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Fluvial Morphometry Of The South Western Drainage Systems, Ghana

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***Abstract:** An attempt is made to obtain baseline morphometric information to understand the hydro-geomorphic behaviour of the South Western River System which includes the Pra, Tano, Ankobra and Bia. The River system is located between latitudes 5°N and 7.7°N and longitudes 0.3°W and 3.2°W and has a total drainage area covering about 22% of the land area of Ghana. Aside it being endowed with the nation's richest evergreen Forest which supports the Agriculture and Lumbering sectors, the South Western River System hosts some very important resources of the country like Gold, Bauxite, Diamond and Oil reserves. In this present study, GIS and RS tools have been employed to evaluate 25 morphometric parameters. Some thematic maps including Lithological and elevation maps have been prepared using ArcGIS software. From the study, it has been found that the Pra is of the 8th and highest order while the Ankobra and Bia have the 5th and Lowest order. Based on the bifurcation ratio, lithology has had and influence in the drainage development of the various river systems especially the Bia and the Tano. Calculated form factors, circularity ratio and elongation ratio indicate that the Tano and Bia basins are relatively more elongated than the Pra and Ankobra basins.*

***Keyword:** Hydro-geomorphic, morphometric, bifurcation ratio, lithology*

I. INTRODUCTION

Water is at the center of everything but not all countries have easy access to it. Most countries especially in Africa have been relying on neighboring/riparian countries for major water resources such as hydro-energy for the powering of their various economies because of the lack of such natural resources (Rivers). Ghana has in a long while been one country providing such services to Burkina Faso, Togo, Mali and Cote D'ivore due to the abundance of surface water bodies notable among which are the Volta, Tano and Pra rivers. Upon all the abundance of these water resources, the country has in often times experienced Power and even water shortage to such an extent of industries shutting down and people being laid off. Such problems under normal circumstance shouldn't have been the issue of a country blessed with numerous surface water bodies if watershed management issues had been taken critically.

Watershed management is a major problem in Ghana due to insufficient and unavailable flow data which arises due to the lack of necessary equipment, inaccessibility or remoteness of the few gauge stations and inadequate funding as well as man power. This situation does not enhance solutions to the annual hydro-geomorphic mishaps such as, low flows and their attendant power shortages, floods, erosion, siltation, sedimentation and other denudational as well as aggradational processes.

Integrated Water Resources Management (IWRM) have been set by the Water resources commission and are being implemented in an attempt to help control these many problems bedeviled with the numerous river basins in Ghana. IWRM is a systematic process for the sustainable development, allocation and monitoring of water resources use in the context of socio-economic and environmental objectives. Executing such measures disjointly from data on the hydro-geomorphic behavior of these rivers will lead to a no problem solved.

Hydro-geomorphic processes occurring within a drainage basin can best be understood, under the above scenario, by analyzing the morphometry of the various drainage basins.

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This is because every drainage basin is unique and complicated in its own way since broad variations in climate, hydrology, geology, and vegetation impart strongly on the regional morphology and dynamics each particular river system (Hicks and Griffiths, 1992). Morphometry is the measurement and the mathematical analysis of the configuration of the earth surface, shape and dimensions of the landforms (Agarwal, 1998). Thus, by analyzing a basin's Morphometry, the geology, climate, topography, geomorphology and structure of the basin can be expressed- based on which some level of planning and management execution measures could be done.

Various hydrologic phenomena such as erosion characteristics and soil/subsurface properties can be connected with the physiographic characteristic of the basin including the size, shape, slope and length of tributaries (Rastogi et al, 1976). Horton (1945) and Strahler (1964), the pioneers of these parameters have grouped them under linear, areal and relief aspects. Prominent among these parameters are the bifurcation ratio; is a linear measure of how one basin order discharges into another and is relevant in hydrograph time relation according to Chorley (1969)—as bifurcation ratio reduces so as the incidences of flood increase. Drainage density describes the interaction between climate and geomorphology (Rodriguez-Iturbe & Escobar, 1982); drainage intensity measures the ability of a basin to discharge its water and this has implication on flood management; basin shape describes the time of peak and concentration and sinuosity measures the meandering nature of a basin and this has implications on sedimentation, erosion and water quality (Chow, 1964).

Morphometric analysis is eseential in watershed prioritization for conservation and management, landsliding analyses, river basin evaluation and ground water quality. This study will measure basin variables in the south-western drainage basin system to assess hydro-geomorphic attributes of the basins to ascertain the dynamics of the various sub-basins within the system.

II. STUDY AREA

The south-western basin system is located at the extreme south-western corner of the Ghana and consists of four principal rivers including the Bia, Tano, Ankobra and Pra. Approximately, this basin system is located between latitudes 5^{o}N and 7.7^{o}N and longitudes 0.3^{o}W and 3.2^{o}W. their drainage area covers about 22% of the land area of Ghana.

