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CHANGES IN THE SUMAMPA STREAMFLOW FLASHINESS IN THE FOREST-SAVANNAH TRANSITIONAL ZONE, MAMPONG-ASHANT, GHANA 1985-2009

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ABSTRACT

The Sumampa stream is located in the Municipal capital of Mampong-Ashanti in the forest-savannah agro-ecological zone of the Ashanti Region in Ghana. The study investigated the changes in the flashiness of the Sumampa stream as a result of increasing human activities in the catchment by assessing the stream's pathlength and Richards-Baker's new flashiness Index (R-B Index), annual and decadal variation in the flashiness Index using daily flow data from 1985 to 2009. The daily flow data was generated from the stream's daily stage data using the stream's rating curve developed by the Department of Hydrology, Kumasi, Ghana. The landuse change scenarios and the rainfall trend coupled with 43.8% of catchment land on 5-10^o slope represent a potentially high erosion risk and an important factor to influence flashiness in a fast expanding urban catchment. The stream R-B Index dropped by 12.15% and the flow pathlength by 13.89% in 2000-2009 decade. The total decadal stream discharge also decreased by 35.22% in the 2000-2009 decade. The daily stream flow hydrograph shows a decrease in the stream's flashiness between 1989 and 2006 after which it increased above the mean period flashiness index. The increase in R-B Index after 2006 was due to rapid expansion and rehabilitation of urban facilities and is regulated by a sharp increase in agricultural activities for livelihood.

Keywords: stream hydrograph, stream flashiness index, urbanization, flow pathlength.

1. INTRODUCTION

Streamflow, or discharge, is the volume of water in the stream flowing past a given point within a specific period of time (m^3s^{-1}). Flow, the product of the cross-sectional area and the velocity of streamflow, is an important determinant of water quality and aquatic habitat conditions. A river flow regime describes an average seasonal behaviour of flow and reflects the climatic and physiographic conditions in a catchment. Differences in the regularity (stability) of the seasonal patterns reflect different dimensionality of the flow regimes, which can change subject to changes in climate conditions. Global warming has a significant impact on the catchment's hydrology (Middelkoop *et al*., 2001).

Minimum river/stream flows occur when a prolonged dry period coincides with a time of the year when groundwater levels are at their lowest. During a period of drought, as flow decreases, the proportion of river flow arising from surface runoff becomes negligible. In absence of rainfall, the magnitude of the baseflow component also continues to decrease with time. The main determinants of low flow at a particular location on natural streams, without lakes and unaffected by impoundment or abstractions are; lack of rainfall, the size of the catchment area contributing to the flow at the location and the variability in geology and surface cover which can vary within catchments as well as from catchment to catchment (Smakhtin, 2001).

The natural flow of a river/stream varies on time scales of hours, days, seasons, years, and longer. Many years of observation from a streamflow gauge are generally needed to describe the characteristic pattern of a river's flow quantity, timing, and variability that is, its natural flow regime. Five critical components of the flow regime regulate ecological processes in river ecosystems: the magnitude, frequency, duration, timing, and rate of change of hydrologic conditions (Richter *et al*., 1996). These components can be used to characterize the entire range of flows and specific hydrologic phenomena, such as floods or low flows that are critical to the integrity of river ecosystems.

Runoff coefficient is the percentage of contributing area to runoff generation (Hebson and Wood, 1982). The rainfall-runoff transformation is a non-linear process. The most important cause of non-linearity is represented by the effect of antecedent conditions; consequently the runoff coefficient depending on the initial conditions of soil moisture is a major control on catchment response. The amount of impervious surface in a stream catchment is a landscape indicator integrating a number of concurrent interactions that influence a catchment's hydrology (Schueler, 1994). The direct hydrologic effect of impervious surfaces occurs as a change in the magnitude and variability of velocity and volume of surface flow. When the landscape is covered with large impervious surfaces, precipitation that would normally infiltrate to recharge groundwater instead flows over impervious surfaces to receiving stream via storm sewers. This alteration of the natural hydrologic process reduces runoff lag time, increases the peak rate of streamflow discharge, increases stream flashiness and low-water streamflow, and brings about subsequent increases in the scouring and incision of the stream channel (Booth, 1990).

The effect of topography on erosion in RUSLE is accounted for by the LS factor. Erosion increases as slope length increases, and is considered by the slope length factor (L). Slope length is defined as the horizontal distance from the origin of overland flow to the point where either (1) the slope gradient decreases enough that deposition begins or (2) runoff becomes concentrated in a defined channel (Wischmeier and Smith, 1978).

The inter-disciplinary nature of water resources problems requires new attitude towards integrating the technical, economic, environmental, social and legal aspects of these problems into a coherent analytical framework. Improving water management in the watershed is one of the keys to producing enough food to alleviate the suffering of the growing population. The Sumampa stream catchment has undergone major anthropogenic changes affecting its land cover for over five decades. These changes, however, have not been quantified in a manner to allow wider scale understanding of the causative factors, their effects integrated management and show hot spots that require immediate attention, technical support and intervention.

