Mapping and Analysis of River Garanga Basin with S.P.O.T. H.R.V. Xs Imagery

by Ufoegbune Gideon 1993/94/M. Tech/SSSE/001

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ABSTRACT

This study was carried out bearing in mind the need to update the maps of river basins and analyse the Garanga river basin. Most maps available in the country were made years ago and there is need to update these maps especially in terms of hydrologic features. There was also the need to determine the flood plain of the basin. The study also tried to analyse morphometically the Garanga river basin.

A print out of S.P.O.T. H.R.V. XS imagery in compose and preprossed form was used for the study. The scale of the print out is 1:62,500. A topographic map of Rano with scale 1:250,000 was used for comparism.

A manual interpretation approach found that it was possible to map the basin and identify more streams than are found in the topographic map. The study found that it was also possible to demarcate the flood plain of Chalawa river which the Garanga river flows into and also to attempt a discontinious delineation of Garanga river.

The basin was also analysed morphometrically. The bifurcation ratio showed that the stream is an ordinary stream. The length ratio showed a digression of 2 to 1 and 4 to 3 order of stream lengths. The main stream is a fifth order stream and the basin is a subdendritic in pattern.

The study above all things showed that it was possible to update a topographic map using Remote Sensing data and to perform the mapping in a given time even with Manual interpretation approach.

DEDICATED TO MY PARENTS

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Thank you all in Jesus name.

CERTIFICATE PAGE

I certify that this work was carried out by Ufoegbune Chukwuma Gideon as part of the requirements for Masters of Technology (M. Tech.) degree in Remote Sensing Applications, School of Science and Science Education, Federal University of Technology Minna.

Dr. G.N. Nsofor
Supervisor's Signature

20/4/97
Date

APPROVAL PAGE

This thesis has been read and approved as meeting the requirements of the School of Science and Science Education (Geography Department).

External Examiner | Date

Head of Department | Date

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CHAPTER ONE

Introduction

1.1 Background

Water, water everywhere but there is none to drink as the old maxim goes, indicates the nature of the problem of water supply and avaliability in the world today. The mere mention that water occupies more than 70% of the Earth's surface, gives a wrong indication of both the spatial and temporal distribution of water for man's use.

Location	Volume 000's of km	Percentage of Total water
Fresh water lakes	125.00	
Rivers	1.25	0.62
Soil moisture	65.00	
Ground water	8,250.00	
Saline lakes and Inland seas	105.00	0.008
Atmosphere	13.00	0.001
Polar Ice caps, glaciers and snows	29,200.00	2.1
Seas and Oceans	1,320.000.00	97.25
Total	1,360.000 or 1.36 x $10^{18} m^3$	100%

Table 1.1 Estimated Earths Water inventory (After Wilson).

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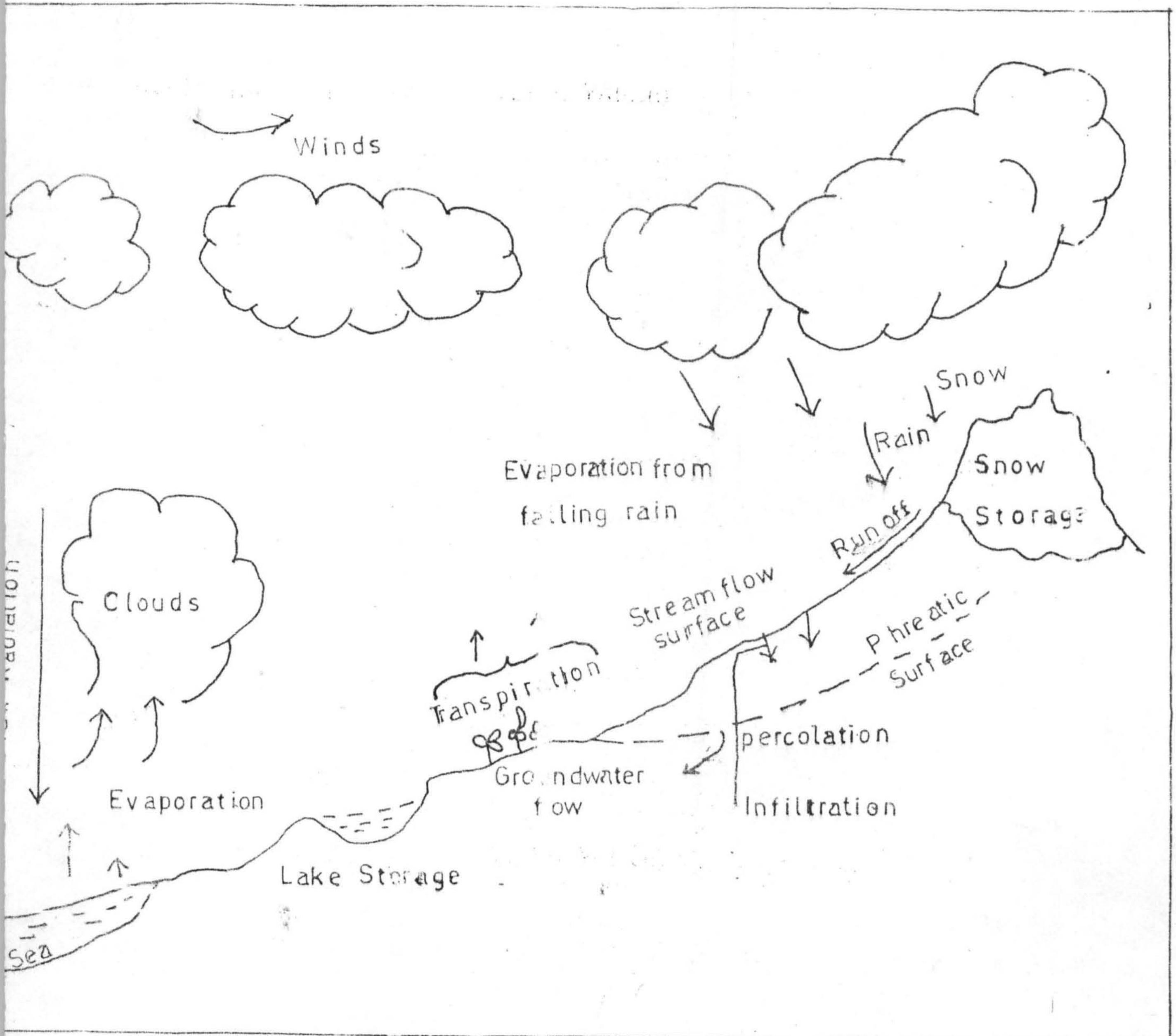

ig 1 The Hydrological cycle (after Wilson)

Of the 0.62% of the total water avaliable as fresh water, half lies below a depth of 800 metres. At that depth it is difficult to extract it for mans use and so stream water is mostly relied on. It gives a total of 1250 square kilometres of water all over the earth.

In Africa, there is a serious problem of water shortage because of the following reasons.

- Locations of the great deserts
- Climatic variability
- the geology
- the cultural practices of the people.

The great sahelian drought of 1969 - 1973 and subsequent droughts have increased the problem to greater dimension.

With reference to Nigeria, where there are two major climatic zones - the humid south and the dry north, the problem is more of temporal and areal distribution water supply. The dry north, because of its nearness to the Sahara desert and the influence of North-East (N.E.) trade wind is more susceptible to this variability in the water supply. The distinct long dry and short wet season influencing the north with rainfall generally less than 1000 milimetres portrays the problem of the Northern Nigeria to a great extent.

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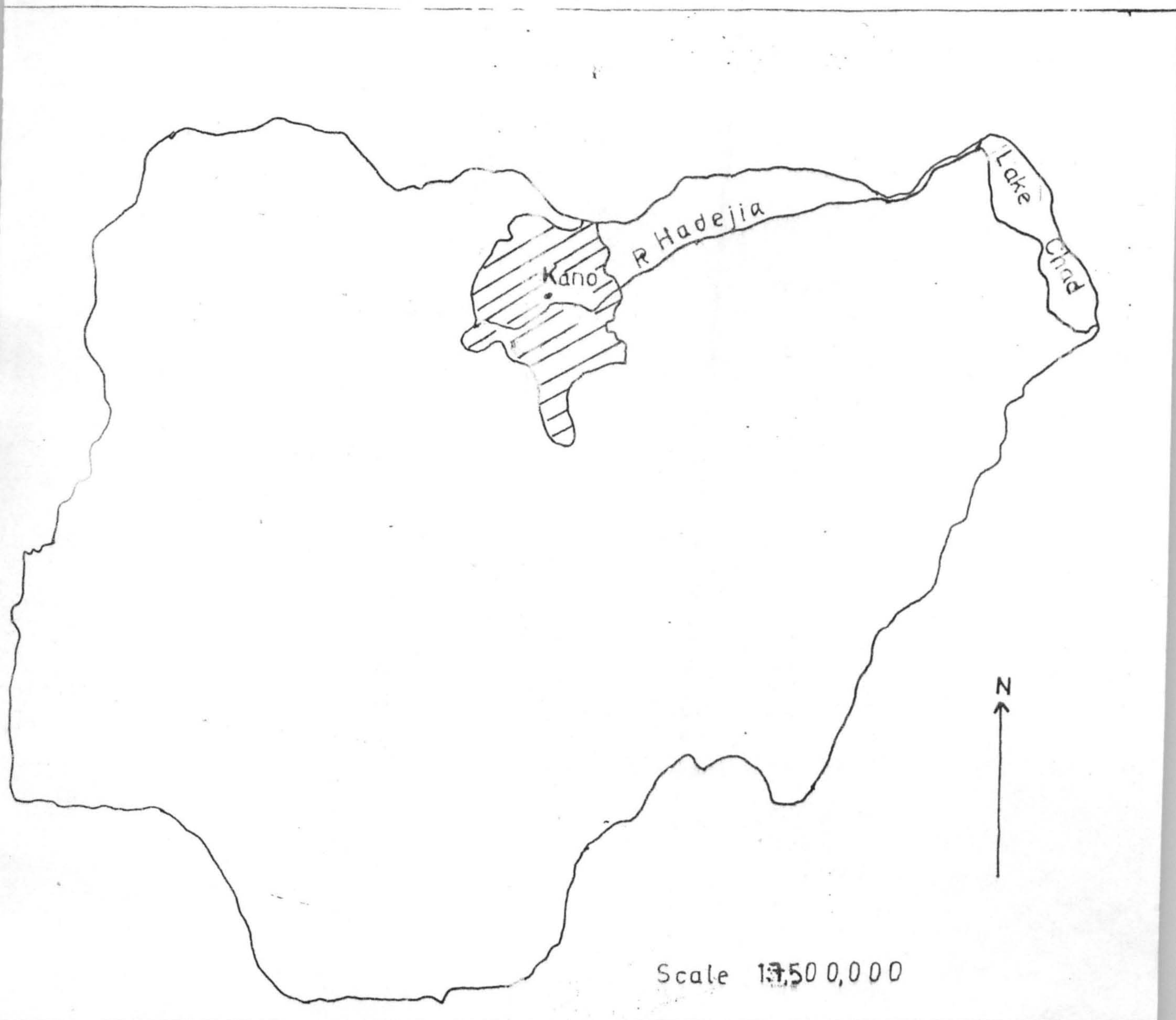

Fig 2 Map of Nigeria showing Kano State

This problem is compounded by the fact that the few streams in the North dray up generally with little water surviving the scorching dry season. Of this, much is used for irrigation by farmers.