This basin system comes strongly under the influence of the moist south west monsoons and has a double maixma rainfall regime peaking in May/June and September/October with annual rainfall in the range of 1137-2156mm. Its vegetation consists of tropical rain forest and moist semi-deciduous forest. Soils of the tropical rainforest are forest oxysols, which is acidic, and that of the semi-deciduous forest is forest ochrosols, which is alkaline and well drained.

The basin is underlain by pre-Cambrian formation, and is classified into Birrimain and Tarkwaian rocks. Apart from the Ankobra and Pra which empties into the gulf of guinea in Ghana, the Bia enters the sea in La Cote d'Ivoire whiles the Tano flows through the international boundary between Ghana and Côte d'Ivoire before entering the Aby-Tendo-Ehy lagoon system wnich is an inlet to the Atlantic ocean and also in Côte d'Ivoire.

The topography of the south western basin system is characterised by some relatively flat lands to peaks. Some major tributaries include rivers Abu, Amama, Boin, Disue, Gaw, Kwasa, Sumre, Suraw and Totua all of the Tano; Anum, Birim and Offin of the the Pra; Huni, Bonsa and Mansi of the Ankobra;

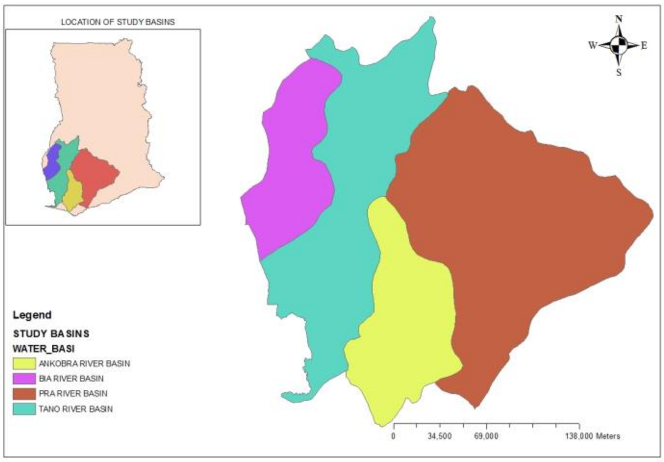

Figure 1

III. MATERIALS AND METHODS

The study used the Aster gdem (version 2image, downloaded from the United States Geological Survey (USGS). It is a Digital Elevation Model (DEM) with a 30m resolution has an overall accuracy of around 17-m at 95% confidence level and a horizontal resolution on the order of 75-m Again using Aster DEM in hydrological studies comparatively is able to help in the performance of more advanced analysis since it comes with the quality assessment file provided by the Aster DEM. The DEMs are indexed N07W003, N07W002, N06W003 and N05W003 for the Tano basin; N04W003, N05W002, N05W003 and N06W003 for the Ankobra basin; N06W003, N07W003 and N06W04.

In addition to the soft copy of survey of Ghana toposheets on a scale of 1:50000 indexed (0501a, 0502d, 0601a, 0601c, 0602a, 0602b, 0602c, 0602d, 0603b and 0603d) for the Pra basin; (0501a, 0501b, 0501c, 0602a, 0603a, 0603b, 0603c, 0603d, 0702c, 0703c, 0703d) for the Tano basin; (0403b,0503b, 0503d, 0502a, 0502c, 0602c, 0603d) for the Ankobra basin and (0703c, 0603a, 0603c, 0604d, 0604b) for the Bia basin. DEMs' were reprojected from Clarke (1866) to the Ghana meter grid. These DEMs' were mosaicked in Erdas imagin (9.2). The since the toposheets had been layered already, the hydro layer containing the river networks were just reprojected to the Ghana meter grid and used.

Geological data was also obtained from the Ghana Geological Service to analyze the stratigraphy of the basins.

For meaningful morphometric analysis, the DEM was reconditioned so that elevations direvt drainage towards the vector information (topo data). This involved a lot of ArcGis functionalities. Hydrologic terrain analysis were done after the

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reconditioning to fill sinks, calculated flow direction and flow accumuilation. This also involved watershed delineation and stream ordering. All these were done with the Arc Hydro pluck-in of the arc map version10.1. the first step in any morphometric analysis is the stream ordering and stream numbers. These were done in the Arc map and the other parameters were calculated based on these results using established formulae established.