Rainfall is a major factor for planning and managing of irrigation project and agricultural production. The rainfall change, especially the reduction in annual rainfall, may have a great effect on the effectiveness and accuracy of planning of irrigation project. Majority of the population in the Mampong Municipality rely largely on rainfed agricultural production. Moreover, the Sumampa catchment contributes substantial amounts of water to the Ghana Water Company Limited's reservoir on the Kyirimfa River. Therefore, a reduction in rainfall may have a great effect on the economy of the Municipality and the region which is one of the productive zones for agriculture in the country. Drought and floods affect many sectors in society and therefore there is a need for different ways of defining or characterizing these extreme events.

Already a number of the stream's tributaries cease to flow in the dry season and vegetable farmers on the banks dig wells on the stream courses for water for their crops and the number of wells and the depths are increasing. This calls for significant, conservation-oriented increase in productivity and water use efficiency. The amount of water pumped by farmers from the catchment's aquifers is gradually catching up to natural recharge. The dependency on groundwater in the Sumampa catchment is rapidly increasing. The catchment is rich in natural resources, including deep productive soils, adequate water supply, and favourable climatic conditions for agriculture resulting in two crops per year. Agriculture is the main source of livelihood of the people and the heavy dependence on groundwater is evident in that groundwater is used for major and dry season irrigation.

The catchment is experiencing intensive agricultural activities with their attendant impact of reducing the forest areas. Stream Sumampa is one of the perennial tributaries of Kyirimfa, the main source of surface water for the Ghana Water Company Limited reservoir, even under prolonged drought when all the other tributaries cease to flow. There has never been any hydrological study in the Sumampa watershed to establish the flashiness and its annual variation and changes in the streamflow and prevailing climatic factors. With the rapidly degrading characteristics of the catchment due to increasing human activities, expansion of settlement area and savannaization, including increases in climatic factors, it has become necessary to examine the stream's response to storms of varying intensity and magnitude and to bring in, design or develop the needed interventions to address the condition. The Mampong-Ashanti Municipality has experienced series of droughts since 1980 caused by rainfall failure, rain coming rather late causing short agriculture season or excessive rains which cause damage to properties and affect valley bottom and wetland agriculture.

The objective of this study was to investigate the flashiness of the Sumampa stream in a rapidly changing catchment condition from 1985-2009. This will hopefully help in better understanding and interpretation of the catchment hydrological conditions and its socio-economic and ecological implications. The paper looks at the changes in stream's pathlength and flashiness index during the 1980-2009 decades. Decadal comparisons have been made within the period. The challenges and major priorities for future research have been highlighted, and it is hoped that this will promote a better understanding of water erosion processes and related hydrological issues in the catchment.

2. MATERIALS AND METHODS

2.1. Study area

Mampong Municipal, one of the 27 administrative districts in the Ashanti Region of Ghana, is located on the northern part of the region, and shares boundary with Atebubu, Sekyere East, Afigya-Sekyere, and Ejura-Sekyeredumasi districts to the north, east, south, and west respectively. The Municipal is located within longitudes 0.05^o and 1.30^o west and latitudes 6.55^o and 7.30^o north, covering a total land area of $2346km^2$. It has 220 settlements with about 70% being rural. The rural areas are mostly found in the Afram Plains portion of the District where communities with less than fifty (50) people are scattered here and there (MLGRD, 2006).

The Sumampa stream catchment ($07^o04^{'}$N and $010^o024^{'}$W) is located within the forest-savannah transitional zone, Mampong-Ashanti in the Ashanti Region of Ghana, with a population of 44, 380 and a growth rate of 4.2% (SWDA, 2008). The catchment highlands are at 457m above sea level and the lowlands are at 290 m above sea level at the stream's confluence to the Kyirimfa River near the Ghana Water Company Limited's Reservoir. The catchment, which has an area of $38km^2$, is bounded by the Municipal Assembly, Mensah Saahene Junior High School, Kontonkyi Guest House, the Mampong Cemetery, Ammaniampong Senior High School, the University of Education, Winneba, Mampong Campus, the water treatment headworks road, Abonkunso, Tadeeso, Bimma and Daaho Bosofour from the main Kumasi-Mampong-Ashanti trunk road. The main occupation of the people is agriculture. The major crops produced in the area are cocoa, oil palm, cassava, maize and vegetables. Dry season agriculture is mainly in the area of vegetables (SWDA, 2008).

