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The Impact of Droughts and Climate Change on Electricity Generation in Ghana

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Abstract

Ghana has occasionally being experiencing harsh weather conditions such as flooding and hydrological droughts. Electricity power for the country depends mainly on hydropower generated from a hydropower dam at Akosombo built in 1965. In the years 1983-4, 1997-98, 2003, 2006-2007 the country suffered from serious electric power rationing. The 2006/2007 electricity power rationing, equating to about 24hrs light in 48 hrs was the severest power rationing ever witnessed in Ghana and the consequences were catastrophic. Out of about 1180MW generated by the two hydropower dams, only about 400MW was produced. This affected all sectors of the economy including industry, mining and domestic. Manufactures were reducing output, shortening the workweek and contemplated investments in power generators. Revenue to the state dwindled due to shortfalls in production by several million dollars in 2006. Power rationing left factories idle and broad swaths of Accra and other cities dark at night with the most feared result that years of efforts spent creating an image of Ghana as receptive to foreign investment could be jeopardized. This paper analysis 37 years of rainfall in the Volta basin and intake water levels in the Dam site on the Volta lake for hydropower generation to establish whether in reality, the main causes of the power rationing due to low water levels in the Akosombo dam was due to drought. The paper establishes that the 1983, 1997 and 2006/7 power rationing was truly as a result of hydrologic drought whereas the

2003's was not. The paper also reports of consequences such as loss of revenue, loss of jobs, extra power generation through diesel plants and many more which in monetary terms amounted to several million United States dollars at a time when the nation was termed a highly indebted poor country according to the Bank of Ghana and World Bank. The paper also suggests that if climate change effects on the water resources of the country are not managed sustainably, drought and floods could affect hydropower generation in future.

Keywords: Drought, Climate Change, Ghana, Volta Lake, Electricity generation

1. Introduction

Hydrological drought which is considered in this paper is when the water reserves available in the dam/reservoir fall below the statistical average. Hydrological drought tends to show up more slowly because it involves stored water that is used but not replenished. The Volta River Authority (VRA) was established under the Volta River Development Act 1961 (Act 46) with the objective to develop the hydroelectric potential of the Volta River for supply of electric energy for industrial, commercial and domestic use in Ghana and to some neighboring countries. The principal functions of VRA were to generate electric power, initially, by the construction of a dam and hydroelectric generating station at Akosombo, and to construct and operate a transmission system to carry the power to serve industrial, commercial and domestic needs of the country. VRA's generation activities cover the operation of two hydroelectric plants one in Akosombo (912 MW) and the other at Kpong (160 MW), also on Volta River, downstream from Akosombo. In addition VRA runs a 30 MW diesel generating station at Tema, which was commissioned in 1992. In 1995, the VRA started constructing a new 330 MW Combined Cycle Thermal generating Plant, comprising two 110 MW Combustion Turbines and one 110MW Steam Turbine Generator and associated Heat Recovery Steam Generator (HRSG) at Abaodze, near Takoradi. The Thermal Project at Aboadze is bringing on board about 660 MW of power. The Asogli Thermal Unit (a private power producer) power plant brings about 12% power. In all electricity from hydro is about 60% against thermal of 40% (PURC, 2011). VRA has been exchanging electrical power with its Ivorian counterparts Energie Electrique de la Cote d'Ivoire (EECI) and Compagnie Ivorienne d'Electricite (CIE) since February 1984. Currently however, VRA is a net importer of electricity from CIE.

Since VRA's establishment, water shortage due to droughts or low rainfalls have befallen the Authority in some years. In the year 2007, Ghana experienced the severest electricity power rationing, equating to about 24hrs light in 48 hrs. This rationing was attributed at the time to the low water level in the Volta Lake which harbours the Akosombo and the Kpong Dams due to poor rainfalls in the Volta Basin. Nearly all industries in the Country suffered production problems culminating in some folding up. This paper presents some of the effects of drought which is an extreme weather phenomenon on the operations of hydroelectricity generation in Ghana. It does so by analyzing rainfalls in the basin and lake (dam water levels at the intake point) water levels of the Akosombo dam in the Volta Basin to establish whether in reality, the main causes of the water shortage (hydrological drought) were due to drought and whether as a country we have the expertise to forecast drought.

