

THE ROLE OF EARTH OBSERVATION SATELLITE DURING THE INTERNATIONAL  
COLLABORATION ON THE 2012 NIGERIA FLOOD DISASTER

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Although the year 2012 flood in Nigeria is the worst ever to have devastated the country in the last fifty years it wasn't the only flood disaster, notable ones are also the 2010 and 2011 floods. The 2012 flood displaced tens of thousands of people and affected over half of the thirty six states destroying properties running into billions of naira. Farmlands and fertilizers were destroyed, settlements were totally submerged and cultural artifacts were lost. The flood was the result of many underlying factors of which the main ones were the release of water from the Lagdo Dam a reservoir located in Cameroon, and the persistent rain fall due to a changing global climate. In response to the flood, a UN-CHARTER was invoked and satellite images were provided by various international space agencies. Likewise organizations such as the World Bank, and various UN agencies together with national stakeholders collaborated in the post disaster recovery efforts. The use of space technology during the response proved to be of great economic benefit particularly in the assessment of the extent of the disaster which assisted the government in its reconstruction efforts. Also the foray of Nigeria into space technologies has opened up its economy in diverse ways especially in the areas of local and international collaborations, employment creation and technological spinoffs.

## LINTRODUCTION

One of the developments associated with the 21<sup>st</sup> century that has enhanced the process of collaboration across diverse geographical boundaries, is globalization. According to Kouman<sup>1</sup> Globalization and collaboration simultaneously drive each other and the better, faster and smoother the collaboration processes and tools are, the more empowered industries and organizations become in a global economy. The pace at which technological infrastructure is evolving and being embraced even by some developing nations especially in the area of satellite technology has quickened and enhanced the process of collaboration among nations. A forceful factor that has necessitated collaboration amongst nations is natural disaster as it transcends

geographical boundaries, race, and economies. For example, Hurricane Katrina affected one of the world's richest countries and the Haitian earthquake affected one of the least developed countries in the world. Nigeria, a developing nation was also not spared as it experienced flooding especially in the year 2012 on a monumental scale affecting many parts of the country.

The frequent occurrence of natural disasters in the 21<sup>st</sup> century has helped to improve and enhance the technology associated with earth monitoring and Earth Observation Satellites have been the beneficiaries. Thus disasters are now being

monitored in real time with correspondents having all the necessary geospatial data required to work.

## **II. THE NIGERIAN SATELLITES**

Nigeria's foray into satellite technology began in 1963 when the first Prime Minister Abubakar Tafawa Balewa, onboard a satellite communications ship, had the first satellite relayed telephone conversation with President John F. Kennedy<sup>2</sup>. This was the first of its kind ever between heads of states.

Forty two years later Nigeria's first space earth observation satellite, NigeriaSat-1 captured the traumatic events of Hurricane Katrina. Katrina was one of the strongest hurricanes ever recorded that made landfall in the United States<sup>3</sup>. Nigeria's space adventure has been a collaborative effort from the onset; its optical satellites were built in partnership with Surrey Satellite Technology UK with launch sites in Russia. On the other hand its telecommunication satellites were built in partnership with the China Great Wall Industry Cooperation (CGWIC).

The Nigerian satellites, NigeriaSat-1, 2 and X carry optical multispectral sensors and acquire images in the optical region of the electromagnetic spectrum. NigeriaSat-1 has three spectral channels in the red, green and infrared region and a panchromatic mode. It has a spectral resolution of 32 meters and a temporal resolution of 3-5 days. It had a life span of 5 years and at present is decommissioned. NigeriaSat-2 and Sat-X are the second generation earth observation satellites. Nigeria-Sat 2 has two very high resolution sensors (VHRS) with spatial resolutions of 2.5m and 5m respectively. The 5 m resolution sensor acquires image in the near infrared, red, green and blue channels while the 2.5 m acquires images in the panchromatic mode. It also has a 32 meter resolution sensor to acquire data similar to that captured by NigeriaSat-1. Its revisit period is 2-4 days with a life span of 7 years. NigeriaSat-X has a ground sampling distance of 22 meters, a revisit period of 3 days and acquires images in the red, green and infrared spectral channels. It has a life span of 5 years.

Nigeria re-launched its telecommunications satellite (Nigcomsat-1R) after the first one failed in orbit. The satellite has a payload of transponders in the C, Ku, Ka and L bands.