There is then the need to regularly up date the maps of river basins while analysing the streams to provide an avenue for effective utilization of streams in the north. The importance of water to man for his domestic, agricultural and industrial uses calls for this updating of maps, and regular analyses of the hydrologic features of streams. The analysis of a basin yields a lot of information about the geology and geomorphology of the basin area and the types of development processes that could be carried out in the basin. That is, it gives an idea of how to use and tame a basin, gives climate. Remote Sensing data gives the best kind of up-to-date information especially for mapping a drainage basin. This is because Remote sensing gives an authentic and verifiable carthometic information due to its spatial resolution ability. analyses of Remote Sensing data is quicker because it is subject to computerisation. It is possible to use the properties of Remote Sensing data, where available to measure stream velocity, depth and topographic differences.

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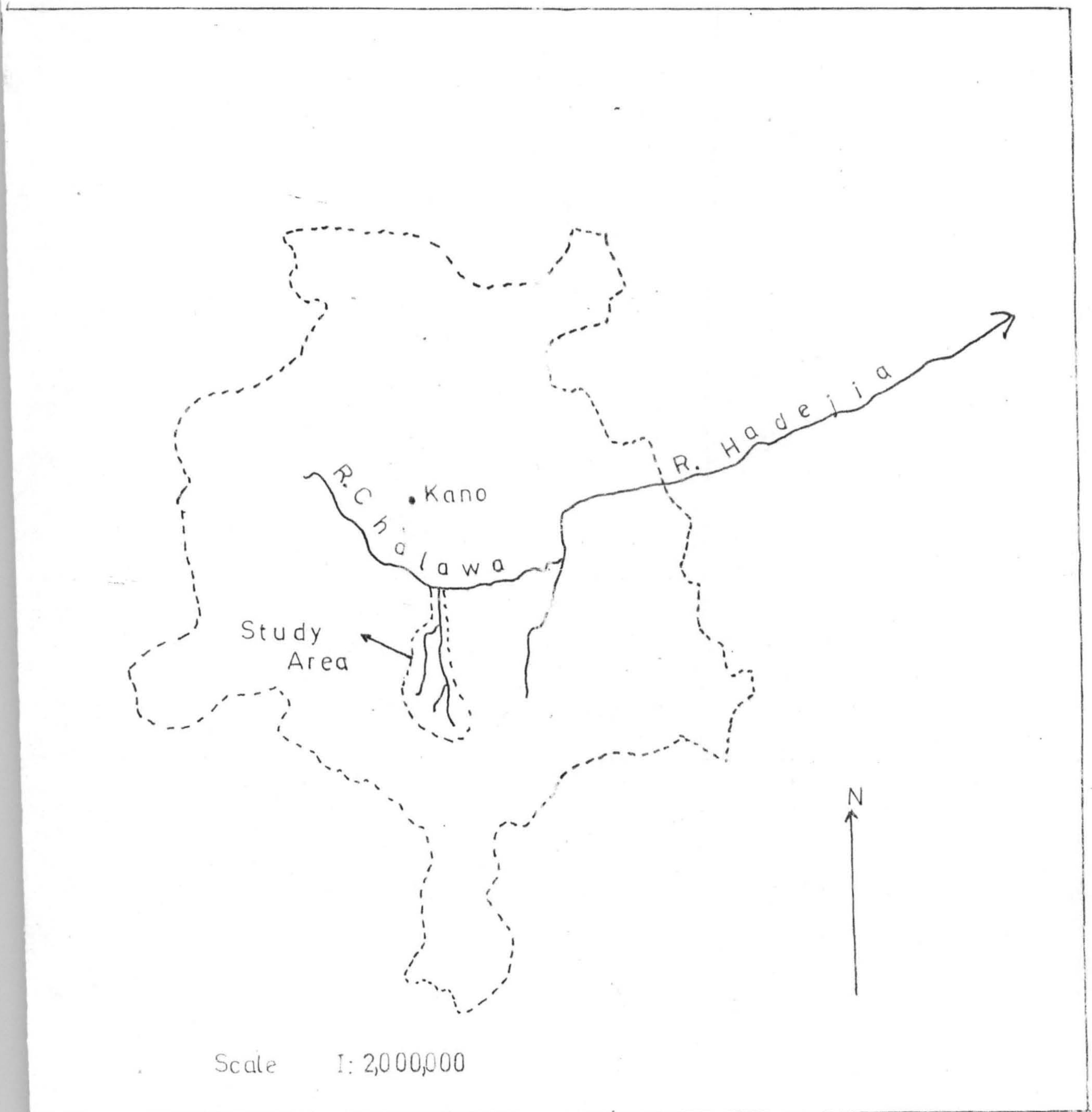

g 3. Map of Kano State showing the Study Area

1.2 <u>Occurance of water in the Earth</u>

The cyclic movement of water from the sea to the atmosphere and thence by precipitation to the earth where it collects in streams and runs back to the sea is referred to as thehydrological cycle. Such a cyclic order of events does occur but it is not as simple simple as that, first the cycle may short-circuit at several stages. For example, the precipitation may fall directly into the sea, lakes or river courses. Secondly, there is no uniformity in the time a cycle takes. During droughts, it may appear to have stopped altogether during floods, it may seem continous. Thirdly, the intensity and frequency of the cycle depends on geography and climate, since it operates as a result of solar radiation which varies according to the latitudes and seasons of the year. Finally, the various parts of the cycle can be quite complicated and man can exercise some control only on the last part, when the rain has fallen on the Earth and is making its way back to the sea.

Although the concept of the hydrological cycle is oversimplified, it affords a means of illustrating the most important process that a hydrologist must understand. The cycle is shown diagramatically in figure 1.1.

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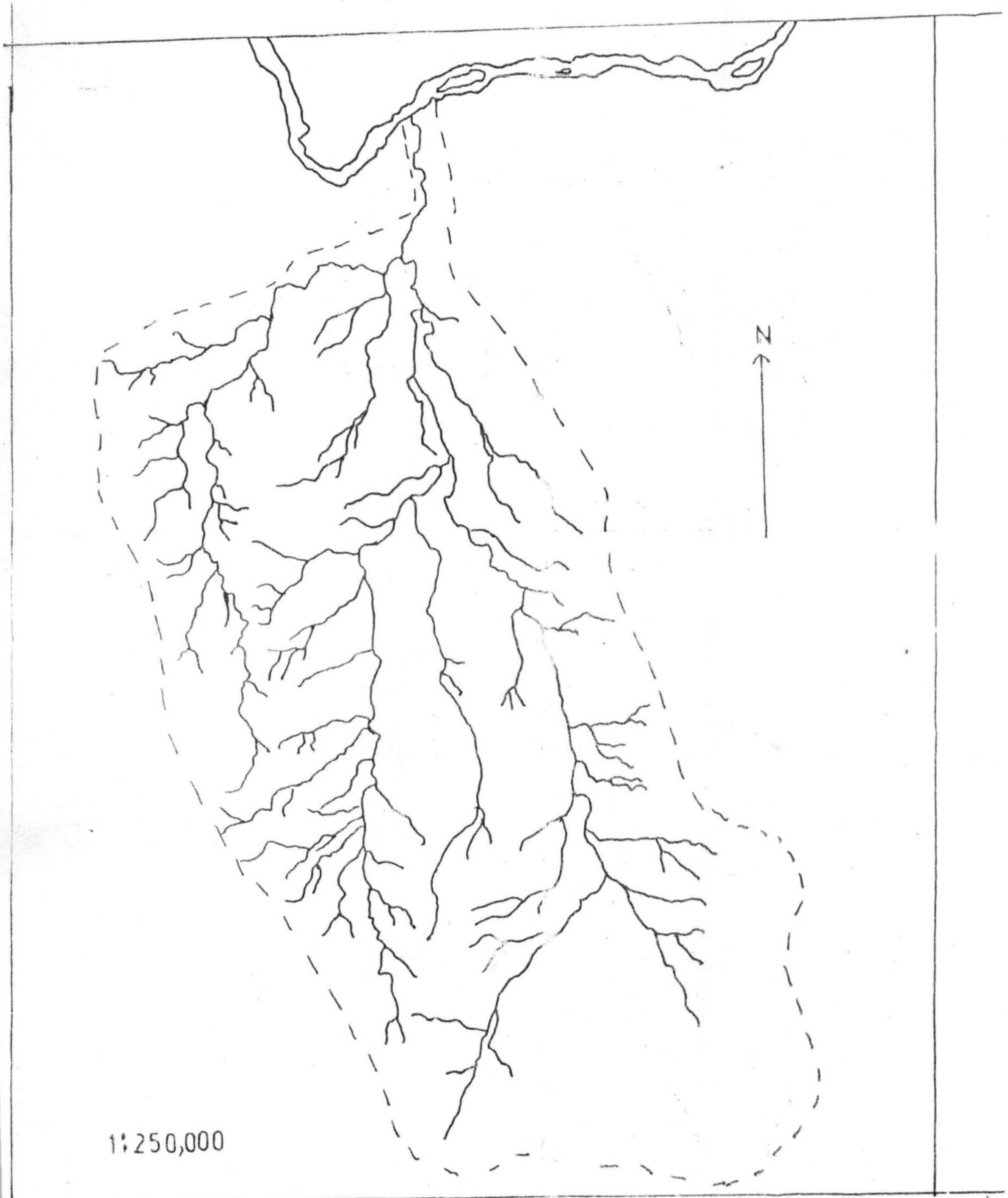

Fig 4 Map of the Study Area

Water in the sea evaporates under solar radiation and clouds of water vapour move over land areas. Precipitation occurs as snow, hail or rain overland and water begins to flow back to the sea. Some of it infiltrates into the soil and moves down or percolates into the saturated ground zone beneath the water table or phreatic surface. The water in this zones flows slowly through acquifers to river channels or sometimes directly to the sea. The water which infiltrates also feeds the surface plant life and gets drawn up into the vegetation and transpiration takes place from leafly plant surfaces. The water remaining on the surface partially evaporates back to vapour, but the bulk of it coalesces into streamlets and runs as surface runoffs to the river channels. The river and lake surfaces also evaporate water so that more water is removed here. Finally, the remaining which has not infiltrated or evaporated arrives back at the sea via the river channels. The groundwater which is moving much more slowly, either emerges into the stream channels or arrives at the coast line and seeps into the sea and the whole cycle starts again.