2. Materials and Methods

2.1 Location

The Volta River Basin (Figure 1) is a trans-national catchment shared by six riparian countries: Ghana, Burkina Faso,Togo, Cote d'Ivoire, Benin and Mali. It lies between latitudes 5°N and 14°N and longitudes 2°E to 5°W and drains a total land area of 400,000 km^2. About 15 million people, with per capita income of $650/yr live in the Volta basin. The watershed is 42% in Burkina Faso, 40.2% in Ghana, 6.35% in Togo,

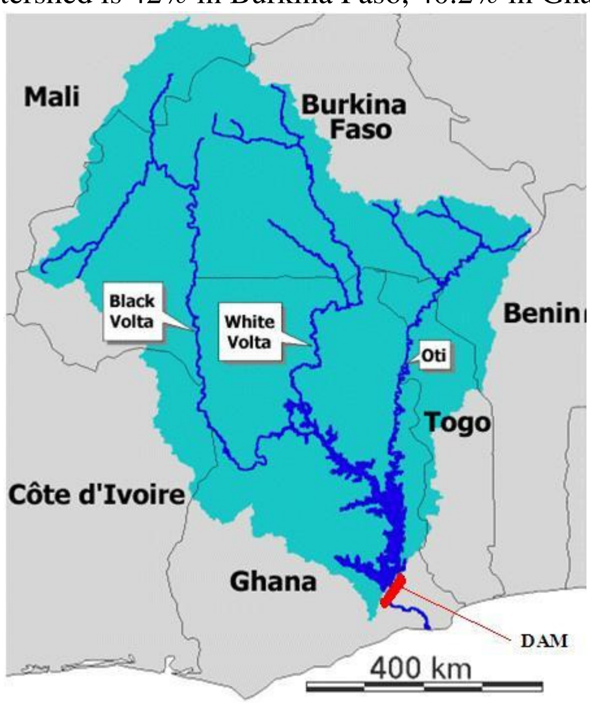

Figure 1 The Volta River basin (shared by Ghana Ivory Coast, Burkina Faso, Togo, Benin and Mali)

4.57% in Mali, 3.62% in Benin, and 3.24% in Cote d'Ivoire (Green Cross International, 2001; Andreini et al., 2000). The Volta Lake has a maximum submerged area of 8500 km^2, and is one of the most important physiographic features in Ghana. Major tributaries to the lake include the Black Volta, the White Volta (both rivers flow south from Burkina Faso), the Oti and the Daka rivers. The landscape is predominantly flat with elevations below 1000 m. Temperatures vary between approximately 16^{o}C and 40^{o}C depending on season, time of day, and elevation. Highest rainfall levels occur in the south and can be as high as 2000 mm/yr, where levels in the driest regions can be as low as 200 mm/yr. The rainfall pattern is usually unreliable, while declining soil fertility and accelerated erosion are evidence of land degradation within the basin and throughout the region. The main land cover types include savanna, grassland, rain forest, water bodies, shrubs and croplands (Oguntunde, 2004).

2.2 Data Collection

Rainfall figures for the period 1971 to 2007 were collected from six stations (Figure 2) namely Bole, Kete-Krachi, Tamale, Yendi, Wa and Navrongo representing the

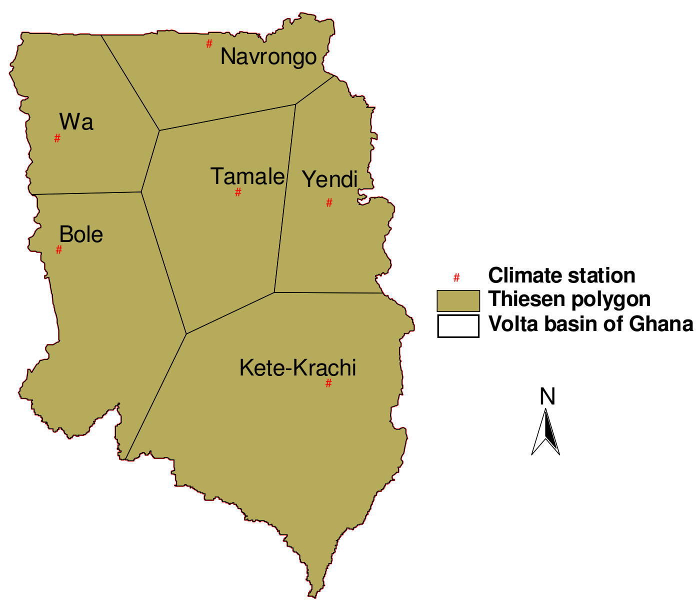

Figure 2 Map showing the rainfall stations used for the computation.

