Geomorphic Assessment of Floods within the Urban Environment of Gbawe-Mallam, Accra.

Kwabena Awere Gyekye[a]

ABSTRACT

This study examined urban geomorphic conditions that lead to flooding in urban areas of Gbawe and Malam. The main objective of the study was to identify the geomorphic causes of urban flooding. The study used ArcGIS analysis to present the results on land use change. Information on geomorphic and geological characteristics, rainfall pattern and human-induced activities and their impact on the environment were examined. The result of the research indicated that Malam Junction, Abease and Gbawe-Zero Road are areas with the highest vulnerability to flooding. The main input to flooding is rainfall, with the heaviest ranging between 200 and 500mm, and occurring from May-July and August-October. Relief, geomorphic factors, the urbanization of streams, the drying up of wetlands, the elimination of vegetation cover as well as deficient drainage networks and waste disposal problems are the factors that aggravate flooding in the study area. Some major suggestions were made for effective land use and land management

[a] Department of Geography & Resource Development, University of Ghana, Legon, Tel:+2333547041803, e-mail: kagyekye@ug.edu.gh

INTRODUCTION

Before the appearance of Homo sapiens on Earth, a purely natural system ruled our planet. Many geophysical events such as earthquakes, volcanic eruptions, landsliding and/or flooding took place but threatened only the prevailing flora and fauna. Millions of years later, the presence of humans transformed the geophysical events into natural disasters.

This transformation occurred simultaneously with the appearance of the human system, when human beings began to interact with nature. The human system itself was subjected to significant transformations, where the concept of work and hence of social division of work, production relations and economic–political systems appeared. These transformations and their links to the natural system have served as templates of the dynamics of natural hazards and therefore of natural disasters.

A natural hazard such as flooding has the characteristic of posing a danger to the different social entities of our environment; nevertheless, this danger is not only the result of the process per se (natural vulnerability), it is the result of the human systems and their vulnerability to natural disasters (human vulnerability). When both types of vulnerability have the same coordinates in space and time, natural disasters can occur (International Decade for Natural Disaster Reduction, 1992).For example, Hamza and Zetter (1998) argued that urban areas are not disaster prone by nature but that the structural process that speeds up rapid urbanization, population movement and population concentrations greatly increase the vulnerability of low-income urban dwellers to disasters (Zetter,2004).

Floods often result in widespread contamination that poses both immediate and long-term threats to human health and the environment. The environmental consequences of flooding, however, can be extremely complex and difficult to assess due to their large spatial extent, multiple sources, sinks and types of pollutants, and potential effects on nearly all components of the environment (Tilotta *et al.*,2003).

Natural hazards and geomorphology.

The role of applied geomorphology in urban management calls for the study of the geomorphic processes and features of urban landscape and the development of the requisite fundamental applied research (Elyles, 1997; Scott, 1998). Urban geomorphology combines ambient geology, landforms, and geomorphic processes with an evaluation of their impacts due to urbanization (*Alexouli-Livadits et al.*, 1997).

The study deals with urban flooding caused by rainfall overwhelming drainage capacity. However, the cause of urban flooding is seen to be aggravated by land use and by the characteristics of geomorphic processes and landforms. The risk of flooding is defined as a function of both the probability of a flood happening and its impact. In urban areas, the impact can be very high because the areas affected are densely populated and contain vital infrastructure (*Maroukian et al.*, 1994).

Floods constitute one kind of natural hazard. The term natural hazard implies the occurrence of a natural condition or phenomenon which threatens or acts hazardously in a defined space and time. A natural hazard has been expressed as the elements in the physical environment harmful to man (Burton & Kates, 1964); an interaction of people and nature (White, 1973) the probability of occurrence of a potentially damaging phenomenon (UNDRO, 1982); and a physical event which makes an impact on human beings and their environment (Alexander, 1993).

A flood hazard is strongly related to the exogenous geomorphic process since it is an important ingredient of the Earth's surface dynamics. Geomorphic hazards can be regarded as the group of threats to human resources resulting from the instability of the Earth's surface features (Gares *et al.*, 1994). The importance of these features is concentrated on the response of the landforms to the processes, rather than on their original source. The prohlem related to the control and regulation of land use in many parts of Accra has serious impacts on landform dynamics and disaster management.

Magnitude and frequency, as well as temporal and spatial scale, are key geomorphic concepts strongly correlated to natural hazards. For a given event, such as a flood hazard, magnitude and frequency exert a very important control on the impact of geomorphic processes since they have an influence on landform change and therefore on the dynamic equilibrium in geomorphological systems. The concepts of magnitude and frequency are essential for the assessment of natural hazards. For example, the consequences of a flood are measured using return periods, giving an idea of the characteristics the flood may have (magnitude) and how often it is likely to occur (frequency). The dynamism of the Earth's surface is enclosed within a temporal and spatial scale. The response of the landform to the changes caused by the processes corresponds to the magnitude and frequency of the events, the resistance of the involved materials and the size of the concerned landform (Summerfield, 1991)on a time basis. Hence, the intensity and duration of rainfall in conjunction with the nature of the landform and fluvial system, developed also on a time basis, would determine the characteristics of the flooding. In this regard, elevation and hydrogeological characteristics play a crucial role in the nature of urban flooding.

The occurrence of different types of disasters by regions of the globe indicated that by far floods are the most frequent and dominant phenomenon in Africa and constitutes nearly 29 percent of global flood incidence and 54% geomorphic related disasters by type in Africa followed by storms (25%), earthquakes (16%), landslides (3%) and volcanoes (2 %) from 1900 to 1999 (Source: EM-DAT database). **For the period 1900 to 2011 the total affected people by flood disasters in Ghana, which** occur between June-July and September-October, **is** 3,743,772, (average per event affected 25,000), while the av**erage economic damage cost is estimated at 74,700 USD per event** (EM-DAT: The OFDA/CRED International Disaster Database, 2011**).**

A number of case studies from different parts of the world dealing with increased flood problems indicated that floods are the greatest cause economic losses from natural disasters, mainly in more developed countri and a major cause of disaster-related deaths, mainly in the less developed countries. Hence, investigating the conditions of flooding generation and recording them in vulnerable urban areas is indispensable to urban planni and socio-economic development (Smith & Ward, 1999, p.9.). Douglas *et* (2008) noted that floods are very common in African cities, are becoming more frequent and affect the urban poor most severely. The situation becomes serious in defenseless societies where the social system has neit control over the situation nor the capacity to cope with it (Barkun, 1974).

