DEGRADATION OF THE NASIA RIVER BASIN IN NORTHERN GHANA

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ABSTRACT

The Nasia River Basin is located within the Guinea Savanna Ecological Zone in the Northern Region of Ghana. It is the drainage basin of the left bank tributary of the White Volta along and on which several domestic and commercial activities take place. Activities such as farming very close to water bodies lead to environmental degradation with its associated effects. The study was aimed at assessing the effect of land degradation on the flow pattern of the Nasia River. To achieve this, rainfall data, vegetation maps, infiltration data, information on Nasia soils and a semi-structured questionnaire were used in the study. Results of the study revealed that within the time interval of 10 years there was an area loss of 10% closed savannah and 3.2% of open savannah woodland and a percentage change increase of - 4.1% dense herbaceous plants and - 0.6% for grasses and herbs. Burnt area increased from 0.5% to 0.7% indicating high level of burning. Built-up and bare land also increased from 2.7% to 11.4% while water bodies consisting of dugouts, dams, wetlands, streams and rivers reduced by an area of 24.61 km^2. Variation from the mean annual rainfall of 1045.18 mm (for a 33 year period) ranged from + 13.82 mm to + 534.82 mm above annual mean and - 10.18 mm to - 382.78 mm below annual mean. Rainfall intensities of 100 to 200 *mm/h and infiltration rates of 43.0 to 61.9 mm/h suggested that overland flow and water erosion occurs.*

KEY DESCRIPTORS: River Basin, Vegetation, Environment, Land Degradation, Agricultural Productivity.

INTRODUCTION

Environmental land degradation is a global issue of topical importance which must be given high priority, especially in developing countries, because of the need to meet the food and fiber needs of increasing populations with limited resources. Land degradation can be viewed in terms of the actions which increase the breaking down of soil aggregates from agricultural and non-agricultural lands resulting in increased soil loss through soil particle detachment and transport down slope. This affects the productivity of crops and pasture, and eventually increases sediment loads of streams, rivers and reservoirs when finally deposited.

According to the World Resources Institute (1992), an estimated 1.2 billion hectares or 11% of the world's vegetated surface had been moderately or severely degraded since 1945. Tulu (2002) observes that roughly 12 million hectares of sub-Saharan Africa (SSA) are arid or semi-arid, while 4 million hectares of forests have been lost over the past two decades. It has also been observed that about 320 million hectares of vegetated lands in SSA have been degraded over the few past decades. About 26% of the arid regions of SSA areas suffer from varying degrees of land degradation ranging from light to extreme (FAO, 1999). In Ghana about 57% of the total land area is suitable for agriculture. However, there are many indications of land scarcity as a result of degradation, access and cumbersome land tenure arrangements (MoFA, 2002). Kranjac-Berisavljevic, Bayorbor and Obeng (2002) report that erosion hazards in the Northern Region is the highest in Ghana. They attribute the situation to the sparse grassland and light tree vegetation cover of the region, as well as environmental hazards such as bush burning, runoff and extreme deforestation. High temperatures and annual bushfires also reduce the organic matter content in the surface horizon to just about 2%.

According to Millar (2004) the issue of farming very close to water bodies must also be mentioned as a major contributor to the environmental degradation problem being experienced in Northern Ghana. This is a very serious practice especially during the long dry season as it eventually results in the drying up of streams and rivers with its attendant effect of reducing agricultural yields. The implications of land degradation are vast, having serious environmental and socio-economic consequences on agricultural productivity and other livelihoods of peasant farmers. Among the direct damages caused by land degradation are loss of soil quality, structure, stability and texture, all of which lead to the loss of productive lands. Alfsen, Bye, Glomarob and Wiig (1997) also estimated the effect of soil degradation on the broader economy of Ghana and it showed productivity losses of 2.9% per year in all forms of agriculture except cocoa with a loss of 2.1%.

In view of the effects of land degradation as outlined above, the study aimed at assessing the effects of land degradation on the flow pattern of the Nasia River, which is a major input for agricultural production in Northern Region of Ghana. Specifically, it sought to first, determine the level of land degradation of the Nasia River Basin and its effect on the river flow and second, assess the catchment characteristics and their influence on river flow of the Nasia River.