2.2. Hydrology, climate and vegetation

The combined effects of climatic and geological conditions on the catchment's topography has yielded sub-dendritic drainage pattern characterized by a network of channels and 12 streams. The site experiences double maximum rainfall patterns. The peak rainfall periods are May-June and September-October with dry periods between July-August and November-February. The climate is typically tropical, with total annual rainfall between 1270mm-1524mm (MSA, 2006), giving an annual average of 1300mm. Temperatures are uniformly high throughout the year ranging from 25-32^{o}C with a daily mean temperature of 30.5^{o}C. The potential evapotranspiration (PET) is estimated at 1450mmy^{-1}. The average humidity during the wet season is typically high (86%) and falls to about 57% in the dry period (MSA, 2006).

2.3. Geology

In considering the groundwater resources of Sumanpa catchment, the geological formations have to be considered. The main geological formation is the consolidated sedimentary formations underlying the Volta Basin (including the limestone horizon) characterize the catchment area's ground structure (WARM, 1998).

2.4. Topography

The hydrological, topographical and slopes distribution maps of the catchment were prepared from the Arc View GIS dataset. The maps are presented in Figures 1, 2 and 3, respectively. The catchment's slopes were classified into slope classes of 0-2^o, 2-5^o, 5-7^o and 7-10^o. The distribution of slope classes within the catchment is presented in Table-1. A topographic map (sheet 0702D3) of scale 1:50 000, in feet with a linear scale in metres, published in 1973 by the Survey Department of Ghana was obtained from the Department of Survey in Kumasi, Ghana. They were used to produce digitized copy of catchment topographic map (Figure-2) total stream length, slope lengths, delineation of the catchment boundary by means of identifiable ridges between the Sumampa and neighbouring catchments (Figure-2). The area of the catchment was determined from satellite imagery (ArcView GIS). The contour maps produced have contour interval of 15m. The highest point in the catchment is 457m and the lowest point is 320m above sea level.

2.5. Catchment soil (Bediesi-Sutawa-Bejua Association)

Very shallow, eroded, exclusively well-drained, rocky lithosols, mainly sandstone outcrops occurring in summits and upper slopes of moderately undulating land (Yaya Series); moderately shallow humous, redish brown, well drained, loose, ironstones concretions overlying weathering sandstone rock found on gentle upper slopes (Pimpimso Series). These soils occur in association with very deep to moderately deep, humous, red, well drained (Bediesi Series) and moderately well drained, yellowish red, (Sutawa Series), fine sandy loams to clay loams found on gentle upper and middle slopes. The lowland soils comprise very deep to deep, brownish yellow imperfectly to poorly drained, loamy and very deep to deep, poorly drained, grey, loose loamy sands found on broad valley bottoms (Bejua Series) (CSIR, 1980). The soil is characteristically deep red sandy loam free from concretions and stones, well drained, friable and has satisfactory water holding capacity. The soil which normally occurs on the upper middle slopes was from the Voltaian sandstone of the Afram plains. It belongs to the savanna Ochrosol class and forms part of the classification. It is classified as Chromic Luvisol by the FAO/UNESCO legend (Asiamah *et al*., 2000).

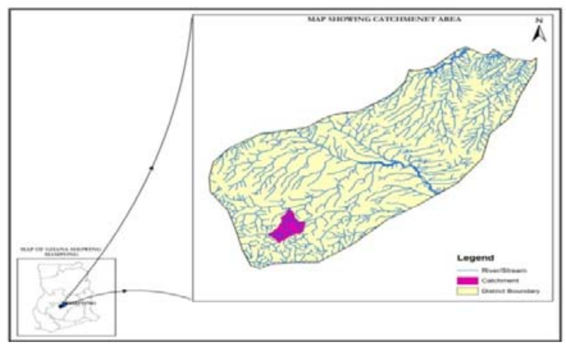

Figure-1. Location of the Sumampa catchment area of the Sumamapa stream in the mampong-ashanti municipality.

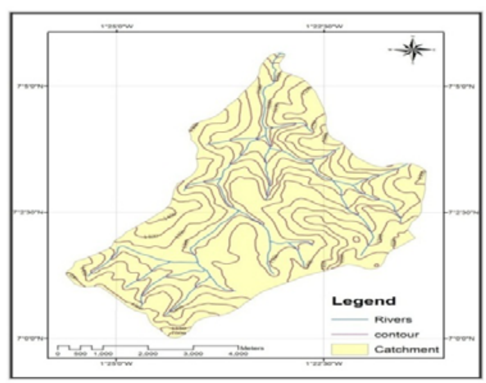

Figure-2. Topographical map of Sumampa catchment area.

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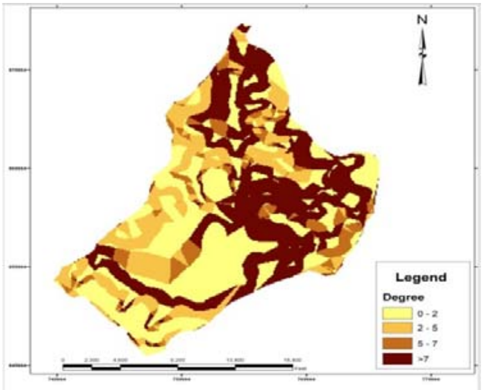

Figure-3. Slope distribution map of the Sumampa catchment area.