## **III. THE NATIONAL SPACE RESEARCH AND DEVELOPMENT AGENCY**

The National Space Research and Development Agency (NASRDA) is Nigeria's space agency created to manage products derived from the Nigerian satellites. One of its functions is to collaborate with International Research Centres, Governmental Organisations, Universities, industries, National and International Space Agencies<sup>4</sup>. NASRDA in conjunction with the National Emergency Management Agency (NEMA) is responsible for providing data and manpower during, or in the aftermath of a disaster. The agency has been involved in proactive monitoring of flood prone environments such as the Katsina Ala River Basin where flood disaster risk and vulnerability were assessed in apprehension of the collapse of Lake Nyos Dam in Cameroon. Another collaboration is the mapping and monitoring of watersheds in the northern part of Nigeria in partnership with Bayero University in Kano, Nigeria using satellite images. The investigation of the hydrologic cycle near and over the surface of Lake Chad was also carried out in collaboration with the University of Missouri, Kansas USA.

Apart from being a member of the International Charter Space and Major Disasters, NASRDA is a member of the Disaster Monitoring Constellation. This is an Earth Observation Satellite Constellation that delivers high frequency imaging over the whole earth. Nigeria's first Satellite NigeriaSat-1 is part of DMC-I while NigeriaSat-2 and Sat-X are both part of DMC-II. These satellites have been used in responding to disasters all over the world. Images generated from the DMC are used in various disaster response and mitigation scenarios, for example, twenty NigeriaSat-1 images were employed for the Asian tsunami disaster under the RESPOND<sup>1</sup> initiative.

NigeriaSat-1 was also the first of the DMC Satellites to capture images of the Hurricane Katrina-affected areas of the USA<sup>5</sup> (Figure 1) thus emphasizing the coincidental role and "sans frontier" nature of orbiting satellites. This paper highlights the role Earth Observation satellites played during the 2012 flood in Nigeria and the international and local collaborative response during the course of the floods.

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<sup>1</sup>RESPOND is a segment under the Global monitoring for environment and security (GMES) which was used to address the geospatial information requirements of the humanitarian aid community.



**Figure 1: 32m GSD image of New Orleans, Gulf of Mexico after Hurricane Katrina from NigeriaSat-1 satellite 2005**

Source: NASRDA 2005

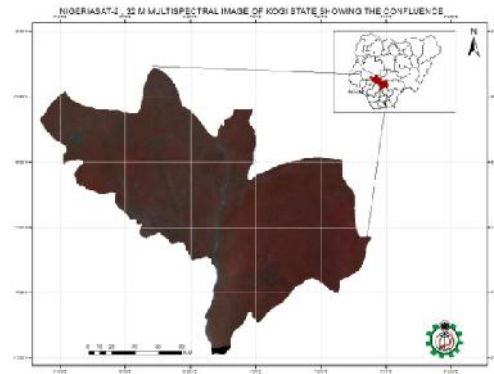
#### **IV: FLOODING IN NIGERIA**

Floods have been a bane of the Nigerian environment but they never gained international recognition until the advent of earth observation satellites. The most notable floods since the emergence of these satellites were the 2010, 2011 and 2012 floods. In 2010 the flood was as a result of a breach in the Guronyo dam in Sokoto state and in 2011 it was due to a breach in the Eleyele dam in Oyo state. The 2012 flood was as a result of the release of excess water from the Lagdo Dam in Cameroon and excessive rainfall together with poor dam management practices and poor communication amongst relevant stakeholders. Because of the extent and severity of the flood on the Nigerian populace and infrastructure, local and international organizations became involved in the response process and various satellite images were made available to Nigeria.

Nigeria has two major drainage systems flowing through it. These are the Rivers Niger and Benue. The two drainage systems (Figure 2) divide the country into three uneven geographical regions, with a confluence in the Lokoja Area of Kogi State (Latitude 7°49'8.89N and Longitude: 6°44'5.85E) (Figure 3) and this confluence made Kogi one of states most affected by the 2012 flood.