MATERIALS AND METHODS

The Study Area

The Nasia River Basin is located on the north-eastern part of the Northern Region of Ghana and lies between latitudes 9°55 'and 10°40 'N and longitude 1°05 'W and 0°15 'E (Adu, 1995). The basin lies within the Northern Region of Ghana and it is the drainage basin of the left bank tributary of the White Volta. The area is characterised by high temperatures (average 29°C), one rainy season and total annual rainfall of about 1000-1300 mm/y. The rainy season is 140–190 days in duration, while the estimated reference evapo-transpiration (ET_o Penman) is about 2000 mm/year creating a great seasonal deficit every dry season. Peak rainfall period is usually late August or early September. About 60% of the rainfall occurs within three months (July to September) with torrential rains creating serious drainage problems (Adu 1995). The Nasia River Basin falls within the Guinea Savannah Ecological Zone and Figure 1 shows the location of the Basin (shaded area - green).

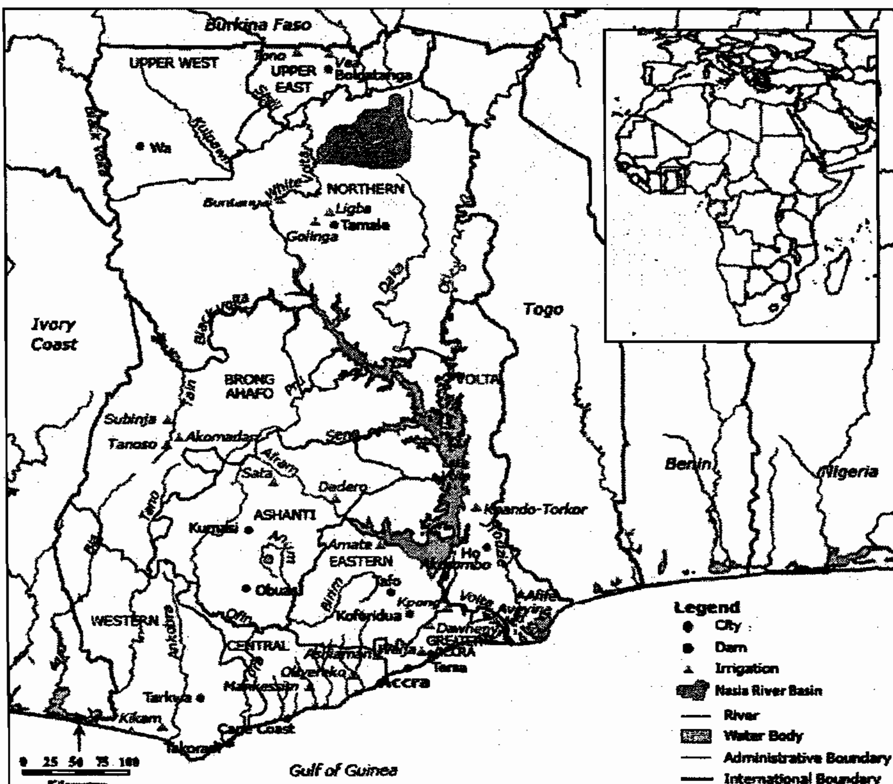


Figure 1: Map of Ghana showing the Nasia River Basin

Materials and Data Collection

Data of various types were used for the study and this includes rainfall, vegetation and land use maps, infiltration data, information on Nasia soils and a semi-structured questionnaire. To be able to arrive at the objectives of the study, the following data were collected for analysis.

Rainfall Data

Representative rainfall data for the study area was obtained from the Tamale Synoptic Station at latitude 9°05 'N and longitude 0°85 ' W to 0°05 'E and at an elevation of 183 m above mean sea level. Data covering 33 years (1974–2006) of daily rainfall was obtained from the Ghana Meteorological Agency in Tamale.

Information on Nasia soils

Secondary data on soils of the study area were obtained from a detailed reconnaissance soil survey report of the Nasia River Basin undertaken by Adu (1995).

