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HYDROMETEOROLOGICAL NETWORK UPGRADE DESIGN FOR OGUN-OSHUN RIVER BASIN

A.O. ERUOLA

[1]Department of Water Resources Management and Agrometeorology,
Federal University of Agriculture, Abeokuta, Nigeria

***Corresponding Author:** *layosky@yahoo.com*

ABSTRACT

Hydro-meteorological data useful for hydrological monitoring, agricultural production, research and planning in the tropics are grossly inefficient in terms of their practical values as a large number of the stations fall short of the international standard established. This study examined the effectiveness of the existing hydro-meteorological network in Ogun –Oshun river basin in terms of providing useful data for hydrologic processes and agricultural planning. This is with the overall aim of designing an upgrade for the network suitable for providing useful data for agricultural planning and hydrological processes. The design of hydrometeorological network upgrade in Ogun–Oshun river basin was carried following WMO standard for network design. The primary data and field information were obtained from the working files and existing stations of Ogun-Oshun River Basin Development Authority. Results obtained showed that, complete data were scarce and a lot of interpolations had to be done. Thus, important hydrometerological information relevant to agricultural planning and hydrological processes were missing. Also, that the existing spatial distribution of the networks has been found to be highly inadequate in most parts of the river basin. The reliability of hydrometeorological characteristics depends not only on the accuracy of observations, but also on the mathematical background for interpretation of the results. The need to optimize networks, means and methods of observations as well as the procedures and techniques of data processing is also discussed.

Keywords: GIS, hydro-meteorological, network, optimum, Ogun - Osun.

INTRODUCTION

Data on temporal and spatial characteristics of water resources of a region are obtained by a network of observational stations. To achieve a minimum cost in the design of such a network, there is need for scientific planning. No useful planning can be achieved without knowing the purpose for which the water resources and meteorological data are meant. This will help formulate general rules for network design. Hence, in designing hydro-meteorological networks, it is necessary to know the variables to be measured, the frequencies and duration of observations, the location of gauging stations, the instruments to be installed, the methods of observation and data 'observation and transmission system'. It should be borne in mind that there should be a good coordination among the hydro-meteorological data networks providers in order to reduce expenditure on data gathering and improve the data quality. Hence, the collection of reliable hydrometeorological data in most part of the tropics and Nigeria in particular has been difficult due to scanty distribution of observational stations within a network. The government of Nigeria in its strive towards a better, less costly and beneficial data acquisition systems, had established several river basins development authorities that are charged with the responsibility of developing both surface and underground water resources for multipurpose uses with special emphasis on irrigation agriculture. One of such river basin authorities is the Ogun river basin. However, no meaningful water resources development can be done without continuous assessment of the reliability of hydrometeorological data provided in the planning and management of water resources in the area. It has been observed that majority of the studies carried out on content analysis of hydrometeorological networks are mostly restricted to the technologically advanced countries (Cisleriora *et al.* (1974); Dawdy *et al*. (1979); Kreuder, (1979) and Osborn and Keppel (1965). The conclusion from these studies is that stations in developed countries are use-specific, and possess strategies which reduce political considerations and interagency conflicts in the allocation of water resources. Only few studies have reported situations in the tropics among are the work of Oguntoyinbo, (1987) and Ologunorisa, (2009). The few available studies showed that most of the existing stations are not in their proper location, and their locations have been determined and influenced more by political considerations without little or no consideration as to how representativeness these locations are to the surrounding area in question and their relationship with existing stations. Although, the World Meteorological Organisation (2008) has made its recommendation for the number of rain-gauges needed in certain areas, research has however shown that modifications are necessary in such locations due to some local conditions Ologunorisa, (2009).

