



The October 13, 2010 Landslides on The Azenge Mountain in Imande Ukusu, Nkomon District, Kwande Local Government area, Benue State, Nigeria

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Abstract

A swarm of 14 landslides occurred spontaneously within the Azenge Mountain on October 13th, 2010 between the hours of 1-6 am after torrential rains. The landslides were studied using interviews, field observations and laboratory study of the soil samples collected from the major landslide site. Results of the study show that the event that was reported by many local media in Nigeria as volcanic eruption was a spontaneous massive slope movement along the mountainous terrain of Imande Ukusu, Mon village. About 1,123,918 m³ of rocks and debris were moved along the sliding surface for more than 1.5 km to the toe of the mountain within a very few minutes. The size of the materials moved decreases from the top to the toe of the slope which range from 50° at the top to 5° at the toe. These materials range in size from block of rocks of various sizes, soil to mud. The largest boulders moved measured 71.2 m and 88.5 m in size respectively. The rock types in the area include gneisses, granites, basaltic rocks and dolerite dykes which have a general strike of 240° NW with a dip of 038° NE and are highly fractured. The fractures and dip are in the direction of the slope. Laboratory result of the soil samples reflect two types of grain sizes. Those with very high degree of susceptibility to sliding above the sliding surface which plot in the failure zone and those less susceptible from the sliding surface and plot outside the failure zone. Torrential rainfall towards the end of the year was the main triggering mechanism of the landslides. Other causes are attributed to geological, morphological and human factors. The landslides led to the death of 1 person, destruction of vegetation, soil structure and texture, farmlands and remodeling of the geomorphology of the area. It is recommended that human activities along the toe of the hills be reduced and settlements should be sited far away from the hills to avoid further loss of lives in future.

Keywords: Landslide scar, Imande Ukusu, Nkomom District, sliding surface, boulders and debris, susceptible.

Introduction

Landslides are geological phenomenon which occurs as a result of ground movement, rock falls, and failure of unstable slopes, sand and debris flow on slope and can cause a lot of damages with direct and indirect effect on human settlements and physical infrastructure (Renwick et al, 1982). According to Varnes (1978), landslide describes a wide variety of processes that result in the downward and outward movement of slope forming materials including rocks, soil, artificial fills or a combination of them. Landslides are common in areas where slope stability has been compromised.

Several landslides have occurred in Nigeria but many of them are not recorded except when people are killed and/or a good number of properties are destroyed. Literature on landslides in Nigeria is limited to short reports from the Nigeria Geological Survey Agency (NGSA), Ministry of Environment, internet and eye-witness reports that simply make mention of the disaster and casualties (Igbokwe et al., 2008). No thorough investigation regarding the triggering mechanism and extent and nature of the landslides is usually carried out. Description of the various possible causes of the landslides, nature of the rock types and weathered materials affected are also not always reported. Most of the occurrences are not reported due to negligence and lack of appreciation of this natural phenomenon at both States and Federal levels. Landslides have occurred over the time in some parts of Nigeria destroying lives and properties such as in Oshun, Benue, Enugu, Abia, Anambra, Ebonyi and Imo States (fig. 1).

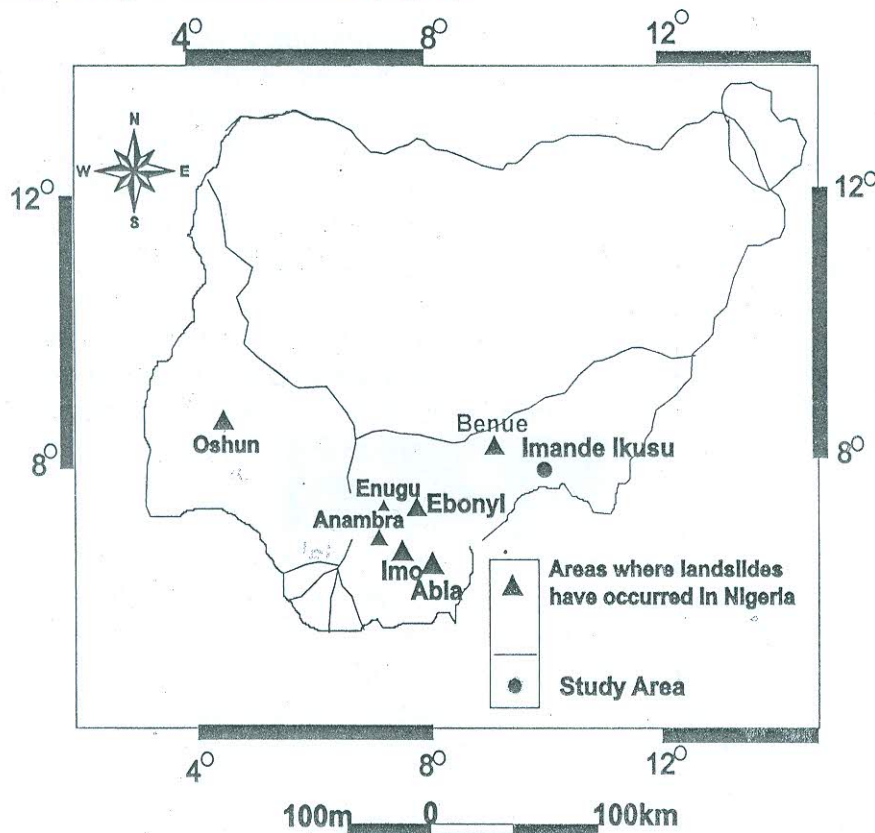


Figure 1: Map of Nigeria showing areas where landslides have occurred (adopted from Igbokwe et al., 2008).

According to Igbokwe et al. (2008), landslides occur in different parts of southern Nigeria due to wide spread impact of gully erosion resulting from annual rainfall and subsequent flooding. The results of their analyses showed that landslides occur mostly as earth movement, and occurred in the Ogbajala hills of Benue State on 3rd September, 1987 after days of consecutive rainfall and subsequent flooding. Field measurement of the landslides showed that the slip originated on the upper one third of the hill at depth of 1.37m and extended uniformly to about 50m down slope before turning into a flow (Okagbue, 2003). Similarly, in September, 1997, two separate rain-induced complex landslides occurred along the slope of the Akovolwo mountains near Jato-Aka in Kwande Local Government area of Benue State. The two movements developed on bedrock slopes covered by a thin cover of colluviums and residium not more than 1.5 to 2m deep.