Volta Basin at Akosombo together with dam water levels spanning 1970-2005 were assessed for this study from the Ghana Meteorological Agency and VRA respectively. Stations in Burkina Faso and Mali were not considered because availability was a problem and more so, with the construction of an irrigation dam in 1995 at Bagri in Burkina Faso the flows from this area is controlled except during spilling which normally occurs in the wet season.

2.3 Data Analysis

With the close relationship between water availability and drought, analysis of rainfall, drought and water levels was carried out to establish whether occasional water shortage experienced in Ghana in the years 1983, 1993/94, 1998 and, 2006 and the attendant rationing of hydro electricity power (VRA, 2011) for those years were really droughts years. The Thiessen Polygon method was used to weight the six rainfall stations to compute the annual areal rainfall (Table 1).

Table 1 Rainfall station weights in the Volta Basin

Station	Fraction contributed to rainfall	Percentage Total Contribution
Kete-Krachi	0.3	32.4
Tamale	0.2	15.6
Yendi	0.1	11.7
Bole	0.2	18.2
Navrongo	0.1	10.6
Wa	0.1	11.5
	1.0	100.0

The annual areal rainfall distribution graph is shown in Figure 3 and that of the water levels in the dam at Akosmbo shown in Figures 4&5. Due to the non-continuous nature of rainfall in time and space, its statistical description can be quite complex. A drought threshold is an essential element in categorizing the drought events in drought analysis. Drought threshold is a constant demand where the droughts are defined as periods during which the discharge is below the threshold level (Fadhilah Yusof and Foo Hui-Mean, 2012; Fleig et al., 2006). A threshold that applied commonly in monitoring rainfall and preparing drought alerts is at the seventieth percentile of the rainfall when the rainfall in a certain period is less than seventy percent of normal precipitation (FAO, 2003). Following, the Probability of Exceedence (POE) method was used for analysis. In determining the threshold values, the rainfall figures were sorted in ascending order where the value at the seventy percent of the rainfall data is recognized as the seventieth percentile of