In assessing, the content of hydro-meteorological networks therefore, the existing hydro-meteorological network would have to be audited, in order to determine how effective and efficient they are. Geographical information system is increasingly used in many industries due to recent improvements in computer hardware especially desktop, workstation and server processing capabilities. Researchers in the field of hydrology are cognizant of the benefits of GIS applications in hydrology. In essence, the applications of GIS in the field of hydrology has enabled the planners of water resources projects (WRPs) to address various conflicting issues as regards hydrological network by taking into considerations the spatial dimension and temporal variations on a regional scale. It is in this respect, that this study focuses on the use of GIS in the design of hydrometeorological network in the Ogun-Ohun River Basin, Nigeria. This is in order to provide effective values for the networks which can be used for agricultural research and planning so as to develop a reliable data platform that will enhance increased food production.

MATERIALS AND METHODS

Description of the Study area

Ogun- Ohun River Basin lies within latitude 6°33'-9°00'N and longitudes 2°40'- 5°05' E in the rain forest zone of Nigeria covering a total area of 66,246 km^2. It is drained by two rivers, Ogun and Osun (after which it is named) and a number of tributaries and smaller rivers, the most common amongst which are the Sasa, Ona, Ibu, Ofiki, Oni and Yewa (Fig.1). The climate is influenced by cool, rainfall- bearing southwest trade wind being blown from the hot Atlantic Ocean while the dry season is controlled by the continental North- Easterly harmattan winds coming from the Sahara desert. The area is located within a region characterized by bimodal rainfall pattern which commences in March and reach its peaks in July and September, with a short dry spell in August. The long dry period extends from November to March. The basin area is characterized by strong climatic variations and an irregular rainfall that ranges between 1250mm and 1400 mm with coefficients of variation ranging from 15 to 30 percent and mean annual air temperature of about 30°C in the basin area and environs. The topography of the basin reflects the contrast between the hummocky terrain underlain by the crystalline rocks north of Abeokuta, with its compact drainage pattern, and thickly forested undulating hills and swampy lowlands of the sediments to the south (Martins, 1987).

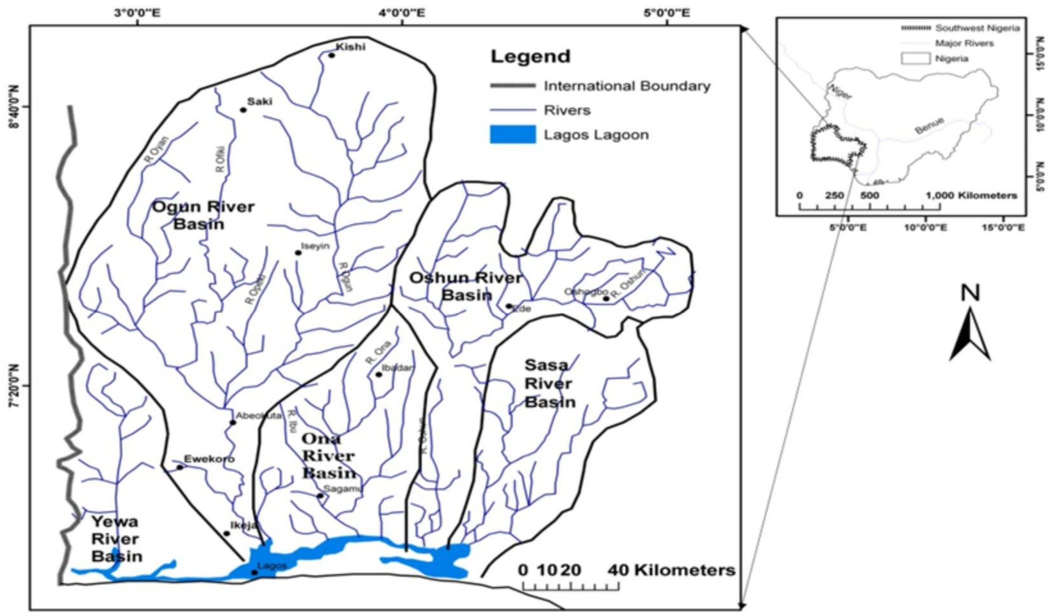

Fig. 1: Map showing the Ogun-Osun River Basin Area in Nigeria.