On Thursday, 9th November, 2010, The Sun Newspaper reported the occurrence of volcanic eruption in Benue State supporting its report with a photo of smoke, fire and ash that normally accompany volcanic eruptions. The Guardian Newspaper also reported this on Thursday, November 9th, 2010 edition of the occurrence of a volcanic eruption in Benue State. It was as a result of these reports that led to this study in Imande Ukusu, Mon village in Nkomon district, Kwande Local Government Area of Benue State and it was discovered that what was widely reported by the media was not really a volcanic eruption but a series of landslides.

This work is aim at studying the causes, degree and extent of the landslides that occurred in the study area on the 13th of October, 2010 as well as proving remediation. Also, identification of the geology of the affected area, determination of the triggering mechanism of the landslides, effects on people and the environment and mitigation measure are discussed. This will assist to evaluate the disaster and risks associated with landslides and eventually provide guidance for the management of such events in Nigeria and other parts of the world.

Geology and Geography of the study area

General Geology

The geology of Benue State consists of both Precambrian basement complex rocks and Tertiary sedimentary rocks. However, much part of the state falls within Benue Trough during the tertiary and possible the inter-glacial periods of the quaternary glaciations, the Benue and Niger valleys, otherwise known as the Benue Trough, were transgressed by water from the Atlantic Ocean. Consequently, marine sediments form the dominant surface geology. The sediments within the trough have undergone varying grades of metamorphism and are underlain at variable depth by basement complex rocks (Obaje, 2009). The sediments are dominantly sandstones with some shales, siltstones and limestone. Basement Complex rocks occur at higher topography further away, especially in Kwande (Fig. 2) along the Cameroon-Nigeria boarder. These basement complex rocks comprise of igneous and metamorphic rocks including porphyritic granites, migmatites, diorites, pegmatite and gneisses. Both the Basement Complex and Tertiary sedimentary rocks have been deeply weathered resulting in the formation of regolith and sapprolite tenths to hundredths metres deep (Obaje, 2009).

Local Geology

The study area falls within the Eastern and North-Eastern highlands (Ileoje, 1981). These highlands consist of masses of Basement Complex rocks and plateaux of basaltic rocks within the range of 1800 to 2400 meters high. Imande Ikusu lies within the Cameroon-Nigeria boarder and is characterized by hilly terrain with appreciable local relief where the terrain is characterized by steep slopes and generally rugged topography. River Benue is the main river draining in the area into which smaller rivers like Nkomon, Amile, Aya and Katsina-Ala discharge.