The historical planning of Accra has contributed to the emergence of som urban disasters, such as flooding, which could have easily been prevente The unplanned growth of Accra is attributed to the neglect of land management and weak spatial planning when the government of Ghana v implementing various economic development projects. Prior to 1983 lanc use planning and development control were non-existent in the cities of Ghana, especially Accra (Larbi, 1996). During the period of colonial rule land-use planning was primarily concentrated in newly developing areas occupied by Europeans and on state lands to the neglect of customary lan although the latter constitute the dominant type of land in Accra (Larbi, 1996). After independence, the situation did not change and the planning development of Accra continued in the colonial pattern (Larbi, 1996). When the government of Ghana started implementing the Structural Adjustment Programme in 1983, land use planning was seriously tackled land management did not receive enough attention (Larbi, 1996; Grant ar Yankson, 2003). However, the management of land is fundamental to an improvement in the quality of an urban environment (Aryeetey-Attoh, 2(

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The city of Accra is faced with a number of human settlement challenges: increasing population, poor land use, fast growing and uncontrolled constructions, inadequate and inefficient drain networks, poor waste disposal and overcrowding. These factors escalate flood occurrence. The problem appears to be especially critical in areas where planning and enforcement of building regulations are ignored. The contribution of urbanization to flooding has been documented in many urban disaster research issues. For example, it was noted that out of the ten major floods events recorded for the Greater Accra Metropolitan Area (GAMA) from 2001 to 2005, seven occurred during the major rainy season from March to June, which reflects the severity of flooding from rivers, streams and drainage channels within GAMA that has claimed several lives and destroyed public infrastructure and private property (Songsore *et al.*, 2009). The economic loss brought about by such flooding is immeasurable. It is estimated that, on the average, an amount of ten million Ghana cedis is spent annually by the National Disaster Management Organization (NADMO) on disaster prevention and management programmes.

The causes of flooding are many but generally, precipitation and spilling from dams are the main source of floods in many countries.Rainfall in the tropics is usually associated with several types of synoptic phenomena: tropic cyclones, the monsoon system and easterly winds, and the Inter Tropical Convergence Zone. Total annual rainfall may rise due to a combination of these phenomena, but episodic high magnitude rainfall events are usually from the first three (*Gupta & Ahmad,* 1999). The most impressive high magnitude event in Ghana is the Inter Tropical Convergence Zone. However, floods in Ghana are largely influenced by the bimodal character of the rainfall pattern in Ghana. Flood phenomena generally occurred in low-lying topographic areas in many parts of the Accra Metropolis, for example in Mallam, Awoshie, Odawna-Circle, Dansoman and Wireless 2, and in portions along the coastal zones. In June-July 1997 and 1999, the areas of Gbawe and Mallam experienced heavy rainstorms, which resulted in intense floodings of the downstream sections. Since then there have been repeated flood cases in these areas. The more recent ones in Gbawe and Mallam occurred in June 2007 and 2009, the outcome of which was substantial property damage along with the destruction of public utility networks, roads, bridges and other man-made structures and the slowing down of economic activities. Such damages and losses underscore the importance of undertaking this study. This paper investigated the geomorphic causes and effects of flooding using ArcGIS interpretation and field investigation. The main objective of this paper is to examine the causes and effects of floods in Gbawe and Mallam and to recommend appropriate solutions to the problems.

MATERIAL AND METHODS.

The study applied the ArcGIS vector data to analyse the different parameters of environmental change: drainage, land use/land cover and the geology of the study area. Drainage network and wetlands were digitized from older edition survey maps. In addition, roads and buildings were digitized and combined with the digital terrain model's drainage network (fig.2 and fig.3) as an overlay in order to identify changes in the natural environment.
Land cover and land use maps were obtained for the periods of 1990 and 2000 from satellite image photographs which had been worked out to a scale 1:280,000 (CERSGIS, 2009). This offered an opportunity to carry out a comparative assessment on the extent and nature of changes that have occurred in both land cover and land use over the period. Rainfall data from three synoptic weather stations (Aburi, Weja and Accra) was obtained from the Ghana Meteorological Services. The observation period for monthly

rainfall patterns extended from January 1991 to December 2006 and the information was analyzed through simple graph presentation. Monthly rainfall patterns were determined using monthly observable trends. Monthly rainy seasons were defined as the rainy season (mid-April - July, September and October) and the dry season as November-March. Primary data was collected though field investigations and a semi-structured interview guide.

To assess the nature of geomorphic processes, a slope classification scheme based on slope percentage categories was used; this was derived from slope maps (Ghana Minerals Commission, 1998). Relief, drainage and common open water areas were identified. The gradient range reflects the nature of the naturally/and or culturally dissected landscape. The following gradient range was classified:

Table 1. Gradient /Slope Classification scheme of the study area

Gradient (degrees)	Relief /drainage characteristics, geomorphic processes.	Location
A 0-3	River basin, creeks, marshy lowlands Poor drainage, flood plain area, siltation.	Central Gbawe, Cemetery Road, Mallam Junction Mallam Station, Bola Road
B >3-10	Plain lowland areas with isolated hill slopes, inselbergs, rills, and sand dunes, fairly drained/good drainage areas, sedimentation.	Abease, Electricity Corporation of Ghana,
C >10-30	Good drainage, numerous sand dunes, gullies.	Wireless, Post Office, Zero, Old Gbawe
D >20-30	Good drainage, frequent sand dunes Catchment and watershed area Cuts from sand winning.	Bulemi, Gonste
E > 30-40	Portions of dissected lands or badlands due to gully erosion, soil creep, Stone quarrying.	Bulemi North (Stone Quarry)
F >45	Watershed area, gully erosion, soil creep, flows, soil erosion.	Zero North, Bulemi North

The naturally/and or culturally dissected landscape is a special type of slope category and represents a combination of individual slope categories covering the full range from zero to greater than 45 degrees (0 to >45°), each of which characterizes a geomorphic unit but which collectively form a large area to represent a heterogeneous landscape that has broad implications for geomorphic processes.

A range of 30 to >45 degrees was classified as the slope boundary limit of the study area where most slope processes originate; this classification was used to identify flood prone areas, and partly respondents; the selection of respondents however was based on purposive and random sampling in order to get the targeted people and to avoid extreme bias. Respondents answered questions on three categories of flood related components, namely land use and land cover changes, causes, effects and solutions to flooding.

The sample size, 120 respondents, was proportionately divided between the two communities of Gbawe and Mallam based on population size of over 5000 (National population census, 2000) and the extent of the problem. In the selection of respondents, consideration was also given to the number of years respondents have lived in the study area. A range of 3-15 years was chosen (from preliminary survey conducted) as a period considered reasonable for respondents to have a fair knowledge of flood incidents in their vicinity.

The data obtained was analyzed through descriptive statistics and the use of bar and linear graphs for comparing data points and for determining the frequency of the occurrence of events.

THE STUDY AREA

The study area, Mallam-Gbawe, is a lowland area, except for a range of undulating hills on the northern section. Mallam-Gbawe is situated southwest of the Accra plains and expands from the drainage divide of McCarty Hills to the southern lowland plains of the Odokor-Mallam road where it joins the main Pambrose marshy lowlands (fig.1). The population of the study area is predominantly Ga and Moslem, while the rest belong to the ethnic minority groups of Adangbe, Akan, Ewe and Fanti. The relatively fast growth in the size of Gbawe and Mallam which were rural in 1984 but have now attained urban status mainly as a result of the spillover of the growth of the AMA into localities in the surrounding districts, has serious implications for land use. Gbawe and Mallam each has a population exceeding 5000 with a growth rate of 2.1 percent (2000 Population Census).