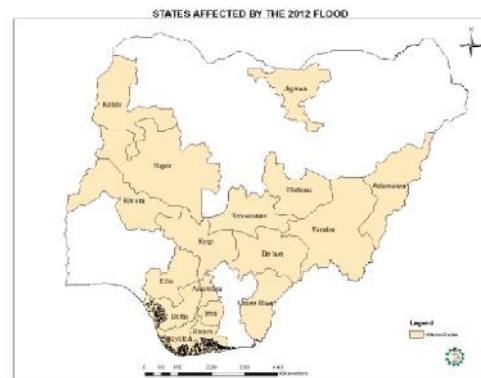


**Figure 2: Rivers Niger and Benue**



**Figure 3: Kogi State**

Excessive rainfall swelled the Rivers Niger and Benue, and the release of excess water from the upstream Lagdo Dam in Cameroon both contributed to the disastrous 2012 flood. About 16 states out of the 36 states were affected as a result of the flood (Figure 4). Under normal circumstances, Nigeria is given warning of release of water from Lagdo Dam so that it can take appropriate action to avert flooding in the lowland communities in the north eastern part of Nigeria. These communities located downstream within the river Benue drainage basin are areas which are usually flooded whenever water is released from the dam. However in 2012, rain water flowed into the Lagdo Dam at a rate of  $6,240 \text{ km}^3 \text{ sec}^{-1}$  according to the Cameroonian authorities<sup>6</sup>. Simultaneously water was being released from the dam at a rate of  $3,000 \text{ km}^3 \text{ sec}^{-1}$  and in a bid to prevent the dam from collapsing. Unfortunately due to the urgent nature of the situation Nigeria was not given timely warning of the release thereby causing devastating consequences for Nigeria.



**Figure 4: States affected by the 2012 flood**

## **V. THE ROLE OF EARTH OBSERVATION SATELLITE DATA DURING THE 2012 FLOOD DISASTER IN NIGERIA**

Satellite images have played a major role in the response and recovery phase of the 2010-2012 floods. Nigeria has been a beneficiary of a number of images from different space agencies. In 2010 and 2011 the UN-CHARTER was invoked as a result of the failure of the Goronyo (Figure 5) and Eleyele dams in Sokoto and Oyo states respectively. Images such as Terra SAR, RadarSat, and ENVISAT were obtained. Other data that were used include NigeriaSat-1, SPOT and Landsat. In 2012 the charter was invoked three times due to the severity of the flood. The first invocation was on the 29<sup>th</sup> of August, for Adamawa and Taraba states. The second occurred on the 25<sup>th</sup> of September for the Kogi state and the third occurred on the 10<sup>th</sup> of October for Bayelsa state. By the third invocation the flood had become a National Disaster.

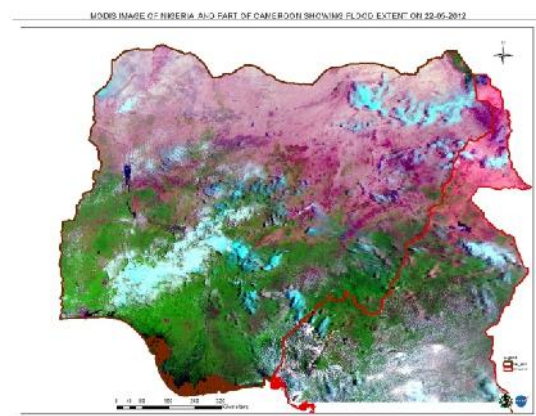


**Figure 5: NigeriaSat-2 image of the Goronyo dam**

The Images obtained in 2012 from the various international space agencies were also radar and optical. Additionally MODIS and SRTM data were obtained freely from their respective websites. The sheer scale of the flood meant that the medium and low resolution images were used which provided synoptic views of the overall extent of the flooding across the whole of Nigeria. Initially NigeriaSat-2 data were to be used for high resolution monitoring of infrastructural damage, however cloud cover at that time of the year prevented the acquisition of cloud free imagery. Optical data such as archived SPOT-5 and Cartosat were received from Astrium GeoInformation Services and the Indian Space Research Organization (ISRO) respectively. These were used for the visual identification of ground structures. The radar data received for the 2012 flood disaster included TerrarSAR-X, from Astrium GeoInformation Services, RADARSAT from the Canadian Space Agency and ENVISAT from the European Space Agency.

Radar has always played a major role in flood management in Nigeria due to its ability to penetrate cloud cover. This ability is one of the reasons why radar data was utilized during the 2012 flood as the Niger Delta Region in Nigeria is always cloudy for most of the year. Likewise the ability to capture both day and night time data adds to its desirability since disasters never give a forewarning of the time of occurrence thus the flooded areas were mapped using RadarSat and TerraSAR and a flood extent was generated. One of the constraints faced was the inability to view the whole of the Nigerian terrain using radar due to cost implications.