No.	Morphometric Parameters	Formulae	Reference
1.	Stream order (u)	Hierarchical rank	Strahler (1964)
2.	Stream length (L_u)	Length of the stream	Horton (1945)
3.	Mean stream length (L_{sm})	$Lsm = Lu/Nu$	Strahler (1964)
4.	Stream length ratio (R_l)	$Rl = Lu / Lu - 1$	Horton (1945)
5.	Bifurcation ratio (R_b)	$Rb = Nu/Nu - 1$	Schumn (1956)
6.	Mean bifurcation ratio (R_{bm})	R_{bm}= Average of bifurcation ratios of all the orders	Schumn (1956)
7.	Basin Length	GIS software	Schumm 1956
8.	Basin Area	GIS software	Schumm 1956
9.	Basin Perimeter	GIS software	Schumm 1956
10	Length Area relation	Lar =1.4*$A^{0.6}$	Hack (1957)
11.	Stream frequency (f_s)	$Fs = Nu / A$	Horton (1932)
12.	Sinuosity Index	Si= Ci/Vi	Mueller (1968)
13.	Drainage texture (R_t)	$Rt = Nu / P$	Horton (1932)
14.	Form factor (F_f)	$Rf = A / Lb2$	Miller (1953)
15.	Circularity ratio (R_c)	$Rc = 4 * Pi * / P2$	Miller (1953)
16.	Elongation ratio (R_e)	$Re = 2\sqrt{\frac{A}{\pi}}/Lb$	Schumn (1956)
17.	Length of overland flow (L_g)	$Lg = 1 / D * 2$	Horton (1945)
18.	Drainage Density (Dd)km/kms^2	Dd=Lu/A	Horton (1932)
19.	Constant of channel Maintenance (Kms^2/km)	C=1/Dd	Schumm(1956)
20.	Drainage Intensity (Di)	Di=Fs/Dd	Fainiran (1968)
21.	Infiltration Number (If)	If=Fs*Dd	Fainiran (1968)
22.	Height of Basin mouth (z)m	GIS Analysis/DEM	--
23.	Max Height of basin (Z)m	GIS Analysis/DEM	--
24.	Toatal Basin Relief (H)m	H=Z-z	Strahler (1952)
25.	Relief Ratio (Rhl)	Rhl=H/Lb	Schumm (1956)

Table 1

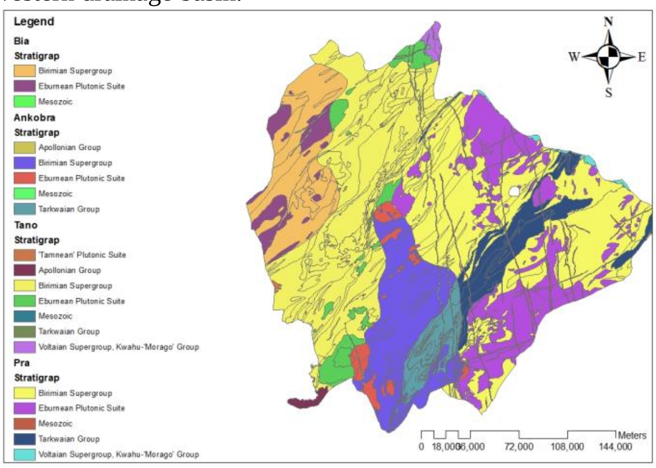
IV. RESULTS AND DISCUSSION

LITHOLOGICAL CHARACTERISTICS

In order to understand the behaviour and form of the rivers, a stratigraphic map has been prepared from the geological map sourced from the Geological Service of Ghana. The principal rock formation running through all the individual basins was the Birrimian Supergroup. This was found purely to be of the volcanic origin for the Pra, Ankobra and the Bia basins and was made upe of rocks such as andesite, hornblende biotite granotoids, argillitic sediments, wascke sediments and volcaniclastic sediments. However, in the Tano basin the Birrimian comprised all the aforementioned rock types and also added another rock type known as the amphibolite which is partly of contact metamorphic origin. It was identified to be of the synvolcanic intrusive origin.

The Eburnean Plutonic suite also is a formation that ran throughout all the basins but not occupying as much area as the Birrimian supergroup. This formation is composed of mafic and utra mafic igneaous rocks as well as biotitie granite and granotoids. Big outcrops of the Tarkwaian formation were found only in the Ankobra and the Pra basins. This formation is in a variety of four categories including the Kawere (conglomerate), Huni (sandstone), Tarkwa Phyllite (argillite, siltstone, tuff) and Banket (conglomerate, quartz pebbles and quatzose sandstone) formations. Though all four formations were found in the Akobra basin, only the Banket formation was found in the Pra basin. Traces of the Mesozoic and Voltain supergroup were aslo found in the Pra and the Tano.

One unique formation identified from the lithological analysis was the Tamnean plutonic suite which was only found in the Tano basin just at its mouth. It was made up of Hornblende-biotite tonalite, minor granodiorite, minor quartz diorite. Below is a map of the stratigraphy of the south western drainage basin.



Source: Lithographic Analysis

Figure 2: Stratigraphy of the South Western Drainage System

MORPHOMETRIC ANALYSIS

Morphometric parameters examined in this paper have been grouped under four categories namely drainage network parameters, basin geometry parameters, drainage texture and relief parameters.

DRAIANGE NETWORK ANALYSIS

Table 1 is a summary of the parameters which examined the drainage network of the southe western drainage basin namely stream order (Su), Bifurcation ratio (Rb), mean bifurcation ratio (Rbm), stream length (Lu), mean stream length (Lum) and Stream length ratio (Lur).