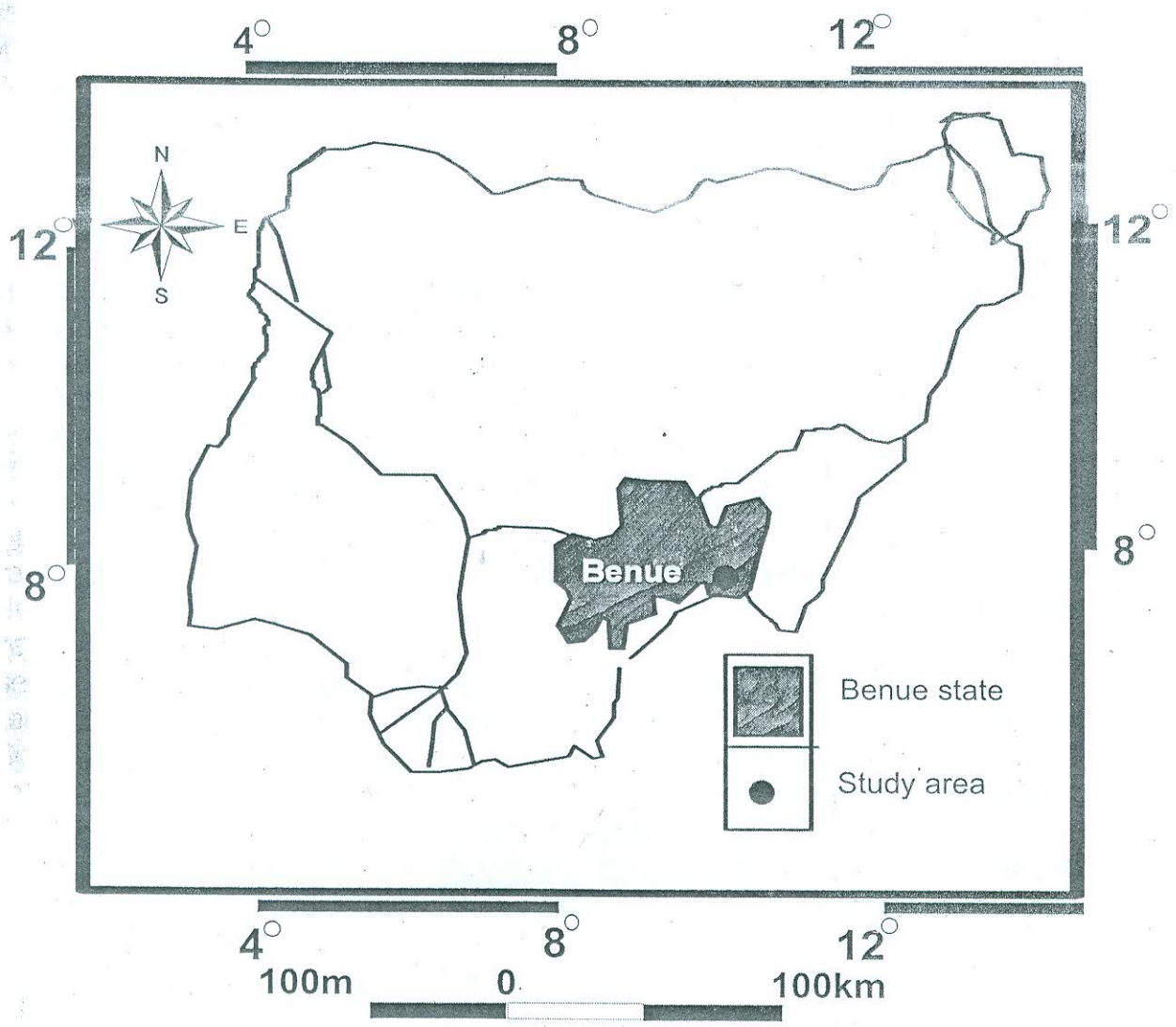


Figure 2: Map of Nigeria showing the study area

Climate and Physiography of the Area

The climate in the area is a tropical sub-humid type characterized by two distinct seasons; the wet and dry seasons. The wet or rainy season lasts for seven months from April while the dry season starts in November and ends in March. The annual rainfall total ranges from 1,200mm to 1500mm. Temperatures in the area are generally very high during the day, especially in March and April. The state capital Makurdi, for examples, records average maximum and minimum daily temperatures of 35°C and 21°C in the wet season and 37°C and 16°C in the dry season. These relatively high humidity and high temperatures produce debilitating weather conditions. The study area lies in the Southern Guinea Savannah scharacterized by grasses and scattered trees which are mainly those of economic value such as locust beans, shear butter, mango and oil palm. However, dense forest occurs around Kwande, Vandeikya and Okpokwu. The forests are typically made up of rain forest trees such as Mahogany, Obeche, Iroko and Afara which are exploited for timber and firewood (www.onlinenigeria.com/links/benueadv.asp?blurb=212).



Materials and Methods

Field Work

Fieldwork was carried out shortly after the event occurred. During the period, information on the landslides was gathered from eye witnesses and the representative of the village head. Information obtained from them includes the number of landslides that occurred along the slopes, the numbers of lives loss, number of farmlands and buildings destroyed. Apart from the eyewitness accounts, archival data on rainfall in mm for the year in question provided another important source of data for this research (Adambe and Ujoh, 2012).

Mapping of the area was carried out to determine the geological and environmental factors that must have caused the landslides and attention was paid on the rock types, fractures and degree of slope and human activities along the slope toe of the hill and types and sizes of the materials moved. The length, width and depth of the landslide scar were also determined so as to calculate the volume of materials moved. The nature and amount of destruction to lives and property were recorded and finally collection of soil samples within the major landslide site for grain size analysis in the laboratory. The soil samples were collected from above, below and away from the landslide surface. Similarly, measurement of landslides scar was taken from the major landslide site out of the 14S that occurred in the area that night. This is because it was at this site that great movement of materials occurred followed by severe destruction, while others were just small tongues of soils rolled along fractured zones without any measurable destruction to the environment.

Laboratory Analysis

The grain size analysis was performed in the Civil Engineering laboratory of Federal University of Technology, Minna, Nigeria. Grain size analysis was carried out on fourteen soil samples collected from the field. About 30g of each sample was air-dried and ground to very fine particles using a ceramic crucible and pestle. Sieves with the following aperture sizes were used for the grain size analysis: 2.0mm, 1.18mm, 850 μ m, 600 μ , 425 μ , 300 μ , 150 μ and 75 μ . The stack of sieves was placed on a mechanical sieve shaker, and was vibrated for about ten minutes. The weight of the samples retained in each sieve was subsequently measured in order to ascertain the mass passed, percentage retained and cumulative percentage retained. The result of the grain size analysis was plotted on a grain sizes triangle after Howard et al., (1988) and Telerico et al., (2004) to establish the range of grain sizes that are susceptible to sliding.

Result

Eye Witness Accounts

According to Hange Iordye, the tour guide and the representative of the village head of Imande Ukusu Mon, in Nkomon district, the landslides occurred on the 13th October, 2010 in the morning between the hours of 1am and 6am after a torrential rain that lasted from 4pm on the 12th of October, 2010 to 7am the next day. The sliding was accompanied by loud explosions and vibration that was heard in the surrounding villages within the

district. A total of fourteen landslides occurred along the huge mountain range surrounding the area but only the one that caused most damage to the area was studied (plate 1). According to him, only one person lost his life. He must have been killed by the remaining large boulders that were sliding towards the toe of the hill on his way to the farm around 5 am. No buildings were affected because human settlements were located away from the area where the landslide occurred.