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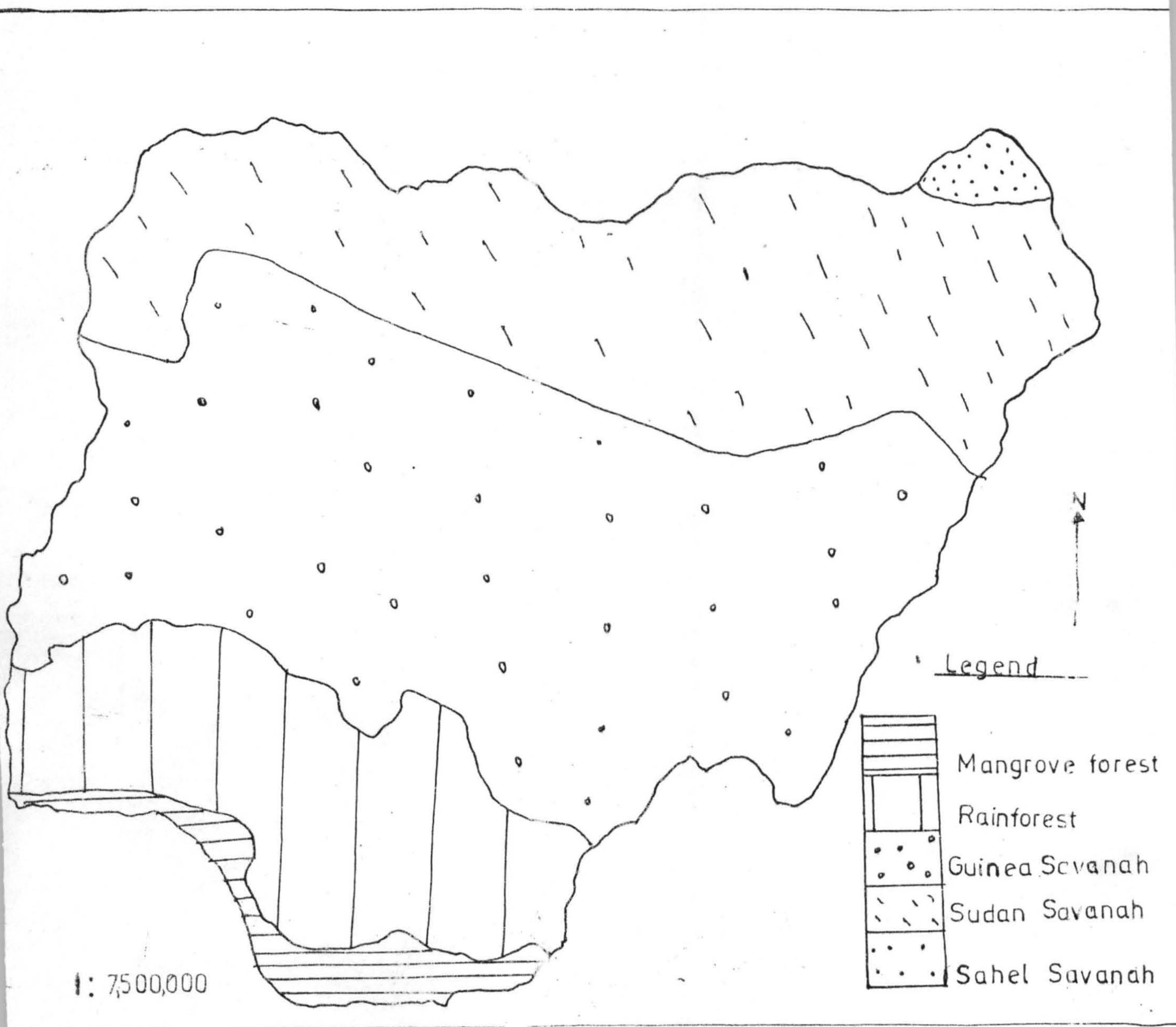

Fig 5. Major Vegetation Zones of Nigeric

1.3a Problem Statement

Every nation in trying to optimise the use of its water resources adopts different methods of doing this. In Nigeria, the option is River Basin Development Authority Concept. These Authorities and other development agencies rely generally upon Topographic maps made years back for their activities. Much as one cannot say that these maps are outdated but it must be understood that the features of a river basin are continually changing. This problem is complicated by the fact that most River Basin Authorities are not single basin developers. The demarcation of river basins are mostly along political boundaries and careful studies are not usually made of the river systems to understand the ways in which these streams could be of benefit to communities they are meant to serve. This could lead to underutilization or wrong utilization of rivers' potentials by these authorities.

So as at now, the Garanga river basin as indeed most other river basins in the country have not had their maps updated and their hydrologic features analysed. Remote Sensing data has not been applied in the study of this river basin before. The flood plains of the basin has not been mapped in recent times.

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Our problem here was to explore the Remote Sensing options/advantages in tackling these problems. Among others, these advantages are

- amenability to spatial analysis, that is, spatial integrity.
- Consistency of information.
- Broader view and more selective ability to detect the variations in environmental conditions.
- Physical ability to combine and enhance multiple images.

1.3b Aims and Objectives

The project focused on using the advantages of Remote Sensing to:

- Map the Garanga River Basin.
- Analyse the hydrologic features of the basin, that is morphomettic characteristics.
- Compare the number of streams identifiable in a Topographic map and the number of streams identifiable in a Remote Sensing image in order to establish if a Topographic map could be updated and revised by Remote Sensing data.

1.3c Hypothesis

- Is it possible to use Remote Sensing data to produce a map of Garanga river basin comparable to topographic map

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- Will morphometric analysis of the basin with Remote Sensing data contribute to a better understanding of the hydrology of the basin.
- Is it possible to delineate the flood plain (fadama) of the basin with Remote Sensing data.

1.4 The study Area

The Study area is Garanga river basin, a part of Chalawa river basin in Kano state. The river is to the west of Rano, an ancient city in Kano state. The area lies within $8^{\circ}30'$ East and $8^{\circ}47'$ East and $11^{\circ}20'$ and $11^{\circ}50'$ north.

Geology and Geomorphology.

The study area is under lain by the Basement complex Rocks. Though the Basement complex was authomatically classified as pre-cambrian on the grounds of the close agreement in petrology shown with the well known rocks of Fennoscandia, radioactive dating by Jacobson and others (1958) have now completely altered this picture and it is now transpires that much of the basement rocks falls within the time boundary of the early palaeozoic.

Reyment and Tait (1972) group the study area under the late Jurrassic Igneous rocks referred to as 'young granites' which are discordently intensive into the chrystalline Basement complex.

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They form part of a North-African petiographic region ranging from Ondovian-Silurian, middle Jurassic to Palaeocene. It probably has an outlying occurance of Turonian age in Brazil.

The Basement Complex rocks, themselves, have had a long history during which they suffered varying degrees of alteration by heat and pressure, were folded and crumpled, raised into mountain ranges and then eroded. The basin area lies between 400 metres and 650 metres above the sea level. It also lies within the chrystalline area of the ground water province where the groundwater avaliability is unpredictable, unconfined and water table is restricted to subbasins.

Climate: The climate of the area is the Tropical Hinterland with the prevailing wind as N.E. trade wind during the months of October through March and S.W. Monsoon in the months of May to September. The N.E. trade wind is dust laden and it dries as it passes through Sahara desert into West Africa. The S.W. monsoon wind brings rainfall from the coast of West Africa as it pushes the N.E. winds upwards. Being far in the hinterland, the effects of the moiture laden S.W. monsoon winds are not highly felt as rainfall is as low as between 800 - 950 milimetres per annum.

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The rainfalls are generally convective or associated with line squalls. Being far in the hinterland, the humidity is also generally low especially in the dry season.

Temperature is high with mean annual temperature between 76^{0} F and 78^{0}F. The annual range of temperature is as high as the daily range which may be upto 10^{0}F or above, The high temperature is due to high insolation which in turn is caused by insufficient cloud cover to sheild the excessive insolation. The problem of insufficient cloud covers causes the annual sunshine hours to be as high as 3084 sunshine hours. According to the 'Atlas of Federal Republic of Nigeria (1978) 'the area receives about 185 kg. cal.cm^{-2}yr^{-1} of radiation per annum.

<u>Ecological Zone</u>: The area falls within the Sudan savannah belt consisting of grasses and shrubs with very few trees. It approximates the parkland vegetation of the temperate zone. The forests here are associated with reparian zones. The general species include Anogeissus leiocarpus and Accacia spp.

The area is used for annual crops, usually grain crops and cotton is produced along the Fadama. Extensive cattle rearing is done under normadic herding system of agriculture by the fulanis.

1.5 Limitation and Scope

The thesis was based on using data from a Remote Sensing image to map and analyse the Garanga river basin. The image used for the study is a S.P.O.T. (Satellite Pour la' observation de la Terre) H.R.V. (High resolution Visible) image in XS (multipectral) mode. A print out of the study area was made by a computer from a digital tape. Since the imagery is a print out copy, the features were not very clear and the stereoscopic ability of S.P.O.T. images were lost. A manual approach was used in the analysis reducing the occuracy that would have been possible with computer based approach. Due to inavaliability of appropriate data, velocity and relief characteristics of the basin was not analysed. The scale of the imagery was not avaliable so the scale was computed from a Topographic map. In situation where there are two sets of figures, the figure in brackets is Topographic map data while the other is satellite image data.

1.6 Justication for the study

The need to update the map of the Garanga River Basin using a Remote Sensing data is the main purpose of this study.

The normal conventional method of map making involving field surveys is very slow and energy consuming. It involves collecting point data which makes data collected from different stations susceptible to human errors. Data from Remote Sensing imagery are mechanically collected with high spatial resolution. This makes Remote Sensing data more accurate and time saving in map making.

There is also the need to apply a manual approach to see if it is possible to get an acceptable map without the use of a computer. This need cannot be over-emphasised in a developing country like Nigeria, where computer facilities may not be avaliable to all conce- concerns that might require that type of study.

To use the ability of Remote Sensing data to give information as regards the phreatic water divide in delimiting the basin is another justification for this study. This is because conventional data only gives information as regards the topographic water divide. There is also the need to study morphometric structures of the Garanga river basin.

1.7. The Place of Remote Sensing

This chapter will not be complete without discussing the place of Remote and its relationship to this study. Remote Sensing is the art and science of obtaining information about an object, area or phenomena through the analysis of data acquired by a device that is not in contact with the object, area or phenomena under investigation. The information is received by a sensor on board a platform. The platforms used for carrying the sensors are of different types and ranges from ground platforms (towers and hydraulic lifts) ballons, aircraft to spacecrafts.

The information recorded about an object depends on the reflected emitted or transmitted electromagnetic energy emanating from the target. The electromagnetic energy could be recorded in a photographic or non photographic forms depending on the portion of the electromagnetic spectrum the sensor is recording in. The variation in received energy is detected and recorded in the format that the sensor records in. Usually the electronic sensors generate signals that are recorded into magnetic tapes from where it could be converted to pictorial forms.

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Remote Sensing provides information about the earth resources over a large area thereby permitting accurate and real time evaluation and continous monitoring or surveillance through repititive coverage. The invention of airplanes later complemented and paved way for other advantages of the techniques. The advant of spacecrafts saw the use of multispectral scanners.

As early as 1840, the Director of Paris Observatory had recognised the potentials of Remote Sensing to Topographic mapping. The first aerial photograph of a place was obtained by a Parisien photographer known as Gaspard Felix Tourudrin using a ballon. The photograph was over Bierre in France. In 1860 a man called James Wallace Black obtained a photograph of Boston, Massachussetts, U.S.A. The photograph was described as 'Boston as the eagle wild goose see's it. In the 1880's Kites were used for obtaining meteorological data and the first meteorological data was obtained by E.R. Archibald, an English Meteorologist. After the great earthquake of San Francisco in 1906, an American, G.R. Lawrence obtained an aerial photograph of the city, hoisting his camera six hundred meters above the ground.

By 1891, Ludwing Raharaman of Germany had been granted a patent for a 'new improved apparatus for obtaining birds eye photographic views.' But the advent of airplanes in 1903 marked a turning point in the use of aerial photographs in the study of the earth and its phenomena. The aircrafts as platforms has improvement on stability in flight, pre-arranged directions, positioning and heights at about which the air photographs could be taken. This, in addition to improvement in photographic processes led to great expansion in aerial photography in the early 20th century. In 1909, Wilbur Wright produced a motion picture photograph of the town of Centrocelli in Italy. From then on the advantages of air photography was utilized by all sectors of human resource management. The military reconnaissance flights during the world war's utilized air photography to a great extent.

