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The effects of irrigation dams on water supply in Ghana

SK Agodzo[1], E Obuobie[2], CA Braimah[3]
[1]*Agricultural Engineering Department, College of Engineering Kwame Nkrumah University of Science and Technology, Kumasi, Ghana*
[2]*Water Research Institute, CSIR, Accra, Ghana*
[3]*Agricultural Engineering Department, School of Engineering, Tamale Polytechnic, Tamale, Ghana*

Abstract: - Dams are constructed to even-out floods and droughts. This involves storing water when there is more than enough and using it when there is less than enough. The largest dams in the world (the Three Gorges dam (22.5 GW) in China, Itaipu dam (14 GW) in Brazil and Guri Dam (10 GW) in Venezuela) have been built for hydropower generation. Considering dams with a reservoir capacity of over 1 billion m^3, Africa counts 54 of such dams with a total reservoir capacity of about 726 billion m^3. Of these dams, 20 are multipurpose dams, mainly used for both hydroelectricity and irrigation, 22 are used mainly for hydroelectricity and 12 mainly for irrigation. In Ghana, the Akosombo, Kpong and Bui dams with a combined reservoir capacity of 162 billion m^3 are the largest hydropower facilities but Kpong and Bui also have irrigation purposes covering 3,000 and 5,000 ha of land respectively. Some lake shore irrigation activities also take place on the shores of the Akosombo lake. In addition, there are many other large, medium and small dams serving the purposes of irrigation and other multiple uses in Ghana. The largest irrigation dam in Ghana is located at Tono in the Upper East Region, with a capacity of about 93 million m^3 at full supply level. Irrigation dams in Ghana have been used mainly in rice and vegetable production. There are over 380 small to medium reservoirs in the three northern regions with surface areas averaging at 6 – 20 ha. Recently, commercial irrigation activities have sprung up where such water facilities are used for growing fruits and other horticultural crops for export, thus generating jobs and income in crop production. The embankment and catchment protection has been a major problem regarding the management of the dams and reservoirs in Ghana. Larger dams can be disruptive to the surrounding ecosystem, both upstream and downstream. In northern Ghana especially, the problem of reservoir siltation limits the benefits from the reservoirs. In the Upper East Region, crocodiles which are considered sacred and protected animals, live in about 27 reservoirs and often make burrows in the dam walls, thus weakening such structures and making them vulnerable to failure during floods. Structural failures also occur due to poor design and construction. For Ghana, nearly 9.44 million animals in 2010 would have consumed up to 22 million m^3 of water. This should be equivalent to the maximum safe storage of the Bontanga reservoir in the Northern Region of Ghana. Irrigation dams in Ghana have served purposes other than irrigation and the need for multiple considerations in design cannot be over-emphasised.

***Keywords**: - dams, floods, droughts, irrigation, multiple use, ecosystem disruption, structural failure.*

I. INTRODUCTION

The global water estimate (Table 1) amounts to about 1.36 x 10^9 km^3. Only about 0.6 % of the total water is available as fresh water but even about half of that amount is groundwater which is estimated to be below a depth of 800 below ground level (*bgl*). What is said to constitute fresh water amounts to about 2.7 % of the total available water while 97.3 % constitutes salt water. With the global population of about 7 billion as of February 2012, a per capita fresh water resource is about 5 million m^3. This does not account for animals and other ecosystem uses, suggesting that the rising demand for fresh water is putting a lot of pressure on the resource. The world consensus is that future wars may be fought because of water and not oil.

Ghana is divided into three river basin systems—the southwestern rivers system, the coastal rivers system and the Volta River system—based on topography, rainfall and vegetation. The total annual mean runoff for Ghana is 54.4 billion m^3 of water, of which 39.4 billion $m^{3,}$ or 68.6 percent, is generated within Ghana's borders (WRI, 2010).

Table 1. Estimated earth's water inventory

Location	Volume (10^6 km^3)	% total water
Fresh water lakes	0.125	0.62
Rivers	0.00125	
Soil moisture	0.065	
Groundwater	8.250	
Saline lakes and inland seas	0.105	0.008
Atmosphere	0.013	0.001
Polar ice caps, glaciers and snow	29.20	2.10
Seas and oceans	1320	97.27
Total	**1358**	**100**

Source: Wilson (1982)

The remaining 32.4 percent, or 15 billion m^{3,} is generated outside Ghana's borders. About 70 percent of Ghana lies within the Volta River system, 22 percent within the south-western rivers system, and 8 percent within the coastal rivers systems. These provide 64.7 percent, 29.2 percent, and 6.1 percent, respectively of runoff (WRI, 2010).