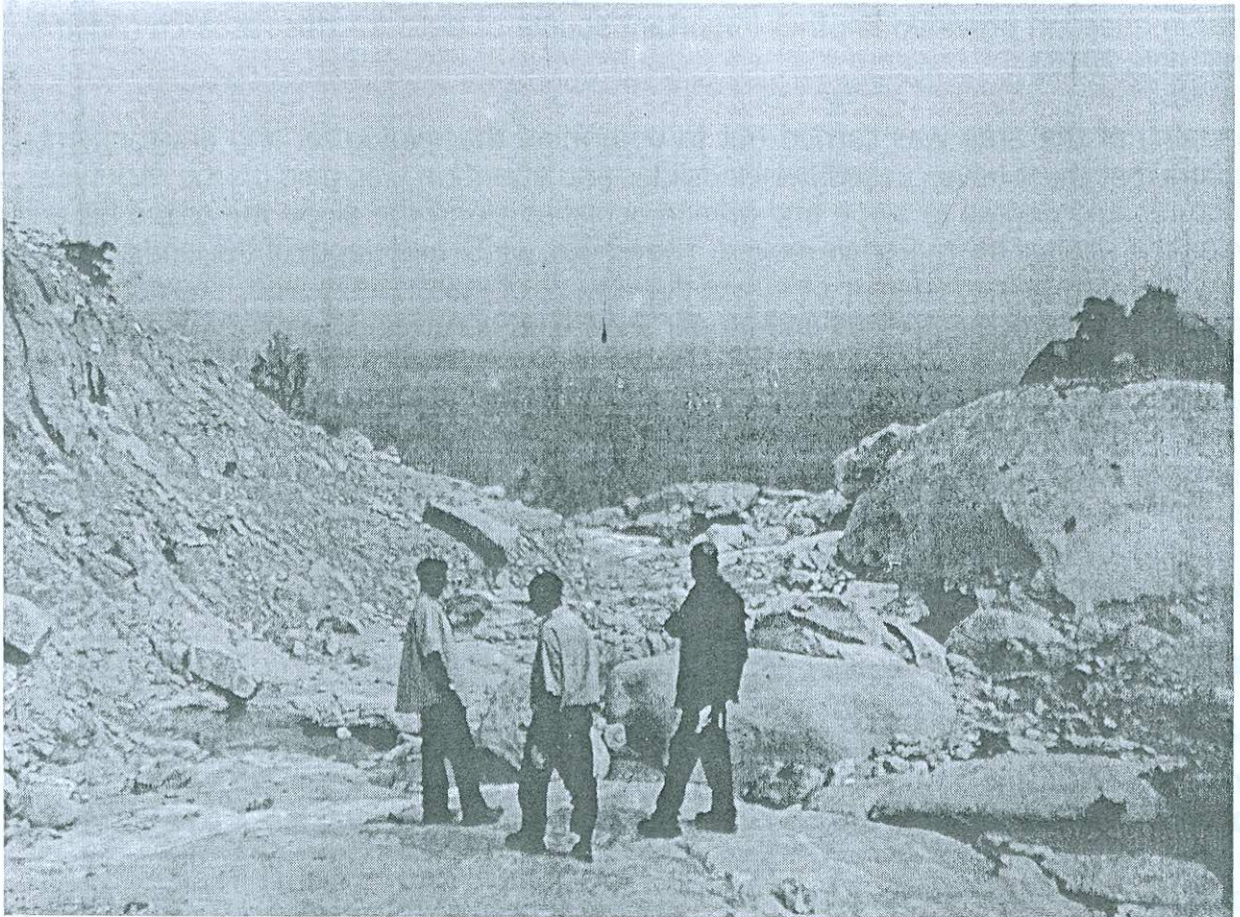


Plate 1: Photograph of major landslide out of the fourteen that occurred in the area

Field Observations

The rock types encountered in the area include gneisses, granites, dolerite dykes and basaltic rocks. Field evidence indicated the existence of granites, gneisses and dolerites lying uncomformably on basaltic rocks. The rocks in the study area have a general strike of 240°NW with a dip of 038°NE and were highly fractured. The deep and penetrating fractures in the rocks must have brought about gradual weathering (plate 2). This resulted in slow but steady decrease in the strength of the materials, thus increasing the likelihood of sliding along slopes with gradients of 50° from the top to 5° at the toe (Plate 3).

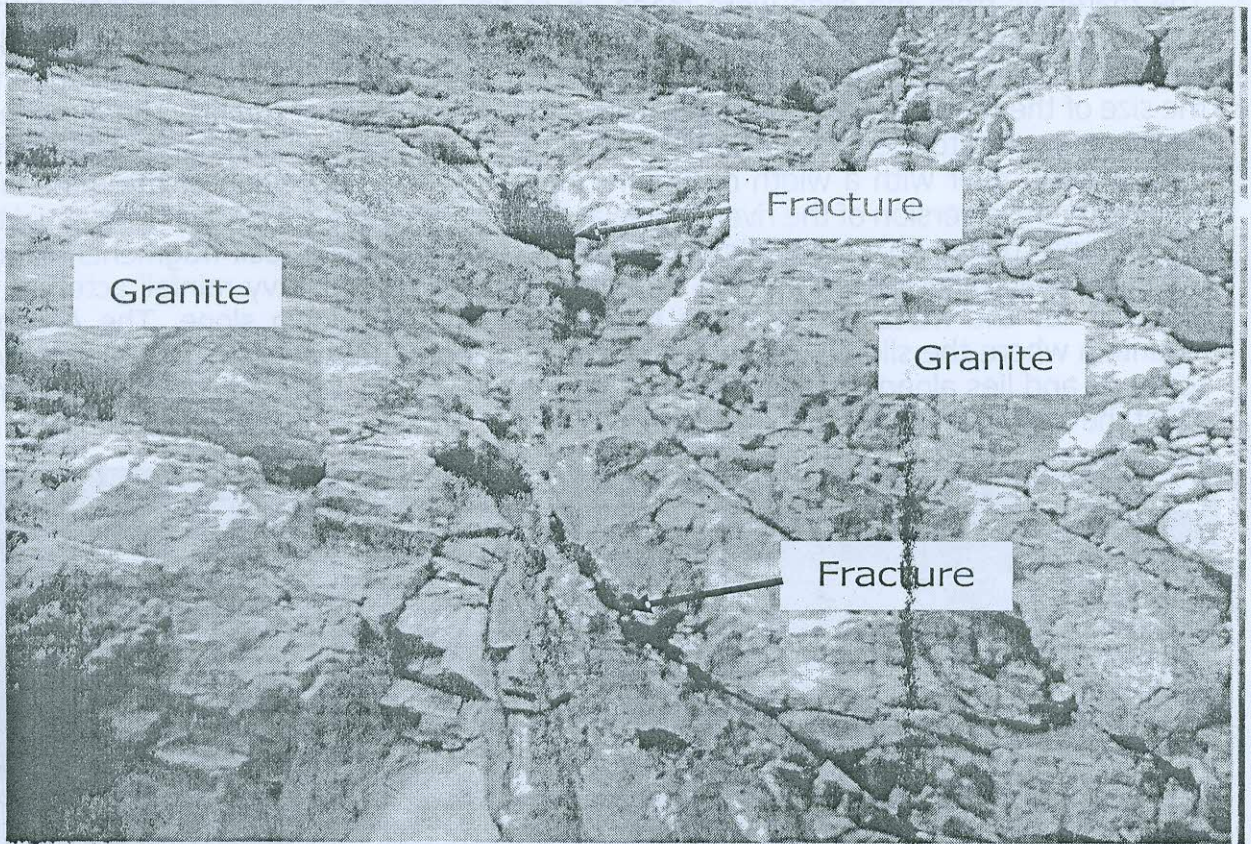


Plate 2: Photograph of fractures that permit water to percolate and cause weathering and weakness of the rock unit