In between the great wars, aerial photography remained in the domain of the military. After the second world war, the application of aerial photography to resource survey was made to great results. The sixties, sixties, with unmanned space flights by rockets, exposed Remote Sensing (as aerial photography has become then) to exiting future.

A mercury satellite in 1961 obtained the first coloured photograph of parts of the Earth Surface. By the nineth mercury rocket, photographs of unmapped areas of the world had been made. The Germini Series used Seventy milimetre and Sixteen milimetre format camera in not only visible portion of the electromagnatic spectrum but also in near infra-red (N.I.R.) portion using false colour. The Appolo Series made great improvements with the introduction of multiband and mult camera array.

The first American Space workshop, the Skylab, took over 35,000 images of the Earth with the Earth Resources Experimental Package (E.R.E.P.). In 1967 the U.S. Department of Interior started a feasibility study on a series called 'Earth Resources Technology Satellite (E.R.T.S.). This was later renamed 'Landsat'. In 1978, the French government in collaboration with Sweden and Balgium disigned and started the S.P.O.T. programmes.

The S.P.O.T. H.R.V. XS data was used for this project. The S.P.O.T. is designed to carry two H.R.V. cameras which use charge couple device (CCD) array as sensing element and collect data on continious basis every 26 days.

The H.R.V. XS Sensor has a ground resolution of 20 metres. A scene has an area of about 3600 square kilometres. The S.P.O.T. image has the ability to give sterwoscopic 3 dimensional view.

The image is traced out and used to prepare the map of Garanga river basin. The image was acquired in collaboration with the National Institute of Water Resources, Kaduna. The image was on the 8th day of April, 1986. It is in a preprocessed form. The image taken at an angle of inclination of 02^{O}R.

1.8 Organisation of the Thesis

The Thesis was organised into five chapters. The first chapter introduces the Thesis giving the background, definition of the problem, aims and objectives, the study area, justification and the role of Remote Sensing to the study. The second chapter reviews the past works on related topics. The third chapter discusses the method used in carrying out the study. The fourth chapter explains the analysis of the data and the findings. The last chapter concludes and summarises the work.

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CHAPTER TWO

Literature Review

The earliest works on drainage basin mapping and analysis could be traced to the early Egyptian surveyors, who in a bid to safeguard the individual plots along the river Nile often map their sections of the river showing individual plots during the flooding season. This traditions with improvement here and there was carried through the middle ages until the nineteenth century.

The first definitive study of Drainage basins and their mapping was done by W.M. Davis (1899). He laid a revolutionary landmark by studying a series of streams to find a way of classifying them. He concluded in his finding, a new method of classifying streams as consequent, subsequent and obsequent tributeries of a main stream. The classification of streams as consequent, subsequent and obsequent could not generally be used to accomodate all streams so in 1932 E.R. Zernitz undertook a study to generally classify streams according to the geology of the areas in which they are found. He found a new mode of classifying streams into six basic types and twenty-four modifications. He also collated an elaborate set of terms and examples to show the effects of geology and topography on drainage patterns.

Amongst his findings were that dendritic network reflect a relative lack of geological control while the trellis network develope in areas with parallel belts of dipping strata having differential resisstance to erosion. His findings concluded that geology plays an an important part in drainage patterns of streams.

The real foundation for modern Network analysis in stream was laid by the epoch making work done by Horton in 1945. Previously most works involving drainage basins were usually qualitative. They often described the basins and their constituent network without subjecting them to mathematical analysis. Horton decided to replace the qualitative description of drainage basin with quantitative ones. This, he did, by ordering the streams in a hierarchical structure. He found that the number of streams of different orders in a given drainage basin tends closely to approximate an inverse geometic series in which the first term is unity and the ratio is the bifurcation ratio. Horton found two laws called the laws of drainage composition relating to number of orders ratio called the bifurcation ratio and length of streams in an order ratio to the nest higher streams.

Strahler in 1952 in a study with Hortons model modified the methods by simplifying the ordering system. The modified system had the order 1 as all finger tip tributeries in a basin. The linking of two order 1 streams gives order 2. The junction of streams of order U forms a downward segment of order U + 1. The junction of two streams of unequal orders, U and V, where U is greater than V creates a downward segment of higher order tributery U.

Javis in 1976 studied the ordering of Nested tributeries in the analysis of drainage basin. He deviated from Hortonian model and concluded his studies by stating that ordering of streams in which order U stream meeting an order V stream of a lesser order still remains an order U stream is wrong. He stated that Hortonian ordering of streams as modified by Strahler violates the associative law of algebra. Not only that, when streams of lower order enters a higher order the properties of such higher order stream changes. So it will be improper for it to remain as before. He then laid the groundwork for new ordering system called the link magnitude system in which streams change their order according to their former order number, for example, a fourth order str stream entering a fifth order stream will give a new order of nine.

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In his 'statistical law of stream numbers,' Shreve in 1966 studied the influence of extranous factors on bifurcation ratios of streams. He tried to find how geologic and climatic conditions influence the drainage characteristics. He found that in normal drainage basin bifurcation ratio range between 3.0 and 5.0. This is for water sheds in which geologic conditions do not distort the drainage pattern. Any abnormal bifurcation ratio will indicate the occurance of dorminant geologic control or be related to flood discharge so that basins with a high bifurcation ratio would yield a low but extended peaks whereas basins with a low bifurcation ratio would produce sharp peaks.

Many works have been done on river systems using conventional methods and D. Knighton in his book 'Fluvial forms and processes' declared in 1984 that 'Riversare dynamic and increasingly important part of the physical environment. Their behaviour is of interest to a wide variety of concerns, ranging from flood control, navigation and water resources development to recreation. They represent a potential threat to human population and property through floods, drought and erosion. They therefore have potential social, economic and physical relevance', The importance of drainage basin analysis to resource development is a sine-qua-non because in the fluvial system system the transfer of water and materials from land surface to oceans is characterised by a tendency towards increasing concentration and organisation. In 'Drainage basin as a fundamental geomorphic unity Chorley (1960) said that 'avaliable in a hierarchy of sizes, the drainage basin is typically a well defined topographic and hydrographic entity which is regarded as a fundamental unit'.

Other major works using conventional data in drainage basin mapping and analysis include the following: Chetvertkou, S.S. (1968) made an analysis of streams in South Yaukutiya in USSR to find their water network densities. He used 1:1,000,000 scale maps for streams other than 4th order streams and 1:2000,000 scale maps for streams other than 3rd order streams. The water network densities (W.D.) which he set out to find is a product of the total length of water per unit area. He connected lines of density coefficients by interpolation forming lines of identical water network densities. He analysed the result of maps of equal density for South Yaukutiya and gave the conclusion that:

- Water network densities increase in zones of most recent folding.

- Water network densities is subject to changes from 0.6 to 1.0
- the industrial areas have greatest water network densities from 1.5 to 2.5.

Zavuianu, I. (1969) in 'Determination of the Drainage Density of hydrologic network based on Horton's law' based his work on many measurements of different basins. He found that the formula of drainage density determination is not satisfactory because the first term of the law of stream numbers is missing. This term, according to Horton (1945) would equal to one unit. Zavuianu proposed the introduction of this term after it had been determined graphically or by calculation. He concluded that to obtain the bifurcation ratio ($1^{-}b$) and the ratio of length ($1^{-}c$) one should resort to the weight average. He exemplified the suggestions by calculations but gave comparative analysis of the result for the two instances. In each case, he stated the error of determination.

Another treastise on Horton's law was made in 1970 by W.E. Sharp. In streams as a measure of sample source uncertainity', he studied streams in relation to probability theory. Horton's order, sharp argued in his findings, is related or is directly proportional to the entropy (uncertainity) of the source supplying any discrete particle to that stream.

He therefore formulated a formula for the sample number required to deduce the location of any source of contamination for a number of different cases. The different cases include single or multiple sources in Hortonian structured networks, Fibonacci drainage nets and for networks, numbered by Shreve's link magnitude method. Scheideggar consistent order is equal to the number of samples required for a single source, he concluded and derived empirical formulae for natural networks.

In 1970 in 'Discharge and Hydrological similarities of of drainage basins' printed in Japanesse, Toshie Nishizawa studied the Kanna and Koshin rivers with the aim of describing the similarities between basins in terms of discharge and Hydrology. He made a morphometric analyses of the two rivers and a conclusion that discharge is related to stream order, stream length and stream number. He then formulated empirical equations relating discharge to basin area supported by field observations using floating methods. These works, using conventional data usually are estimates and a lot of time, manpower and money is spend on trying to carry out fieldwork or otherwise for mapping of drainage basins , Knighton, (1984) explain this problem 'that channel deliniation in the field is time consuming.

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most network analysis, (especially in Africa) have always been based on data derived from Topographical maps which represent an average stream network.

Gregory, K.J. and Walling, D.E. (1968) in their paper 'The variation of drainage density within a catchment' quarrelled with the definition of fingertip tributeries and their headward limit which is complicated by short term flunctuation in stream head position.

In 1977, Javis, R.S. made a study analysing different drainage networks. He tried to replace empirical and inductive methods with definitive theory and concluded that the prior empirical and inductive procedure does not go deep down for the express purpose of identifying structural characteristics and as a bases for demonstrating the effects of environmental controls on the fluvial systems, for suggesting how networks might evolve and for predicting basin out-put variables such as Stream discharge which is related to the net. Therefore, he said, the provision of adequate data base is critical, involving the problem of consistent sampling and channel definition.

These problems highlighted by Knighton (1984), Gregory and Walling (1968) and Javis (1977) lend credence to the fact that point data or conventional data are inadequate for mapping, especially, of hydrological features.

As early as 1967, Charles J. Robinove in 'Remote Sensing Potential in basic data acquisition' made a treatise on how Remote Sensing advantages could be applied to water resource inventory, planning and hydrological mapping. He discussed the general objectives of modern Hydrology by using Remote Sensing instruments (sensors) from aircrafts and space plat forms. Photographs and other images relating to hydrology could be provided economically, in short time and continously. Sensor data could be correlated to point data to describe environmental characteristics, he concluded after analysing the different techniques of image interpretation in relation to Hydrology. These features or advantages of Remote Sensing data could be useful in overcoming the problems of morphological analysis of basins highlighted above and have subsequently been used.

R.M. Mcloy (1969) 'Drainage Network Analysis with K. Band SLAR images' made a study on use of K-band slar Images on drainage basin morphometry He used SLAR (Side Looking Airborne Radar) Images with wavelength of about one centimetre. Among the parameters he tested are identification, mapping and measurement of such hydrologic features as drainage areas, stream length, circularity ratios, stream ordering and bifurcation ratio.

After making an extensive study he concluded that the Radar imagery from side looking Air Borne Rader of K-band and wavelength of about one centimetre at a scale of 1:200,000 could produce drainage information comparable to that derived from a 1:62,500 topographic map. Therefore, Radar, apart from producing day and night and cloud free images also provide potentials that are not compararable to ordinance survey mapping.

In a 1970 research carried out with Nimbus H.R.V. (High (High Resolution Visible) sensor image, Norman Mac Lerd 'Hydrology of the Niger' made a hydrological and Land cover mapping of the Niger. He used the different reflectance values of plants to identify them. The outcome was encouraging and he was able to provide an accurate ecological map that is subject to changes. He concluded that the Nimbus imagery provided an integrated view of the entire water shed on a daily basis.

