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AN ASSESSMENT OF NIGERIAN METEOROLOGICAL AGENCY'S COMPLIANCE TO THE WORLD METEOROLOGICAL ORGANIZATION'S STANDARD IN THE ESTABLISHMENT OF ENCLOSURES FOR FLOOD WARNING SYSTEM.

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Abstract

The Nigerian Meteorological Agency (NIMET) is positioned to issue weather and climate related information for the socio-economic development of Nigeria. To do this NIMET has meteorological stations in every state of Nigeria. The Agency generates product such as annual Seasonal Rainfall Prediction (SRP) and Drought and Flood Monitoring Bulletins in order to warn Nigerians as early as possible about flood that annually devastate Nigeria. The data required for the rainfall predictions should be accurate and for this to be achieved meteorological stations should be established in compliance to World Meteorological Organization (WMO) Standard. This study aimed to assess the extent of compliance by NIMET to WMO's standard in meteorological stations (enclosures) establishment. Two Hundred and Eighty Seven responses affirmed that the enclosures of NIMET were established in compliance with WMO's standard. The results shows that all the 287 respondents confirmed that the meteorological station were established using WMO's Guide. This study concluded that NIMET's data based on these findings can be effectively used for flood warning system in Nigeria. The study recommended that meteorological station should be established at every 150km intervals for surface stations and every 300km for upper air station for total coverage to *be achieved in Nigeria. Also training and retraining of staff that will effectively manned the stations.*

Keywords: WMO Standard, NIMET, Meteorological station, Flood Warning System

Introduction

The meteorological observation is an evaluation or measurement of one or more meteorological elements. Meteorological observations are either sensory, i.e. taken by a human observer without the use of measuring instruments; or instrumental, which are generally known as meteorological measurements and made by the use of meteorological instruments (Guide to Instruments and Methods of Observation - WMO-No., 2008). A place at which the evaluation of one or more meteorological elements is carried out regularly is called a meteorological observing station.

Meteorological stations are established on land or at sea and, ideally, are spaced so as to guarantee adequate meteorological coverage, thus forming a meteorological observing station network. As an example, principal surface synoptic stations should be spaced at intervals not exceeding 150 km and upper-air stations at intervals not exceeding 300 km (WMO-No. 2008). A closer spacing of network stations enhances the observation network data output. An optimum spacing of observing stations is one for which cost has been taken into account, depending on the purpose for which the data are to be used, the spatial and temporal variability of the meteorological element observed and the nature of the topography of the Earth's surface over which the network is to be established. A strict conformity exists as regards observing programmes, siting and exposure of meteorological instruments at meteorological network stations. Depending on the kind of observations made, the meteorological observing stations of a network are usually connected to a collecting centre by a suitable telecommunication link. The data collected are subjected to quality control before being disseminated to users.

Meteorological stations are designed so that representative measurements (or observations) can be taken according to the type of station involved (WMO, 2010d*)* (. Thus, a station in the synoptic network should make observations to meet synoptic-scale requirements, whereas an aviation meteorological observing station should make observations that describe the conditions specific to the local site. Where stations are used for several purposes, for example, aviation, synoptic and climatological purposes, the most stringent requirement will dictate the precise location of an observing site and its associated sensors. A detailed study on siting and exposure is published in WMO (1993a).

The importance of having effective flood early warning systems is widely accepted as one component to manage disaster risk. The Hyogo Framework for Action (2010 – 2015) made early warning a priority for action and the post 2015 framework for Disaster Risk Reduction is expected to further strengthen early warning systems and tailoring them to user's needs, including social and cultural requirements. As such, the primary objective of a flood warning system is to reduce exposure to flooding (Linham and Nicholls, 2010). A people-centred early warning system comprises four key elements: knowledge of the risks; monitoring, analysis and forecasting of the hazards; communication or dissemination of alerts and warnings; and local capabilities to respond to the warnings received (Basher, 2006). Ultimately an early warning system will only be effective if all components are effective.