The geology of the area (fig. 1) is composed of the Togo series and flanked on both sides by the Dahomeyan. To the southeast of the Dahomeyan lies the Accraian (Mid Devonian). The Togo series are made of quartzite, schist, sandstone, shales and phyllite; these are common varieties of metamorphic rock. Shale is common and is metamorphosed into slate in a low-temperature environment. The geology of the environment indicates, in some parts, a weak-soil environment. The land area consists of gentle slopes interspersed with plains in most parts and generally undulating at less than 76m above sea levels. The slopes are mostly formed over the clay soils of the Dahomeyan gneiss, with the alluvial areas surrounding the coastal lagoons being generally flat. The Akwapim range and the Weija hills rise steeply above the western edge. The crest of the Akwapim range lies generally at 300m southwards. This line of hills continues through to the Weija hills, with the highest point reaching 192m near Weija.

From the hydrolithological characteristics of the area, the geology of the area varies from impermeable and semi-permeable to permeable layers of rocks and these have a profound effect on the nature of drainage, the type of sediment transport and flooding. For example, the upper and middle courses of river Baley show a narrow and zigzag pattern of drainage whiles at its lower part the drainage basin is broad, indicating a change in the geological layout and relief form. This formation influences the nature of flooding effects as flood waters are concentrated at the deep-narrow upper section, causing substantial erosion and sediment transport, while at the lower section a wider area is affected during flooding, causing deposits of sediments and damage to properties.

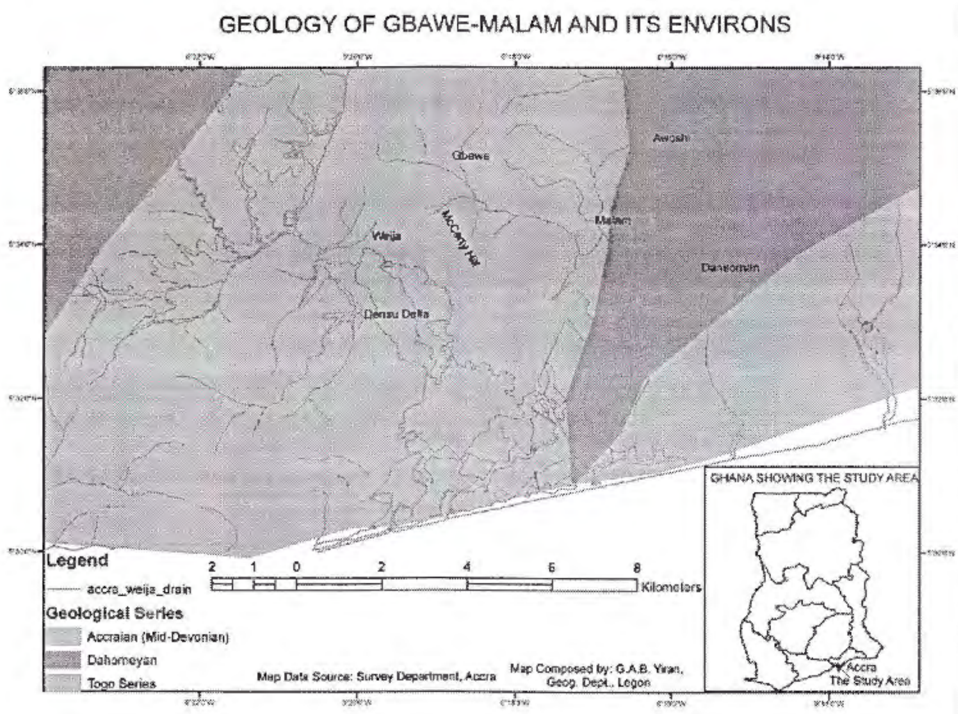


Fig.1. Geology of Gbawe-Mallam and its environs.

Climate

The climatic condition of Gbawe-Mallam is not different from the general tropical climate of the country. As depicted from the average rainfall rates, Gbawe and Mallam fall within the bimodal pattern of rainfall with the major rainy seasons occurring from May to July and from September to October (100-500mm), and the lean season occurring from November to mid April with an average rainfall of less than 200mm.per annum. Rainfall data from the three weather stations, Weija, Aburi, and Accra indicated that monthly rainfall totals of the study area varied between 80 and 120mm for the years 1991 to 2006.Monthly distribution of rainfall showed marked variation, especially between the months of May and November when monthly rainfall totals range between 50 and 300 mm. Severe flooding usually occurs within the main raining months of June-July and September-October. This is associated with rainfall formation from the direction of Aburi hills and/or squall lines from the Coast and Weija (usually of short duration but of high intensity rainfall, 200mm).

RESULTS AND DISCUSSION

Land cover and land use

Land cover and land use maps were obtained for 1990 and 2000 from satellite image photographs and worked out to a scale of 1:280,000 (Fig.2).

Within the study areas, patterns of land use represent a response to the various processes of urban growth. Traditional land use includes agriculture and mining while current land use comprises housing, roads, markets, schools, car parks and roadside business.

Competition for land is strong both between and within different functions. For example, lands on the outskirts are more needed for residential and commercial purposes while businesses compete for the best locations within and near road arteries. Such competition affects not only the land use pattern of the area but also the urban morphology and nature of flooding because flood prone areas have been taken over by business activities.

Accra is inhabited by more than 3 million people, with a growth rate of 4% per year, which implies that the population will double in 16 years (United Nations, 2005; World Bank, 2007; World Bank, 2009). These projected increases are likely to expand the city's built up area and affect land use, and in this respect Gbawe and Mallam are no exception.

On the land use map of 1990, the land use cover of Gbawe was primarily grassland with scattered savanna trees. Apart from the Gbawe township, which formed the nucleus of the area, settlement was chiefly scattered or dispersed in nature and consisted of traditional thatch huts and mud-brick houses. The main occupation was farming and growing of vegetable crops. There also prevailed some form of traditional hunting restricted to specific zones. During this period the land use and land cover situation in Mallam was quite different (511); settlement was the main land use, followed by a limited amount of quarrying. In a few cases, patches of grassland and shrubs could be found.

The land cover and land use for the period 2000 reflects some substantial changes; almost the entire stretch of Gbawe was converted into settlement. In Mallam, settlements continue to expand southwards to the coast, and parts of the coastal lagoon (7400) were turned into sites for salt wining. Changes in land use have seriously affected drainage in the study area to the extent that current mapping of drainage would be difficult to execute, except in a few places where fluvial processes show semi-permanent flood morphology and where the geologic and physiographic conditions can easily be discerned.