Parry and Turner (1971) in 'infra-Red photos for Drainage Analysis' performed a comparative study of modified infra-red photographs and panchromatic air photographs at medium scale to compare with regards to their effectiveness on revealing drainage networks. The Study area was a forested area of New Brunswick in Eastern Canada.

He used the advantages of Infra-Red in selective reflectance of vegetation and water to conclude that there were more immidiate recognition of water channels on the photographs and considerably more network details were detected.

Return Beam Vidicom (R.B.U.) images and Multispectial scanning system (M.S.S.) images of Earth Resource Technological Satellite (E.R.T.S.) later called landsat were used in 1970 by G.E. Stoertz and D. Carter 'Hydrology of closed basins and deserts of South America - E.R.T.S. Interpretation' to study the hydrogeology of deserts and semi deserts of South America. The basic aim was to devise a model for use in interpreting E.R.T.S. Images in arid and semi-arid areas including the deserts. They mapped the drainage divides and underground flow of water using different bands and channels in closed basins. They found that there is relationship between permenent drainage basin characteristics and seasonal snow cover/flood water and ground water flow.

R.B. Clark's (1974) "Application of Remote Sensing in floodway delineation" used Earth Resources Technology Satellite (E.R.T.S.) images in addition to high altitude aircrafts photographs to conduct a flood delineation project for Planning Department of Cochise Country of Arizona, Usa.

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He found that combination of E.R.T.S. data and medium scale airphotographs makes delineation of flood plain easier as spatial resolution becomes clearer with the sets of images.

R.P. Bukata and J.E. Burton (1974) used the LANDSAT (E.R.T.S. -1) during the overpasses of Lake Ontario on August 20th and 21st of 1972 in a computer compatible magnetic tapes form to make a non supervised classification schemes of water Regimes of Lake Ontario area. They used different band images to form a composite image for their study. In conclusion, they said that based on its 4 vector solar reflectance responses, it is possible to classify water regimes from colour and false colour composites. The tittle of their work was 'Digital Classification of Water Regimes Comprising Lake Ontario".

Also in "Water Resources" Vincent V. Salmonson (1973) studied the aquisition, analyses and use of E.R.T.S -1 data in Hydrology. He used different strategy models to describe the process of acquisition of E.R.T.S. -1 data, its analyses, processing and utilization with regards to scale, special features of the data in terms of sensor system, mode of acquisition and different band avaliable.

He concluded that the different band systems of the E.R.T.S. would be advantageous in survey of watershed, surface water mapping, river monitoring, flood area assesment and flood plain mapping.

In June 1973, Andizej B. Kesik in "Analysis of the Drainage Pattern of selected Areas of Canada using E.R.T.S. -1 Imagery as a Base" conducted a study of drainage patterns in different parts of Canada. He used the manual techniques to trace the drainage networks as well as measurement of densities as this is simplest method applied by interpreters from Seven different examples all over Canada, he draw these conclusions, firstly that drainage pattern on the E.R.T.S-1 images show great variability dependent upon the factors related to the environment. Secondly, the indexes of drainage densities calculated from the E.R.T.S -1 images for the lowlands and uplands are smaller than indexes obtained from the maps 1:1,000,000. Thirdly, indexes of drainage densities for the mountain areas are higher for the E.R.T.S images than for the maps 1:1,000,00. Fourthly, colour composites transparencies, particularly from channel 4,5,6 as well as black and white copies from channel 5, and 6 show the best applicability for the interpretation of drainage pattern.

Lastly, Drainage pattern extracted from the E.R.T.S.s-1 images is much more regionally differentiated than the network presented on the maps 1:1,000,000.

W.D. Bruce, in 1974, studied the uses of advantages of high attitude air-photographs, small scale maps to map and analyse drainage basins. In a study tittled "High Altitude Photography: an improved data source for drainage system Analysis," he worked on areas of disadvantage of conventional data sources. He arrived at these conclusions. Firstly, that High altitude air photographs provided drainage network data which overcomes most of the deficiences of conventional data sources. Also, that certain unique advantages like consistency of data statistically and in details are provided that far exceeds any possible or practical source of information.

In related works, Peter A. Castruccio and Havvy L. Loats Jr (1974)" Practical Utilization of Remote Sensing Technology for the management and conservation of Natural Resources" and U.S.A. National A Academy of Sciences, National Research Council (1975)" Inland water Resources: Practical Application of Space Systems" studied respectively the different approaches to uses of Remote Sensing data for the study of Water Resources.

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They discussed different methods of using Remote Sensing data in water shed management, surface and ground water detection and mapping, flood area assesment and flood plain mapping. They concluded in their different works that Remote Sensing data represent a Sine-qua-non in mapping of hydrologic features most especially in groundwater detection. They provided models for flood plain identification, mapping and construction of ungaged watersheds.

D.L. Henninger et al (1975) "Flood plain delineation using aircraft data" worked on flood plain delineation with aircraft data as dataset. He used computer to analyse aircraft multispectral scanning system (M.S.S.) data set by stretching the contrast between the different reflectances by plants within the flood plain. The basis is that plants with avail available water have different radiometric resolution from plants without enough water. He attempted to delineate the flood plain using their boundary as the boundary of the flood plain. He found that he could not use the computer to delineate a continous flood flood plain but the computer did indicate a break between flood plain and non-plain with small areas which correlated with one or more flood plain limits established by other methods.

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In "Estudo Corparative entre documents Cao cartografica (1:50,000) e.a. aerofotografical (1:25,000) para a analise da drenagem" (Comparative Study between cartography and aerophotographic documentation for drainage basin analysis), Antonio Christofoletti and Archimedes Perez Fillio (1975) made a comparative study of cartography by ordinance survey and airphotography. They used maps (1:50,000) and air photos (1:25,000) and analysed many drainage basins, considering their different orders, magnitude and area. They made the following conclusion. Considering magnitudes, great variation found was ex explicated by the inclusion of rills generated by runoffs on airphotographs. They did not consider the rills, in that sense as belonging to fluvial drainage networks. Also the values about area showed a suggestive relation and it was possible to express the following formula in a correlation between areas measured on maps and in airphotographs.

$$Y = -6.33 + 1.137x$$

where Y = areas measured in air photographs (dependent variable)

X = areas measured in maps (independent variables)

George R. Hawker and J.W. Rousse Jr (1977)

[illegible]

George R. Hawker and J.W. Rousse Jr (1977) "Flood plain delineation using multispectral analyses" used multispectral scanning system (M.S.S.) data, simulated by density slicing differences in a false colour composite infra-red transparency to study a section of Navasota River in Texas. The transparency was taken from a low-flying aircraft and covered an area approximately a square mile. The simulated data were processed by an automatic classification technique previously developed in Remote Sensing field. The technique used involves the application of the maximum likelyhood rule in order to catagorise the data being processed. They were able to distinguish between areas known to be in flood plain and those without. A reasonable correction was found between boundaries based on computer processed multispectral data and those produced by techniques currently in use.

Hannock and Schlossner (1976) "Water Mapping Setallite data: an automated procedure" used different techniques to provide accurate data for water mapping. They developed a model called - DAM (Detection and Mapping) model which could be used to provide accurate, up to date, economical and properly formatted maps of surface waters using LANDSAT (Earth Resource Technology Satellite) digital data in 1976. The model could be applied to other satellite systems.

"Etude de Delta Central du Flueve Niger Project Saphyr" (study of the Central Delta of the Niger river project saphyr) was made by M. Bled-Charre-ton and others in 1977 in Mali. The objectives were to conduct a hydrological analysis of the River Niger with the aims of determining the underground flow system and causes of abnomalies observed in the river inland delta zone. They were able to determine the undergound water flow system direction of central Delta) of river Niger, state the causes of anomolies observed and map the river with a study of its morphology. The study area covered about 50,000 square kilometres.

D. Brown and R.S. Kaggs (1974) "Remote Sensing Application to Hydiology in Minnesota" conducted a model planning analysis with the aim of finding solution to a variety of hydrological problems including flood plain detection and delineation, surface runoff/ discharge relationship using the Earth Resource Technology Satellite (E.R.T.S.) data. They found that they were aboe to solve a series of questions including investigation of surface cover data to develope surface runoff coefficient for non-instrumental watersheds.

In "Water Resource Evaluation using photogrametric and Remote Sensing Techniques", P.R. Petit (1976) made a comparative study of uses of air photographs and Satellite data to evaluate water resources. He used the different methods of analysing airphotographic and satellite images in water resource application. He concluded that satellites provided a useful means of collecting and transmitting information to a number of ground based stations. Also the advantages of using aerial photography has particular significance in hydrologic mapping.

Robert K. Holz and Victor R. Baker (1979) in "An Examination of Flurial morphological characteristics of Western Amazon Streams from Appolo-Soyuz photographs" studied the strems of Amazon based on a three type sinousity pattern distinguished from colour photographs generated by the Apollo-Soyuz Test project (A.S.T.P.). The 3 river types were choosen as representatives of remarkable variations in flurial regimes and morphology that exist in the Amazon basin. Empirical formulae were tested in estimating the hydrologic properties of the rivers.

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The study demonstrated lack of precise understanding of regime behaviour in tropical streams and the difficulty of transfering the results of research on humid mid-latitudes and semi-arid mid-latitudes streams to those of the humid tropical areas. The results show that the low sinuousity Amazon Basin streams transport much finer sediments than do streams of equivalent sinousity described for semi-arid regions. Many of the fluvial complexities of the western Amazon basins appear to result from the relative abilities of different rivers to rework coarse, relict alluvium that was deposited during the relatively arid post - glacial phases of the pleistocene.

In the "Delineation of Drainage and physiographic features in North and South Dakota using NOAA-5 infra-red data" of 1979, Stanley R. Schneider and others used the enhanced night time 1km thermal infra red imagery and digital data from the NOAA-5 polar orbiting satellite to map drainage patterns and landforms in North and South Dakota. Features delineated include the missouri Escarpment from Saskatchewan to the Nebraska border, the Manitoba Escarpment, Coteaudes prairesi reccessional morraines on the Coteau du Missonri, and partial drainage boundaries for the following rivers:

James, Big Sioux, Minnesota, Red of the North, Souris and the main stem of the Missouri and its western tributeries in the Dakotas. In several instances drainage from gentle sloper in the Midwest was discerned and correlated with local relief. Analysis of the satellite digital thermal data for western tributeries of the Missouri River, using topographic map for location determination, revealed north facing slopes to be warmer than south facing slopes by an average of 1.5°C. This attributed to differences in soil moisture between north and south facing slopes.

In a paper presented in 1990, Ononiwu N.U. discussed the effective management of river basins using S.P.O.T. images. He used S.P.O.T. images with panchronatic resolution of 10m for linear features and 0.04 hectares for areal measurements. He also added Xs band 3 and 4 produced in false colour composite to improve resolution. The study area was parts of Kaduna River basin. He found that S.P.O.T. is very effective for gathering repititive information of surficial data in a river basin for effective management.

Ananaba, S.E. also mapped the surface water resources in Nigeria with Remote Sensing data.

A case study of the effectiveness of small scale remote sensing imagery for the inventory of surface water resources in Northern Nigerian was presented. The data consisted of 30 LANDSAT images at the scale of 1:1,000,000 in spectral band 5 and 7. The method used was visual monoscopic approach and a mosaic of the drainage drainage lines was made to produce a drainage map covering all parts of Niger north of latitude 8° North, South of these latitude images were poor and cloud cover excessive. The drainage map has given a clear and up to date picture of the regional drainage work, drainage density and by inference the lithological differences in those parts of Nigeria. The implication of the drainage density for both surface and ground water resources were also discussed.