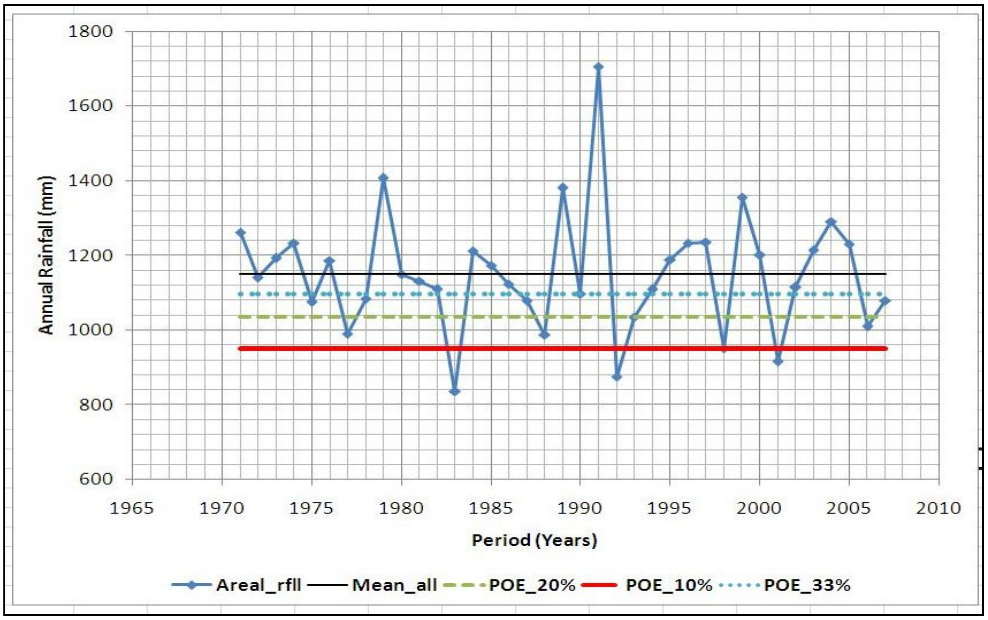

Figure 3 Annual Rainfall for the Volta Basin from 1971-2007

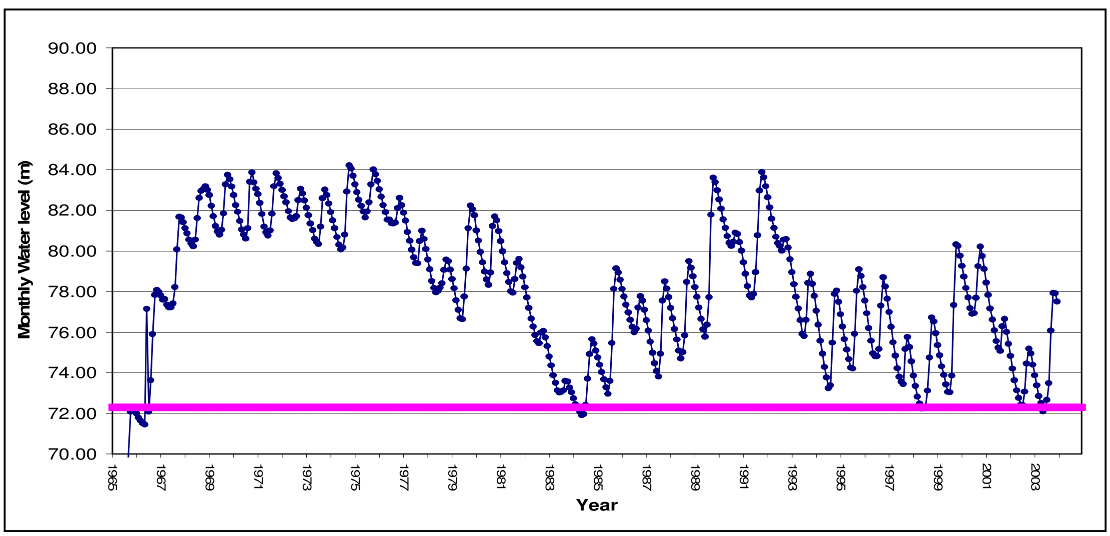

Figure 4 Graph showing monthly water levels of Akosombo Dam (1966-2003) {Courtesy, VRA}

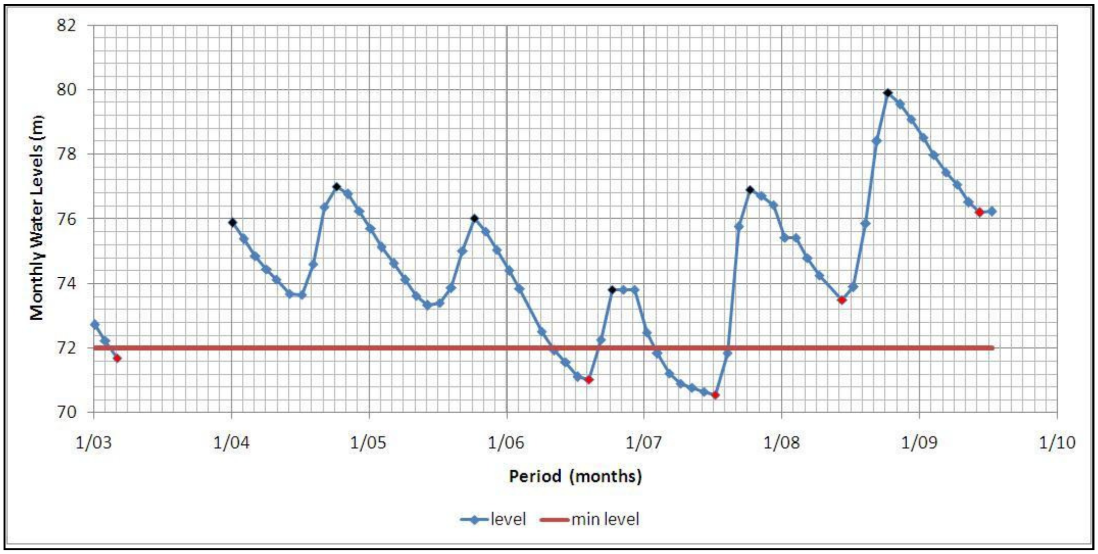

Figure 5 Graph showing monthly water levels of Akosombo Dam (Jan 2003-Jul, 2009)