	Pra	**Tano**	**Ankobra**	**Bia**
Su				
I	1,290	825	413	420
II	578	380	96	94
III	59	41	21	19
IV	11	14	4	2
V	4	2	1	1
VI	2	1	--	--
VII	1	--	--	--
	1,945	1,263	535	536
	Pra	**Tano**	**Ankobra**	**Bia**
Rb				
I/II	2.23	2.17	4.30	4.47
II/III	9.80	9.26	4.57	4.95
III/IV	5.36	2.93	5.25	9.50
IV/V	2.75	7.00	4.00	2.00
V/VI	2.00	2.00		
VI/VII	2.00	--		
Rbm	4.02	3.98	4.53	5.23
Lu (Km)				
I	4,655.80	2,394.29	1,188.68	1,314.94
II	1,928.30	1,292.08	623.50	637.47
III	793.14	515.87	258.68	282.28
IV	315.59	269.49	203.89	128.86
V	301.89	35.33	36.16	129.50
VI	142.90	255.90	0.00	0.00
VII	129.25	0.00	0.00	0.00
	12,922.67	4,762.96	4,762.96	2,493.05
Lum(Lu/su)				
I	3.61	2.90	2.88	3.13
II	3.34	3.40	6.49	6.78
III	13.44	12.58	12.32	14.86
IV	28.69	19.25	50.97	64.43
V	75.47	17.67	36.16	129.50
VI	71.45	255.90	0.00	0.00
VII	129.25	0.00	0.00	0.00
Lur (Lu+1)/Lu				
I	0.00	0.00	0.00	0.00
II	0.92	1.17	2.26	2.17
III	4.03	3.70	1.90	2.19
IV	2.13	1.53	4.14	4.34
V	2.63	0.92	0.71	2.01
VI	0.95	14.49	0.00	0.00
VII	1.81	0.00		
	1.78	3.12	1.50	1.78

Table1: Summary of Drainage Network Parameters

STREAM ORDER

In determining the stream order which is ther first step in drainage basin analysis, strahlers method was fowllowed. In this system, the smallest unbranching streams are tagged as 1st order streams; when two of such streams join it forms the 2nd order and two 2nd orders join to form the 3rd order and so on. However, two streams of different orders join and the highest order of the two is maintained (Strahler 1952). The trunk stream is the stream with the highest order. This system or concept of ordering was first advocated by Horton.

Within the south western system, the Pra river basin has been found to be the one with the seventh (7th) and highest order followed by the Tano river basin which has a sixth (6th) order. The Bia and Akobra river basins are of the lowest and the same order, that is the fifth (5th) order. All the basins nonetheless experience a decrease in their stream frequency as their order increases but the stream frequency is maximum in all the first order segments of the various basins. Thus, the Pra with the highest order has about 1,290 total number of first order streams followed by the Tano which also has about 825 number of first order streams. Interestingly, though the Ankobra and Bia river basins are of the same order, the total number of first order streams in the Bia is just Seven (7) more than the Ankobra whiles the number of second order streams in the Ankobra basin are also just more than the Bia by 2; 420 and 413, 96 and 94 respectively. These notwithstanding, all the various stream segments of each order within each basin follows the first law of Horton which states that the number of stream segments of each order form an inverse geometric sequence with order number.

LAW OF STREAM NUMBERS/BIFRUCAION RATIO

The law of stream numbers which has often been referred to as the bifurcation ratio is the most important of the three laws of Horton on streams. This law considers the topology of the river network while the other two is concerned with the metric (Scheidegger, 1967b). It states that “the numbers (n) of stream segment of order in a given drainage basin form, on the average a geometric sequence”. Thus

$$n_{i+1=}\alpha ni$$

Bifurcation ratio is mostly defined as the ratio of the number of stream segment of given order (Nu) to the number of streams in the next higher order (N_{u+1}) has been considered as an index of relief and dissectation by Horton (1945). Strahler (1957) has also indicated that for different regions or environments, rb which is a dimensionless property shows a small range of variation (3.0-5.0) except where powerful geological controls dominates. Also the irregularities in rb values from one order to the order within a drainage basin has been explained by Strahler (1964) as being influenced by the geological and lithological controls. Thus lower rb values imply less structural controls and high rb values indicate more structural contols on the pattern.

From Table 1, within all the four basins there are strong structural controls on the characteristics of the various patterns of the basins, however that of the Ankobra and the Bia basins are very strong as the rb values range from 4.0-5.25 and 2.0-9.5 respectively. This implies that there have been some influences on the lithology or geology which has also distorted the structures and patterns imprinted on these two basins. Unlike the afore mentioned, the Pra and Tano basins though have been disturbed are not as prevalent. From the table, only portions of the watershed have strong distortions but between the two, the Pra basin has stronger distrotions in its structure and pattern than the Tano basin. This is true from the calculated mean birfurcation ratios of 4.02 and 3.98 respectively.

Based on this law of stream numbers given by Horton, a plot of stream against order should yield on the average, a straight line on a semi-logarithmic paper.