Ononiwu (1990) in his paper had made a case for the use of S.P.O.T. imagery as against LANDSAT for mapping drainage basins. This he based on greater resolution of S.P.O.T. data (pixel size - 10 metres). His study showed that with computer application there is increased resolution of S.P.O.T. data because of higher precision of computer application.

The present work is along the same line as Onomiwu's paper but made case for using the greater resolution of S.P.O.T. imagery for the deliniation of flood plains especially of areas where fadama farming is of great importance. A manual approach was used in the study to show that if is possible to use such an approach for hydrological studies in the developing world.

CHAPTER THREE

Methodology

3,1 Theoritical Bases for the study: The River lies within a region where the climatic condition makes it necessary for the people to rely on water from streams for most of their uses whether industrial, domestic or agricultural use. It is therefore necessary for every available source of water to be mapped and analysed. There is therefore the necessity to regularly up date the map of Garanga river basin by using a method that could produce a quick result. Remote Sensing with its numerous advantages, is the only method avaliable to this mapping producing not only a quick map but also for regular updating of a base map.

There was also the need to analyse the basin to see if it fits into the known models of basin study. Lastly an attempt was made to delineate the flood plain as a bases for understanding the consequences of agricultural use of the flood plain yearly. These above reasons adviced the need for this study.

3.2 Materials: The following materials were used for this research work.

A computer print out of the S.P.O.T. imagery of the area was obtained with the identification profile in Table 3.1.

Table 3.1: Identification Profile of the S.P.O.T. imagery

Satellite	Sensor	Path & Row Id. No.	Date of Capture	Time	Centre of Image	Angle of Inclination	Product Type
S.P.O.T 1	H.R.V 1 X s	075-327/0	8/4/86	10:10	11°31' N	02°R	Pre-processed. Precision Corrected Scene

A topographic map of Rano with scale of 1.250,000 produced in 1957 with air coverage of 1950 and 1956.

Mirror Stereoscope was used to enhance the image. A pair of dividers spaced at 3mm apart was used to determine linear distances. The image was traced unto a tracing paper.

3.3 Methodology

The print out copy from the S.P.O.T. imagery was mounted on a light table and held with adhesive tapes. Mirror Stereoscope was used to observe the features to enhance identification of features. It was not possible to observe the 3 dementional qualities of stereoscopic viewing because there was only one image use and it was a print out form so relief observation was not possible.

The main stream-river Ganranga, was traced out. Other streams were also traced out.

The boundary of the drainage area, that is the catchment area, was demarcated and delineated. There are two major boundary systems of a drainage basin. The topographic divide is the highest point between two adjoining basins while the phreatic divide is the ground water divide between two basins. The topographic divide may not always coincide with the phreatic divide. In this mapping study, it was not possible to put into consideration the topographic divide as the advantage of stereoscopic viewing in terms of 3-dimensional relief viewing was not avaliable. The phreatic divide was easier to demarcate because of the vegetational allignment, otherwise the mid distance between two adjoining basins was used as the water divide.

The cultural features in the basin were traced out. The cultural features traced out included the roads and towns. These were used basically as identification marks. The flood plains of Chalawa river and parts of Garanga river identifiable were traced out. The delineation of the flood plain was done using the spectral reflectance of vegetation. This was based on the principle that healthy vegetation and unhealthy ones have different reflectance values especially on near infra red (N.I.R.) portion of the electromagnetic

The vegetation that has enough water avaliable to it often gives a luxuriant or bright red colour on a false colour image. This principle was used in delineating the flood plain as the vegetation nearer to the stream have constant supply of ground water so reported a bright red colour on the image while those in the hinterland of the stream gave a very dull red to brown colour.

The streams were ordered using the strahler's (1952) modification of Horton's (1945) method of stream ordering. It gives the fingertip tributeries originating at a source an order One (1). The junctions of two streams of order U form a downstream channel of order U + 1. The junction of two streams of unequal order U and V, where V > U, creates a downstream segment having an order equal to that of the higher order tributery V.

The lengths of the different orders of streams in the basin was measured in milimetres using a pair of dividers set at 3 milimetre range. This gave the lengths of streams in different orders. When summed up, it gave the total lengths of streams in the basin.

The area of the basin was measured using a square grid paper in 5 milimetres and 1 centimetre. The total number of one square centimetre was summed up. The halves and quartre portions that fell within the basin were summed up and divided by 0.5 and 0.25 as the case may be.

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The area was found in square centimetres. The topographic map was spread on a light table also and held with adhesive tapes. The basin of the Garanga river was delineated. The boundary between the two basins was taken here as the mid-distance between two streams of two different basins. This was so done because there were not added feature or parameters to use in delineating the basin. The streams in the Garanga river basin were ordered on the topographic map using the previous method described above.

The different number of streams in each order in the topographic map and S.P.O.T. H.R.V. Xs imagery were compared.

The scale of the S.P.O.T. imagery was then determined. This was done by comparing the distance between two settlements in the imagery and in the topographic map. The two settlements used are Barkun and Kumunya. The distance between the two settlements in the topographic map was 3.5cm and the distance in the imagery was 14 centimetres. The scale of the imagery was then determined using the formular.

(map distance) (Scale of map) = (Imagery distance) (Scale of imagery)

i.e. $3.5 \times 250{,}000 = 14 \times x$

$$x = \frac{3.5 \times 250{,}000}{14} = 62{,}500$$

With a scale of 1:62,500, the length of the map that will make up one kilometre was found with the method -100,000 centimetres is equal to one kilometre therefore

$$100,00 \div 62,500 = 1.6$$

So 1.6 centimetres on the image equals to one kilometre.

The lactitude and longitudes were determined on 5' intervals. Since 1.6cm on the map represents 1km on the ground, the 5' will be equal to 5 x 1.6 = 8 centimetres on the map.

The distance from Rano was then given in terms of longitudinal and lactitudinal differences of 8 centimetres on the map mode from the image.

Ground truth verification visits were made to ascertain the veracity of the Remote Sensing data.

The data from Remote Sensing imagery and data from Topographic map were subjected to chi square (x^2) test to see if there is any significant difference between them.

The scale of the imagery is 1:62,500
The morphometric analysis of the basin was made using the data collected from the imagery and the topographic map. Morphometry refers to the measurement of shape and pattern. The following analysis were made.

Law of stream numbers (Horton 1945). It is called the bifurcation ration calculated by the formular

$$Rb = \frac{Nu}{Nu-1}$$

where Rb = bifurcation ration
Nu = number of streams of order U

The bifurcation ration of streams are normally between 2 and 5 but could be larger for elongated streams or streams where geology and climate play important roles. Compared to other natural features, it was reported that bifurcation ratios for tices is about 3.2, for lightening strikes 3.5 and for blood vessels 3.4, implying that ratios in this range approach a natural optimum (Gordon N.I.) and others 1993).

Law of stream length (1945). This is calculated by the formular.

$$Ri = \frac{Lu}{Lu-1}$$

where Lu = Average stream length of streams of order U

Drainage Density. This gives the average of stream per drainage area unit calculated with the formular

$$Dd = \frac{\Sigma L}{A}$$

where ΣL = total lengths of streams in the basin
A = Area of the basin. The unit of measure of drainage density is in unit of length per unit area.

Basins with high drainage density are characterised by a finely divided network of streams with short length and steep slope. The low density basins have larger streams lengths, flatter valley sides and steams further apart. It reflects the climatic patterns, geology, soil and vegetation cover of a catchment.

Average length of Overland Flow (LO)

$$Lo = \frac{1}{2D}$$

where D = drainage density

Form Ratio: This is used to describe the shape of the basin. It was calculated with the formular

$$Rf = \frac{A}{L^2}$$

where Rf = form Ratio

A = Basin area while L = length of the main stream

Elongation Ratio (Re): calculated using the formular

$$Re = \frac{Dc}{L}$$

where L = length of main stream (Garanga river)

Dc = diameter of a cycle with the same area as that of the basin. The Dc is calculated with the formular

$$Dc = \sqrt{\frac{4(A)}{\pi}}$$

where A = basin area.

π = Pie, a constant with value of $\frac{22}{7}$

π

The Form factor was also calculated. It expresses the ratio of the average width to the axial length of the basin. The axial length is measured from the outlet to the most remote point of the basin. The average width is obtained by dividing the area by the axial length. For basins with side outlets the width may exceed the axial length, giving a ratio greater than unity (Gordon, N.D. and others, 1993).

The form factor gives some indication of the tendency towards flood and the rate at which water enters the stream. This is because a low form factor is less likely to have an intense rainfall simultenously over its entire extent than an area of equal size with larger form factor.

The Compact Coefficient is the ratio of the perimeter of the basin to the circumference of a cycle whose area is equal to that of the basin, gives by

$$Cc = \frac{Pb}{2} / \sqrt{\pi A}$$

where Pb = Perimeter of basin.

The geographical cordinates of the map area was determined using the cordinates of Rano ($11^{o}37'$N,8^{o} $34'$E) as reference point and bearing in mind the fact that 1^{o} of lactitive equals one hündred and eleven kilometres, r' of lactitude will be $\frac{111}{60}$ km = 1.85 km

CHAPTER FOUR

Analysis of the data

This chapter examines the findings of the study. The data was presented and discussed as well as the Action, Implications and various ways of implimenting the results.

4.1 Presentation and Analysis of the data

The mapping of the basin was made bearing in mind the principles of Remote Sensing with regards to the basic characteristics of the features of S.P.O.T. imagery These characteristics common to other satellite imageries includes the features of shape, size, pattern, shadow, tone, texture and site of the phenomena on the imagery.

The tone, shape and pattern of the drainage system courses, and that of the vegetation cover were influenced by their absorptivity in the near-infra-red portion of the electromagnetic spectrum.

The river Garanga flows northwards into the Chalawa river. The pattern of the basin is sub-dendritic generally except towards the south and south east where it tends towards sub-trellitic, This points to the facts that towards the north, where the river flows into Chalawa river, there is uniformity in the geologic features while in the south, especially in the south-east, there is presence of rocks that affects the drainage pattern.

These rocks could be noticed on the imagery. With the spectral reflectance of vegetation it was possible to generally delineate the areas liable to flooding or the flood plains of Chalawa river. On the main study area, river Garanga it was only possible to delineate a discontinious zone of flood plain. Garanga river is a smaller stream and as such does not have enough discharge to produce a continious flood plain as in Chalawa river. The absence of a continious flood plain could be explained in terms of presence and influence of rocks in the southern parts of the river. The streams were ordered. This gives fingertip tributeries order 1 and where two streams of same order (U) meets, it gives a higher order (U + 1). If two streams of different order meet, the stream with higher order supercedes the lower stream. The result of the ordering is given in Table 4.1.

Order of Streems	Number of Streams		Differences
	Satellite Image	Topographic map	
1st Order	162	150	12
2nd Order	44	39	5
3rd Order	12	10	2
4th Order	3	3	-
5th Order	1	1	-

Table 4.1 Number of Streams of different orders in S.P.O.T image and Topographic map.

It was observed that with S.P.O.T. image of scale 1:62,500 more streams were dentified than in a topographic map of scale 1:250,000. This was with a manual interpretation method. With computer application, there might be better identification of features.