the rainfall series, p70 (POE of 30). The drought rainfall threshold L (FAO, 2003) is then set according to equation (1)

$$\frac{PN}{100} = L \qquad (1)$$

P is the selected percentile and N is the total number of measurements in the data set. The threshold is the L^{th} value of amount of rainfall.

The recurrence or Return period of the drought T is also computed using the method

$$Return\ Period\ (T) = \frac{n+1}{m} \qquad (2)$$

Where n is the number of years considered and m is the rank of the rank of the event being considered

3. Results

For this analysis conservative values of threshold between the Probability of Exceedence (POE) 33% to 20% was considered a dry year but no drought, POE between 20% and 10% is dry and nearing drought with POE (10%) and below considered a very drought year because Ghana seldomly experiences drought. These POE's were computed and is also shown in figure 3.

From figures 3 it could be deduced that the years 1983, 1992 and 2001 were actual drought years in Ghana. On the other hand 1977, 1988, 1993 and 2006 fell within the POE (20%) indicating that they were nearing drought years.

From the water levels plot (Figures 4 & 5) it is established that the dam fills up from July–October, and commences drawdown from November –June. According to VRA, the designed minimum drawdown of the impounded water for electricity generation is 72 meters. Yet in Figures 4&5, the years 1983, 1998, 2003, 2006 and 2007 had the recorded water levels falling below the minimum level for power generation indicating that the inflows into the dam was not adequate.

In Table 2, comparing rainfall in the nearing drought and drought years and electricity rationing years, it can be said that the power rationing years of 1983/84, 1998, 2006/07 were actually due to drought. However, the rationing year of 2003 cannot be wholly explained as a drought year. This may be due to effects of previous drought years of 2001 and below average rainfalls in 2002.

Table 2 Comparison of drought years and rationing years

Rainfalls nearing drought and drought years	Electricity rationing years
1997, 1983, 1988, 1992, 1998, 2001, 2006	1983/84, 1998, 2003, 2006/07

The computed hydrological drought using equation (2) shows a return period of 10 years from the 37 years of rainfall indicating that hydrological drought may return every 10 years.

4. Discussion

Socio economic consequence of Low inflows

The 2006/2007 electricity power rationing reduced power supply to households and Industry to about 24hrs light in 48 hrs and was the severest ever witnessed in Ghana with catastrophic consequences. Out of six turbines, only two were in operation churning about 400MW out of 1180MW from the hydropower generation unit. This affected all sectors of the economy including industry, mining and domestic. Manufactures reduced output, shortened the workweek and invested heavily in power generators. Drought left factories idle and broad swaths of Accra and other cities dark at night with the most feared result that years of efforts spent creating an image of Ghana as receptive to foreign investment could be jeopardized. Databank, a brokerage firm in Ghana estimated at the time that the outages were forcing companies to spend \$62 million a month, or about \$744 million a year, on extra power generation, or about 6% of the country's entire economic output. Databank-Ghana forecasted at the time that the power shortage cut 2007 economic growth from 6.5% to between 4% and 5% (Philips, 2007). The Statesman Newspaper of 19/2/2007 featuring an article titled "Power rationing cost Ghana ¢140bn in taxes" extolled. Further, the commissioner of Internal Revenue Service at the time disclosed at Akosombo that the power rationing programme made the Internal Revenue Service to lose revenue estimated at ¢140 billion (US\$ 14 Million) which could have been collected as taxes for Government in 2006. This, the Commissioner said was so because the power cut exercise made many companies in the country to record low earnings which affected taxes. In another comment on energy rationing in 2006 the Chief Executive of the Ghana Chamber of Mines reported on VOA news (VOA, 2006) that "Cutting back by 50 percent means that, it is almost like cutting back production by 50 percent, because, although we have installed capacity for self-generation, it's extremely expensive…," "It will mean getting regular supply of diesel, at the cost that we get it will perhaps mean generating power at 15 cent per kilowatt hour, which is almost three times what we get from VRA" (VOA, 2006). Also commenting on the sufferings of Ghanaians on the power rationing, Dr. Kwabena Anaman, director of research at Ghana's Institute of Economic Affairs said "if the situation persists, growth rates set out in this year's government budget will not be achieved. He says reliable energy is vital to the development of the country's economy" (VOA, 2006).