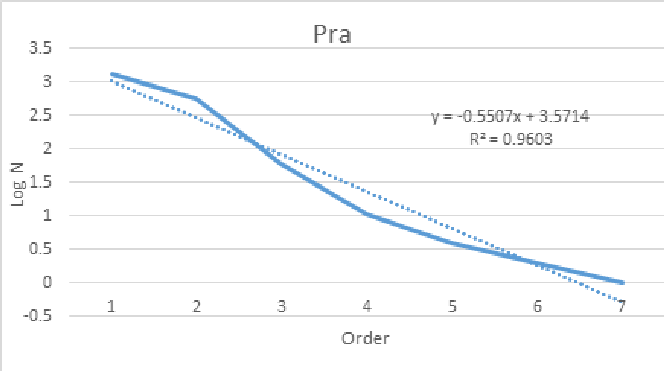


Figure 3

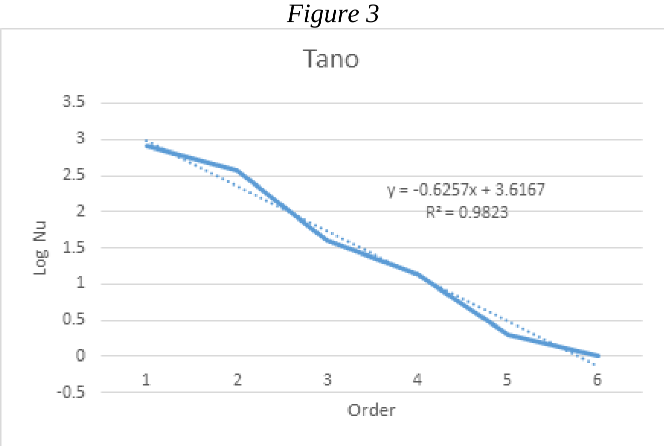


Figure 4

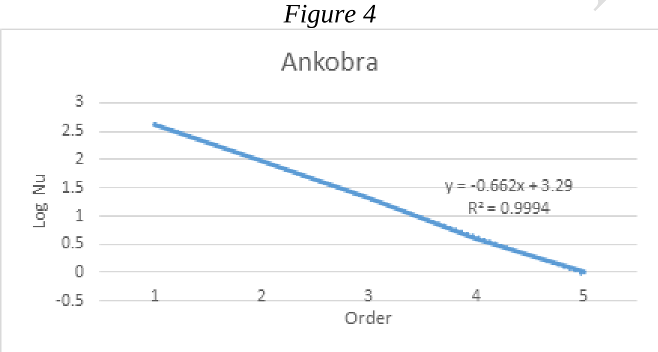


Figure 5

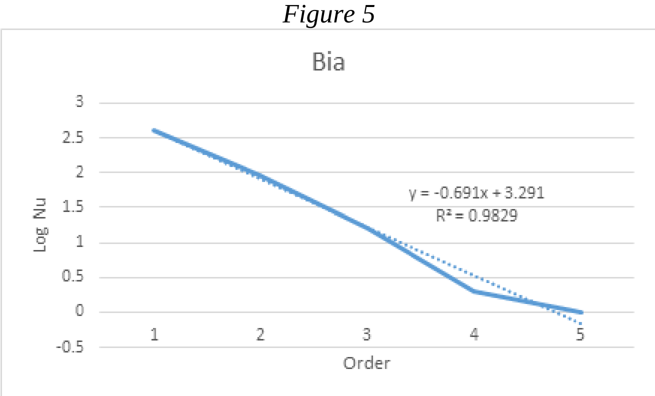


Figure 6

But from the graphs preceeding, all the basins' structures obey the Horton's law but they are not perfectly structurally Hortanian. In structurally Hortonian Rivers, the plotted line would have been a straight line indicating that conditions leading to the existence of the rivers from one generation to another generation are statistically invariable. They deviate slightly from the straight line and the regression co-efficient generated for each one of them also attest to this fact. However it is the Bia river system which is almost close to Hortonian structure. The structurally Hortonian river has been explained by Horton using the model of "allometric growth" of river systems by Woldenberg (1966).

This model speak of cycles or generations of river systems and implies that conditions surrounding the existence of all rivers are invariable overtime. Thus all rivers possess an intrinsic topological structure.

STREAM LENGTH

Calculation of stream length is very essential as it reveals the surface run-off characteristics of a basin. While shorter lengths indicates areas have fine textures and larger or steeper slopes, longer lengths are indicative of areas with flatter slopes. Total length of stream segments are maximum in first order streams and decrease with increasing order as in the case of stream numbers.