Table-1. Catchment slope distribution.

Slope (°)	**Area** (km^2)	**Percentage** (%)
0-2	13.718	36.1
2-5	7.637	20.1
5-7	3.147	8.28
7-10	13.503	35.52
Total	38.005	100

Mean slope of the catchment = 5.6519°

Programme used: ESRI GIS (Environmental Systems Research Institute, (1996)

2.6. Stream order, catchment area and the drainage density

The stream order is a classification reflecting the degree of branching or bifurcation of the stream channels within a catchment (Reddy, 2007). The main stream has a third order segment making the stream a gaining type. The catchment size is an important influence on absolute values of runoff amount and peak flows and is an essential parameter in runoff formulae that predict the hydrological characteristics. It was determined by the Environmental Systems Research Institute's (ESRI ArcView GIS Programme, 1996).

Drainage density is defined as the ratio of the total length of streams of all orders within the catchment to its catchment's area. It is a measure of the closeness of the stream channels (Reddy, 2007). It is defined by the expression:

$$D_d = \frac{Total\ Length\ of\ Streams\ in\ the\ Catchment(L)}{Catchment\ Area\ (A)} \quad (1)$$

Where

L is in kilometres (Km) and A is in square kilometres (Km^2). The total length of the stream network was determined using the ESRI GIS Programme.

2.7. Catchment elevation and relief ratio

The mean elevation of the catchment (338.5m) was determined by means of the ESRI Arc View GIS, 1996 Programme. Relief ratio is the difference in altitude between the highest and lowest points, in the basin, divided by the maximum basin length (Reddy, 2007). The highest and the lowest points in the catchment read from the topographic map are respectively 457m and 320m above sea level. The maximum basin length measured along the main stream from the divide is 10.55km (10550m). The difference in altitude between the highest and lowest points in the catchment (457m -320m) is 137m. The catchment's relief ratio is, therefore, 0.016 (dimensionless).

2.8. Mean slope length and distribution

Most of the slopes are concave as shown in Figure-4. Under field conditions effects of slope length on runoff and erosion are confounded by the interacting effects of slope gradient, slope aspect, slope shape, and the changes in soil physical and hydrological properties along the hillslope due to differences in soil forming factors. The catchment slope distribution is shown in Table-1. From the Table 36.1% of the catchment area is found on slope range of 0-2°, 20.1% on 2-5° and 43.8% on 5-10°. This is an indication of higher risk of erosion in the catchment where urban expansion is high and rainfall events have been predicted to increase further in coming decades.

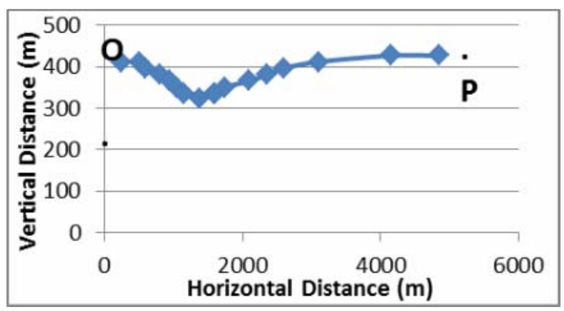

Figure-4. Cross-section of one of the longest slope in the Sumampa catchment.

2.9. Stage-discharge rating curve (RC)

It is not practical for a stream gauge to continuously measure discharge. Fortunately, there is a strong relation between river stage and discharge and, as a result, a continuous record of river discharge can be determined from the continuous record of stage (USGS, 2011). A stage-discharge rating curve (RC) describes a relationship between the water level, a channel cross section and the rate of discharge at that section. Ideally, a rating curve describes a unique functional relationship between stage and discharge; therefore, it is obtained as a smooth and continuous curve with reasonable degree of sensitivity. Unfortunately there cannot be a unique stage-discharge relationship unless the flow is uniform. And due to stochastic nature of rainfall, river flow is also not uniform. Hence ideal relation to show between stage and discharge is not the truth and it is only for approximation (Henderson, 1966).

The stream's stage data were obtained from the Department of Hydrology, Kumasi for the period 1985-2009. The continuous records of stage were translated into river discharge by applying the stage-discharge relation obtained from Department of Hydrology, Kumasi.

Mean daily Sumampa stream stage data were obtained from the Department of Hydrology, Kumasi, from March 1, 1985 to February 28, 2009. Thus, the study period consisted of 25 water years. Changes in landuse and adoption of agricultural best management practices (BMPs) since that time were recently analyzed. The current work was initiated to determine the changes in flashiness that may accompany landuse changes and the adoption of BMPs in the catchment area of the streams. In addition, daily flow data generated directly from the state rating curve were used to determine and assess the pathlength values. To compare R-B Index values and low flow discharges, the 90th percentile flow exceedency values for the period of record were chosen to represent low flow discharges.