Draining and filling of drainage areas for construction purposes have not only led to the drying up of some of these areas,but have also changed the morphology of the drainage network and are thus making the natural flow of these rivers difficult. For example, the construction of buildings and roads within the drainage basin and areas of low elevation in Old Gbawe, Gbawe-Zero and Mallam Junction have led to impeded water flow in periods of heavy rainfall (especially in May-July), resulting in flooding. This was well noted atMallam Junction and across the Mallam-Kaneshie road where the construction of the road has reduced the accessibility of the surface run off to the Panbrose-Densu delta and finally to the sea, thus causing severe flooding in these parts of the area. Currently, over a 300 meter stretch of the main road between McCarthy Hill Junctionand Mallam-Kaneshie Junction lies within the same elevation as the immediate surroundings of Mallam Junction. As a result, during heavy and prolonged rainfall, the road becomes easily flooded. As depicted from the landcover and land use maps, there had been considerable changes in land cover and land use patterns between 1990 and 2000, indicating a significant transformation of the natural environment as a result of human interventions. Such changes in land cover and land use have led to a reduction in the environment's capacity to regulate flood waters.

In the absence of coordinated human settlement planning and strict enforcement of regulations on land use, addressing flood problems within Mallam-Ghawe and for that matter floods within the urban environment looks extremely difficult.

Fig. 2. Land use cover/land use map covering the study area for the period 1990.

1990 Landcover/Landuse Map of the Project Area

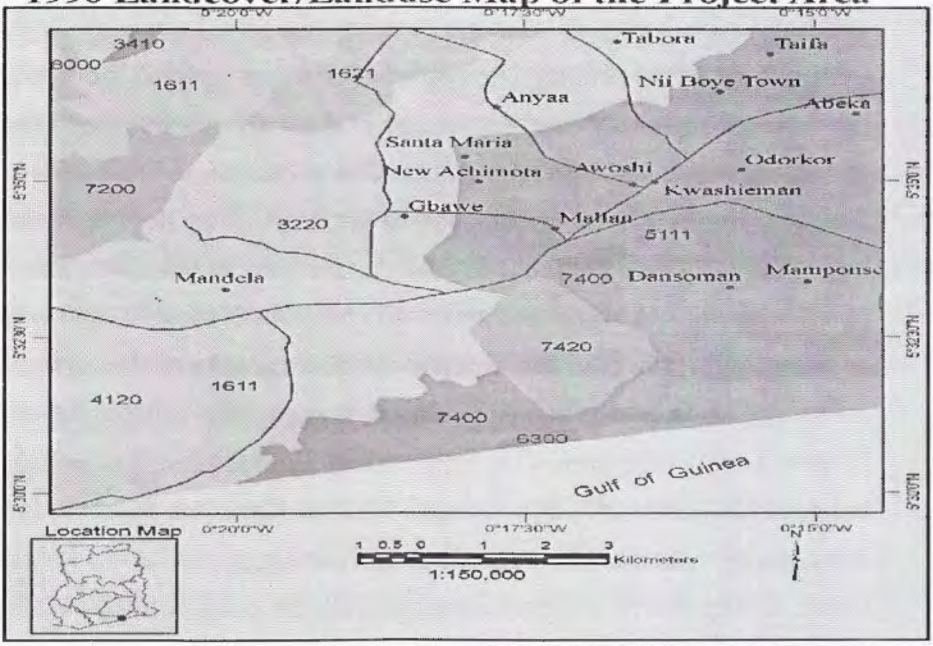
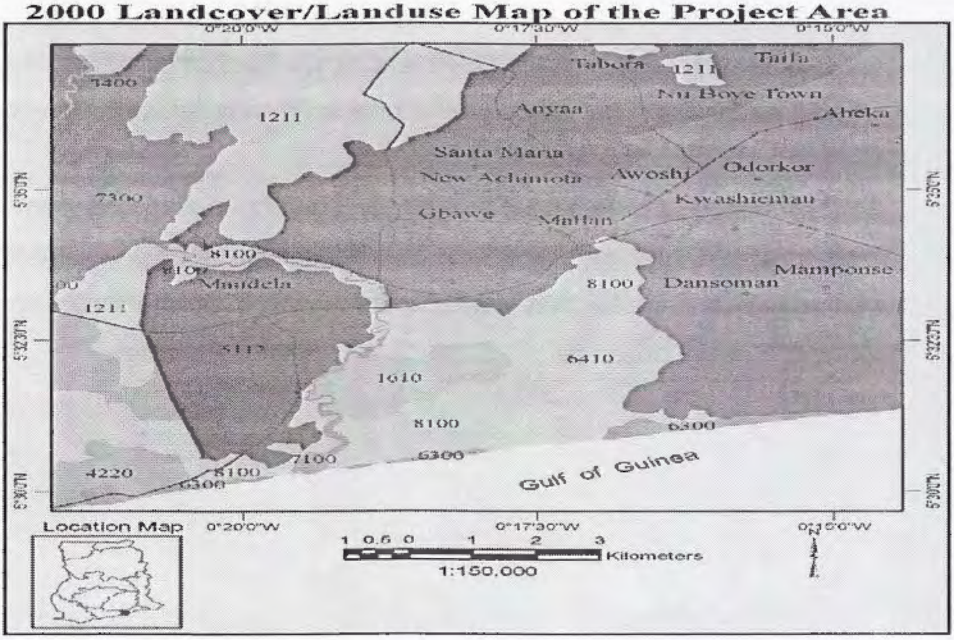


Fig. 2a. Land use cover/land use map covering the study area for the period 2000.

2000 Landcover/Landuse Map of the Project Area



Drainage characteristics

The study area is drained by numerous rivers, streams and pockets of marshy areas forming a broad drainage network. The area is characterized by gentle slopes with low elevation; these areas are developed over semi-permeable or impermeable formations. The drainage network consists of parallel-dendrite streams of temporary flow in a southward direction, following the gradient of the relief (fig. 3).

One of the major rivers in the study area is the Bale river; it takes its source from the low hills of north Gbawe and flows southwards in a dendritic pattern, joined by other hill streams from north eastern Gbawe, through the main township of Gbawe and Mallam and finally to the Panbros wetlands.