2.2 Reconnaissance survey of existing stations in study area

A total of 3 agro-meteorological stations (Table 1), 21 rainfall station (Table 2) and 37 stream gauging stations (Table 3) under the jurisdiction of the Ogun- Osun River Basin Development Authority were visited. In all the stations visited, personal observations were made of available equipment. Auditing of the stations were carried out in all the stations visited to determine the actual location of the stations, frequency of measurement at each hydro-meteorological station and to ascertain reasons why the stations were established, year of establishment of the stations, and how much of their objectives have been met, the quality of instruments and maintenance facilities put in place, qualification of the observatory staff and the frequency of supply of needed materials for recording information. Also, an on-the-spot reading was made to compare with readings available from existing records in order to test for consistency.

Table 1: Existing Agrometeorological Stations in Ogun-Oshun River Basin

Location	Stations	Latitude	Longitude
Ogun	Abeokuta	7.14793N	3.34968E
Lagos	Itoikin	6.6500N	3.8000E
Oyo	Sepeteri	8.62808N	3.64482E

Source: (Ogun-Oshun River Basin Authority)

Table 2: Location of existing rainfall stations in Ogun-Oshun River Basin

S/N	Location	Stations	Latitude	Longitude
1	Ogun	Ilase	6.69677N	2.79073E
2	Ogun	Ebute-igboro	6.89842N	2.87067E
3	Ogun	Ilaro	6.88621N	3.01559E
4	Ogun	Igbogila	7.05773N	2.98013E
5	Ogun	Oyan dam	7.2500N	3.26667E
6	Ogun	Igan-Alade	7.0667N	2.96670E
7	Ogun	Abeokuta	7.14793N	3.34968E
8	Ogun	Ajilete	6.7000N	2.9333E
9	Oyo	ORBDA,Ibadan	7.35722N	3.89341E
10	Oyo	C.A.C Grammar School Apata	7.3667N	3.93330E
11	Oyo	St Luke Grammar School	7.3500N	3.90000E
12	Oyo	Middle Ogun Irrigation Project	7.8833N	3.75000E
13	Oyo	Sepeteri	8.62808N	3.64482E
14	Oyo	Ikere Gorge Dam	7.7333N	4.15000E
15	Oyo	Fiditigrmmar School	7.7167N	3.91667E
16	Lagos	Badagry	6.41101N	2.88228E
17	Lagos	Epe	6.5333N	3.51667E
18	Lagos	Ikorodu	6.4667N	2.41667E
19	Oshun	Iwo	7.62538N	4.17778E
20	Oshun	Ilesha	7.63174N	4.74268E

Source: (Ogun-Oshun River Basin Authority)

The stations' workers were also interviewed and their responses were utilized in forming part of the primary data used in this design study. The proposed stations were estimated from the range of norms for minimum network area per kilometer square as recommended by WMO for each terrain unit which is shown in table 4.