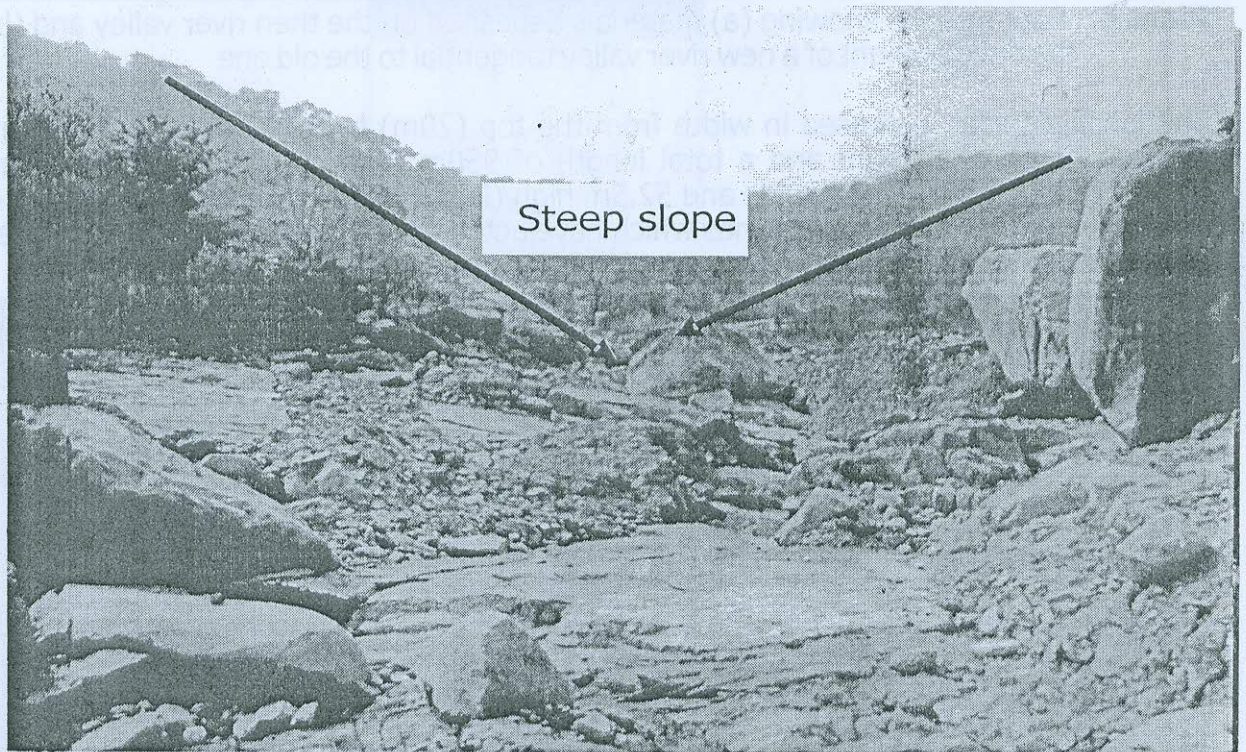


Plate 3: Photograph of steep slopes the facilitated the movement of material down slope

The materials from the slide were made up of fine debris to large fragments of the granitic and gneissic basement complex which has been intruded by dark coloured rocks believed to be volcanic rocks. The materials were deposited along the sliding path and the size of the materials decreases from the top to the bottom of the hill. The materials that were moved to the foot of the hill were deposited in the bed and flood plain of the then existing river with a width of 38.5m (plate 4a). The deposition of the materials resulted in the diversion of the river course and development of a new river tangential to the old one (plates 4b). Materials deposited were mainly small rock fragments, sand, mud and dead plant materials. The saturated soils following heavy rainfall acted as a lubricant for the materials to move rapidly and in mass down slope. The Azenge Mountain where the sliding took place has an elevation of between 950-2100m above sea level and lies along the Nigeria-Cameroon border with slope angles ranging from 25° at the top to 60° at the foot or toe.

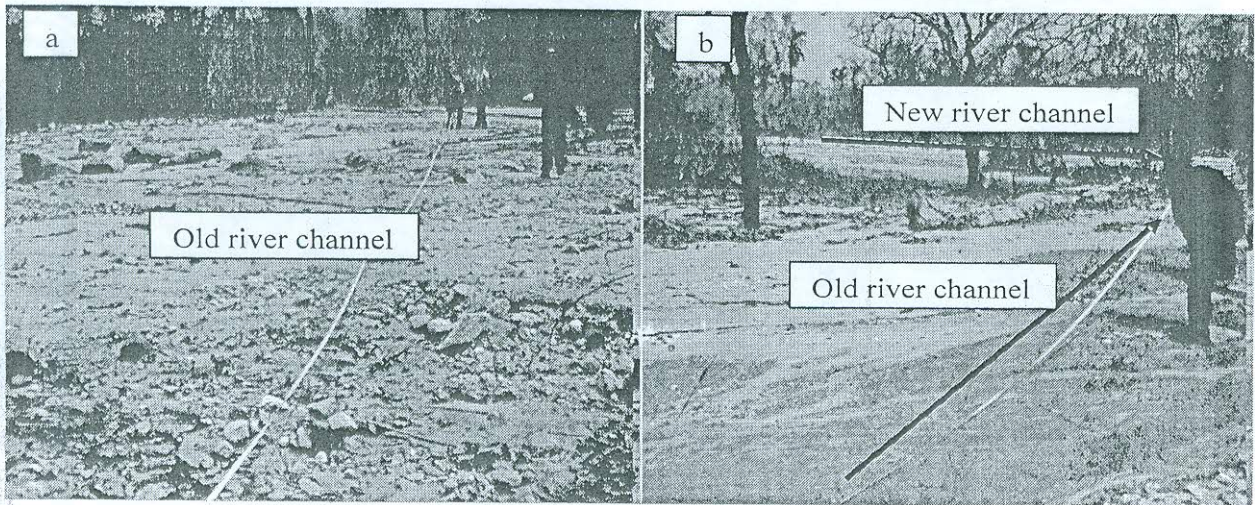


Plate 4: Photographs showing (a) materials deposited on the then river valley and (b) the development of a new river valley tangential to the old one

The landslide scar increased in width from the top (20m) to the base (75m) with an average depth of 58.73m and a total length of 950m. The largest boulders moved measured 15m long, 10.6m wide and 52.5m high (Plate 5a and b). The sites of the 14 slides correspond to old fault planes which have acted as conduits for the flow of water during the rainy seasons.