The Nigerian Meteorological Agency (NIMET) came into existence by an Act of the National Assembly, NIMET (Establishment) ACT 2003, enacted on 21st May 2003, and became effective on 19th June 2003 following Presidential assent. It is a Federal Government agency charged with the responsibility to advise the Federal Government on all aspects of meteorology; project, prepare and interpret government policy in the field of meteorology and to issue weather and climate forecasts for the socio-economic development. The Act also makes it the responsibility of the Agency to observe, collate, collect, process and disseminate all meteorological data and information within and outside; co-ordinate research activities and publish scientific papers in the various branches of meteorology in support of sustainable socio-economic activities in Nigeria.

The Nigerian Meteorological Agency provides weather forecasts, Drought and Flood Warnings and Seasonal Rainfall Predictions. This informs early warning alerts for climate related disaster threats across the country.

Meteorological Station should have the presence of conventional instruments like Rainguage, cup counter (Wind) Thermometers (Dry and Wet), Solarimeter, Thermograph, Hygrograph, Barograph and Automated Instruments and the Automatic Weather Observation System (AWOS), Thunder and Lightning Detector, Ceilometer, Automatic Rainguague and other relevant instruments related to what purpose the station is serving. All the instruments should be installed according to World Meteorological Organization (WMO) Guide to Instruments and Methods of Observation (WMO-NO.8) Standard.

Having a meteorological station that is established according to WMO's standard is the first requirement to having an accurate meteorological data that will lead to an effective flood warnings system (WMO- NO.8., 2008)

Study Area

The country Nigeria is situated between Latitudes 4^oN and 14^oN and between Longitudes 3^0E and 15^0E (see Fig 1). It is bordered on the north, east, and west by Niger, the Cameroon, and Benin Republic, respectively (Nigeria's First National Communication, 2003; Nwilo and Badejo 2006; Oguntunde, Abiodun and Lischeid, 2011).

Climate and Vegetation

Nigeria's climate scenario shows a better understanding to its adaptive capacity. Geographically, Nigeria is located within the lowland humid of the tropics and is generally characterized by a high temperature experienced continuously throughout the year. Nigeria falls within the Tropical Continental Climate. Temperatures across the country is relatively high with a very narrow variation in seasonal and diurnal ranges (22^oC-36^oC). However, there are clear differences in temperatures between the country's South and North. While the far south of the country has the