The Pra basin being of the highest order among the four, has 4,655.80km as the total length of all its first order streams, followed by the Tano which has 2,394.29km also for its first order streams' length and the and Bia with 1,314.94 before the Ankobra basin which has 1,188.68 aslo being the length of its first order streams only. Interestingly, there is a spectacular fact about the Tano where the total length of its streams making up the fifth order total up to only 35.33km while total length of its stream segments making up the 6th order 255.90km. This simply can be explained with the elevation on which the fifth order streams are flowing; that is the stream segments are flowing on a steeper gradient, thus explaining the shorter distance. Another fascinating issue has to do with the total length of streams in both Tano and Ankobra being the same that is 4762.96km. It had been expected that with the greater number of streams being in the Tano than in the Ankobra, the lengths of them too would vary in favor of the Tano. But again it may be explained with differences in the gradients over which the respective river segments are over flowing.

The stream Length ratio (Lur) which is defined as the ratio of the mean stream length of a given order (So) to the mean stream length of the next lower order which tend to be constant throughout the successive orders (Horton, 1945). It is a very good indicator of the surface flow and discharge. According to Singh et al 1997, changes in stream length ratio from one order to another indicate their late youth stage in geomorphic development.

From Table 1, it is observed that there are variations in the stream length ratio (Lur) from one order to the order which means Lur is not constant throughout the various basins. This therefore agrees with Singh et al 1997, that all the basins of the south western drainage system are in their late youth stage in geomorphic development.

BASIN GEOMETRY ANALYSIS

Parameters analyzed to describe the geometry of he south western drainage basin include Basin area (A), Basin Perimeter (P), Length of basin (Lb), Length Area Relation (Lar), Form factor (Ff), elongation ratio (Re), Circularity ratio (Rc) and Drainage Texture (Dt). Table 2 is a summary of the parameters evaluated.

Basin Name	A(km^2)	P(kms)	Lb(kms)	Lar	Ff	Re	Rc	Dt	Si
Pra	23,606.00	749.50	185.5	588.76	0.41	0.36	0.52	2.59	1.46
Tano	15,026.00	883.10	238.0	448.98	0.18	0.24	0.24	1.43	1.55
Ankobra	8,793.00	449.60	174.6	325.54	0.31	0.31	0.55	1.19	1.45
Bia	6,793.00	400.90	143.7	51.04	0.28	0.30	0.51	1.33	1.37

Table 2: Summary of Basin Geometry Parameters

DRAINAGE AREA

The drainage area is defined as a collecting area from which water would go to a stream or river. The boundary of the area is determined by the ridge separating water flowing in opposite directions. Among the four basins in the South western system, the Pra has biggest area collecting water to drain its rivers. Total area is about 23,606km^2 before the Tano and Ankobra, the Bia basin has the smallest area of 6793km from which it gathers water to drain.

PERIMETER

Basin perimeter is the outer boundary of the drainage basin that encloses its area. It is measured along the divides between basins and may be used as an indicator of basin size and shape, Schumm (1956). The perimeters of the four basins have been measured in Arc GIS and it has been found that even though the Pra basin has a larger area, the Tano has a bigger size using its Perimeter of 883.10km while the Bia basin again is smallest in terms of size using its Perimeter (400.90km).

BASIN LENGTH

Basin length (Lb) has been given different meanings by different workers (Schumm 1956; Gregory and Walling 1973; Gardinder 1975). The Lb is the longest length of the basin, from the catchment to the point of confluence (Gregory and Walling, 1973). The Tano has the longest length of basin within the South western drainage system whiles the Bia has the shortest length from basin to confluence. But the Pra though has the biggest area has its length over that of the Ankobra by only about 10.9km.

FORM FACTOR

Form factor ratio (Ff), is a quantitative expression of drainage basin outline and is the dimensionless ratio of basin area to the square of basin length form (Horton, 1932). For a perfectly circular watershed, the Ff will always be around 0.754. The elongated basin with a lower form factor indicates that the basin will have a flatter peak of flow for longer duration. Flood flows of such elongated basins are easier to manage than of the circular basin. (Christopher et al., 2010).

From Table 2, the Tano with a form factor of 0.18 indicates that it is more elongated than the Bia which has an Ff of 0.28. the Pra basin is much more circular too with a form factor of 0.41 than the Ankobra with a Ff of 0.31. floods within the Tano and the Bia basin can much more be managed that floods in the Pra and Ankobra river basins. The Pra and Ankobra also are likely to have high peak flows of shorter duration that the Tano and the Bia basins.

ELONGATION ratio

Elongation ratio (Re) is defined as the ratio of diameter of a circle of the same area as the basin to the maximum basin length (Schumm, 1956). Values near to 1.0 are typical of regions of low relief (Strahler, 1964) and this ratio runs between 0.6-1.0 over a wide variety of climate and geology. Index of elongation ratio has been given as circular (0.9-1.0), oval (0.8-0.9), less elongated (0.7-0.8), elongated (0.5-0.7), and more elongated (<0.5). It is a very significant index in the analysis of basin shape which helps to give an idea about the hydrological character of a drainage basin.

From Table 2, all the basins have elongation ratios nowhere near to one thus indicating that their various reliefs are not that low. Again, using the elongation ratio index, since all the values are less than 0.5 it means that they are all more elongated. However, the Tano has a vlue of 0.24 implying that it is much more elongated than the Bia basin which follow with a value of 0.30. the Pra and Ankobra though are aslo elongated are not close to the Tano basin.