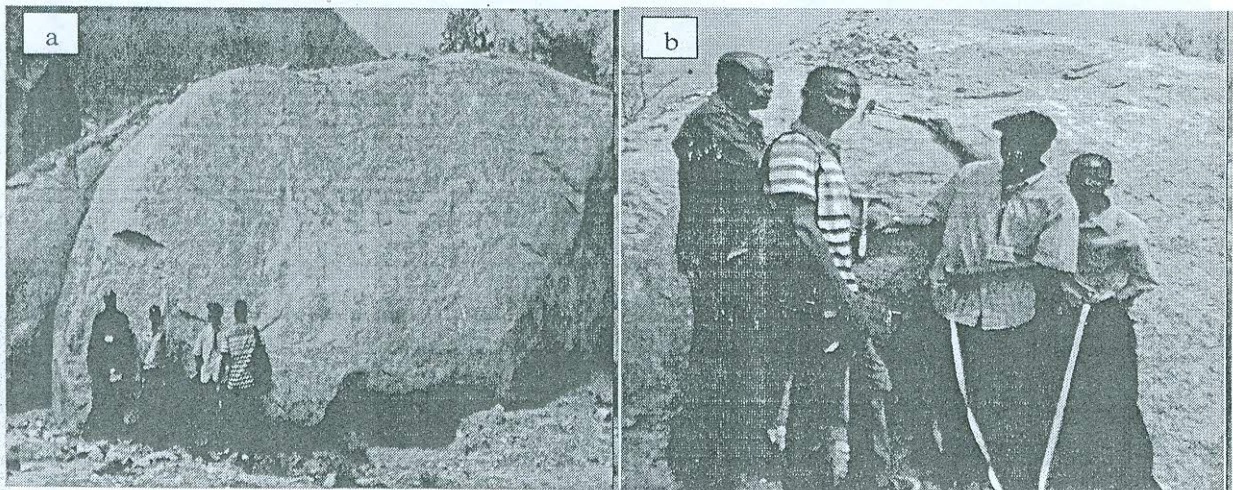


Plate 5: Photographs of boulders moved down slope (a) has a diameter of 71.2 m while (b) has a diameter of 88.5m. Size of materials moved decreases down the slope.

To calculate the volume of materials moved during the landslide, the average width and depth of the landslide scar was determined the volume determined according to this formula (Ayonghe and Ntasin, 2008):

$$V = \frac{1}{6} \pi (D + W + L),$$

Where V = volume of the materials generated from the landslide

n is a constant, 3.142

D= average depth of the landslide scar

W= average width of the landslide scar

L= total length of the landslide scar

Therefore, the volume of materials moved or generated from the landslides,

$$= 0.1667 * 3.142 (58.73 * 38.46 * 950) \text{ m}$$

$$= \mathbf{1,123,918 \text{ m}^3}$$

Human activities like farming and lumbering have been taking place within the area where the sliding occurred. The erosive action of the river and flood waters at the toe or foot of the hill was very visible as small and steep gullies appeared within the area where the landslide occur (plate 6a and b).

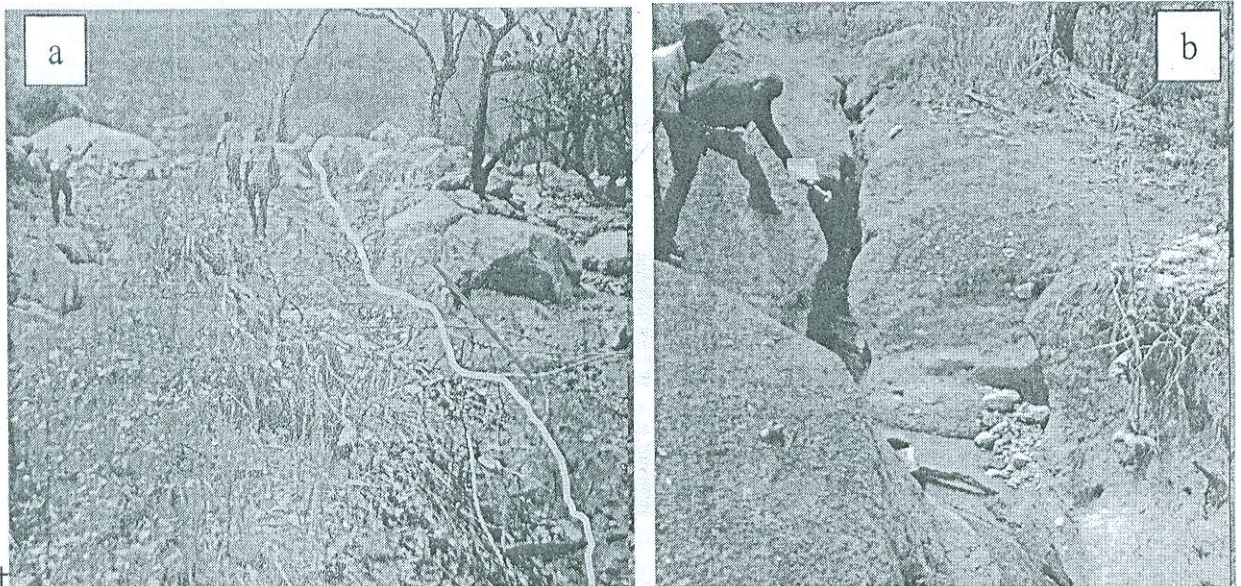


Plate 6: Photograph of gullies produced (a) at the top and (b) at the foot of the hill. Note that the depth and width of the gullies increase from the top to the foot of the hill

Field investigation equally showed that three rice farms, plantain and yam farms of about 200 square km and a large number of palm trees and other economic trees were destroyed (plate 7a and b).