2.10. Composite runoff coefficient

The Sumampa catchment's composite runoff coefficient was determined from equation (2).

$$C = \frac{C_1A_1 + C_2A_2 + C_3A_3 + C_4A_4}{A} \qquad (2)$$

Where

C_1 = Runoff coefficient for 70% impervious urban surface (0.65)
C_2 = Runoff coefficient for rolling secondary forest on a sandy loam soil (0.30)
C_3 = Runoff coefficient for rolling agricultural land on a sandy loam soil (0.52)
C_4 = Runoff coefficient for forest on sandy loam soil up to 2% grade, (0.1)
The results are presented in Figure-4.

2.11. Richards-baker flashiness index (R-B Index)

Baker *et al*., (2004) developed a new index of stream flashiness, the R-B Index, has several advantages over previous flashiness indices. Unlike many hydrological parameters, the new index has low year-to-year variability. Consequently, fewer years of stream gauging are required to quantify the flashiness of a stream. Furthermore, statistically significant trends in flashiness can be observed in a relatively short period of time. The new index is a modification of the recently developed Richards Index. The method measures the pathlength of daily flow oscillations for data from gauged streams. Longer paths correlate with flashier streams, while more constant flows have shorter pathlengths. The Richards-Baker Flashiness Index (R-B Index) has several advantages over previous flashiness indices. The new index uses data from gauging stations to quantify the frequency and rapidity of short term changes in streamflow (Baker *et al*., 2004). Values for the R-B Index could theoretically range from zero to two. It would have a value of zero if the stream flow were absolutely constant. Its value increases as the pathlength, and flashiness, increase.

2.12. Calculation of R-B index

The pathlength of flow variations for the Sumampa stream for the 1985-2009 period was divided by the total discharge during that period. The pathlength of flow variations was calculated as the sum of the absolute values of day-to-day changes in mean daily discharge and has the units of flow (m^3/s). Pathlength can be viewed as the length along the y-axis of the line tracing the annual hydrographs. Equation (3) was used to calculate the R-B index for the stream:

$$R - B\ Index = \frac{\sum_{t=1}^{n} 0.5(|q_{t-1} - q_t| + |q_{t+1} - q_t|)}{\sum_{t=1}^{n} q_t} \qquad (3)$$

Where t is the day of water year and q is mean daily discharge (Baker *et. al*., 2004).

Comparison of two decades (1990-1999 and 2000-2009) of R-B Indices have been carried out and the results presented in Table-2.

3. RESULTS AND DISCUSIONS

3.1. Field observations

The interaction of groundwater and surface water systems were directly observed in the catchment. A field reconnaissance survey carried out at the initial stages of the research to assess specific locations (hotspots) that warrant further investigation involving more detailed monitoring and sampling. The areas assessed reveal that:

Water demand in the catchment is ever-increasing due to the formidable effects of population expansion, economic development, and changing life-style of the people as the catchment plays host to one University, two Colleges of Education and four Senior High Schools whose annual enrollments keep increasing and putting variable seasonal, annual and intra-annual pressure on the catchment's water resources.

Six major effects of urbanization in the catchment have been identified: a higher proportion of rainfall appears as surface runoff, catchment's response to rainfall is changing with a decreasing lag time, increasing peak flow magnitudes, increasing abstraction and intensified exploitation of sand and gravel deposits for urban and rural development. The Sumampa stream catchment has undergone major anthropogenic changes affecting its land cover for over five decades. These changes, however, have not been quantified in a manner to allow wider scale understanding of the causative factors and their effects.

3.2. The rating curve equation

The rating curve equation was generated from the flow-stage data from the Department of Hydrology, Kumasi using the excel bestfit function. The relation derived from the excel function is given by

$Q = 3209(h-0.025)^{2.328}$. From this daily flow data were generated from daily stage data for the period.

3.3. Sumampa streamflow flashiness (1985-2009)

The flashiness indexes of the Sumampa stream, as can be observed from Figure-5 were very high before 1989 recording indexes above the period mean index. However, it dropped below the average index from 1991 to 2006. The 2007, 2008 and 2009 indexes were a little above the mean flashiness index. Averagely, the stream's flashiness in 1990-1999 decade was higher than the 2000-2009 decade. The flashiness was highest between 1985 and 1991. The decrease in the stream's flashiness in 2000-2009 indicates that greater part of the stream's flow during the period was baseflow. This could be due to improved surface conditions for higher infiltration and increase in arable land area (Table-2), since the total rainfall magnitudes (Table-3) show increasing trend during the three decades. The 2000-2009 decade recorded a higher total rainfall but lower total streamflow (Table-2); an indication of the impact of increasing imperviousness which allows majority of the rainfall to runoff quickly into stream channels. The increase in temperature and ET may also have contributed to the decrease in total streamflow value .