The streams in the basin were measured according to the different orders. The length of the main stream (River Garanga) was also measured. The Satellite imagery gave the stream length as 79.9cm while the topographic map gave a length of 19.5cm. The length was converted to kilometres using the formular

$$\frac{\text{Length x Scale}}{100,000}$$

The length of Garanga river was found to be 49.94 km in Satellite image and 49 km in topographic map.

The lengths of streams given in cm and km are displayed in Table 4.2 and Table 4.3

Order of Streams	No. of Streams	Total length of Streams(cm)	Total Length of streams (km)	Average Length of Streams (cm)	Average length of streams (km.)
1st	150	78.8	197.000	0.5253	1.3133
2nd	39	44.228	110.570	1.1341	2.8351
3rd	10	21.744	54.360	2.1744	5.4360
4th	3	14.1194	35.298	4.7065	11.7660
5th	1	6.5868	16.467	6.5868	16.4670
Total		165.4782	413.695		

Table 4:3: Lengths of streams of different orders in the basin (Topographic map)

The area of the basin was calculated using the

$$\sqrt{1542} = 39.268cm$$

The product of the length and scale of the imagery gives the length on the ground. This 39.268 x 62,500 = 2454250cm. The length on the ground was divided by 100,000cm to give the length in kilometres

$$\frac{2454250}{100,00} = 24,5425km$$

The squaring of the length gave the area of the basin in kilometres, this $24.54^2 = 602.334\ km^2$

The area of the topographic map basin was found with the same method. The area in Cm^2 was $98.5cm^2$

$$\sqrt{98.5}cm^2 = 9.925cm$$

$$\left(\frac{9.925 \times 250,000}{100,000}\right)^2 = 615.625km^2$$

The differences in areas as calculated by using the S.P.O.T image and Topographic map could be explained in terms of the fact that there is wide disparity between the scales used and the fact that the S.P.O.T. image drainage basin boundary delineation took into account the phreatic divide of the drainage basin.

The morphometric analysis of the basin was performed this with results.

The law of Stream numbers or Bifurcation Ratio (Rb) was determined for all the orders of streams in the basin with thr formular $Rb = \frac{Nu}{Num}$

The result was given in Table 4:4

Stream Order	Satellite Imagery		Topographic map	
	Number of Streams	Bifurcation Ratio	Number of Streams	Bifurcation Ratio
1st Order	162	3.68	150	3.85
2nd Order	44	3.67	39	3.90
3rd Order	12	4.00	10	3.33
4th Order	3	3.00	3	3.00
5th Order	1	.	1	3.00

Table 4.4: Bifurcation ratio of streams in Satellite imagery and Topographic map.

The average bifurcation ratio was got as the average (mean) of all bifurcation ratio.

Rb (Satellite image) = 3.68 * 3.67 +4.00 + 3.00/4 = 3.588

Rb (Topographic map) = 3.85 + 3.90 +3.33 + 3.00/4 = 3.520

Shreve (1966) found in an extensive study that normal bifurcation ratio lies between 3.00 and 5.00 except in areas where there is dorminant geologic control or if the precipitation regime is so much as to influence the the pattern of the basin.

With a mean bifurcation ratio of 3.588 (3.520), the Garanga river basin could be regarded as normal basin without much influence of geology and precipitation. This result is true of the basins that falls within the basement complex rocks that have been eroded and so not exerting much influence on the basin. As regards precipitation, the area falls within the continental Hinterland climate that does not have excessive rainfall. Rainfall is between 800 and 1000 milimetres in the basin.

The law of Stream length was also applied to the basin. The law looks at relationship between length of streams in different orders of the basin. The formular is Rl where Lu + average length of streams in order 4 The kw was applied in centimetres. The results for the Satellite Imagery and Topographic map data are given in table 4.5 and 4.6.

Order of Streams	Number of Streams	Total length of streams (cm)	Average length of Streams (cm)	Stream length ratio
1	150	78.8	0.5253	2.1590
2	39	44.228	1.1341	1.6215
3	10	21.744	21.1744	2.1645
4	3	14.1194	14.7065	1.3995
5	1	6.5868	6.5868	

Table 4.6: Law of Stream length or stream length ratio (Topographic map).

The results show that the second order and forth order streams are generally longer than the length of next lower order streams. But the average length of streams in the basin could be found to generally increase as the otder increases.

The drainage density was found with the formular

Dd $\frac{El}{}$ where El = total lengths of streams in

basin A = area of basin

for the satellite imagery, the drainage density is

0.7087 km of channel per square km.

for the Topographic map, the Drainage density is 0.672 km of channel per square km.

This is a relatively high density. It means that the area is highly dissected as on the average 0.7087 km (0.672km) of stream occurs in every square kilometre. There is a large number of streams in the basin. It could be déduced from the basin that the valleys are steep sided with short streams.

The average length of overland flow was determined with the formular $Lo = \frac{1}{2Dd}$ where Dd = 0.7053 (0.672)

for satellite imagery the $Lo = \frac{1}{2(0.7053)} = 0.7089$

for the Topographic map the $Lo = \frac{1}{2(0.672)} = 0.744$

The form ratio (Rf) is one of the parameters used in describing the shape of the basin. It is calculated with the formula. $Rf = \frac{A}{L^2}$ A = Basin area 602 . 334 (615.625)

where l = length of main stream 49.94 (48)km.

$$Rf \text{ (Satellite imagery)} = \frac{602.334}{(49.94)^2} = \frac{602.334}{2494.0036} = \underline{0.242}$$

$$Rf \text{ (Topographic map)} \frac{615.625}{(49)^2} = \frac{615.625}{2401} = \underline{0.2564}$$

The form ratio compares the shape of the basin with a square that is length is the same as that of the main stream (River Garanga). The result 0.242 (0.2564) shows that the streams basin does not posses the same shape as the square of its main stream.

The Elongation ratio was determined. It compares the river to a cycle of the same diameter as that of the length of River Garanga.

$Re = \frac{Dl}{l}$ where Dc = diameter of a cycle with the same length as that of River Garanga.

$$Dc = \sqrt{\frac{4\ (A)}{\Pi}}$$

$$Dc \text{ (Satellite Imagery)} = \sqrt{\frac{4(602.334}{3.1416}} = \underline{27.69}$$

$$Dc \text{ (Topographic Map)} = \sqrt{\frac{4(616.425}{3.1416}} = \underline{27.9971}$$

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Re (Satellite Imagery) = $\frac{27.69}{49.94}$ = $\underline{\underline{0.5545}}$

Re (Topographic map) = $\frac{27.9971}{49}$ = $\underline{\underline{0.5714}}$

The result means that compared with a cycle of diameter the length as Garanga river the result gives 0.5545 (0.5714).

This result compared with the form ratio, shows that the basin is nearer to a cycle that to a square.

The form factor was determined with the formular

$Ff = A/L^2b$ where Lb = axial length of the catchment.

The axial length of the basin is for satellite imagery is 68.3 cm

The axial length of the basin for Topographic map is 16.7 cm. In kilometres, the axial length for the satellite imagery is 42.6875 km

For the Topographic map the axial length in kilometres is $\underline{\underline{41.75 \text{ km}}}$.

∴ Ff 9Satellite Imagery) = $\frac{602.334}{(42.68\ 75)^2}$ = $\underline{\underline{0.331}}$

Ff (Topographic Map) = $\frac{615.625}{41.75}$ = $\underline{\underline{0.3532}}$

With a low form factor of 0.331 (0.3532) it means that the basin has a rapid response to flood as there is less likelyhood of having intense rainfall simultenously over its entire length than an area of equal size with larger form factor.

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The data from Satellite Imagery was compared with the data from Topographic map to see if there is any significant difference between them. A non parametric test, (hi-square test was used. The hypothesis was

Ho: There is no significant difference between the observed frequency (Satellite Imagery data) and the expected frequency (Topographic map data)

H_1: There is significant different between the observed and expected frequency.

The test was conducted at 0.001 level of confidence.

	Observed Satellite Imagery	Expected Topo map	O - E	$(O - E)^2$	$(O-E)^2/E$
1st Order shows	162	150	12	144	0.96
2nd " "	44	39	3	9	0.2308
3rd "	12	10	2	4	0.4
4th "	3	3	0	0	0
5th "	1	1	0	0	0
Total length of stream	426.875	413.695	13.18	173.7124	0.4199
Area of Basin	602.334	615.625	-13.291	176.6507	0.2869
rb	3.588	3.520	0.068	0.0046	0.0013
Dd	0.7087	0.672	0.0367	0.0013	0.0019

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	Observed Satellite Imagery	Expected Topo map	0 - E	$(O - E)^2$	$(O - E)^2/E$
Rf	0. 242	0.2564	-0.0149	0.0002	0.0008
Re	0.5545	0.5714	-0.0168	0.0003	0.0005
Ff	0.3310	0.3532	-0.0222	0.0005	0.0014
					$\frac{(O-E)^2}{E}$ - 2.3035

Table 4.7 Chi squaried table of Expected and observed

$$X^2 = \frac{(O - E)^2}{E}$$

The degree of fredom is K - 1, i.e., number of events les one.

If the calculated Chi-square (X^2) is greater than table values, then Ho is rejected. If not, Ho is accepted.

The number of events is 12 so K - 1 = 11

Under the table of Chi-square, the value under 0.001 with degree of freedom 11 is 31.3. Since 2.3035 is less than 31.3, Ho is not rejected. There is no significant difference between values from Satellite Imagery and values from Topographic map.

Ground truth verification visits were made to find out if the Satellite imagery has any bearing with what is on the ground five of the Twelve streams found in S.P.O.T. imagery not found in the Topographic map was selected.

The 5 streams were close to each other so the cost of the visit was put into consideration while selecting them.

Three of the streams had constant flow of water all through the year. The remaining two had dried up with water left in pot holes. This, the inhabitants of the areas around them attributed to the fact the fishermen turns the rivers to lakes by damming. This is used as ishpond. These findings point to the fact that the streams generally carry water all through the year so this could be classified as perenial streams which qualifies them as streams to be ordered. The ground truth visits were made in february during the dry session.

4.2: Discussion of Findings:

The study was carried out with the intention of mapping and analysing River Garanga Basin, a tributery basin of Chalawa river. The findings of the study were treated below.

The mapping of the basin was carried out bearing in mind the elements of interpretation of Remote Sensing data. These important diagonistic characteristics used in analysing and interpreting a Remote Sensing Imagery includes the attribute of size, texture, patterns, site and association. These, amongst other advantages of Remote Sensing helped in producing a hydrologic map comparable to field survey map.

The pattern and size of streams were helpful in the mapping. In areas where the streams were obscured, the spectral reflectance of vegetation and its association with streams were helpful in mapping smaller streams and in demarcating the flood plain.

With the above consideration, it would be possible to manually produce a map, with a computer print out of scale 1:62,500, in terms of hydrologic features, comparable to a Topographic map of scale 1:250,000. More streams were identified in a Satellite imagery. With computer application it would be possible to produce a more accurate map.

It was also possible to delineate the flood plains of parts of Chalewa river in the imagery. It was only possible to delineate a discontinious flood plain for Garanga river. It shows that it would be possible to use Satellite imagery to update a topographic map and for base map production in Geographic Information System (GIS).

It was possible to use the spectral reflectance of vegetation to demarcate the flood plain. This is important in planning for settlement purpose and for agricultural planning. This is because in agriculture, it shows the areas that could be used for all round the year cropping and even the type of crop to be grown with regular mapping of the flood plain, it will be possible to measure the seasonal and annual depletion of the flood plain and plan for a control measure.