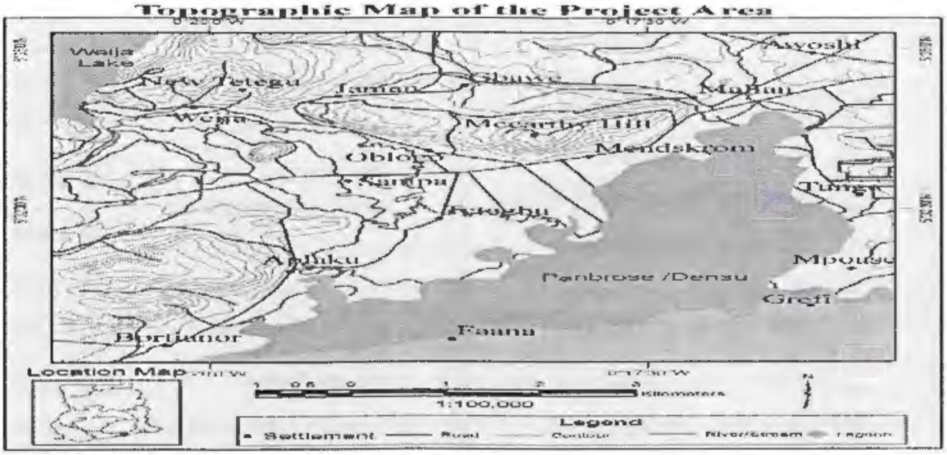


Fig. 3. Topographical map showing drainage of the study area.

Over 65% of respondents interviewed indicated that wetlands, including drainage basins that once received and regulated large volumes of floods, have now been reduced in their area coverage and capacity to carry even small floods. Consequently, the drying up of marshy areas and lagoons of river basins has contributed to flood events in Gbawe and Mallam. Secondary drainage basins are formed where there is a divide between two low depressions. When examining the drainage map (CERGIS, 1990) and the present drainage area, based on field observations, it was noted that:

- Most marshy areas and the inland lagoon do not exist anymore. These areas have been converted into man-made structures.
- The total length of the present drainage network has decreased as compared to that of the 1970s and 80s. The banks and lower parts of the streams are covered with settlements. Consequently, their mapping has been impossible. Inappropriate land use impedes rainwater flow; moreover, drainage network and basins are severely impacted by human activities. As a result, the study area is prone to flooding during periods of heavy rainfall.

Comparing the old drainage network of rivers to the present one (based on field observation), it was noted that the current drainage network has been modified, especially at the plain area of Gbawe and Mallam where slopes fluctuate between 0 and 8%, in such a way that there are just a small number of independent streams flowing directly into the main river. In fact, this situation can only be observed from field observation, as the drainage map could not reflect current changes in drainage development. Furthermore, a number of parallel, independent streams bave been created by detached streambeds that are the result of a large material deposit over a period of time. The sediment deposits muffle the main riverbed and divide it into more secondary beds. The parallel arrangement of the streams is due to an upward morphology bulge between the torrents; even though this could he caused by natural factors such as changes in internal geologic processes and climatic conditions, human activity is the principal cause. Once the original morphology is disturbed, natural regulation of stream flow by morphology is absent. At the base of McCarty Hills, talus cones originated by the change of the gradient and the uncontrolled stream flow are developed. These talus cones are narrower and isolated in most cases. Because of their nature they are ephemeral and quickly disappear after the heavy rains. This fills the flood plains, reducing the ability of the basin to carry the expected volume of water.

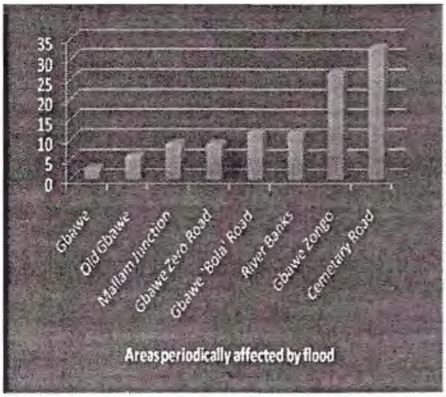
Estimating the magnitudes of low and high frequency floods that occurred in the past was not possible because evidence of high-water marks, debris, organic deposits and other ephemeral features has been destroyed. However, in a few cases, the high energy of large floods was sufficient to transport coarse sediments from the channel bed onto adjacent flood plains.

The anthropogenic interventions and the uncontrolled building construction are more frequent on a gentle relief where the waters of the parallel streams end up. However, recent high demand for land has caused a situation whereby the highest slopes are being used for settlement. Buildings cover the lower parts of the drainage network as shown in the land use map (Fig. 2), and they are constructed upon the stream channels. Hence, during periods of intense rainfall, the artificially diverted torrential streams/flows find it difficult to transport the rainwater into the lagoon and the sea. Searching for a natural way out, the large quantity of water flows in the direction of the gradient of the land; as a result, strong torrential streams are generated within the streets of the city and speed up to reach the sea, causing flooding and great damage in the urban area to buildings and streets, bringing about the loss of lives and properties.

The locations with high risk of flooding are presented and discussed under Figs. 2 and 3, comprising the whole drainage between Gbawe, Mallam Junction and Panbrose.Other affected areas are Zero Road, Zongo, Mallam and Abease Junction.

As indicated in fig.4, the most seriously affected areas are Ceemetery Road, Gbawe and Zongo, Mallam Junction and Mallam Bola Road. The main reason for the flooding of these areas is poor planning. Field observation revealed that many of these areas experience floods due to clusters of structures built in low lying areas and in the paths of water ways which are liable to flooding. A good example of these structures is the Total 1 fuel station at Mallam Junction which stands in a water way. Also, these areas lack good drainage facilities.

The major features that characterize these areas vulnerable to flooding are the low-lying relief, poor drainage network and waste disposal, poor accessibility and inefficient land use. These findings correspond with respondents' views (fig. 5) on what are the causes of flooding.



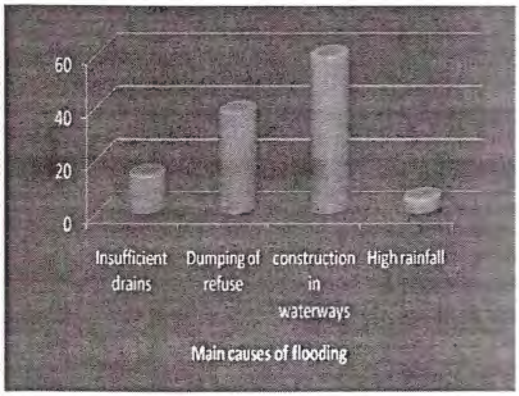
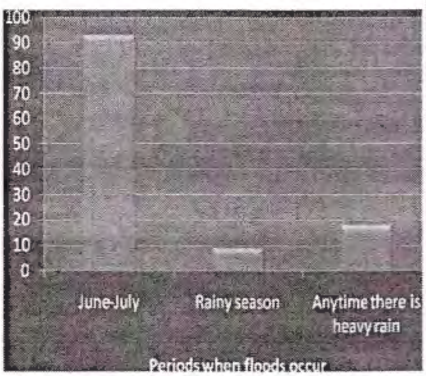


Fig 4.Areas periodically affected by flood. **Fig. 5 Main causes of flooding.**

Interaction with respondents indicated the following: 93 (77.5%) respondents interviewed expressed that the highest peak of flood occurs in June/July (Fig. 6) even though there have been sporadic floods reported over the years.

Over 66% respondents indicated that there has been yearly flooding of varying magnitude for the past fifteen years but research shows an increase in intensity (Fig. 7).