CIRCULARITY RATIO

Miller (1953), used circularity ratio as a quantitative measure to describe the out-line of the watershed. He defined it as the ratio of the area of a basin to the perimeter of the basin. It is affected by the lithological character of the basin. The ratio is more influenced by length, frequency (Fs), and gradient of streams of various orders rather than slope conditions and drainage pattern of the basin. It is a significant ratio, which indicates the dendritic stage of a basin. Its low, medium and high values are indicative of the youth, mature and old stages of the life cycle of the tributary basins. According to Miller, Rc ranges 0.4-0.5 which indicates strongly elongeated and highly permeable subsoil. Such drainage systems are partially controlled by the structural disturbances (Zavoiance, 1985).

The calculated Circularity ratios within the South Western drainage systems shows that, it is only the Tano basin which has a low Rc of 0.24. This indicates that its dendritic stage is low and it is in its youthful tributary life cycle. Apart from the Tano, all the other three are in the matured tributary life cycles falling a little over Miller’s range thereby suggesting the partial control by structural disturbances unlike within the Tano.

DRAINAGE TEXTURE

The drainage texture is considered as one of the important concept of geomorphology which shows the relative spacing of the drainage lines (Chorley et al., 1957). This concept explains the underlying lithology, infiltration capacity and relief aspect of the terrain. Drainage texture (<2 indicates very coarse), (2 - 4 as coarse), (4 - 6 as moderate), (6 - 8 as fine) and (> 8 as very fine drainage texture Smith (1939).

In this present study, the Tano, Ankobra and Bia basins have drainage texture of less than 2 implying very coarse texture and indicates good permeability of sub-surface materials. The Pra basin however has a coarse drainage texture whose subsurface materials are not so much different from that of the very coarsed textured drainage nature of the other three.

SINUOSITY INDEX

Sinuosity is highly significant in studying the effects of terrain characteristics on the river course and vice versa. Sinuosity shows the deviation of the course of a drainage line from the theoretic straight path. Muller (1968) gives the methodology to calculate the sinuosity and a value of unity (1.0) of Si shows straight river course, values from 1.0 -1.5 indicate the sinuous shape of the stream and the values above 1.5 put the streams in meandering course.

From the Table 2, it is observed that all the rivers in the south western drainage system are sinuous in shape since calculated sinuosity fall within the range of 1.3-1.5. Sinuosity is therefore generally low within the drainage basin system.

DRAINAGE TEXTURE ANALYSIS

Parameters assessed to expound the drainage texture of the south western drainage basin system include Stream frequency (Fs), Drainage density (Dd), Constant of Channel Maintenance (1/Dd), Drainage Intesity (Di), Infiltration number (If) and Length of overland Flow (Lg). Table 3 summarizes the drainage texture analysis.

DRAINAGE DENSITY

The measurement of Drainage density is a useful numerical measure of landscape dissection and runoff potential and an expression of the closeness or spacing of channels (Chorley, 1969; Horton, 1932). According to Schumm (1956), in timing the travel of water in a basin, the drainage density is highly significant. Aside being the outcome of interacting factors controlling he surface runoff (i.e., climate, vegetation, soil, rock properties, relief and landscape evolution processes), the drainage density influences the output of water and sediment from the drainage basin (Ozdemir and Bird, 2009; Moglen et al., 1998

The calculated drainage densities in the study basins show very low results. Dd range from 0.3-0.55. Low drainage density leads to coarse drainage texture while high drainage density leads to fine drainage texture (Strahaler, 1964). Thus, from this it can be understood that all the basins making up the south western drainage system are coarsely textured. It has been observed from drainage density measurement made over a wide range of geologic and climatic type that low drainage densities are more likely to occur in regions with highly resistant or highly permeable subsoil material under dense vegetative cover and where relief is low.

STREAM FREQUENCY

Stream frequency (Fs), is expressed as the total number of stream segments of all orders per unit area. It exhibits positive correlation with drainage density in the watershed indicating an increase in stream population with respect to increase in drainage density. The Fs for the basins range from are almost the same except for the Ankobra which also has the lowest drainage density.

CONSTANT OF CHANNEL MAINTENANCE

The inverse of drainage density has been used to the constant of channel maintenance by Schumm (1956) C. provides information of the number of square feet of watershed surface required to sustain one linear foot of stream so in units of square feet per foot and has the dimension of length.

From this present study, Ankobra needs the greatest (3.33sq.ft) surface to create one linear foot of the stream channel while the Pra needs the smallest surface of 1.82sq ft. to create the same foot of stream channel.

LENGTH OF OVERLAND FLOW

The hydrologic and physiographic development of a basin is also influenced by the Length of Overland flow parameter, Lg. it is the length over which water must flow on the ground before being concentrated into a definite channel.