3.4. Change in stream's flashiness

The R-B Index may be useful as a tool for assessing the effectiveness of programmes aimed at restoring more natural streamflow regimes, particularly where modified regimes are a consequence of landuse/land management practices (Baker *et al*., 2004). The Sumampa intra-annual daily streamflow hydrograph indicates a decrease in the mean daily flow during the 2000-2009 decade (Figure-6) an evidence of decrease in the catchments baseflow.

The streamflow hydrograph in Figure-6 shows the stream had quicker responses to storms and higher mean daily flows in 1990-1999 decade. This is confirmed by the computed R-B Index in Table-1 showing a decrease index from 0.107 in 1990-1999 to 0.094 in 2000-2009 (12.15%). The pathlength has also decreased from 9791.42 to 7853.70 (13.88%) for the same period. The total decadal stream discharge also decreased by 35.22% in the 2000-2009 decade. The most common effects of changes in landuse and land management are increases in stream flashiness and decreases in baseflow (Poff *et al*., 1997). The conversion of the catchment's forests, grasslands and wetlands to cropland and subsequent agricultural improvements have greatly modified the natural flow regimes of the Sumampa stream and its tributaries and resulted in a drop in R-B Index (flashiness). The stream has become less flashy, especially in the major season, in the last decade due to increased agricultural activities in the season. The increase in the frequency of ploughing and harrowing of arable land decreased total discharge for the 2000-2009 decade. The impact is minimized by the increase in the size of arable land and the degree and frequency of ploughing and harrowing of agricultural land.

Table-2. Streamflow flashiness index.

Elements	**Decadal changes**		
	1990-1999	**2000-2009**	**Change** (%)
R-B Index	0.107	0.094	-12.15
Pathlength (m^3)	9,791.42	7,853.70	-13.88
Total discharge (m^3s^{-1})	96,860.03	8,494.10	-12.30

Table-3. Decadal rainfall and streamflow magnitudes and their percentage contributions.

Decade	**Total stream discharge** (m^3)	**Percentage contribution** (%)	**Total rainfall** (mm)	**Percentage contribution** (%)
1980-1989			12,016.20	31.70
1990-1999	379,255,884.00	58.72	12,543.00	33.08
2000-2009	266,679,172.00	41.28	13,351.00	35.22

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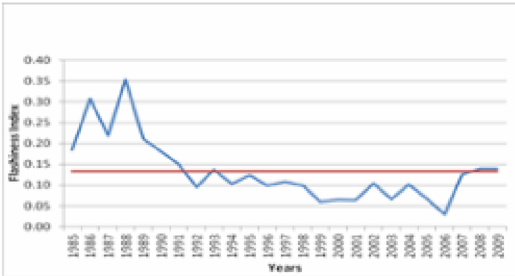

Figure-5. Annual variation in sumampa streamflow flashiness (1985-2009).

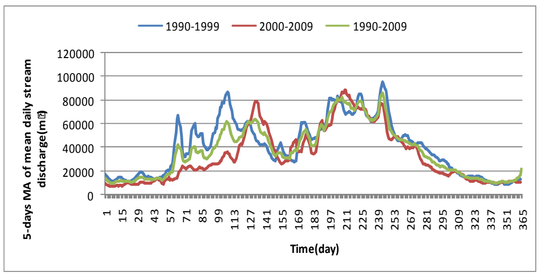

Figure-6. Annual streamflow hydrograph of the two decades, 1990-1999 and 2000-2009 showing a change in the stream's flashiness.

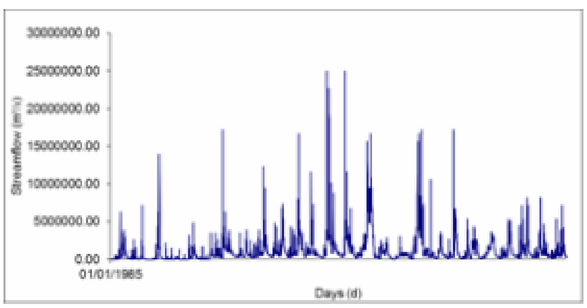

Figure-7. Daily flow hydrograph of the Sumampa stream (1985-2009).

3.5. Variation in runoff coefficient

As pressure for urban development in the Municipality intensifies, agricultural land in the fringe zone is converted into residential, and small scale industrial and other non-agricultural landuses, like expansion of garages, gravel and sand winning, which may create food security challenges. Again, urban encroachment into forest and secondary forest lands around the municipal capital, Mampong-Ashanti, has resulted in serious degradation of vegetation cover and loss of biodiversity. As Mampong-Ashanti, Bonkro, Nsuta-Ashanti, Jatiase, and Bosofour expand into the fringe areas and into the buffer zones of stream banks, in unplanned and uncontrolled manner, sprawling low-density development is created that is uneconomic in the use of land. The development in these fringe zones is haphazard and they lack infrastructural facilities and services like water supply and sanitation. Water, electricity, roads, and other facilities have not reached these areas long after the settlements or communities have been established. Extending these facilities to such areas is impossible without demolishing structures or very expensive. Planning and development control measures have been inadequate or ineffective in containing such developments.