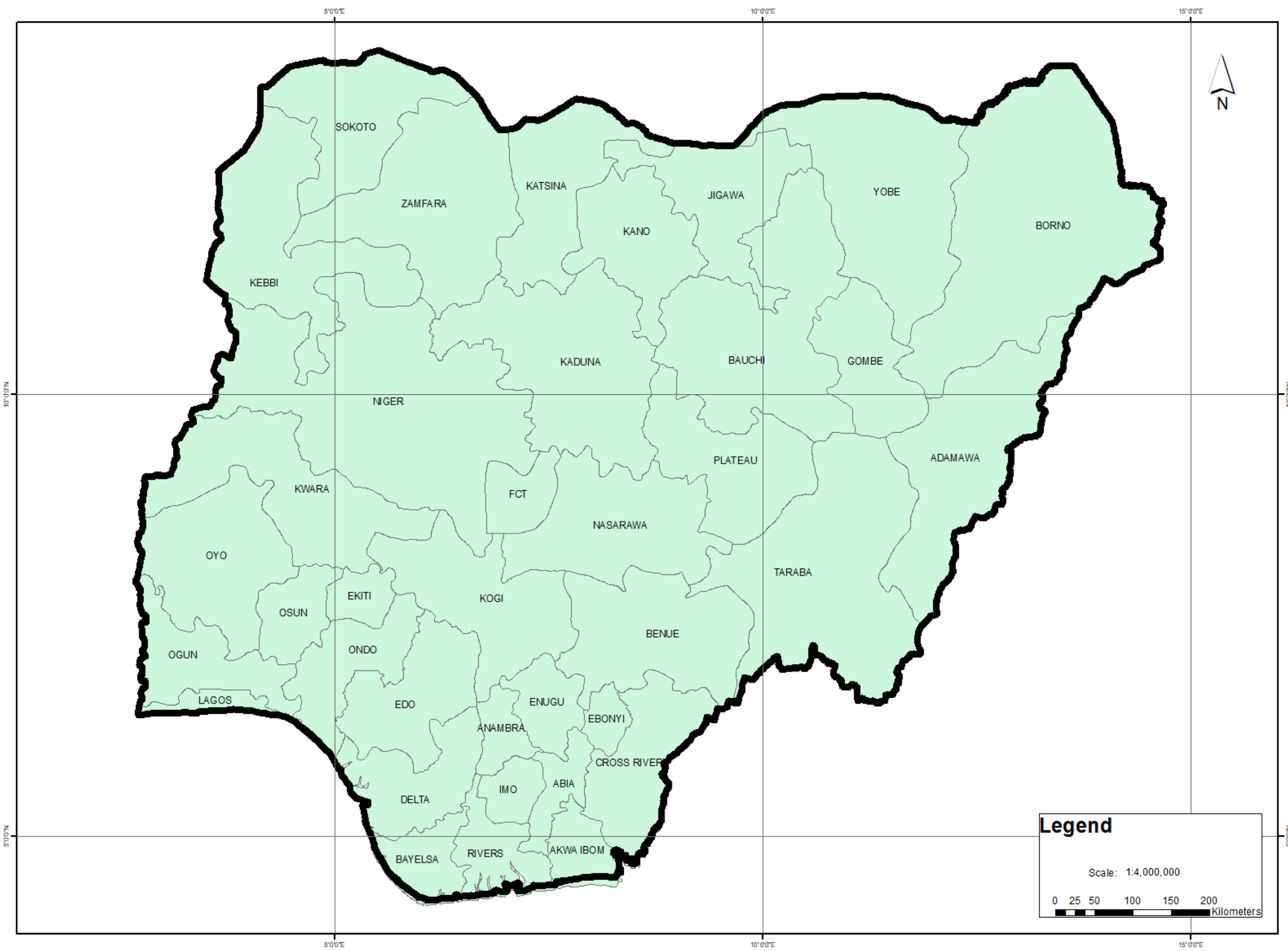

Figure 1: The Study Area

Source: Geo-Fractal Axis Nigeria Limited.

mean maximum temperature of 32°C, the North has a mean maximum temperature of 41°C. Conversely, the mean minimum temperature in the northern region is under 13°C, indicating a much higher annual range and the mean temperature for the southern region of Nigeria is 21°C. The mean minimum temperature for the entire country is 27°c in the absence of altitudinal variations (Nigeria's First National Communication, 2003).

Annual rainfall generally decreases from the coast inland from an average of about 3000 mm in Warri on the coast to less than 500 mm in Nguru in the Sahel of the north-east. There are six commonly identified vegetation zones in Nigeria. These are; Mangrove and Freshwater swamps along the coast, giving way northwards to Rain Forest, Guinea savannah, Sudan savannah, and Sahel savannah. It has been observed also, that, the actual vegetation cover in all the vegetation zones have shown heavy imprint of centuries of human activities (National Adaptation Strategy and Plan of Action on Climate Change for Nigeria (NASPA-CCN, 2011). This further suggests that there are significant human negative impacts on the environment within the Nigerian.

Materials and Methods

Reconnaissance survey was conducted through visits to synoptic stations within the six zonal offices of Kano, Kaduna and Maiduguri, Lagos, Enugu and Port Harcourt. Also the central forecast office (CFO) at Abuja was visited. These visits were done for the sake of familiarization with the staff, to know the exact location of the synoptic offices, the meteorological stations and their mode of operations.

The data used for this study was collected from the Directorates of interest which include: Weather Forecasting Services, Directorate of Applied Meteorological Services of the Nigerian Meteorological Agency, The Directorate of Research and Training and the Directorate of Engineering and Technical Services of the Agency as secondary data. The data comprises on how the Meteorological Stations were established for the issuance of Flood Monitoring Warnings and Seasonal Rainfall Predictions and the types of Instruments installed in the Meteorological Stations. Guide to Meteorological Instruments and Methods of Observation (WMO- NO. 8) was used to establish compliance and conformity.