The MODIS data proved to be some of the most useful and relevant images because of their large swath widths and coarse spatial resolution. These properties enabled a synoptic view of large tracts of the Nigerian terrain and therefore highlighted the dynamic nature of the flood. Additionally the daily temporal resolution meant that daily changes in the flood extent could be monitored which aided in the different responses to the disaster. A comparison of the images captured by the modis sensor during the course of the flood and that captured months after the flood shows visually the increase in area of the flood. Figures 6, 7 and 8 show pre flood to post flood conditions as captured by the MODIS satellite. Figure 6 which is a pre flood image shows the normal flow of the drainage system on the 22<sup>nd</sup> of May 2012 in which the Kainji dam in Niger State and the Lagdo dam in Cameroun can be easily identified. Figure 7 shows the flood extent as captured by the MODIS sensor on the 22<sup>nd</sup> of September 2012 and it shows the increase in the extent of water as a result of the floods and also evidence of floods in the hadejia jama'are flood plains in the north eastern part of Nigeria while the image in figure 8 captured on the 11<sup>th</sup> of November 2012 shows that the flood waters had receded.



**Figure 6: Pre-Flood image**



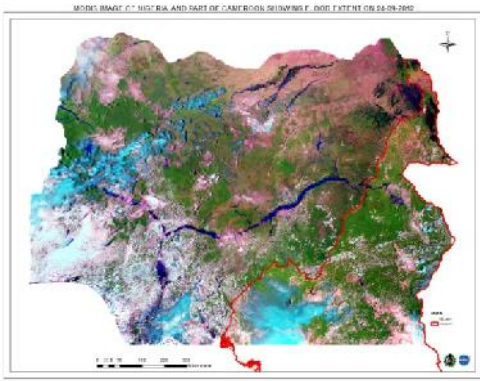


Figure 7: Flood

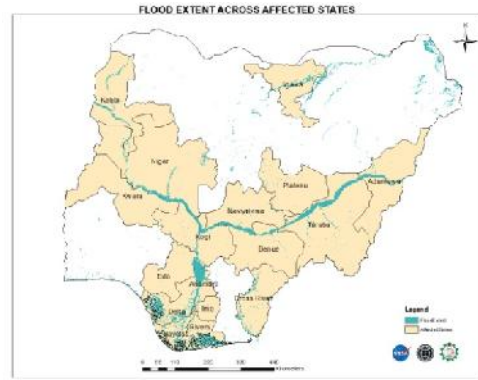


Figure 4: MODIS generated flood extent across states

**Shuttle Radar Topography mission**

SRTM data was used to create a DTM. The DTM revealed low lying flood prone and flooded areas as well as high ground where people could be evacuated to during the response phase of the flood and also areas where the flood impact was minimal (Figure 10). These are earmarked for future resettlements. It was also used during the rapid mapping of the affected states and is presently been used in the ongoing flood vulnerability assessment mapping.

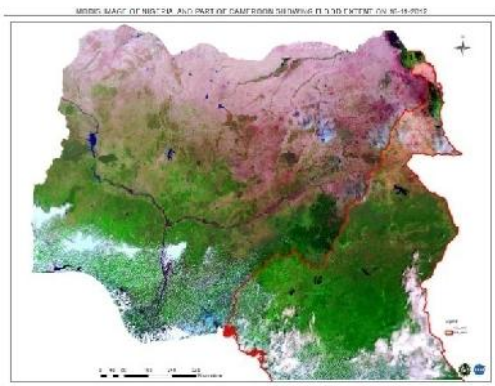


Figure 8: Post Flood

A multi date composite flood inundation extent layer was generated from the MODIS data (Figure 9). This flood extent layer was overlaid on the country's shape file (Figure 9) which enabled various geospatial analyses to be carried out from it. Clipping the flood extent with individual state shape files enabled responders to also understand to what extent states were affected.