From Table 3, water in the Pra does not flow on the ground for long before getting into a channel. However, within the three other basins water must flow for almost around the same time before getting into its confinement.

Basin Name	Dd	Fs	1/Dd	Di	If	Lg
Pra	0.55	0.08	1.82	0.15	0.05	0.91
Tano	0.32	0.08	3.13	0.27	0.03	1.56
Ankobra	0.30	0.06	3.33	0.20	0.02	1.67
Bia	0.37	0.08	2.70	0.21	0.03	1.35

Table 3: Summary of Drainage Texture Parameters

RELIEF CHARACTERISTICS

Parameters considered for characterizing the relief of the basin system includes height of basin mouth (z), maximum height of basin (Z), total basin relief (H)m, Relief ratio (Rh) and Ruggedness number (Rg). Table 4 is a summary of the relief characteristics of the study area.

RELATIVE RELIEF

Relative relief analysis (z, Z) sort to examine the height of basin mouth and the maximum height of the various basins through the visual analysis of the digital elevation model prepared from Aster Gdem data. Relative relief shows the actual variation in the altitude with respect to its unit area and so indicates the steepness of a basin from its summit to mouth. All the basin mouth were found to be below sea level. However, the Pra had the highest elevation implying that with this basin there are some very high lands and this was around the Kwahu area.

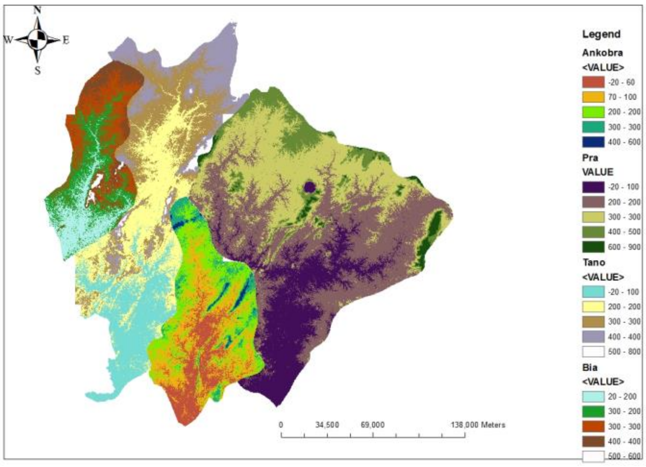


Figure 7: DEM of South Western Drainage System

RELIEF RATIO

Relief ratio measures the overall steepness of a drainage basin and is an indicator of the intensity of erosion process operating on slope of the basin (Schumm, 1956). It normally increases with decreasing drainage area and size of watersheds of a given drainage basin (Gottschalk, 1964). It has been recorded from the Table 3 that among the Four basins relief ratio ranges from 0.1-0.25 which implies that the entire drainage system have very steep slopes indicating very high reliefs.

RUGGEDNESS NUMBER

It is a product of maximum basin relief (H) and drainage density (Dd) where both parameters are in the same unit. Ruggedness number is a parameter that looks at how prone and area is to erosion and its intrinsic structural complexity.. From this present study, the ruggedness number is low throughout the four basins ranging from 0.17-0.48. this means the various basins are less prone to soil erosion and have an intrinsic complexity in relationship with the relief and drainage density

Basin Name	z (m)	Z (m)	H (m)	Rh	Rn
Pra	-22.00	870.00	848.00	0.10	0.46
Tano	-19.00	799.00	780.00	0.16	0.25
Ankobra	-19.00	590.00	571.00	0.22	0.17
Bia	-21.80	640.00	618.20	0.25	0.23

Table 4: Summary of Relief Parameters

V. CONCLUSION

The South Western Drainage System is a very important area in terms of Ghana's economic development. Aside it being endowed with the nation's richest evergreen Forest which supports the Agriculture and Lumbering sectors, some very important resources of the country like Oil reserves have been discovered and is being mined in the Tano basin. These attributes and many more have led to a boost in the population in this area and its attendant socio-economic mishaps including the illegal mining (Galamsey) in some of the areas rivers and chain saw operations (wood logging). Such activities have been exploiting the river basins so much though scientific documentation on the river basins are very scarce.

This study generates baseline information on the characteristics of the basins in the South western drainage system. The Pra has the highest order (7th) while the Ankobra and Bia have the lowest orders (5th). The Tano is rather a 6th order basin but unlike the Ankobra and the Bia, the structural control of the lithology on the pattern imprinted on the Tano and the Pra is not that much based on the bifurcation ratio. The Tano and Bia basins do not have much issues with floods controls as the Ankobra and the Pra based on the calculated form factors, circularity ratio and elongation ratio. This is because the Tano and the Bia basins are relatively more elongated than the Pra and Ankobra basins and elongated basins are easier managed than in circular basins like the latter.

GIS approach in conjunction with remotely sensed data are very effective in evaluating the geomorphological characteristics of drainage basins based on which watershed management would be easier and effective. It can thus be concluded that evaluating morphometric parameters and their influence on landform and development is very paramount.

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