The number of staff from the Four Directorates of Weather Forecasting Services (DWFS), Applied Meteorological Services (DAMS), Research and Training (R &T) and Engineering and Technical Services (DETS) is One Thousand and Fifteen (1015) as shown in Table 3.1.

Table 3.1 Staff Strength of the four Directorates This Research is Interested in from NIMET

SN	DIRECTORATE	NUMBER OF STAFF
1	WFS	668
2	AMS	47
3	R & T	45
4	ETS	255
TOTAL		**1015**

The sample size was determined using Yamane (1967) formula given as:

n= N/1+N (e) ^2

Where,

n=Minimum sample size

N=Total population

e=Degree of precision (0.05)

Therefore,

n= 1015/1+1015(0.5) ^2

=1015/1+1015(0.0025)

= 1015/1+2.5375

= 1015/3.5375

= 286.93. Approximately 287. The sample size used for this study was therefore 287 respondents.

The research used both probabilistic and non-probabilistic sampling methods. Probabilistically, simple random sampling was used while for non-probabilistic, purposive and convenient sampling were used.

The following Staff of the Agency were purposively selected and interviewed because they are directly involved with the establishment of Meteorological Stations and management of Flood Early Warning System, Seasonal Rainfall Prediction and all other related Bulletins of the Agency:

i. The Director General/ Chief Executive Officer of the Agency
ii. The Director Weather Forecasting Services
iii. The Director Applied Meteorological Services
iv. The Director Research and Training
v. The Director Engineering and Technical Services

Accordingly, the use of purposive sampling was appropriate because it allows the use of units that have the required information with respect to the objectives of the study (Babbie, 2011).

Checklist for Systems and Instruments drawn from Guide to Meteorological Instruments and Methods of Observations standards of the World Meteorological Organizations (WMO-No. 8, 2008) was used to show availability of the required equipment in NIMET Meteorological Stations.

Simple random sampling was used to identify the respondents across the four Directorates.

Respondents from the four Directorates (DWFS, AMS, R&T and ETS) were drawn from the sample size of 287 as shown in Table 3.2.

Table 3.2 Respondents from four Directorates of NIMET

SN	Directorate	Number of Staff	Number of Respondents
01	DWFS	668	175
02	AMS	47	21
03	R & T	45	14
04	ETS	255	77
Total		**1015**	**287**

*WFS- Weather Forecasting Services, AMS- Applied Meteorological Services, R &T- Research and Training, ETS-Engineering and Technical Services.

Results and Discussion

Meteorological observing stations are designed to enable measurements that are representative to the type of station involved. Thus, a synoptic station should make observations to meet synoptic-scale requirements. Where stations are used for several purposes, example, aviation, synoptic and climatology, the most stringent requirement will dictate the precise location of an observing site and its associated sensors. These are to be considered in the selection of sites for climatological purpose:

(a) Outdoor instruments should be installed in an enclosure (at least 10m x 7m) on a level ground, covered with short grass or a surface representative of the locality, and surrounded by open fencing or palings to exclude unauthorized persons. Within the enclosure, a bare patch of ground about 2 metres by 2 metres is reserved for observations of the state of the ground and of soil temperature at depths of less than 30 centimetres;

(b) There should be no steeply sloping ground in the vicinity and the site should not be in a hollow. If these conditions are not complied with, the observations may show peculiarities of entirely local significance;

(c) The site should be well away from trees, buildings, walls or other obstructions. The distance of any such obstacle (including fencing) from the raingauge should not be less than twice the height of the object above the rim of the gauge, and preferably four times the height;

(d) The sunshine recorder, raingauge, and anemometer must have exposures to satisfy their requirements, preferably on the same site as the other instruments;

(e) It should be noted that the enclosure may not be the best place from which to estimate the wind speed and direction; another observation point, more exposed to the wind, may be desirable;

(f) Very open sites which are satisfactory for most instruments are unsuitable for raingauges. For such sites, the rainfall catch is reduced, some simple measures that will not interfere with other instruments should be taken to reduced heavy winds to light winds and some degree of shelter is needed so that the rain will not be blown by winds;

(g) If in the surroundings of the instrument enclosure, maybe at some distance, objects like trees or buildings obstruct the horizon significantly, then for observations of sunshine or radiation alternative viewpoints should be selected;

(h) The position used for observing cloud and visibility should be as open as possible and command the widest possible view of the sky and the surrounding country;

(i) At coastal stations, it is desirable that the station should command a view of the open sea, but it should not be too near the edge of a cliff because the wind eddies created by the cliff will affect the measurements of wind and the amount of precipitation;

(j) Night observations of cloud and visibility are best made from a site unaffected by extraneous lighting.