Respondents expressed different views on the effects of floods on their daily activities. Over 50% of respondents indicated that the occurrence of floods obstructs transportation and movement and thus brings business to a standstill. While 42% said floods displace people, only about 10%



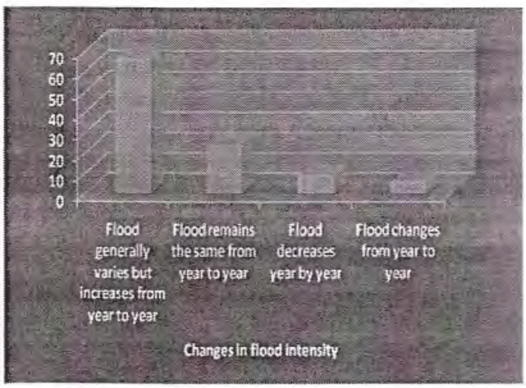
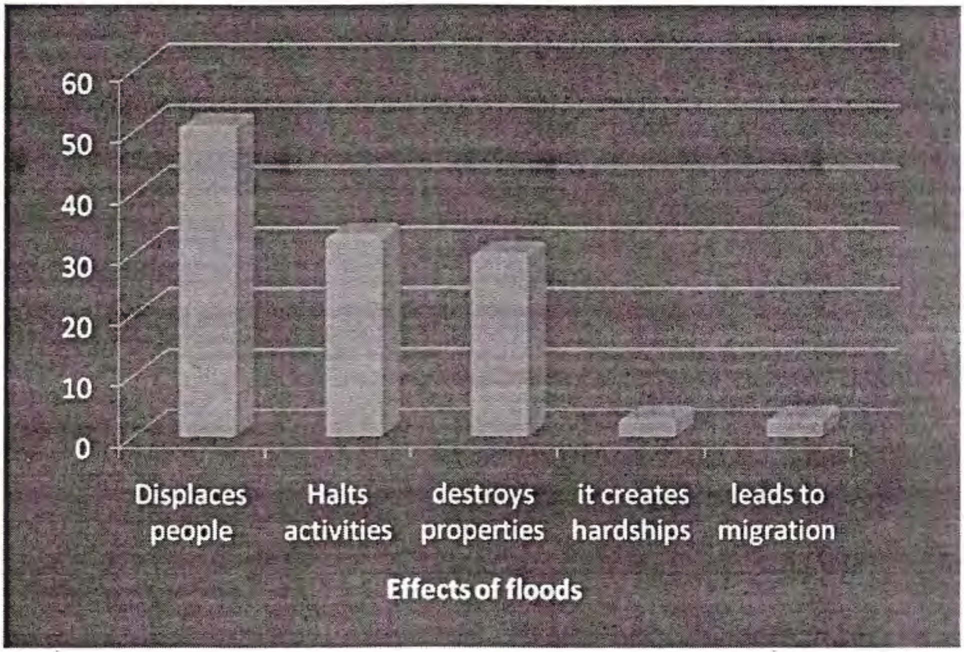


Fig. 6. Period when floods occur **Figure 7: Changes in flood intensity**



Rainfall characteristics of the study area.

The rainfall figures presented demonstrate elements of marked uniformity and variability in their distribution pattern, both on monthly and yearly basis, as noted in figs. 9, 10, and 11. The major rainy period falls within the months of May-June-July with the highest recorded monthly totals ranging between 80 and 300mm.

The lean period of rainfall usually occurs within the months of January-February with rainfall amounts varying between 2.0 and 60mm. However, extreme monthly variations of rainfall amounts of 0.0-100mm were recorded; this period is characterized by dry conditions and the absence of floods.

The rainfall pattern shows the bimodal character; over 80% of high rainfall figures occurred between May and July, with monthly rainfall amounts ranging from 80-400mm, while for September-October a range of 80-

180mm was recorded. During August-mid-September a range of 30-130 mm was observed. The dry season is clearly noted, stretching from December to March and showing decreasing rainfall amounts, from 0-120mm (figs. 9, 10, and 11).

The monthly summary observations of rainfall indicated a substantial variation in rainfall patterns both for monthly and yearly records. The monthly rainfall figures for the Aburi meteorological station, 1991-1999 were generally higher (200-400mm, fig. 9), as compared to the period of 2000-2006 (200-300mm, fig. 9a), indicating a trend of gradual decrease in rainfall amount yearly and towards a drier condition. However, there were high rainstorm cases of different magnitudes within the period of May-July, and September-October 2000-2006, indicating monthly rainfall variability.

From the given rainfall data and field investigations, it was noted that flood events usually occur within the two main rainy periods of June-July when rainfall amounts are higher (250-400mm per month).

From respondents, high floods usually occur after short intervals of rainfall which moisten the ground to an appreciable depth, giving little room for further infiltration to take place. When this is preceded by the main rainy periods of May, June-July, a near saturation condition of the ground is achieved in no time and the high rainfall intensity causes a large volume of surface run off which facilitates flooding.

High monthly rainfall from squall lines in the coastal zone of Accra, Weija and Aburi, (figs.9, 10-10a, and 11-11a respectively), are another cause of flooding within the Gbawe-Mallam community. As indicated, the bimodal rainfall pattern of the three main rainfall recording stations gave the highest rainfall amounts within the periods of May-June-July, with the remaining falling in September-October, which coincide with the periods of floods in the study area. November-March is the lean season of rainfall, and this period shows an anomalous pattern of distribution. Mallam-Gbawe sharply comes under the influence of the Aburi-Weija-Coastal rainfall formation.

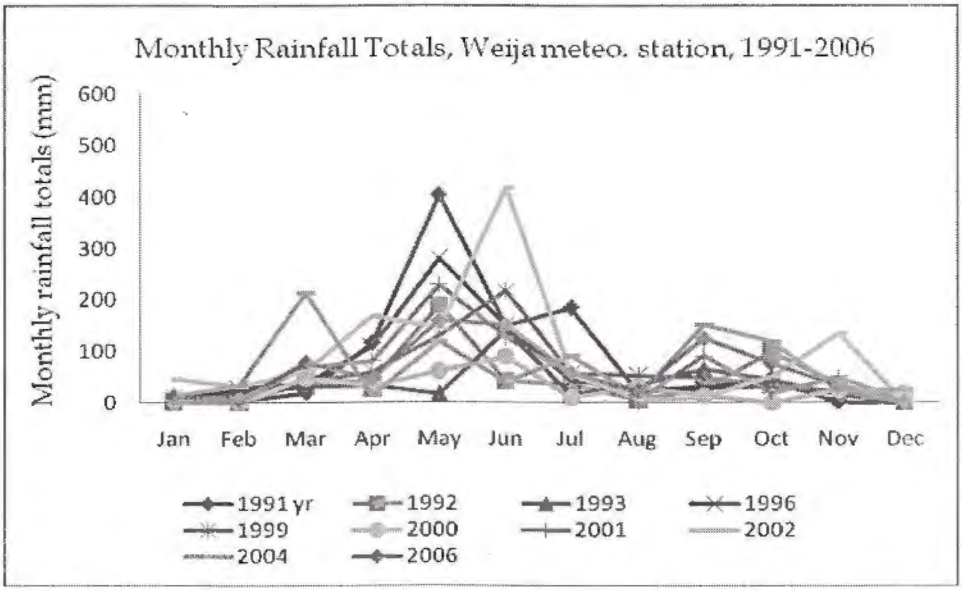


Fig.9. Monthly rainfall total (mm) Weija meteorological station, 1991-2006.