Vegetation Cover and Land Use Data

A remotely sensed vegetative cover data which is important for the establishment of the level of vegetative cover degradation of the area was obtained from the Centre for Remote Sensing and Geographic Information Services (CERSGIS) of the University of Ghana (2000). The spot image data was taken on 1st January 1990 and 2nd February 2000 showing the various levels of ground cover for a ten (10) year period. Ground truthing was also undertaken to establish the level of degradation of vegetation cover in the flood-plains of the Nasia River Basin.

Infiltration Rate Tests

Infiltration rate tests using the double ring infiltrometer were conducted at five locations in five communities in the floodplains of the study area during the dry season. Infiltration data covered areas classified as undisturbed (areas not used for farming activities: two sites) and disturbed (farmlands: 3 sites) in the basin. This data was used to establish the amount of rainfall that could form overland flow in the form of runoff and its potential for erosion in the basin.

Questionnaire Information

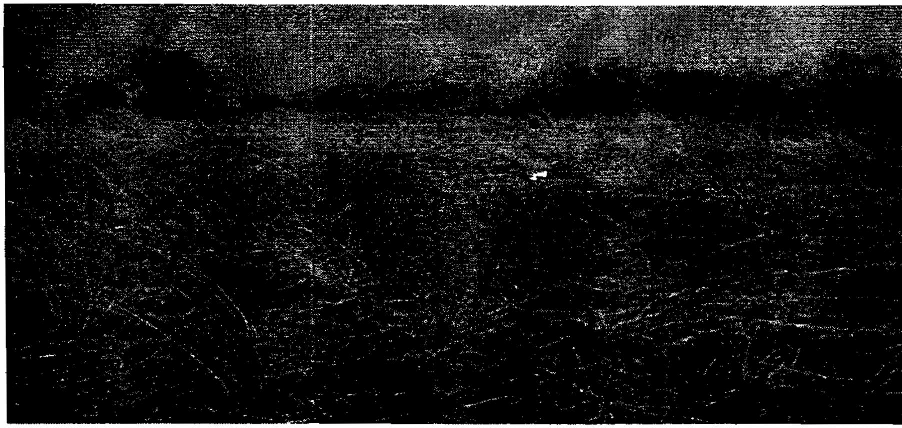
Information from the catchment community perspective on the river flow regime as well as trends of depletion of the surface water resources of the area were collected using semi-structured questionnaire. A sample size of 100 farmers from five communities in the river catchment was used for the study.

RESULTS AND DISCUSSIONS

Seasonal Variation of Vegetative Cover

The vegetation situation of the study area at different times (dry and wet seasons) of the year is as shown in Figure 2. From Figure 2a the grasses and vegetative cover of the area are burnt during the dry season thus exposing the fragile soil of the area to the direct impact of the rains. Lal (1990) indicated that vegetation cover not only dissipate raindrop impact and protect the soil against splash but also alters the volume, drop size distribution, impact velocity, and kinetic energy of rainfall reaching the ground.

According to Morgan (1995), erosion and land use are very strongly related and rates of soil loss accelerate quickly to unacceptably high levels whenever land is misused. Figure 2b also shows patches of exposed soil in the basin during the rainy season of which the direct impact of raindrops are likely to have a marked effect on the soil particles and their possible detachment and transport down slope. Inappropriate land use practices such as leaving the soil surface bare facilitate the process of land degradation (Quansah *et al.*, 1997). In a similar way Nick van, Andrieni, van Edig and Pawl (2001) indicated that changes in land use and land cover may have an important impact on water resources.



Dry Season(Burned Grassland)

b: Wet Season (exposed patches of land)

Figure 2: Vegetation Cover of the Nasia River Basin for Wet and Dry Seasons *(Source: Fieldwork in March, 2007)*

The loss of vegetation cover can be said to be both a consequence and a cause of land degradation in the Nasia Basin area. According to Adu (1995), the Nasia Basin catchment has less palatable plant species emerging and prevailing grazing lands and forage and browse plants become scarce when these degrading activities take place. Figure 3 shows a satellite image depicting the level of vegetative cover depletion of the Nasia River Basin for the years 1990 and 2000. An observation of the satellite imagery of the Nasia River Basin clearly shows the level of degradation of the vegetative cover at various scales.