Table 3: Stream Gauging Stations in Ogun-Oshun River Basin

S/N	Location	Stations	Latitude	Longitude
1	Ogun	Apoje	6.96646N	4.12011E
2	Ogun	Abeokuta	7.14793N	3.34968E
3	Ogun	New bridge	7.14793N	3.34968E
4	Ogun	Olokemeji	7.4284N	3.52638E
5	Ogun	Alamutu	7.4200N	3.2900E
6	Ogun	Mokoloji	6.88438N	3.1964E
7	Ogun	Ibaragun	6.71667N	3.3500E
8	Ogun	EruwaTitun	7.54988N	3.4458E
9	Oyo	Ilaji-Ile	7.9833N	3.0500E
10	Oyo	Sepeteri	8.62808N	3.64482E
11	Oyo	Iseyin	7.97508N	3.59954E
12	Oshun	Ilesha	7.63174N	4.74268E
13	Oshun	Ede	7.73157N	4.43694E
14	Yewa	Ajilete	6.7000N	2.91667E
15	Yewa	Ijaka-Oke	7.1905N	2.90823E
16	Yewa	Eggua	7.06029N	2.90956E
17	Yewa	Ebute-Ibooro	6.89842N	2.87067E
18	Yewa	Idogo	6.83506N	2.9149E
19	Aiye	Itoikin	6.6500N	3.8000E
20	Ibu	Ajura	6.9645N	3.6040E
21	Ona	Shasha	7.48333N	3.91667E
22	Ona	Moore plantation	7.38045N	3.84208E
23	Ona	Idi ayure	7.23333N	3.8667E
24	Orufu	Iwo	7.62538N	4.17778E
25	Ofiki	Ofiki	8.44232N	3.33382E
26	Opeki	Abidogun	7.3333N	3.3333E
27	Ogbere	Oremeji Road	7.31667N	3.93333E
28	Ogbere	Olojuoro Road	7.3000N	3.93333E
29	Ogbere	Akanran Road	7.3500N	3.9833E
30	Ogunpa	Bodija Secretariat	7.41667N	3.91667E
31	Ogunpa	Queen Elizabeth	7.36667N	3.9000E
32	Ogunpa	Gram school, Molete	7.3333N	3.9000E
33	Kudeti	Agbongbon Road	7.3667N	3.91667E
34	Kudeti	Alafan/Adeoyo Road	7.3833N	3.91667E
35	Yemetu	Yemetu/adeoyo Road	7.3833N	3.9000E
36	Owena	Ife/Ondo Road	7.48412N	4.55628E

Source: (Ogun-Oshun River Basin Authority)

Table 4: WMO Recommended Minimum Network Densities of Stations(Km^2/ Station)

Physiographic Unit	Precipitation Non-recording	Precipitation recording	Stream flow	Evaporation	Sediments
Coastal	900	9000	2750	50000	18300
Mountain	250	2500	1000	50000	6700
Interior plains	575	5750	1875	5000	12500
Hilly/undulating	575	5750	1875	50000	12500
Small island	25	250	300	50000	2000
Urban	-	10-20	-	-	-
Arid / Polar	10000	100000	20000	100000	200000

Source: (WMO, 2008)

The topographical map of Ogun –Osun river basin was imported into GIS software (Arc View 3.2a). the key features of the map recognized on land served as the position for geo-referencing the topographical map. Cordnates of stations were acquired with Gemine GPS. The geo-refenced map was digitalized “head up”, features like drainage network, major roads amon others were captured in separate layers. In order to generate spot heights which will later be used to generate the digital elevations, a grid of 0.1cm was created on the topographic map so as to generate large amount of data. The center of the grid were digitized and there co-ordinates calculated using a specialized module for calculating true centroid in GIS.

The digital elevation model represents the altitude of the terrain. Digital elevation model is of paramount importance in hydrometeorological network design. Hence this was obtained from spots height generated. DEM was created by collecting elevations and referencing them to the corresponding points in the mapped area. Digital contour lines generated from the coordinates imported into the arcview 3.2a is the main source o DEM generation. Two main steps followed in constructing DEM. The first step is converting contour data containing elevation attribute into the point data. The second step generated the surface from the point data created in the first step. The DEM provided automatic layers for perspective viewing, terrain analysis, hydrographic analysis, and station distribution.

RESULTS AND DISSCUSION

3.1 Content Analysis of Existing hydro-meteorological stations content analysis

The frequency of observation in the hydro-meteorological stations in the study area was found to be twice daily at 0800 hours (8.00a.m. local time) and 1600 (4.00p.m local time). Also, complete data was hard to comeby. For this reason, so much interpolation had to be done. In addition, in most stations visited, interpolation had to be carried out for 85% of the stations. About 75% of the stations have cases of missing data. The standard size of an observatory is 20 x 20m but only 5% of the stations met the requirements as laid down by WMO. Also, most of all the automatic rain gauges were not functional and about 70% of the rainfall stations in the basin were improperly placed, with records taken by non-professionals. Most of the stations with automatic equipment especially automatic rainguages have no recording papers. Also, 40% of the stations have damaged equipment which have not been replaced. All the stations depend on the Nigeria Meteorological Services, Oshodi, Lagos for help and assistance which in most cases are not forthcoming.