The growth rate of population in the basin is 4.2% (GSS, 2010) and the authorities are unable to cope with changing situations due to both local and national resource constraints and management limitations. As population and land values increase in the area, the effect of uncontrolled runoff is taking an economic dimension and burden and posing a serious threat to health and ecological wellbeing of the catchment. Erosion at these places is very severe as can be seen in Figures 9-13. The composite runoff coefficient from Figure-8 shows a positive trend between 1986 and 2010. Figure-8 shows the trend in the changes of the composite runoff coefficient of the Sumampa catchment over three decades. The sharp rise in the runoff coefficient between 2000 and 2010 is an indication of rapid urban expansion and development (removal of top soil), gravel and sand winning, increase in the frequency of bushfires, decreasing forest size and increasing soil compaction.

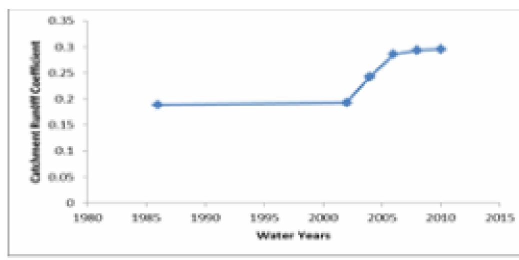

Figure-8. Sumampa catchment runoff coefficient

3.6. Reducing flashiness in the catchment

Restoration of more natural streamflow regimes is a difficult challenge where the altered regimes are a consequence of altered landuse patterns and practices, because the changes are spread across the landscape and involve many stakeholders with diverse interests. This calls for adequate education on the relationship between nonagricultural human activities, the environment and agriculture. However, a variety of land and water management practices are available that could shift flow regimes back toward more natural conditions. These include wetland construction, cropland management to increase infiltration and decrease surface runoff, controlled drainage, use of permeable paving materials in urban and suburban areas, and construction of storm runoff holding basins (Bales and Pope, 2001).

3.7. Landuse changes in the catchment

Cropland is the dominant landuse in the study area. The forest land is most concentrated in the south-eastern part of the catchment while cropland is the dominant landuse in the catchment. The Sumampa stream

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divides the catchment into Western and Eastern zones. About 85% of the Western zone and 25% of the Eastern zone are urban. According to McMahon *et al*. (2003), major drivers for landuse and land cover changes include economics, resource availability (e.g., especially groundwater for irrigation), and biological resource management through State and Municipal programs and policies. Understanding impacts of landuse/land cover change on the hydrologic cycle in the Sumampa catchment is key for optimal management of natural resources.

As the catchment population grows demands multiply for food, water, shelter, fuel and agricultural use and dictates how land is used and for how long. Landuse practices generally develop over a long period under different environmental, political, demographic, and social conditions. These conditions often vary yet have a direct impact on landuse and lands cover and their size at a particular time. Changes in Landuse and cover have significant impact on the catchment's hydrology. Each type of landscape comes along with its own specific impact, or synergic impact with other uses and changes usually directly on ecosystems and directly or indirectly on water resources. The magnitude of the impacts will vary according to the setting's conditions and the technological know how of the users with a wide range of possible landscape changes. According to CSIRO (2001), the removal of forest covers results in decreased interception, ET and increased runoff volumes. Research has shown that tree canopy can intercept 10-40% of incoming precipitation (commonly 10-20%) depending on factors such as tree species, density of stand, age of stand, location, rainfall intensity; and evaporation during or after a rainfall event. Forest logging, annual bush fires and wind damage in the basin have major effects upon the canopy characteristics of forest stands and hydrological processes in the watershed.

Hydrologic changes in the Sumampa stream catchment (SSC) have come about as a result of decrease in wetlands area, increased agricultural drainage of wetlands, and change of landuse from native perennial vegetation to annual crops and settlement. The cumulative effects of these landuse changes include increased runoff and streamflow magnitude, and an overall decline of catchment water quality. The hydrologic effects are long-term.

4. CONCLUSIONS

The Sumampa daily streamflow hydrograph indicates a decrease in the mean daily flow during the 2000-2009 decade an evidence of decrease in baseflow. The streamflow hydrograph shows the catchment had quickest responses to storms in 1990-1999 decade. The R-B Index and the pathlength decreased by 12.12% and 19.79%, respectively from 1990-1999 to 2000-2009. The flashiness was highest between 1985 and 1991.The intra-annual flow hydrograph indicated a decrease in the stream's response to rainfall means and extremes in the catchment. The decrease in the stream's flashiness in 2000-2009 indicates that greater part of the stream's flow during the period was baseflow. This could be due to improved surface conditions for higher infiltration, increased in arable land area, since the rainfall in the last decade was higher than the previous decades.

Figure-9. Eroded topsoil in the sumampa catchment.