Dams are constructed to even-out floods and droughts, thus regulating water supply. This involves storing water when there is more than enough and using it when there is less than enough. The largest dams in the world (the Three Gorges dam (22.5 GW) in China, Itaipu dam (14 GW) in Brazil and Guri Dam (10 GW) in Venezuela) have been built for hydropower generation and have generating capacities exceeding 10 GW. The International Commission on Large Dams (ICOLD) defines a large dam as one with the height of 15 m or more from the foundation. But dams 5-15 m high with a reservoir volume of more than three million m^3 are also classified as large dams. Based on this definition, there are more than 45 000 large dams around the world; most of them were built in the 20th century to meet the constantly growing demand for water and electricity. Almost half of such dams are said to be in China. Hydropower supplies 2.2% of the world's energy and 19% of the world's electricity needs and in 24 countries, including Brazil, Zambia and Norway, hydropower covers more than 90% of national electricity supply. Half of the world's large dams were built exclusively or primarily for irrigation, and an estimated 30-40% of the 277 million hectares of irrigated lands worldwide rely on dams. As such, dams are estimated to contribute to 12-16% of world food production (FAO AQUASTAT, 2007).

Whereas there have been immense benefits to the construction of dams, they have always come under serious criticism due to their ecosystem disruptive nature. For example, the Bui Dam, the third largest hydropower dam in Ghana with 400 MW generating capacity has come under serious criticism for its expected ecological disruptive effects of the Bui National Park in Ghana because it could flood about 20% of the park and impact the habitats for the rare black hippopotamus as well as a large number of the native wildlife species. It will also require the forcible resettlement of 1,216 people, and affect many more.

In line with the increasing pressure on the world's water resources, this paper discusses the effects of irrigation dams on water supply, especially in Ghana. The paper will review irrigation dams in Africa and in particular Ghana in the multiple use context.

II. IRRIGATION DAMS OF AFRICA

Africa regional inventories include almost 1 300 large and medium-size dams in Africa, 40% of which are located in South Africa. Most of these were constructed coinciding with rising demands for water from growing populations. Information on dam height is only available for about 600 dams and of these 550 dams have a height of more than 15 m. Information on reservoir capacity is available for all inventoried dams and more than half have a capacity of more than three million m^3 . Less than 5% of the dams has a reservoir capacity of more than 1 billion m3 , 10% between 0.1 – 1 billion m^3, 20% between 0.01 – 0.1 billion m^3 , and 35% between 0.001 – 0.01 billion m^3 . The majority of dams in Africa have been constructed to facilitate irrigation (52%) and to supply water to municipalities (20%). Almost 20% of dams have multiple purposes, of which irrigation is almost always one of the purposes. Although only 6% of dams were built primarily for electricity generation, hydroelectric power accounts for more than 80% of total power generation in 18 African countries and for more than 50 % in 25 countries. Only 1% of African dams have been constructed to provide flooding control, according to the World Commission on Dams (FAO AQUASTAT, 2007).

Considering dams with a reservoir capacity of over 1 billion m^3, Africa counts 54 of such dams with a total reservoir capacity of about 726 billion m^3, or almost 90% of the capacity of all dams in the inventory. Of these dams, 20 are multipurpose dams, mainly used for both hydroelectricity and irrigation, 22 are used mainly for hydroelectricity and 12 mainly for irrigation. Eight of these large dams have a reservoir capacity of over 10 billion m^3 each and three of over 100 billion m^3 each (Kariba on the Zambezi River with 188 billion m^3, Aswan on the

Nile River with 162 billion m^3 and Akosombo on the Volta River with 148 billion m^3). The reservoir capacity of these three dams represents almost 70% of the total capacity of the 54 dams. While the Kariba Dam and the Akosombo dam have been built for hydroelectricity, the Aswan Dam was built for irrigation in Egypt. (FAO AQUASTAT, 2007). The distribution of the large dams within the different international river basins is given in Table 2.