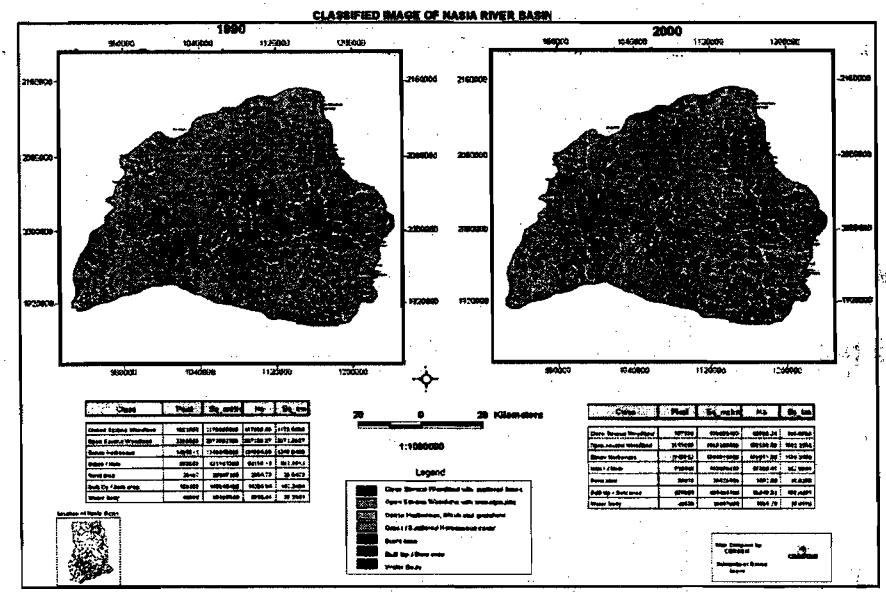


Figure 3: Classified Vegetation Cover Image of Nasia River Basin ***(Source: CERSGIS, Ghana, 2000)***

The significance of vegetation in the drainage basin lies in its influence over net input of rainfall to the basin, through interception and evapo-transpiration; as affecting storage in the basin; and as influencing the rate at which water and sediment are produced and transmitted through the basin system (Gregory &, 1973). The difference in the level of vegetative cover degradation (1990 and 2000) from the study area is visually evident from the satellite image of Figure 3. The vegetative cover of the basin area could be said to have a great influence upon the infiltration rate of the soil and evapo-transpiration. Infiltration is facilitated by vegetative cover not only through the resistance offered but also by the drainage lines which vegetation provides in the soil through which infiltration occurs.

Time Interval Change of Vegetation Cover

Analysis of the extent and rate of degradation of the Nasia River Basin's vegetative cover is presented in Table 1.

Table 1: Analysis of Vegetative Cover of the Nasia River Basin within 10 Year Period

Land Cover/ Land Use	Coverage Area (km²)		Time Interval – Area Change (km²)	% Land Cover		Time Interval – Area % Change
	1990	2000	1990 - 2000	1990	2000	1999 - 2000
Closed Savanna woodland	1,170.90	636.60	534.30	21.90	11.90	10
Open Savanna woodland	2,071.81	1,902.29	169.52	38.80	35.60	3.20
Dense Herbaceous	1,346.05	1,566.32	-220.27	25.20	29.30	-4.10
Grass/Herb	521.15	553.90	-32.75	9.80	10.40	-0.60
Burnt Area	25.65	35.92	-10.27	0.50	0.70	-0.20
Built-up/Bare Area	143.25	608.41	- 465.16	2.70	11.40	-8.70
Water Body	60.30	35.67	24.63	1.10	0.70	0.40
Total Area	5,339.10	5,339.10	-	100	100	-

Source: Field Survey

Within the time interval of 10 years (1990-2000), 534.30 km^2 of closed savannah woodland which formed 10% area loss in the catchment area of the Nasia River Basin was observed. For the same period, 169.52 km^2 of the open savannah woodland had also been depleted and this represents a 3.2% loss of vegetation cover. From Table 1, the closed and open savannah woodlands have been degraded by area percentage change of 10% and 3.2% respectively and these are gradually being replaced by dense herbaceous plants as well as grasslands and herbs which are prone to the vagaries of the weather especially the characteristic bushfires of the area. According to EPA (2002) by disturbing the watershed protection function of forests and woodlands, deforestation and other unsustainable farming practices lead to soil erosion thus causing siltation of dugouts and reservoirs, rivers and their tributaries (Red and White Volta) and increases flooding in their basins. Degradation also causes changes in the water balance components, namely, rainfall, evapotranspiration, runoff and infiltration.