Figure-10. Eroded topsoil in the sumampa catchment.

Figure-11. Eroded topsoil in the sumampa catchment.

Figure-12. Eroded topsoil in the sumampa catchment.

Figure-13. Eroded topsoil at the mampong market in the sumampa catchment.

REFERENCES

Baker D.B., Richard R. P., Loftus T. T. and Kramer J. W. 2004. A new Flashiness index: Characteristics and Applications to Midwestern Rivers and Streams. Journal of the American Water Resources Association, October. 503-522. Accessed 21/06/2010 from http://www.blackwell-synergy.com/doi/abs/10.111/j.1752-1688.2004.tb01046.x.

Bales J.D. and B.F. Pope. 2001. Identification of Changes in Streamflow Characteristics. Journal of the American Water Resources Association (JAWRA). 37(1): 91-104.

Bogaard T.A., Mkhandi S., Parida B.P. and Winsemius H.C. 2008. Water Resources Assessmentin Sub-Saharan Africa: Prediction in Ungauged and Data Scarce Basins; Training Course Reader, Dar es Salaam, Tanzania.

Booth D. B. 1990. Stream channel incision following drainage-basin urbanization. Water Resources Bulletin. 26(3): 407-417.

Hebson C. and Wood E.F. 1982. A derived flood frequency distribution using Horton order ratios. Water Resources Research. 18(5): 1509-1518.

Henderson F.M. 1966. Open channel flow. Macmillan Series in Civil Engineering, MacMiillan Company, New York, USA. p. 522.

Leopold L.B. 1994. A View of the River. Harvard University Press.

McMahon P.B., Dennehy K.F. and Ellett K.M. 2003. Water Movement through Thick Unsaturated Zones Overlying the Central High Plains Aquifer, Southwestern Kansas, 2000-2001. USGS Water Resources Investigation Report, 03-4171. p. 32.

Middelkoop H., Daamen K., Gellens D., Grabs W., Kwadjilk J.C.J., Lang H., Parmet B.W.A.H., Schadler B., Schulla J. and Wilke K. 2001. Impact of Climate Change on Hydrological regimes and Water resources Management in the Rhine Basin. Climate Change. 49: 105-128.

MLGRD. 2006. Mampong Municipal Assembly, cited 21 March 2009 Available from Internet http://www.ghanadistricts.com/districts/?news&r=2&_=26.

MSA. 2006. Annual Report, Accra.

Poff N.L., Allan J.D., Bain M.B., Karr J.R., Prestegaard K.L., Richter B.D., Sparks R.E. and Stromberg J.C. 1997. The Natural Flow Regime. BioScience. 47(11): 769-784.

Richter B.D., Baumgartner V.J., Braun D.P. and Powel J. 1996. A Method for Assessing Hydrological Alteration within Ecosystems, Conserv. Biol. 10: 1163-1174.

Schueler T. 1994. The importance of imperviousness. Watershed Protection Techniques. 1(3): 100-111.

CSIRO. 2001. Land use and catchment water balance. Commonwealth Scientific and industrial research organization, cited 12 June 2009, Available from www.clw.csiro.au/publications/ technical2001/tr18-01.pdf.

Smakhtin V.U. 2001. Estimating Continuous Monthly Baseflow Time Series and their Possible Applications in the Context of the Ecological Reserve. Water SA. 27(2): 213-217.

SWDA. 2008. Annual Report, Mampong-Ashant.

GSS. 2010. Annual Report, Mampong-Ashanti.

USGS. 2011. How Streamflow is Measured, Water Science for Schools, [cited 2 November 2011] Available from Internet < ttp://ga.water.usgs.gov/edu/measureflow.html>.

Van Lanen, H.A.J., Fendeková M., Kupczyk E., Kasprzyk A. and Pokojski W. 2004. Flow Generating Processes. In: Tallaksen L. M. and Lanen H. A. J. van. (Eds). Hydrological Drought - Processes and Estimation Methods for Stream flow and Groundwater. Developments in Water Sciences 48, Elsevier Science BV, the Netherlands. 53-96.

Vörösmarty C.J., Brunner J., Revenga C., Fekete B., Green P., Kura Y. and Thompson K. 2004. Case studies: Population and climate. In: Kabat P., Claussen M., Dirmeyer P.A., Gash J.H.C., Bravo de Guenni L., Meybeck M., Pielke Sr., R.A., Vörösmarty C.J., Hutjes R.W.A. and Lutkemeier S. (Eds). Vegetation Water, Humans and the Climate. Springer, Heidelberg, Germany.

WARM. 1998. Ghana's Water Resources, Management Challenges and Opportunities. Water Resources Management Study, Government of Ghana. Accra.

Wischmeier W.H. and Smith D.D. 1978. Predicting Rainfall Erosion Losses, a Guide to Conservation Planning. Issue 537 of Agriculture handbook, Department of Agriculture, Science and Education Administration.