Droughts and climate change effects on the Hydropower generation

Climate has a great impact on ecosystems and hence the livelihoods of populations that depend on these systems (Boko et. al., 2007). Africa is one of the most vulnerable continents to climate change and variability. Lars (2006) attributed this high vulnerability of Africa to the following four reasons:

- Much of Africa, particularly Sub Sahara African, is in dry or sub humid agro-ecological zones and recent climate change models (GCMs) show that climate change will affect the rainfall patterns in these zones.
- A very large proportion of the African population, especially those in Sub-Sahara Africa, depends on natural resources for food and income. Therefore, changes in climate that impact these resources will have serious effects on the livelihoods of a vast majority of the African population.
- High levels of poverty and an already very high pressure on Africa's natural resource base means people have very little capacity to adapt to climate change.
- The continuous degradation of natural resources in the continent, such as the progressive degradation of the agricultural lands, forests and savannahs due to

unsustainable resource management practices, results in decreased natural capacity of these resources to adjust to changes in climate.

Ghana is well endowed with water resources, but the amount of water available changes markedly from season to season as well as from year to year (WRI, 2000). Droughts; one of the consequences of decreasing rainfalls as shown in this paper could be catastrophic to the nation. In August and September of 2007, the same year that the serious power cuts occurred, the basin saw widespread and devastating floods due to extreme rainfall from July-September. These floods displaced hundreds of thousands of people, particularly in the three northern regions, with resettlement and other mitigating costs estimated to be in the millions of dollars. This was an indication that the climate may be experiencing changes.

Literature such as WRI, (2000), Andah et al. (2004) Kuntsmann and Jung, (2005) and WRI, (2010) shows there is evidence of climate change effects on Ghana and its water resources. Noting that climate change in Ghana is a certainty, in whatever form the change may come hydropower generation could be affected one way or the other. If there is more precipitation than normal the dam could be put at risk because of structural problems and if it is less rainfall, then drought as evidenced in this paper could result.

5. Conclusion

Considering the thirty seven years of data used for this paper and four drought years identified, the return period for drought in this basin is 10 years. This paper establishes that 1983, 1998, 2006 were actually drought years and therefore the power rationing for the ensuing years of 1983-84, 1999, 2006-7 were deserving. However, the rationing year of 2003 could not be explained as a drought year. This may be due to effects of previous drought years of 2001 and below average rainfalls in 2002.

If socio economic consequences as a result of drought are to be mitigated there is the need to manage the hydropower dam and the hydrology of the basin sustainably to forestall many of the consequences such as loss of revenue, power rationing which may affect industry adversely and attendant socio economic problems.

It may be true that the traditional mainstays of Ghana's economy depend relatively little on electricity in the pre 2000 years. However, with the widening of the electricity coverage to most part of the country in the late 1990's and after the year 2000, this assertion may be faulted. From the above analysis vis a vis the socio economic problems encountered, Ghanaians acknowledge that there is the need for power sufficiency as many agree that industry must lead the way to the future if Ghana is to escape poverty. To industrialize means to build new industries which requires vital foreign investment. Though the Ghanaian business people are used to difficult situations like power rationing, investors looking to invest in Ghana, seeing problems like unreliable power supply due to low rainfalls and drought may reconsider their investment.

Thus there is the need to improve forecasting of extreme weather phenomenon such as droughts so that the consequences of this water shortage could be foreseen and curtailed. Adaptation measures could be employed if the problem is climate change. Fortunately the Government of Ghana has brought on board independent power generators who are contributing nearly 40-50 of present power supply in Ghana.

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