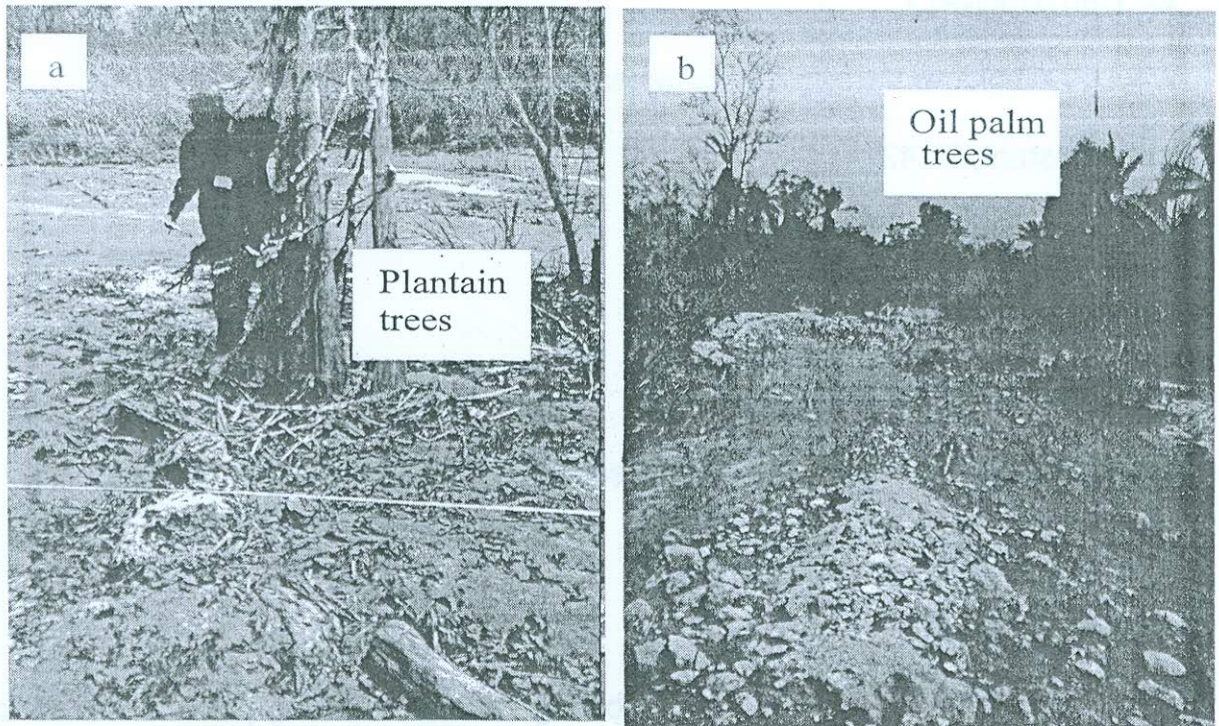


Plate 7: Photograph of (a) plantain and (b) oil palm trees destroyed by the landslide

According to Adamgbe and Ujoh (2012), the annual rainfall for that year was between 1200 and 2000mm. The rainfall pattern for that year indicated two cycles of increasing rainfall that peaked in July and August and October which is usually considered as the last rains. This heavy rain is believed to have triggered the slides.

4.3 Laboratory Results

The results of sieve analysis of the fourteen soil samples collected from the landslides site is presented in table 1 and plotted figures 3. These show that the soil display a wide range of grain sizes including clay, silt and sand fractions. However, most of the samples (1,2,3,5,6,7,8,9,10,11, and 12) are composed of mainly clay sized particles (Table 1). They are interpreted as soils of grain sizes that are mostly susceptible to sliding. These soils combined with water act as lubricant. A plot of these samples on the grain size triangle (Fig.3) reflects soil with very high degree of susceptibility to sliding above the sliding surface. However, four samples (i.e. 4, 7, 13, and 14) that were collected below the sliding and away from the sliding surfaces are mostly made up of sand and are less susceptible from sliding and plot outside the failure zone. These samples tend to be predominant of one grain size fraction that tends to cause instability within the unit (Fig. 3).

Table 1: Summary of results of grain size analysis of the soil samples from the study area

Sample No.	1		2		3		4	
	Wt	%	wt	%	wt	%	wt	%
Clay	61.13	31	78.15	46	60.37	30	0.09	0.1
Silt	76.35	39	62.15	36	77.95	39	18.21	18
Sand	59.1	30	30.95	18	63.15	31	84.11	83
Total	197		171		202		102	
Sample No.	5		6		7		8	
	Wt	%	wt	%	wt	%	wt	%
Clay	60.3	30	33.4	33	0.06	0.1	35.2	18
Silt	78.38	40	40.11	40	16.28	16	97.86	49
Sand	59.8	30	27.1	27	83.59	84	65.95	33
Total	199		101		100		199	
Sample No.	9		10		11		12	
	Wt	%	wt	%	wt	%	wt	%
Clay	47.9	25	33.05	34	60.23	31	55.5	32
Silt	91.59	47	36.8	38	77.17	40	69.1	40
Sand	55.45	28	27.15	28	56.98	29	47.5	28
Total	195		97		194		172	
Sample No.	13		14					
	Wt	%	wt	%				
Clay	9.13	9	10.15	10				
Silt	20.52	20	15.51	15				
Sand	72.01	71	75.65	75				
Total	102		101					

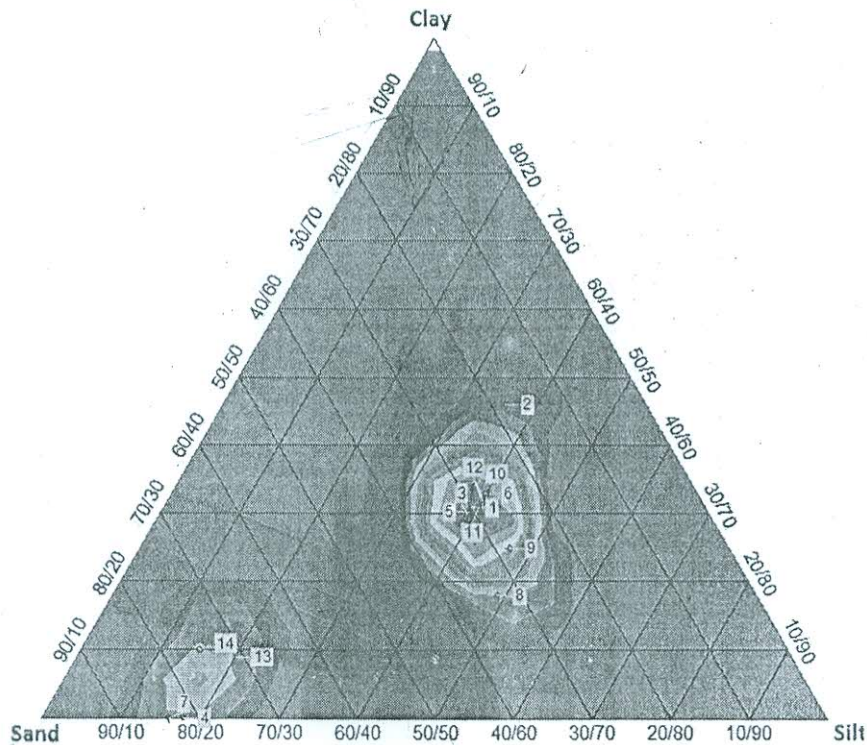


Figure 3: Plots of results of grain size analysis showing two groups of soils based on their susceptibility to sliding (modified from Ayonghe and Ntasin, 2008).