In a study by Nsiah-Gyabaah (1994), in the Upper West Region of Ghana, which is also in the Guinea Savanna Ecological Zone, a comparison of vegetation cover was made using satellite imagery for 1972 and 1989. It was observed that there was far more disappearance of tree cover and severe degradation in intensively cultivated and densely populated areas than sparsely settled areas. The implication of the findings indicated that land degradation is positively related to population pressure and human misuse of the environment. The situation of Nasia is however not different as human and livestock population of the area increases, demand for food, fuelwood and fodder increases proportionally thus resulting in the clearing of more marginal lands including the river banks for crop cultivation, grazing of fragile areas and harvesting of tree vegetation. This increases the level of land degradation and its consequent negative impacts on the flow pattern of the River Basin.

As presented in Table 1, a percentage increase from 25.2% to 29.3% with a time interval percentage change of - 4.1% of the dense herbaceous plants and 9.8% to 10.4% increase with a time interval percentage change of - 0.6% for grasses and herbs implies that the open and closed savannah woodlands are gradually being replaced by the dense herbaceous plants as well as grasses and herbs. The land use of the Nasia River Basin and the entire White Volta is extensive cultivation with land rotation in the villages, with widespread grazing of large numbers of cattle and other livestock up to 100 cattle/km^2 (MoFA, 2001).

According to the EPA (2002) as human population have increased over the years so has the population of livestock, and this population increase has led to overgrazing of marginal lands. During the dry season, there is grazing pressure leaving most of the land bare except for a few withering brown perennial grass cover. The adverse consequences of overgrazing is a general deterioration in the quality and value of the grazing land, soil compaction due to animal feet trampling especially at water points, erosion by wind and water resulting in a reduction in the productive capacity of the range land. The burnt area from the satellite imagery analysis (Table 1) indicates an increase from 0.5% in 1990 to 0.7% in 2000 with a time interval percentage change of - 0.2%. This puts the time interval area change at - 10.27km^2 thus indicating that as the open and closed savanna woodlands are being replaced with the dense herbaceous plants and grasses, the level of burning increases and results in the exposure of more land area to the climatic factors especially the direct impact of rainfall.

EPA (2002) also reported that the pervasive use of fire for land clearing in the farming systems of the desertification prone areas and uncontrolled annual bush fires destroy forests, woodland and crops over extensive land areas. The litter which contributes organic matter to the soil is burnt and the land is laid bare and predisposed to water and wind erosion.

The annual bushfires at the Nasia area have contributed to the slow regeneration of the vegetative cover of marginal lands and other uncultivated lands of the area. The area considered under built-up and bare land also increased within the period. It increased from 2.7% to 11.4% as shown in Table 1 and resulting in a percentage time interval change of - 8.7%. This can be attributed to the level of population growth of the area over the period.

Water bodies consisting of dugouts, dams, wetlands, streams and rivers, and other water collection points have also reduced drastically by an area of 24.6321 km^2. This represents a percentage area change of 1.1% in 1990 to 0.7% in 2000. A time interval percentage reduction in the level of water bodies in the area is 0.4% over the 10 year period. Changes in upstream land use and land management may be accompanied by more or less dramatic changes in the flow regime and quality of the river basin.