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The morphometric analysis showed that the basin is an ordinary basin that fall within the normal range of river basins (bifurcation ratio is 3.588 (3.520). The geology of the basin or the precipitation characteristics of the basin does not have much effect on the basin. The stream length ratio showed that the second order and fourth order streams are much longer than the preceding ones. This is quite often useful in determining the amount of water to be subtracted for agriculture and for damming purposes.

The average length of over land flow, the form ratio and elongation ratio also define the type of basin. These parameters are useful in developing constants useful to particular basins especially in making use of empirical formulars.

The results showed that the basin is closer to a cycle than to a square. The fact that it has a more rapid response to flooding as it will not be possible to have an intense rainfall all over its entire length, will be necessary for calculating of discharge (Q) of the basin using the empirical formular.

$$Q = CA^n$$

where Q = flood discharge in m^3/s

A = Catchment area in km^2

N = an index usually between 0.5 and 1.25

C = a Coefficient depending on climate and and catchment characteristics.

For the Coefficient to be fully determined and the index, more studies on the basin is meaded in terms of it's hydrogeology for a continious period.

The results of the morphometric analysis using Satellite Imagery data and Topographic map data were compared using Chi Squared (X^2) test and it was found that there is no significant difference between the two sets of data. This implies that Satellite imagery is useful in up dating and making of maps.

The study of a River Basin is a continious and multi-disciplinary one. The river basins require satellite imagery for these types of studies, a part from mapping the basin, especially S.P.O.T. imagery because S.P.O.T. satellite is the only satellite that could be provide a stereoscopic capability for measurement of heights for determination of topographic divide. This, in addition to the ability to use the spectral reflectance of vegetation to determine the phreatic divide give a better demarcation of drainage basins.

Images acquired by the River Basin Authorities could be jointly shared by other establishments in Environmental Studies category for their own use. This would help to update the maps of the country with less cost.

Alternatively, a Geographic Information System (G.I.S.) could be set up where satellite images could be used to regularly update information in a data Bank. Different organisations and departments would be involved in this kind of establishment for the purpose of sharing cost.

Order of Streams	No. of Streams	Total length of streams(cm)	Total length of streams (km)	Average length of streams (cm)	Average length of streams (km)
1st	162	321.6	201	1.985	1.241
2nd	44	181.9	113.6875	4.134	2.584
3rd	12	93.3	58.125	7.775	4.844
4th	3	58.6	36.625	19.533	12.208
5th	1	27.9	17.4375	27.9	17.4375
Total		683.3	426.875		

Table 4.2: Lengths of streams of different orders in the basin (S.P.O.T. Images).

Order of Streams	No. of Streams	Total lengths of Streams (cm)	Average lengths of streams	Stream length ratio
1	162	321.6	1.985	2.08
2	44	181.9	4.134	1.88
3	12	93.3	7.775	2.51
4	3	58.6	19.533	1.43
5	1	27.9	27.900	1.

Table 4.5: Law of Stream length or Stream length ratio (Satellite Imagery).

Chapter Five

Summary and conclusions

The study was aimed at two major purposes. Firstly, it was to map the Garanga River Basin with the aid of S.P.O.T. HRV. xs data and also to analyse the morphometric features of the basin. The study was advised on the fact that the River Basin lies in a region where the climate, tropical Hinterland, makes the use of water from streams a necessity for man. The area has an annual rainfall of less than 1,000 milimetres per annum which comes in less than 6 months of the year. In the other months of the year there are no rains and the region experiences a type of drought (Meteorological drought), so the only source of water to the region becomes the streams and ground water.

From the outlined problems, the study was able to achieve the following objectives. Firstly, it used the advantages of Remote Sensing to map the hydrologic features of the basin. Secondly, it compared the hydrologic features visible in Remote Sensing data and an ordinary Topographic map data in terms of the results of morphometric analyses carried out on both of them. Thirdly, it delineated the flood plain of the basin using the spectral reflectance of vegetation in the basin.

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This was possible becausevegetation has special reflectance capability in the near infra red (N.I.R.) portion of the electromagnetic spectrum (E.M.S.) depending on the health and vigour of the vegetation. The health and vigour of vegetation depends largely upon the amount of water available to it for its growth. The study used the spectral reflectance of vegetation within and outside the flood plain to delineate the flood plain. Moreover, the study used both the map derived from Remote Sensing imagery and topographic map to analyse the morphometric features of the basin. The idea behind using the maps to analyse the morphometric feature was to see if it would be possible to understand the basin more.

To carry out the study of print out of the Remote Sensing data was acquired. This print out was from S.P.O.T. H.R.V. Xs composite imagery in false colour. The idea behind using a composite image was to avail us of the advantages of Band 1 (Green), Band 2 (Red) and Band 3 (Infra red) portions of the E.M.S. in one composite imagery. The print out had no scale so the scale was calculated using the distance between two towns in the Topographic map and comparing it with the distance on the Satallite imagery.

The calculated scale was 1:62,500. A Topographic map of the area produced in 1957 with aerial photo coverage of 1950 and 1956 was used also in the study. A manual interpretation approach was used in the study. Mirror Stereoscope was used to enhance the features in the image. It was not possible to observe the 3 - dimensional characteristics of normal S.P.O.T. image because the imagery is a print out copy and also there is no corresponding copy to complement it. A pair of dividers set at 3 milimetres range was used to measure the length of streams.

The print out from the S.P.O.T. imagery was mounted on a light table and observed through the Stereoscope. The main stream, river Garanga was traced out as well as the other streams in the imagery. The flood plain was delineated using the spectral reflectance of vegetation. A continious flood plain was delineated for parts of River Chalawo in the imagery. It was only possible to attempt a discontinious flood plain for the lower parts of the main stream, River Garanga.

The drainage basin divide was demarcated using (ground water divide). It was not possible to determine the Topographic divide which is the highest land between two watersheds.

The inability to use the stereoscope for 3-dimensional viewing was the cause of our not determining the topographic divide.

The cultural features of the imagery e.g. Roads and Settlements, were also traced out. These were used as identification features. It was also used to determine the scale of the map.

The streams in the basin were ordered using the strahlers modifification of Hortons methods. The streams were measured using the pair of dividers. The area of the basin was measured with a square grid paper in 5 milimetres. The area was found and converted to square kilometres. The streams in the Topographic map was ordered using the same method. The streams were also measured using the pair of dividers. The basin was delineated using the mid distance between adjacent watershed as boundery.

The geographical cordinates of the map was fixed using the cordinate of Rano $11^{\circ}37'$N and $08^{\circ}34'$E). As 1° of latitude is approximately equal to 111 kilometres, the latitudinal extend of the map was determined. Each 1' of the latitude was fixed at 18.5 kilometres from calculations.

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Morphometric analysis of the basin using the Remote Sensing imagery and then the Topographic map, was made.

The ordering of the streams gave the results thus. The figure in brackets is for Topographic map data.

The first order stream are 162 (150), The second order stream are 44 (39). The third order streams are 12 (10), the fourth order streams are 3 (3) and fifth order stream is 1 (1).

The bifurcation ratio (Law of stream numbers) was found to be on the average 3.588 (3.52). The dra drainage density which is the total length of streams divided by the area was got as 0.709 kilometres of channel per kilometre (0.672 km. of chanel per kilometre). The average length of overland flow was determined. The form ratio is one of the parameters used to describe the shape of the basin. It was got on 0.24 (0.2564). The Elongation ratio which compares the basin with a circle of the same diameter as length of river Garanga (main stream). The calculated Elongation ratio was 0.55 (0.57). The form factor which is the ratio of the average width to the axial length of the basin was determined. The axial length is measured from the most remote point of the basin to the outlet.

A low form factor was estimated at 0.33 (0.3532).

The result of both satellite imagery data analysis and Topographic map data analysis was subjected to Chi square analysis to determine if there is any significant difference between a Topographic map and a map derived from satellite imagery. The result of test showed that there was no difference.

Ground truth verification tours were made to the study area to determine if the Remote Sensing images map features were authentic. As more first order streams were found in the map derived from the satellite image, those first order streams not found in the Topographic map were considered for the field control visits (for ground truth verification). Of the 12 such first order streams, five were visited in terms of proximity to each other. Three of the fine streams had water flowing in them but the remaining two had puddles and ponds with no flowing water. Time of visitation was February. For the above study carried out, the findings were shown to have illustrated the points below.

It was possible to use the attributes of Remote Sensing to map the hydrologic features of an area.

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The patterns and sizes of streams were helpful in tracing out the streams. In some parts some streams were obscured but the lineaments of vegetation along the streams were useful in tracing them out. The number of streams found in the Topographic map was less than those found in the map derived from Remote Sensing imagery though there is wide disparity in scale. With computer application, clearers mapping could be done. It shows that Remote Sensing imageries could be used to map and up date maps of river basins.

The flood plain delineation was possible especially for the larger chalawa river, thus a continious flood plain was delineated there. In River Garanga (Main stream of the study basin) a discontinious flood plain was possible along its lower reaches near the confluence with Chalewa river. It showed that it was possible to use the properties of Remote Sensing in terms of spectral reflectance of vegetation in the N.I.R. portion of E.M.R. to delineate the flood plains of a large basin. The delineation of the flood plain is useful in determining the use of the fadama. The knowledge of the size of the flood plain could help prevent the over use of the plain by farmers and in determining settlement location.

The basin boundary was determined by using the phreatic water divide. In a situation where stereoscopic viewing is possible, the topographic divide could also be put into consideration. They could give better delineation of basin boundaries than direct from the topographic map where the topographic where the topographic divide is only put into consideration when tracing the boundary of a drainage basin.

In the morphometric analysis, it was found that the basin is an ordinary basin with little geologic or climatic control as a result of bifureation ratio of 3.588 (3.52). The stream length ratio also showed that second order streams and fourth order streams were much longer than the streams of orders preceeding them. Form ratio and elongation ratio showed that the basin is closer to a cycle than a square. It showed that it is closer to a cycle with a diameter, the same length as the axial length of the basin. These results are useful in describing the basin characteristics for other hydrological studies.

The low form factor shows that the basin has a rapid response to flooding because it is less likely to have an intense rainfall simultanously over its entire extent than a basin of equal size with longer form factor.

It is necessary for River Basin Authorities to use the attributes of Remote Sensing data (most especially, the S.P.O.T. because of it's stereoscopic viewing) to update the maps of theis basins. Larsson and Stromquist (1991) estimated the cost of acquiring a S.P.O.T. imagery and fixed it at 0.5 US & per square kilometre. Since the same imagery could be used by other concerns as well, the cost of regularly acquiring S.P.O.T. data could be showed by different establishments and used together.

This kind of combined usage has its own problems. At the cartography department of National Population Commission the Chief Cartographer attributed it to beaurocratic red tapism. In such a situation, it could be necessary to set up a National Geographic Commission in form of Geographic Information System (G.I.S.) to acquire and update the existing Cartographic maps while receiving the contribution from the establishments that could make use of the maps and data. In this case, a central body will be in charge of this acquisition analysis and incorporation of Remote Sensing Imagery data into a base or existing maps. The Federal Government should be in charge of it with the universities contributing into the think Thank. This will help in modernising the survey department of the Federal Ministry of Works without obsorbing the department and also help update the maps and data avaliable in the country with little cost.

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