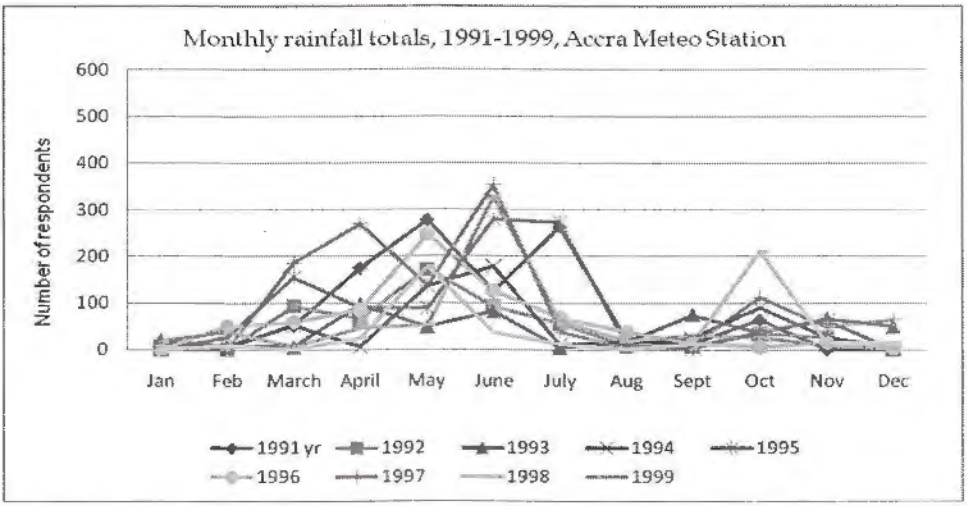


Fig.10. Monthly rainfall total (mm) Accra meteorological station, 1991-1999.

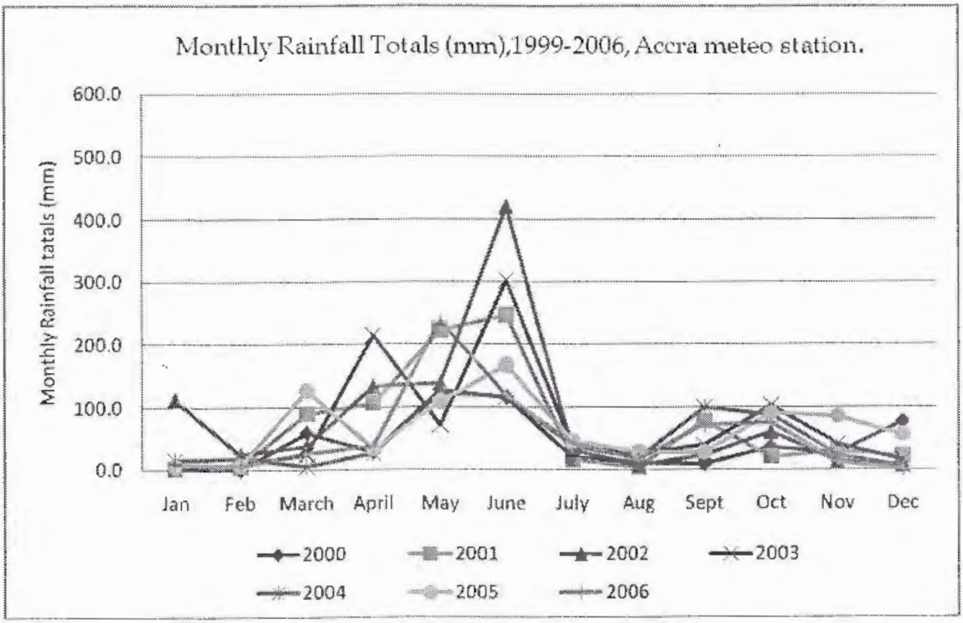


Fig.10a. Monthly rainfall total (mm) Accra meteorological station, 1999-2006.