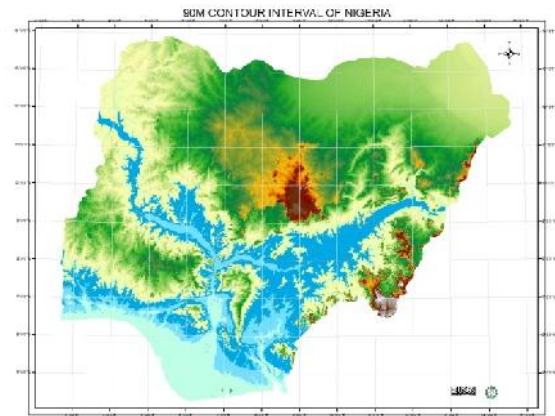


Figure 5: 90m SRTM of Nigeria

**VI: HUMANITARIAN EFFORTS**

The 21<sup>st</sup> century has seen a rise in the frequency of disasters of epic proportions. These have the ability to incapacitate a nation as a whole especially if it is economically challenged thus collaborations that result in humanitarian assistance are always encouraged. During the 2012 flood organizations such as the World Bank, and various UN agencies together with national stakeholders collaborated in the post disaster recovery efforts. These included:

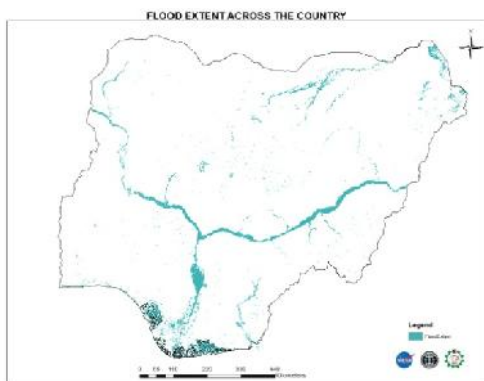


Figure 3: MODIS generated flood extent across the country

### **Post Disaster Needs Assessment:**

The Post Disaster Needs Assessment (PDNA) conducted between November 2012 and March 2013, was organised by the Nigerian Government in collaboration with the UN, World Bank and relevant national stakeholders. The PDNA assesses the impact of natural disaster on infrastructure as well as people and it results in a joint recovery strategy and framework that includes the full financial costs of recovery and reconstruction<sup>7</sup>. In practice, the PDNA estimated the effects of the 2012 floods, including the financial requirements to overcome the impact of the disaster through a set of well defined recovery and reconstruction procedures. NEMA being the lead agency in disaster response and management coordinated the PDNA. The PDNA covered sectors such as social which covered education, health and housing; Productive which covered agriculture, manufacture, commerce, oil industry; Infrastructure which covered water and sanitation, electricity and transport and lastly cross-sectoral which covered the environment. NASRDA's role cut across all the sectors and the agency was given the mandate to co-ordinate all Geographic Information System (GIS)/Remote Sensing (RS) related activities using appropriate satellite imageries to carry out the flood impact assessment mapping appropriate satellite imageries to carry out the flood impact assessment mapping.

### **Post Disaster Recovery:**

The International Federation of Red Cross and Red Crescent Societies (IFRC) through the Nigerian Red Cross Society (NRCS) and the United Nations Office for Coordination of Humanitarian Affairs (UN-OCHA) were some of the notable International Organizations that helped in the post recovery efforts. The IFRC deployed a Field Assessment and Coordination Team (FACT)<sup>8</sup> to support the NRCS in assessments of the current needs and possible evolution of the crisis, and to develop a plan of action. These organizations were involved in setting up camps for internally displaced persons and in the distribution of relief materials. Relief materials such as mattresses, mosquito nets, cooking utensils were distributed by the organizations thus complementing the Nigerian government, corporate national organizations and individual Nigerians in the relief efforts. Nasrda also participated in the recovery efforts by providing maps of affected communities.

## **VII. NATIONAL COLLABORATORS DURING THE 2012 FLOOD**

As a result of the flood NEMA, the Office of the Surveyor General of the Federation (OSGOF) and the National Space Research and Development

Agency (NASRDA) embarked on a Rapid Flood Assessment of all flood affected communities within the country. This mapping was carried out with the flood extent data that was captured using MODIS image and other ancillary data that was received from the International community. One of the reasons of this rapid mapping was to assist the federal government and international community to understand the extent of the impact of the flood and also to generate a database of the affected communities and also communities that are likely to be vulnerable to flooding thus assisting in the various ongoing Humanitarian efforts. Some of the states visited include Adamawa, Cross River, Nassarawa and Kogi (Figures 11-14). The degree of impact differed due to soil types, vegetation cover, proximity to the ocean, population density, rainfall and elevation.