Only the agro-meteorological stations produced the highest quality of information because of the purpose they were meant to serve which is forecasting of weather for agricultural purposes. About 70% of the agro-meteorological stations have at least one sophisticated self-recording equipment. Rainfall stations located in secondary schools and government ministries do not take record during holiday. Many of the hydrological stations still take record of river stage in imperial system, which is in feet and inches which may not allow for error detection in comparison with the metric system. This observation was made in a similar study by Ologunorisa, (2009) in Southwestern Nigeria. Due to sand mining and turbulent debris discharge on riverbeds, some of the staff gauges have become defaced or dislocated, and needs replacement. Generally, about 35

% of the stations studied did not have proper record keeping and retrieving system, while 85% of the stations are manned by non-professionals. Ologunorisa, (2009) and Oguntoyinbo's (1987) also observed that most of the stations in Nigeria and the Southwestern part in particular are grossly inefficient in terms of their practical values since a large number of the stations fall short of the international standards stipulated by WMO.

3.2 Design of proposed additional Hydro- Meteorological Stations

The analysis of stream gauging, evaporation, rain-gauge network efficiency and proposed stations in the design of hydometeorological network for Ogun-Oshun river basin is shown in Table 5. Knowing that most of the stations in the river basin are grossly inefficient in terms of accurate prediction of discharge and rainfall values when compared to international standards, it became essential to bridge the gap by designing new stations as shown in the figures 2,3 and 4. The spatial distributions of the stream gauging station were more to be at the upper north eastern part of the basin. Furthermore, for such sub river basins such as Oshun, Yewa and Ona without agrometeorological stations, there is the need for the installation of at least a station in the sub-river basin for effective networking within the basin. Also, with the minimum rain-gauge network requirement of one station per 575 km^2 in the plains and hilly area, and to ensure effectiveness of rainfall networking in addition to minimize cost of the equipment, 70% of the existing stations were proposed to be added in the network in the design, this was because 15% of the stations met the WMO requirement while 5% of the stations were improperly sited in Ogun river basin. Therefore additional 24 rainfall stations should be provided in order to attain 70% effectiveness in Ogun river basin. Additional 11 rainfall stations should be established in order to make for 70% effectiveness in Oshun river basin, while 9 stations is proposed so as to attain 70% effectiveness for proper networking of the stations. Also to reduce the cost of acquiring equipment for Shasha river station, more stations should be established as none of the existing stations met WMO requirement and were not properly located in the Ona river basin. Therefore, for proper distribution and location, more stations should be installed and the stations are proposed in order to attain 70% effective networking. There is also a need to install automatic rain-gauge station in all the sub-river basin of Ogun-Oshun river basin for proper assessment of rainfall input inside the basin as most of the stations have no automatic rainguage suitable for accurate prediction of precipitation in the entire basin network.

Table 5: Analysis of Stream Gauging, Evaporation, Rain-Gauge Network Efficiency and Proposed Stations in the Design for Ogun-Oshun River Basin

Ogun-Oshun river basin (sub-basins)	Catchment area(km2)	Stream Gauging			Evaporation data			Manual Rain-gauge			Automatic Rain-gauge		
		Expected Number of stations	Existing Number of stations	Proposed Number of stations	Expected Number of stations	Existing Number of stations	Proposed Number of stations	Expected Number of stations	Existing Number of stations	Proposed Number of stations	Expected Number of stations	Existing Number of stations	Proposed Number of stations
Ogun river basin	24096	13	9	4	5	2	2	40	6	30	4	0	4
Oshun river basin	9741	5	2	2	2	0	1	17	2	11	2	0	1
Yewa river basin	6000.5	3	6	0	1	0	1	10	6	4	1	0	1
Ona river basin	6775.3	4	11	0	1	0	1	12	4	7	1	0	1
Shasha river basin	6623.0	4	1	3	1	0	1	12	0	10	1	0	1

