, and presences of small lakes, there are important variations in the number of wet and dry seasons per annum, in the duration of these seasons and in the amount of annual and seasonal rainfall. Results from the study reveal that GIS techniques are exceedingly helpful in assessing rainfall variability. It is easy to calculate and map the mean monthly or seasonal rainfall for specified periods and the deviations from the mean value. It is hard to imagine contemporary rainfall monitoring without GIS applications. GIS tools give very exact and detailed images of analyzed data more effectively than traditional - usually manual techniques. GIS tools also enable the uncomplicated calculation and display of the area under specified rainfall conditions and the display of maps for rainfall assessment purposes.

### 3.1Adaptation option in agriculture for responding to rainfall variability

Crop production has been the most essential sector of the economy in Nigeria, accounting for more than 50% of GDP. In order to minimize the negative impact of climate change/variability (consequential of variation in rainfall), a number of adaptation measures are open to Nigeria. There is no doubt that farmers have the potential to adapt to rainfall variability not only by physiological, but also by social and cultural adaptive measures, such as finding new crop species that would have resistance to fluctuation and reduction in rainfall and agricultural traditions. Owing to these abilities of adaptation, farmers can cultivate throughout the year.

Therefore, it is necessary to study the capacity for adaptation to extreme rainfall events.Adaptation measure include encourage researches in finding new crop species and varieties that would have resistance to fluctuation and reduction in rainfall. It is very important that hybrids of crops that are well acclimated as well as drought and pest resistant be developed. Meteorological Agency need to constantly alert farmers on weather. Farmer should also be encourages to use meteorological forecasts. New irrigation schemes should be introduced to dry land management in Nigeria, which will improve water use efficiency and minimize moisture stress for crops. This is particularly relevant in Guinean Savanna zone where climate variability is expected to result in reduced amount of rainfall for rainfed agriculture. Agroclimatological system should be developed and implemented for accumulation and efficient use of rainfall.

Farmers' responses to seasonal variation in rainfall may take many other forms. Adaptation to extreme rainfall variability may include agro-pastoral management techniques providing for a more efficient use of reduced rainfall. Poverty and hunger resulting from reduction in rainfall may cause migration and degradation, or change of diet. Agricultural production could be increased by doubling the crop areas or by investing in agriculture management and technology. Producing genetically drought-resistant crops would help, as would better water resource management, more efficient storage systems, improved processing methods, better pest management. A number of government policies aimed at enhancing the agriculture “industry” could be instituted (for example, providing all-season access and feeder roads and establishing markets for products, to name a few).

## 4. CONCLUSION

This study aims at examining and mapping the rainfall variability. This study confirmed that GIS Kriging interpolation technique is practically helpful in assessing variation in climate parameters. There are a number of methods available for rainfall variability assessment (Tveito and Sch-oner, 2002), but their application is restricted by theoretical assumptions that must be fulfilled as far as possible. However, well-constructed GIS maps allow presentation at a wide range of spatial scales and virtually unlimited regimens for data processing. At the same time, the construction of digital maps is now possible because of progress in computer science, data availability, exchange and access, and worldwide communication networks. GIS are unique because of their emphasis on providing users with a representation of objects in a cartographically accurate spatial system and on supporting analysis and decision-makings (Burrough, and Rechael 1998). Generally, the main findings in this study are related to its methodology. It is easy to calculate and map the mean monthly or seasonal rainfall for specified periods and the deviations from the mean value. It is hard to imagine contemporary rainfall monitoring without GIS applications. The study concluded that geospatial techniques are powerful tools that should be explored further for realistic assessment of the effects of climate variability on farming activities.

## REFERENCES


Adejuwon, J.O. (2004), "Crop yield Response to Climate Variability in the Sudano-Sahelian Ecological Zones of Nigeria in southwestern Nigeria". *In AIACC Report of Workshop for Africa and Indian Ocean Island*. Dakar, Senegal, pp 15-16.

Adejuwon, J.O. (2005), "Food Crop Production in Nigeria: Present effects of climate Variability". *Climate Research, inter-Research, Germany*.