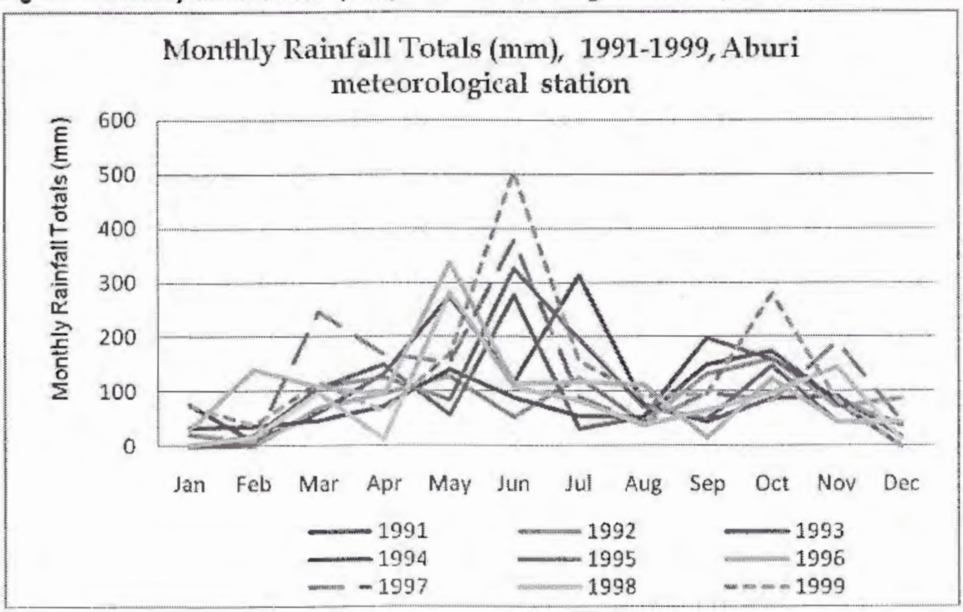


Fig.11. Manthly rainfall total (mm), Aburi meteorological station, 1991-1999

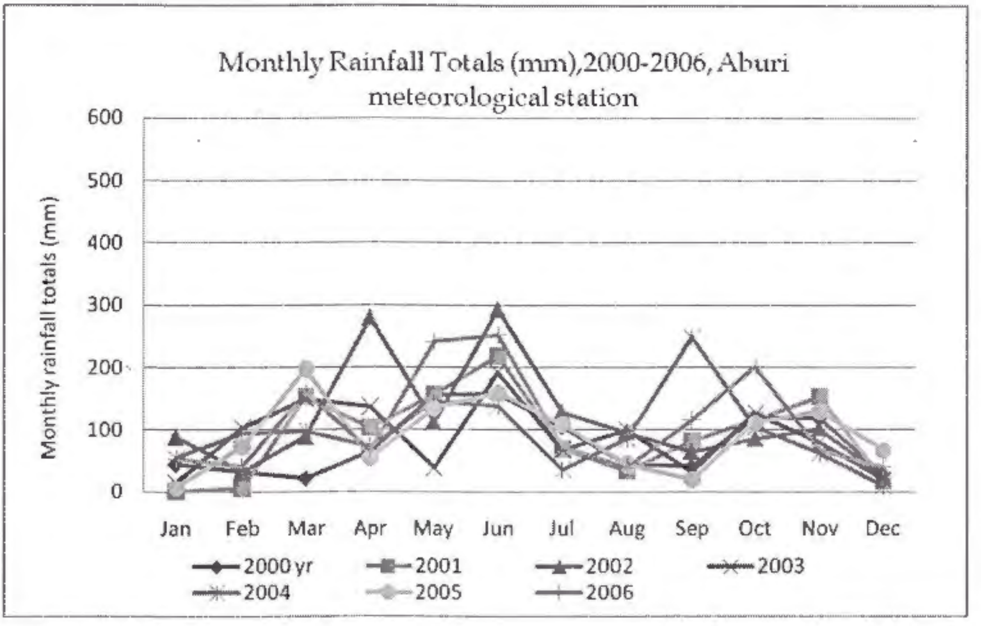


Fig11a. Monthly rainfall total (mm), Aburi meteorological station, 2000-2006

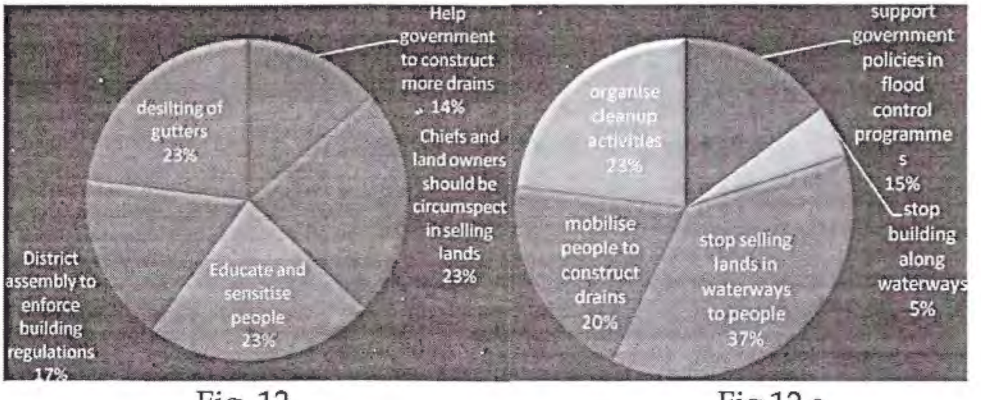


Fig. 12 Fig 12 a

Figs.12 & 12a. The role of public and communities in flood management.

Prevention of flood hazards.

The significance of the prevention of natural disasters is made evident by the commemoration of the International Decade for Natural Disaster Reduction (IDNDR). Since then many countries have shown practical evidence and support through the adoption of comprehensive disaster management strategies. In Ghana, The National Disaster Management Organization (NADMO) and NGOs have been playing a decisive role in addressing disaster issues despite their constraints in terms of funding and logistics. Communities and individuals have shown some form of support through waste management and clean up exercises to desilt drains, and through creating public awareness.

From the study, respondents offered some useful suggestions regarding how to address flood problems but generally emphasized on the roles of communities and the general public in preventing flooding which include controlling sales of land, desisting from building and dumping waste in water courses, constructing more and efficient drains to carry storm water and regulating construction activities (figs. 12 and 13). Other measures are: enforcing building regulations, demolishing structures that stand in water ways and improving efficiency in waste management and disposal.

The study recommends effective land use through integrating geomorphic knowledge which forms an important aspect in the study of earth surface dynamics, a component of disaster prevention.

CONCLUSION

Natural disasters occur all over the world; however, their impact in developing countries is greater due to the geographical location in zones highly susceptible to natural hazards (natural vulnerability), and also due to the different types of economic, social, political and cultural vulnerability that exist. These types of vulnerability are indeed the result of their historical development and their social, political, economic and cultural contexts. Access to opportunities within the social entity is unequal and indirectly proportional to the occurrence of flood disasters (the less opportunities, the more vulnerability, the more affected by natural disasters).

The combination of ArcGIS processing with geologic and geomorphic studies revealed somebasic physical-geographical characteristics of Gbawe-Mallam and its immediate environs that have a direct bearing on floods. The geologic and geomorphic conditions of the study area influence flood phenomena; from a very steep slope to an abruptly lowland area, these conditions facilitate the flow of water and the transport of huge quantities of earth materials from upper streams which are deposited on adjacent lowland areas, causing the siltation of river beds and consequently making the area vulnerable to flooding. Land use, through an increasing proportion of impermeable ground in existing developments, tends to concentrate surface run-off into drains, which increases the risk of flooding.

Floods in the study area are attributed mainly to heavy rains which usually take place during the rainy season (May-July and August-October); however, the situation is exacerbated by human induced activities through the process of urbanization. The peak of floods corresponds with the occurrence of high-magnitude rainfall.

The study revealed that short term changes in flood seasonality suggest that the mean seasonality and variance of flood series often do not remain stationary as the time scale lengthens, and that the occurrence of floods is unpredictable.

In general, the physical-geographical conditions and geomorphic factors of the study area, coupled with socio-economic activities, changes in land use and land cover are the main causes of floods in the study area.

The current situation is irreversible as far as the existing buildings and filling-up of the beds of rivers is concerned. Nevertheless, it is necessary to prohibit any further filling-in and construction within the beds and floodplains to maintain the natural flow of the water. The construction of an efficient drainage network, as well as its thorough maintenance, is an indispensable priority for the efficient control of flooding. Finally, planting of vegetation cover along the slopes of the surrounding area is necessary to check erosion and sedimentation. The study also recognized different kinds of vulnerability that impede flood management, as follows:

- Lack of strong national and local institutional structures and coordination
- Lack of access to information and knowledge
- Lack of public awareness
- Weak buildings owned by weak individuals

An overall coordinated human settlement-planning scheme through the adoption of efficient land-use planning and management is seen as a fundamental tool for integrating flood prevention with urban planning to address the problems of flooding in Gbawe-Mallam. Such a planning scheme would regulate human activities and adopt best environmental practices to prevent the risk of disaster-related problems due to flooding.

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