Source: Field Survey (2014)

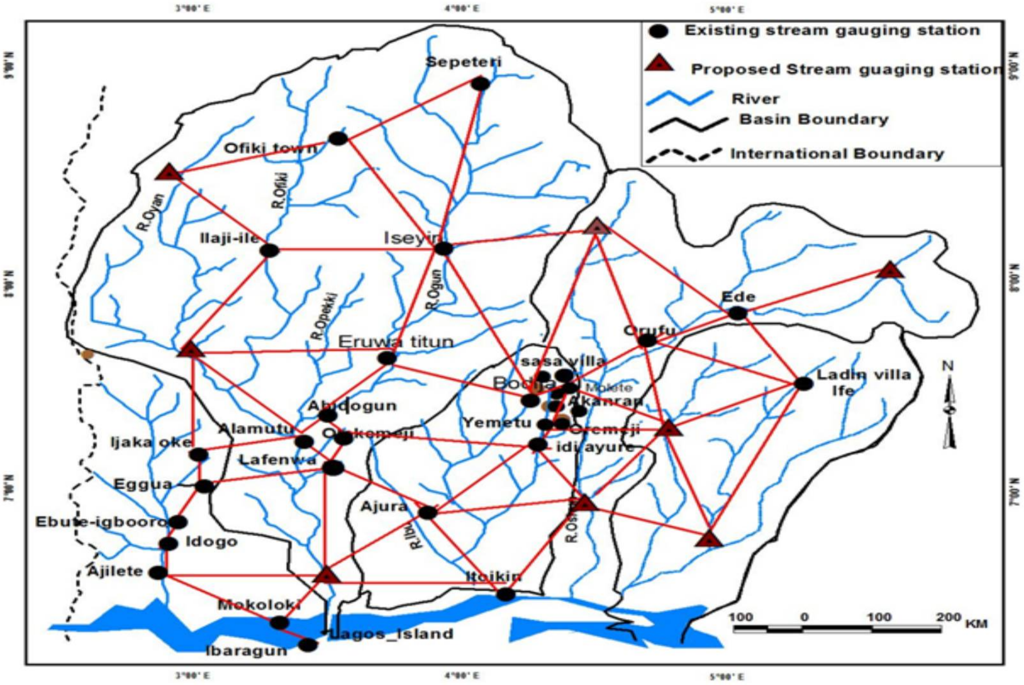

Figure 2: Map Showing Existing and Propose Network of Stream Gauging in the River Basin