Rainfall Characteristics of the Nasia River Basin

The mean annual rainfall for the 33-year (1974-2006) period was determined to be 1045.18 mm. However, variation of the annual rainfall from the mean ranged from + 13.82 mm to + 534.82 mm above average, and - 10.18 mm to - 382.78 mm below average for the period under consideration. For the same period 16 years of annual rainfall departure above the mean rainfall and 17 years below were also noticed. The rainfall departures for the three year moving averages varied from a minimum of + 2.82 mm to a maximum of + 334.15 mm above the average and a minimum of - 230.28 mm to a maximum of - 1.91 mm below the average. Results from three years moving averages of rainfall indicated below average rainfall amounts recorded for the years 1976 and 1977. Favourable rainfall resulting in averages above the mean for the years 1978 to 1982 followed the dry periods of records. However, a dry period of three years (1983 to 1985) showed drought years and this was preceded by a wet year in 1986 and another dry year in 1987. Langbein and Schumm (1958) argued convincingly that a decrease in annual precipitation is associated with a decrease in vegetation cover density from forest through grasslands to desert scrub, providing an increased supply of sediments.

A long period of wet years was recorded for the period 1988-1993 followed by a drop below average in the year 1994. The years 1995-1998 presented values above the average rainfall value followed by a drop below average for the years 1999-2003. Similarly, above average values of rainfall were recorded for 2004-2005 followed by low values below average in 2006 indicating a dry year. Figure 4 is a graphical representation of the relationship between annual rainfall, three-year moving averages and mean rainfall of the Nasia River Basin.

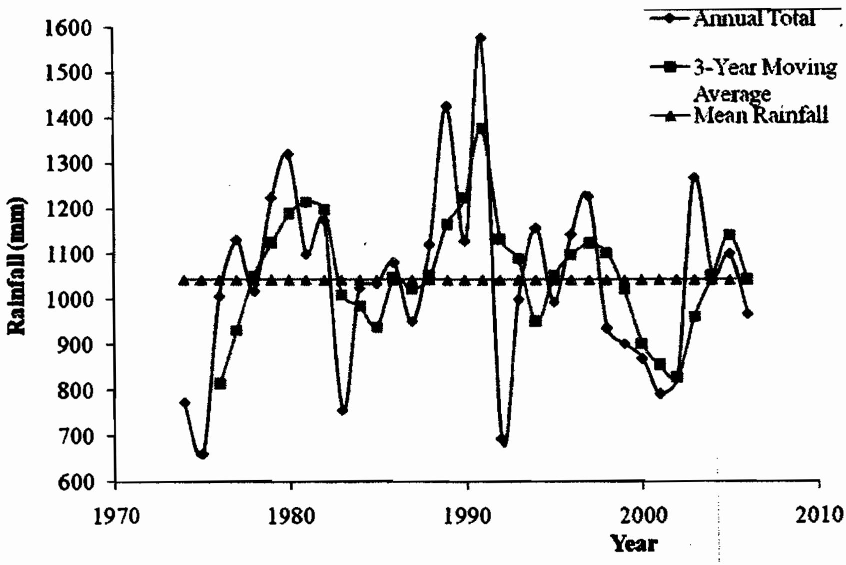


Figure 4: Rainfall Characteristics of the Nasia River Basin

Wet Season Rainfall Analysis of the Nasia River Basin

About 60% of the annual rainfall in the Nasia River Basin falls in a six to seven month period. Changes in the rainfall pattern can therefore have a marked effect on the hydrologic system. Surface-water runoff and ground water recharge occur during this period when the antecedent soil moisture is considered to be high. Single mass plot of wet season rainfall for the period 1974-2006 where each value was cumulatively added up showed no significant departure from the normal trend of rainfall for the Nasia River Basin Figure 5. This was done for the period from April to October for the 33 years using a single mass plot. This therefore shows the potential of more luxuriant vegetation cover production which have a protective effect on the soil surface from raindrop impact. The potential of raindrop energy absorption during this period by the vegetation cover therefore has a marked effect on reducing soil particle detachment and water erosion in particular.