To minimize tampering by animals and people, it is very desirable to fence the weather station. A sample layout is shown in Figure 4. 1. This layout for northern hemisphere stations is designed to eliminate as far as possible the shadowing effect of fence posts on instruments and to ensure that direct sunlight does not enter the thermometer screen during observations. In the southern hemisphere the general orientation of instruments is different from that of the northern hemisphere, the door of the thermometer screen (Stevenson Screen), for example, is open to the south. At equatorial and tropical stations, of course, the thermometer screen have doors opening to both the north and the south. All radiation instruments and sunshine recorders should be carefully mounted in a position free from all shadows at all times. The minimum distance between instruments is also indicated in the figure 4. A larger area is recommended when other instruments and small plants for phenological observations are used.

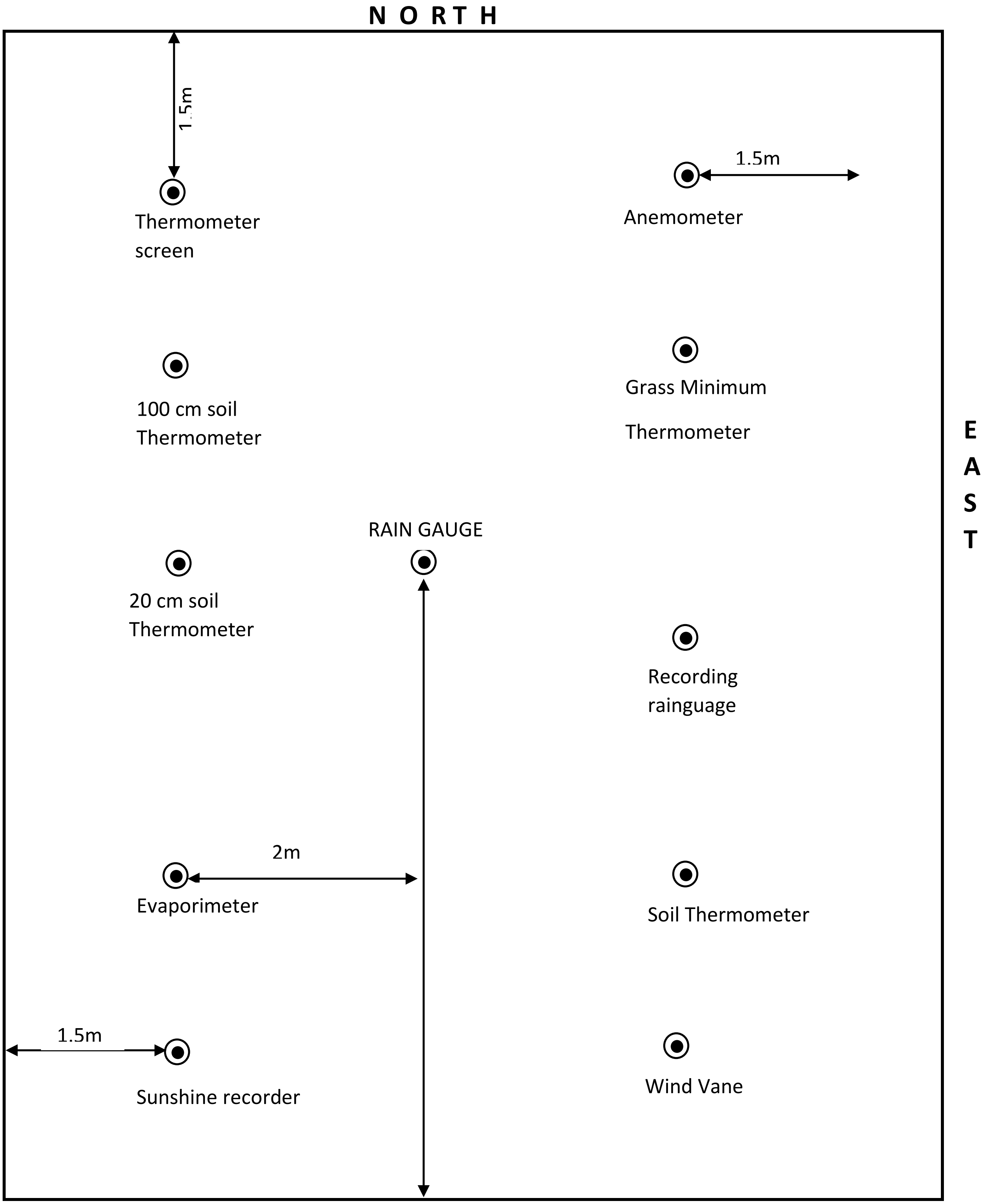

Figure 4.1 Sample layout of station :(Source: WMO-No, 8, 2008).

The establishment of Nigerian Meteorological Agency's Weather Stations must be in tandem with the WMO's Standards. The siting of instruments is important to having observations that represent any surrounding area. Many follow their own policy on selecting sites and the design of a weather station. Design and siting of Meteorological Equipment are well described in WMO Manuals and Guides. It is worthy to note that an ideal site cannot be found because of natural and artificial limitations.

As presented in Table 4.1, there is the presence of meteorological observatory in all the stations listed and this was sighted and also confirmed by all the 287 respondents drawn from Meteorologist, Forecaster and Engineers. Kano has 28% of the respondents, Kaduna has 9% respondents, Maiduguri has 7% respondents, Lagos has 18% of the respondents, Enugu has 7% of the respondents, Port Harcourt has 11 and Abuja has 20% respondents.

Table 4.1 Availability of Meteorological Enclosure

Station	**Number of Respondents**	**Yes**	**No**	**Percentage**
Kano	81	81	00	28
Kaduna	25	25	00	9