Anuforom, A. C., (2004), "Rainfall Variability and Its Impact on Yield of Millet and Yam in Nigeria". Presented at the 30th *International Post Graduate Course at the WMO Regional Training Center*, Bet-Dagan, Israel.

Awosika L., Ojo O. and Ajayi T. (1994), "Implications of Climate Change and Sea Level Rise on the Niger Delta, Nigeria" – Phase 1.*A report for the United Nations Environmental Programme* OKAPIS/UNEP, 92 pp.

Ayoade, J.O (1988), "*Introduction to Climatologic for the tropics*". Abiprint and Pak Limited, Ibadan.

Buchanan, K.M and Pugh, J.C (1955), "*Land and People in Nigeria*". University of London Press Ltd, Warwick square, London, E.C.4

Burray P.A (1990), "*Principal of Geographical Information Systems for Land Resources Assessment*". Claredon Press, Oxiford.

Burray P.A and Rachael A.M (1998), "*Principal of Geographical Information Systems*". Oxiford University Press.

FAO. (2001), *Climate Variability and Change: A Challenge for Sustainable Agricultural Production*. Committee on Agriculture. Available at <http:// apps.fao.org/>

IPCC (2000), "Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories". *The Intergovernmental Panel on Climate Change (IPCC) Working Group I,* National GHG Inventories programme, IGES, Hayama, Kanagawa, Japanhe Regional Impacts of Climate Change: An Assessment of Vulnerability.

Kufoniyi, O. (1995), *Spatial Coincidence Modeling, Automated Database Update and Data Consistency in Vector GIS.* (Unpublished Ph.D thesis), Department of surveying and Remote Sensing, wegeningen Agricultural University, The Netherlands ITC Publication 28, pp 203.

Kufoniyi, O. (1998), Aspects of Institutional Framework for the Implementation of GIS in Nigeria. *Workshop paper presented at the 1998 Survey Training Conference*, Bauchi .June 30 – July 2, 1998. pp4.

NEST (2003), "*Climate Change in Nigeria*": A Communication Guide.

Obasi, G.O.P (2003a), *Statement at the International Symposium on Climate Change (ISCC)* Beijing, China, 31 March 2003.

Obasi, G.O.P (2003b), "Regional conference on climate change and food Sustainability" in the 21st century: *Keynote Address*, Lagos, Nigeria, 11 November 2003.

Ojo K. and Oni F. 2001, *"Fundamentals of Physical and Dynamic Climatology"* . SEDEC , pp 381-83.

Tveito, O. E., Forland, E. J., Heino, R., Hanssen-Bauer, I., Alexandersson, H., Dahlstroe, B., Dreb , A.,Kern-Hansen, C., Jonsson, T., Vaarby-Laursen, E. & Westmann, Y. (2000), *"Nordic Temperature Maps"* DNMI KLIMA, No. 9.

Tveito, O. E. & Sch¨ oner, W. (eds.) (2002), "Applications of spatial interpolation of climatological and meteorological elements by the use of Geographical Information Systems (GIS)", KLIMA, No. 28/02, Oslo.

Zbigniew, U. and Danuta, C. (2005), Application of GIS for the development of Climatological Air-temperature Maps: An example for Poland. Meteorol. Appl. Vol., 12 PP 43-50

## BIOGRAPHICAL NOTES

Ayansina Ayanlade is a researcher in the Department of Geography, Obafemi Awolowo University, Ile-Ife, Nigeria. He is a professional in Geographical Information Science (GIS); Remote Sensing, Web GIS, Metadata Creation and Geospatial Analysis. www.oauife.edu.ng/research/spael/new.htm. He mainly specialised in application of Geoinformatics on climatological studies. Over the years, he has actively participated in the IPCC Research Project as a research assistant. He was the winner of SPAEL Postgraduate Research Fellowship Award and Council for the Development of Social Science Research in Africa (CODESRIA) Small Grant Award.

## CONTACTS

Ayansina Ayanlade
Dept. of Geography,
Obafemi Awolowo University,
Ile-Ife,
Nigeria.
Mobile: 2348061245470
teddy_nakato@yahoo.com
sinaayanlade@yahoo.co.uk