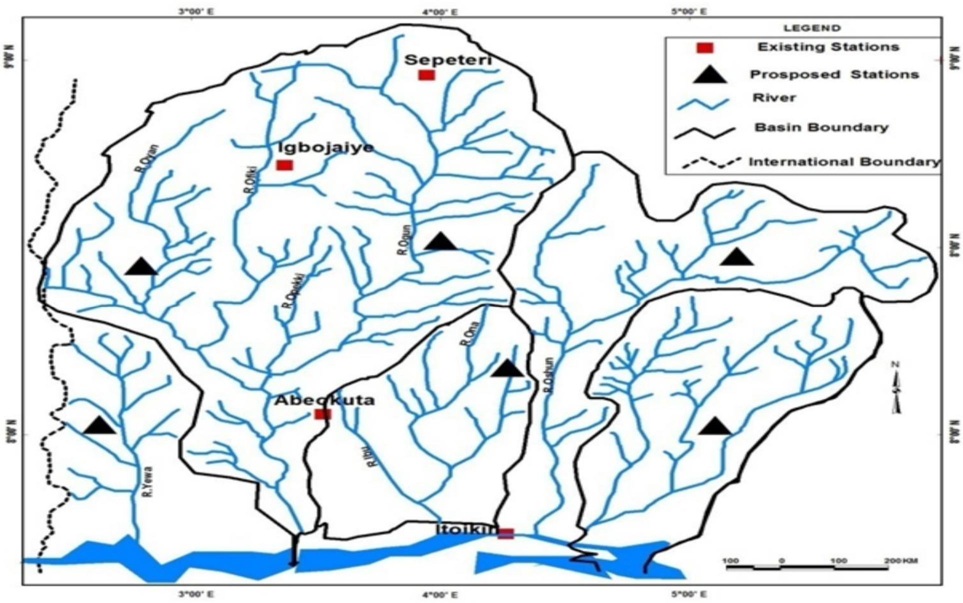

Figure 3: Map Showing the Existing And Proposed Agromet Stations in the River Basin

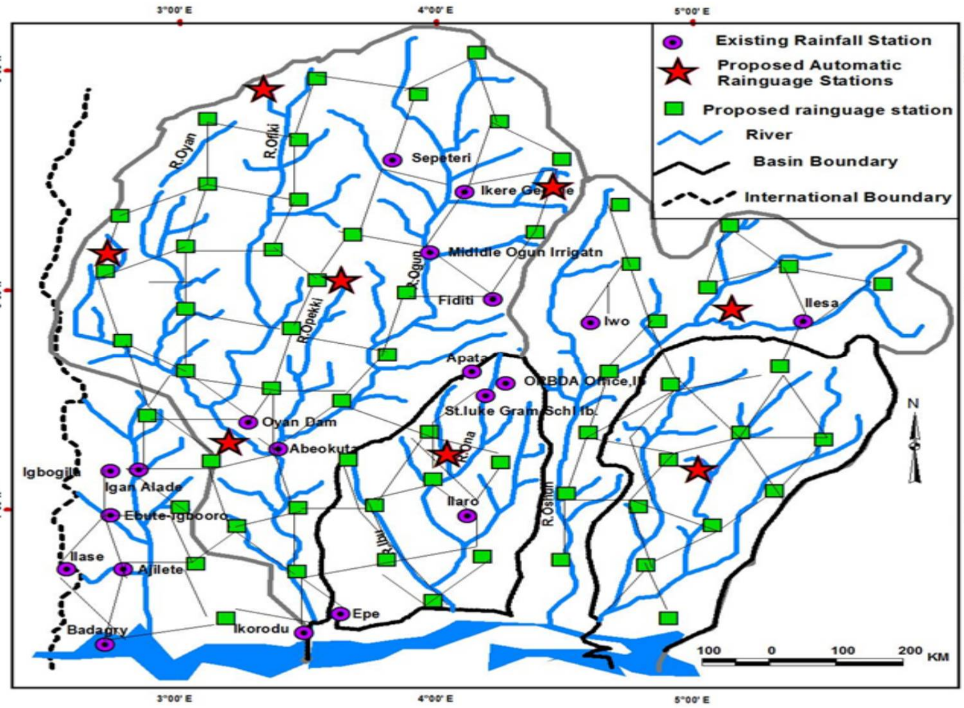

Figure 4: Map Showing the Existing and Proposed Convectional and Automatic Rain-Gauge Stations in the River Basin

CONCLUSION

The study examined the content analysis of hydro-meteorological networks in the Ogun -Oshun River Basin and its implications for agricultural planning. Out of a total of 37 hydrometeorological stations studied in the river basin, results show that complete data were very hard to come by. Furthermore, where available some of the records are still in imperial units (feet and inches) and for that reason, so much interpolation and use of historical data had to be adopted to study and detect changes and anomalies. Hence, the study concluded that there is need to improve the quality of the network by addressing some of the problems already identified with existing stations for the practice of sustainable agricultural production in the region. This can be attained by bridging the gap through the design of new stations which will be well distributed in the region.GIS has been revealed to be an efficient tool in solving the distribution pattern of the hydrometeorological network. It is also advisable that the existing and proposed station when installed should be well maintained and run by professional or trained staff.

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