Maiduguri	19	19	00	7
Lagos	51	51	00	18
Enugu	21	21	00	7
Port Harcourt	32	32	00	11
Abuja	58	58	00	20
Total	**287**	**287**		**100**

(**Source: Authors' fieldwork, 2019)**

Each station making surface synoptic observations should be located at a site where the meteorological data obtained are representative of the state of the atmosphere over a large region. The station should have a plot of land specially assigned to it.

A total of 287 respondents were drawn from Kano, Kaduna, Maiduguri, Lagos, Enugu, Port Harcourt and Abuja. Kano has 81 respondents, Kaduna has 25 respondents, Maiduguri has 19 respondents, Lagos has 51 respondents, Enugu has 21 respondents, Port Harcourt has 32 and Abuja has 58 respondents.

Table 4.2 shows that the meteorological enclosure in Kano was sited according to WMO standards with regards to size, location, fencing, layout, metadata and obstruction issues this was seen and also confirmed by the Eighty One (81) respondents drawn from Meteorologist, Forecasters, Observers and Engineers.

Table 4.2 Compliance of Siting Meteorological Enclosure at Kano

Site Requirement	Number of Respondents	Yes	No
Size	81	81	00
Location	81	81	00
Fencing	81	81	00
Exposure	81	81	00
Layout	81	81	00
Metadata	81	81	00
Unobstructed	81	81	00

(**Source: Authors' fieldwork, 2019)**

Table 4.3 shows that the meteorological enclosure in Kaduna was sited according to WMO standards with regards to size, location, fencing, layout, metadata and obstruction issues this was seen and also confirmed by the Twenty Five (25) respondents drawn from Meteorologist, Forecasters, Observers and Engineers.

Table 4.3 Compliance of Siting Meteorological Enclosure at Kaduna

Site Requirement	Number of Respondents	Yes	No
Size	25	25	00
Location	25	25	00
Fencing	25	25	00
Exposure	25	25	00
Layout	25	25	00
Metadata	25	25	00
Unobstructed	25	25	00

(**Source: Authors' fieldwork, 2019)**

Table 4.4 shows that the meteorological enclosure in Maiduguri was sited according to WMO standards with regards to size, location, fencing, layout, metadata and obstruction issues this was seen and also confirmed by the Nineteen (19) respondents drawn from Meteorologist, Forecasters, Observers and Engineers.