NigeriaSat-2 images have been used to support the post disaster recovery efforts. It is presently being used in carrying out a flood vulnerability assessment mapping. This is being done in partnership with NEMA and OSGOF. States that have been visited are Bayelsa and Sokoto with the modalities for visiting other states being put in place. It is also presently being used by the Federal government of Nigeria in mitigating any flood related disaster that might occur in the future.

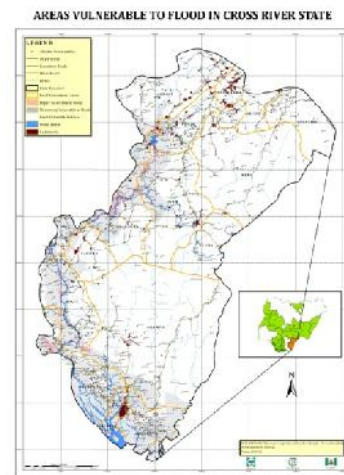


Figure 11

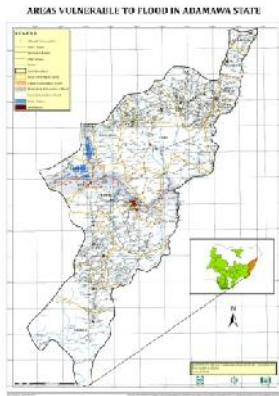


Figure 12



Figure 13:

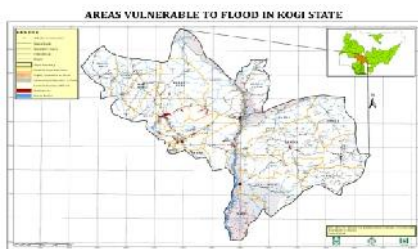


Figure 14:

**VIII: ECONOMIC BENEFITS OF THE COLLABORATION**

A) Nigeria as a member of the International Charter Space and Major Disasters benefitted through the receipt of necessary satellite data for the definition, planning, implementation, monitoring and assessment of the 2012 flood disaster relief operations. Millions of naira that would have gone into the acquisition of images was saved.

- B) Space agencies such as the Canadian space agency, German Aerospace centre (DLR) and EADS Astrium and others have contributed images at no cost to disaster response in Nigeria thus freeing funds for other purpose.
- C) The PDNA sponsored by participating organizations was able to determine the losses in monetary value thus aiding the Nigerian government in the rehabilitation of the affected communities.
- D) Technical Expertise: As a result of the collaboration experts in various disasters related fields were brought in by participatory international organizations and national organizations which gave opportunity for cross pollination of ideas and expertise.
- E) Improved Collaboration. As a result of the flood national stakeholders have cut down on the red tape that normally hinders the exchange of data, technical expertise thus allowing for better co-ordination hence saving costs.
- F) Following the flood experience, a Memorandum of Understanding (MoU) was signed between the Nigerian Government and the Cameroonian government on good dam management practices.

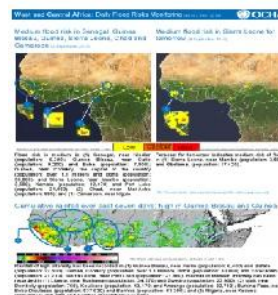


Figure 15: West and Central Africa: daily flood risks monitoring as of September 2, 2013  
Source: UN-OCHA

## **IX: CONCLUSION.**

The 2012 flood was historic in its magnitude and spread. It tested the resilience of a nation to flood related disasters of epic proportion and how it employed space based technology. Satellite images were used to understand the national spread of the flood extent and also in various humanitarian efforts. The flood also provided a platform for international organization with space based products to provide such which helped in the response and recovery phase of the disaster. It also provided relevant stakeholders within the international community the opportunity to test their ability to synergize with national and local responders. The role the international community also played during the response was one of the major reasons no major outbreak of diseases was recorded on a large scale. Disasters of such magnitude has the capacity to overwhelm the sovereignty of a nation but the willingness of international communities to help underlines the need for every Nation to collaborate with each other especially in the area of its strength.

“We should give while we are alive and also when we are young and capable. Sometimes, we need to have the genuine experience of deprivation and poverty in order to appreciate the need to be our brother’s keeper,” Dangote

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