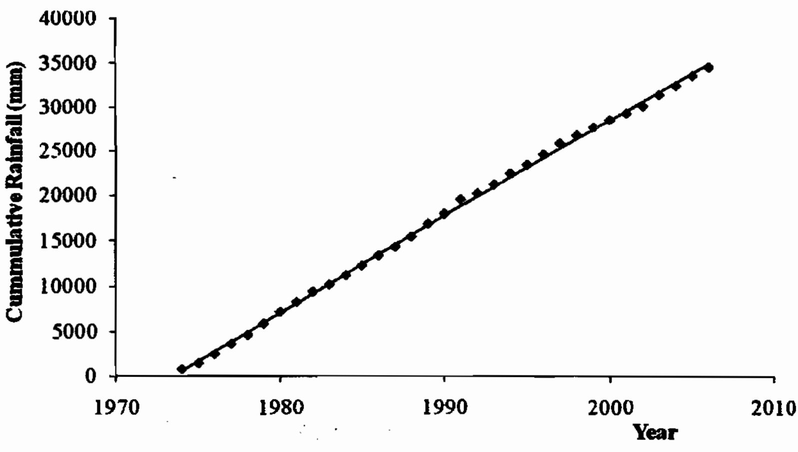


Figure 5: Wet Season Single Rainfall Mass Plot of the Nasia River Basin

Dry Season Rainfall Analysis of the Nasia River Basin

The dry season of the Nasia River Basin varies from five to six months (in the basin), having a great impact on the vegetative cover of the area as well as the antecedent soil moisture. Single mass plots (November to March) for the dry season indicated a remarkable departure of great interest from the normal as in Figure 6. Wide departure values indicate very dry conditions for the basin area and this has a relationship with the amount of biomass covering the soil and the risk of possible erosion of the area. Wide departures and associated high rainfall intensities during the start of the rains would likely result in substantial sediment production which will affect the flow of the river.

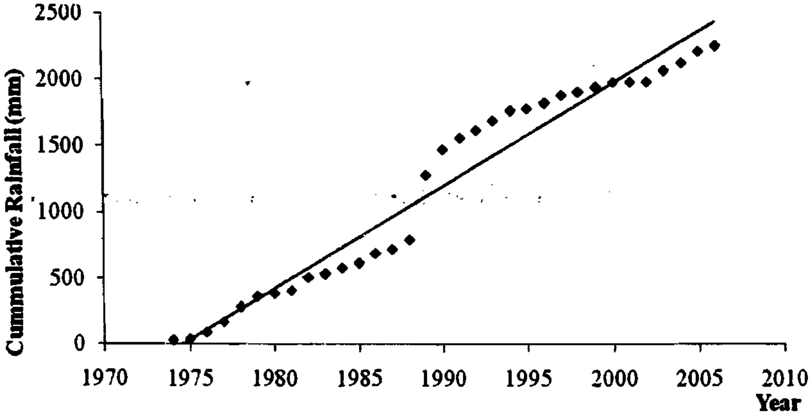


Figure 6: Dry Season Single Rainfall Mass Plot of the Nasia River Basin

Impact of Farming and other Activities on the Nasia River Basin

The cultivation of crops close to the river channel is likely to have a negative impact on the flow regime of the Nasia River if proper conservation practices are not taken into consideration. Fifty-five percent of the farmers have their farmlands close (about 10 m) to the river bank and most of them, 85% employed slash and burn, while 6% undertook planting without burning and 9% remove all vegetative cover as the respective land clearing practice used for preparing their farms. With these land clearing practices and farming close to the river, it indicates that there is no buffer zone to capture sediment from upslope areas in the catchment. Telly (2007) noted that farming close to river banks had over the years caused siltation and subsequent destruction of most water bodies in the Northern Region.

Tillage practices undertaken by farmers in the areas ranged from the use of hand hoe to tractors. 53% of the farmers use tractors for ploughing their fields, bullock ploughing 1%, manual – hand hoe (32%) and manual and tractor combined (14%). In view of the fact that most farmers used tractors to prepare their land, a high level of disturbance of the soil is expected and this has a great impact on soil particle detachment and its possible entrainment down slope depending on the rainfall intensities at the start of the wet season.

The vegetative cover, according to the farmers, had reduced substantially over the past 20 years and they described the vegetative condition 20 years ago as dense and moderately dense. The reduction of the vegetative cover was categorised in this study as tree cover (43.3%), shrub (26.6%) and grassland (30.1%). The main activities which resulted in the reduction in vegetative cover are bush burning, farming close to the river channel, cutting of vegetation for local use and for charcoal production. According to farmers interviewed in the catchment areas, there has been a drastic change in river flow over the past 20 years. This assertion can however be applicable to the peak season flows around August to September when the rainfall is in its peak.