Table 4.4 Compliance of Siting Meteorological Enclosure at Maiduguri

Site Requirement	Number of Respondents	Yes	No
Size	19	19	00
Location	19	19	00
Fencing	19	19	00
Exposure	19	19	00
Layout	19	19	00
Metadata	19	19	00
Unobstructed	19	19	00

(**Source: Authors' fieldwork, 2019)**

Table 4.5 shows that the meteorological enclosure in Lagos was sited according to WMO standards with regards to size, location, fencing, layout, metadata and obstruction issues this was seen and also confirmed by the Fifty One (51) respondents drawn from Meteorologist, Forecasters, Observers and Engineers.

Table 4.5 Compliance of Siting Meteorological Enclosure at Lagos

Site Requirement	Number of Respondents	Yes	No
Size	51	51	0.00
Location	51	51	0.00
Fencing	51	51	0.00
Exposure	51	51	0.00
Layout	51	51	0.00
Metadata	51	51	0.00
Unobstructed	51	51	0. 00

(**Source: Authors' fieldwork, 2019)**

Table 4.6 shows that the meteorological enclosure in Enugu was sited according to WMO standards with regards to size, location, fencing, layout, metadata and obstruction issues this was seen and also confirmed by the Twenty One (21) respondents drawn from Meteorologist, Forecasters, Observers and Engineers.

Table 4.6 Compliance of Siting Meteorological Enclosure at Enugu

Site Requirement	Number of Respondents	Yes	No
Size	21	21	00
Location	21	21	00
Fencing	21	21	00
Exposure	21	21	00
Layout	21	21	00
Metadata	21	21	00
Unobstructed	21	21	00

(**Source: Authors' fieldwork, 2019)**

Table 7 shows that the meteorological enclosure in Port Harcourt was sited according to WMO standards with regards to size, location, fencing, layout, metadata and obstruction issues this was seen and also confirmed by the Thirty Two (32) respondents drawn from Meteorologist, Forecasters, Observers and Engineers.

Table 4.7 Compliance of Siting Meteorological Enclosure at Port Harcourt

Site Requirement	Number of Respondents	Yes	No
Size	32	32	00
Location	32	32	00
Fencing	32	32	00
Exposure	32	32	00
Layout	32	32	00
Metadata	32	32	00
Unobstructed	32	32	00

(**Source: Authors' fieldwork, 2019)**

Table 4.8 shows that the meteorological enclosure at Abuja was sited according to WMO standards with regards to size, location, fencing, layout, metadata and obstruction issues this was seen and also confirmed by the Fifty Eight (58) respondents drawn from Meteorologist, Forecasters, Observers and Engineers.

Table 4.8 Compliance of Siting Meteorological Enclosure at Abuja

Site Requirement	Number of Respondents	Yes	No
Size	58	58	00
Location	58	58	00
Fencing	58	58	00
Exposure	58	58	00
Layout	58	58	00
Metadata	58	58	00
Unobstructed	58	58	00

(**Source: Authors' fieldwork, 2019)**

Conclusion

Meteorological observing stations are designed so that representative measurements (or observations) can be taken according to the type of station involved.

Where stations are used for several purposes, for example, aviation, synoptic and climatological purposes, the most stringent requirement will dictate the precise location of an observing site and its associated sensors.

It has been proven by the reconnaissance survey conducted and from the respondents that were interviewed that all the meteorological stations that covers the scope of this study were established based on WMO Standards using Guide to Meteorological Instruments and Methods of Observation. This is equally an indication that the meteorological parameters expected from these stations can be effectively used for flood warning system in Nigeria.

Recommendations

This study recommends that:

i. More meteorological station be established at every 150km intervals for surface stations and every 300km for upper air station.

ii. Training and retraining of staff on use and maintenance of the instruments and also to make them effectively manned the stations is recommended.

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