Ayonghe and Ntasin (2008), Telerico et al. (2004) and Howard et al. (1988) carried out similar studies of soil from landslides and used the results to establish the range of soil grain sizes that are most susceptible to sliding and established that soils containing large amount of sand or gravel are less susceptible since their components have a stabilizing influence on the soil mass.

Discussion

The Imande Ukusu, Mon village landslides of 13th November, 2010 must have been caused by several factors that range from geological, morphological to human factors. These causes maybe considered to be factors that made the slope vulnerable to failure. These factors predispose the slope to becoming unstable while the trigger is the single event that finally initiates the landslides. Generally this movement was induced probably because stresses in the slope were altered, by increasing shear stress or decreasing the effective normal stress or by reducing resistance to the movement due to decrease in the shear strength of the materials (Plummer, 2003).

Geological causes

Results from field investigation revealed that geological factors must have been responsible for the Imande Ukusu landslides. These geological factors range from weathering of rocks and soils, to changes in groundwater level and deformation of rocks in the area. The weathering of rock units and soil on the slope of the hills must have resulted to the weakening of the slope, causing the movement of materials downhill. The break down and decomposition of rocks by agents of denudation such as rain, temperature changes, plants and animals must have brought about the slow but steady decrease in material strength associated with the weathering of the rocks when the materials became so weak and failure occurred. Whitten (1972) revealed that the introduction of water into a rock results in the chemical weathering of the rocks. For example, a sedimentary or igneous rock containing feldspar when weathered produce clay minerals which are platy-like and absorb water easily, thus, it swells weakening the bond between individual layers making it easy for the materials above to slide.

It is also suggested that rapid changes in the groundwater level along the slope of the hills triggered the landslides. This might have been as a result of rapid fall in the water level adjacent the slope leaving an artificial high water table that subjects the slope to higher than normal shear stress, leading to potential instability.

The landslides occurred during the second cycle of peak period of rain in the area. It can therefore be reasonable to conclude that rainfall played a significant role in the sliding. It caused an increase in the pore pressure in the soils underlying the slope. As the pore pressure of the slope increased along with a rise in the bulk density of the materials, the shear strength decreased, thus resulting in the slide. According to Igbokwe et al, (2008), landslides occur in different part of Nigeria due to widespread impact of gully erosion resulting from intense rainfall and subsequent flooding that results in slope failure. According to Aghamelu et al. (2011), such antecedent rainfall controls the soil moisture and is critical in limiting debris flow on slopes of 30° to 40°. Furthermore, Ng and Shi (1998) found out that rainfall intensity and the original position of the ground water level, affect the stability of slopes. They further suggested that a slope could remain stable even under excessive rainfall, if the initial ground water level is low and that the factor of safety would only decrease if the duration of rainfall is increased.



The presence of too many fractures on both the rocks that were moved and those in the adjoining area suggests fractures in the rock provided passage for weathering fluids (Plate 2). Fractures in the rocks acts as common translational slip planes. The presence of some clay minerals along some fracture zones in the rocks supports the view that the landslides occurred as a result of absorption of water by these clay minerals (Ayonghe et al., 2004 and Plummer, 2003).

Physical factor

The discharge of small springs along the slope and a stream along the foot of the hill must have produced failure as a result of the undercutting of the slopes, especially during the period (raining season) that the slides occurred. This undercutting serves both to increase the gradient of the slope, reduce stability and remove toe weighting which also reduces stability (Nwajide et al., 2004, Polloni et al., 2000).

Morphological factor

Slope and topography are seen as the main morphological factors that triggered the landslides of Azenge Hills in Nkomo District of Benue State. Field measurements indicated that the area is characterized by steep slopes ranging from 17° to 50° , deep valleys and generally rugged relief. This type of slope angle greatly affects the relative magnitude of the driving force on slopes. As the angle of potential slip plain increases, the driving force also increases, thus, landslides should be most frequent on steep slopes. A study of landslides that occurred during two raining seasons in California's San Francisco Bay area established that 75 to 80 percent of landslide activities is closely associated with urban areas on slopes greater than 15% or 8.5° (Nilson et al., 1976). Vegetation is a very important factor in slope stability. Vegetation provides cover that cushions the impact of rain falling on slopes, facilitating infiltration of water into the slope while retarding grain-by-grain erosion on the surface. Also vegetation has root systems that tend to provide an apparent cohesion to the slope materials thus increasing resistance to landsliding. Therefore, the cutting down of trees for lumbering, firewood and farming along the slopes and toes of the hills exposed the slopes to all these factors, thus reducing the stability of the slopes and ultimately resulted in the fourteen landslides.

Conclusion

The geological event that occurred on the 13th of October, 2010, in Imande Ukusu village was not an earthquake but a series of fourteen landslides. The landslides were triggered by continuous rainfall in the area which led to the percolation of much water into the rocks through fractures resulting to weathering of the rocks. The rock and soil materials saturated lost cohesion causing a mixture of rock boulders, fragments and soil to move down slope in large quantities. Apart from rainfall, other factors ranging from geological, morphological to human factors equally contributed to slope failure that led to the landslides.

The landslides did not have a high casualty figure on human as only one person loss his life. However, farmlands and the natural vegetation in the area were destroyed. Also, the then normal river regime in the area was distorted resulting in the development of a new regime and the soil structure and texture in the area was also destroyed. It is therefore, recommended that human activities on the foot of the hill be reduced and settlements should be sited far away from the hills to avoid any further lost of life.



Acknowledgments

We are grateful to the vice chairman of the then caretaker committee of Kwande Local Government, Benue State, Nigeria, Engineer Benjamin Nyior and the chief security officer for providing transportation and security from Adikpo to Imande Ukusu. We also thank Professors Cho Emmanuel Suh and Ayonghe Samuel of the University of Buea, Cameroon, for their contributions and encouragement towards the realization of this work.

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