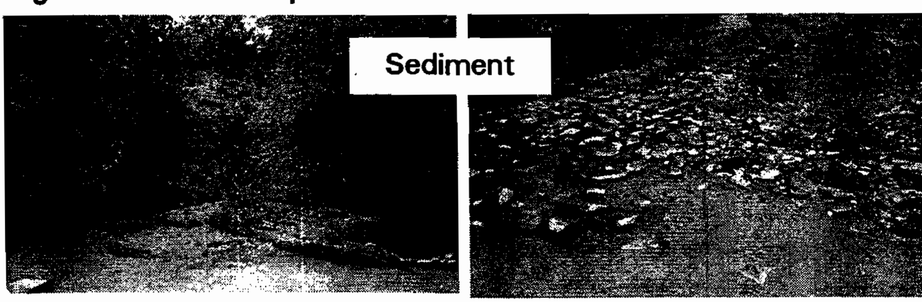
Surface Runoff and Erosion

Infiltration tests conducted at the Nasia floodplains in February 2007 at five different locations of community settlements which are close (about 40 m) to the river channel indicated a minimum value of 43.0 mm/h to a maximum 61.9 mm/h. Comparing the values of these infiltration rates with average intensity of rainfall in northern Ghana which recorded peak rainfall intensities varying from 100 to 200 mm/h (Agricultural Extension Handbook, 2006) then the infiltration rate of the area will be exceeded. Runoff resulting from this excess of the infiltration rate of the soil would therefore result in substantial amount of water erosion in the area.

Soils of the Nasia floodplain have been reported by Adu (1995) to vary in texture from very fine sands to heavy clays and have been developed on levees, old river beds, sloughs and low river terraces and the higher terraces. They also developed pebbly iron-pan horizons in their sub-soils. Depending on the rainfall intensity during any particular rainfall event, detachment of soil particles particularly the fine sands and its consequent transport will be very high.

According to Adu (1995), generally, where organic matter content of the soil falls below 2%, the soils are more prone to erosion. The soil particle binding effect of organic matter is therefore very low thus resulting in more loose soil particles. The high rainfall intensities, low organic matter content of soils coupled with low infiltration rates and farming too close to the river channel could be the possible cause of soil erosion and siltation of the river channel. This indicates that high levels of sediment would be produced and transported into the river channel and its subsequent delivery into the White Volta River. Figure 7 shows the sediment deposition in the Nasia river channel at the start of the rains.

Figure 7: Sediment deposited in the Nasia River Channel



(Source: Fieldwork, April, 2007)

CONCLUSIONS AND RECOMMENDATIONS

Vegetation cover degradation coupled with burning during the dry season in the study area exposes the fragile soil to the direct impact of the rains. The loss of vegetation cover is seen as both a consequence and a cause of land degradation in the Nasia area.

The closed and open savannah woodlands have been degraded and are gradually being replaced by dense herbaceous plants as well as grassland and herbs which are prone to the vagaries of the weather especially the characteristic bushfires of the area. Within the time interval of 10 years (1990-2000), 534.30 km^2 of closed savannah woodland which formed 10% area loss in the catchment area of the Nasia River Basin was observed. For the same period, 169.52 km^2 of the open savannah woodland had also been depleted and this represents a 3.2% loss of vegetation cover.

Crop cultivation close to the river channel is likely to have a negative impact on the flow regime of the river if conservation practices are not considered. The use of tractors in the area coupled with reduction in vegetation cover will have a great impact on soil particle pulverisation and detachment and its possible transport down slope depending on the rainfall intensities at the start of the wet season. The absence of vegetation cover at the start of the rains has the effect of increasing sediment production and its consequent effect of being deposited in the river channel. The high rainfall intensities, low organic matter content of soils coupled with low infiltration rates and farming too close to the river channel could be the possible cause of soil erosion and siltation of the river channel.

The following suggestions should be considered by policy makers to help reduce the level of environmental degradation in the basin area:

- Buffer zones which would keep farmers distant from cultivating near the river as well as in trapping suspended sediment from being delivered into the river channel should be established.

- Establishment of tree plantations for the protection of the Nasia River Basin should be promoted especially with the provision of seedlings for planting by farmers.

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