III. JUSTIFICATION AND OVERVIEW OF IRRIGATION DAMS IN GHANA

The water year in Ghana starts on the first day of March each year and ends on the last of February the following year. Officially, the wet season begins on the first day of March while the dry season ends on the last day of February. However, there are some spatial variations in the hydrological calendar. The average annual rainfall for Ghana is about 1200 mm and this should be sufficient to grow most of the staples in Ghana. Even the coastal savannah belt of Ghana which records the least rainfall has average annual rainfall of about 850 mm. Except in cases of occasional extreme climatic conditions that lead to the destruction of crops, rainfall amounts can be described as adequate for most crops but the distribution has been uneven both geographically and seasonally. Dividing the country into south and north, the rainfall regime is bimodal in the south but uni-modal in the north. Water surplus of rainfall over potential evapotranspiration is higher in the south than the north for the wet months. At the same time, water deficits of rainfall over potential evapotranspiration are smaller in the south than the north for the dry months. This explains why even though the north has fairly good amounts of rainfall, the much higher potential evapotranspiration rates results in huge water deficits for plant growth. Hence the need for irrigation in especially the north of Ghana.

The 1950s and early 60s saw the development of some water schemes in Guinea, Sudan and Coastal Savannah belts, accounting for some 240 earth dams and dugouts in the north and about 66 in the Ho-Keta plains of the south (Nartey, 1983 and cited by Agodzo and Bobobee, 1994).

Table 2. Some large dams by international river basins in Africa

River Basin	Countries in basin	Number of existing large dams (> 1 billion m^3)	Height of dams (m)	Reservoir Capacity range (billion m^3)	Total reservoir capacity (billion m^3)	Main purpose*
Senegal	Guinea, Mali, Mauritania, Senegal	1	70	11.3	11.3	I
Niger	Algeria, Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, Guinea, Mali, Niger, Nigeria	6	23-79	2.2 – 15.0	31.4	I,H
Lake Chad	Algeria, Cameroon, Central African Republic, Chad, Niger, Nigeria, Sudan	4	14 – 48	1.9 – 6.5	16.6	I
Volta	Benin, Burkina Faso, Côte d'Ivoire, Ghana, Mali, Togo	3	? - 135	1.4 – 148.0	162.0	I,H
Nile	Burundi, DRC, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, Sudan, Tanzania, Uganda	6	22 - 111	0.9 – 162.0	174.9	I,H
Zambezi	Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia, Zimbabwe	3	70 - 171	4.9 – 188.0	231.9	I,H
Orange	Botswana, Lesotho, Namibia, South Africa	5	? - 185	1.3 – 5.7	14.2	I,H
Congo	Angola, Burundi, Cameroon, Central African Rep, Congo, DRC, Rwanda, Tanzania, Zambia	2	50 - 58	na	na	H
Rift Valley	Djibouti, Eritrea, Ethiopia, Kenya, Sudan, Tanzania, Uganda	2	42 – 155	1.6 – 1,9	3.5	I,H
Save	Mozambique, Zimbabwe	1	67	1.4	1.4	H
Incomati	Mozambique, South Africa, Swaziland	1	46	1.3	1.3	I,H
Cunene	Angola, Namibia	1	58	2.6	2.6	I,H
Mono	Benin, Togo	1	44	1.7	1.7	I,H

Source: Updated data from FAO-AQUASTAT (2007); * I = Irrigation, H = Hydropower; na = not available

One of the policy objectives of the 7-year development plan of the first republic concerning irrigation was to increase technical efficiency of agriculture through the application of research, irrigation, mechanization and all the fruits of science and technology, with the overall goal of expanding trade, earning foreign exchange and reducing the importation of such foods and raw materials as can be economically grown locally. In 1977, the Ghana Irrigation Development Authority (GIDA) was established by law to perform all duties related to irrigation development in Ghana (Agodzo, 1998). This further propelled the development of irrigation dams in Ghana.

The Kpong and the Bui dams are the largest multi-purpose hydraulic structures, not only generating hydropower but also supporting irrigation. Presently, 3000 ha have been developed under the Kpong irrigation project while 5000 ha is to be developed under the Bui project, with possibilities of further expansion. Although Akosombo dam was not originally intended for irrigation, some lakeshore schemes at Amate, Lamassa and Kpando Torkor, covering 400 ha were developed. Most of the small dams constructed in Ghana are not meant for irrigation only but also animal watering and even domestic uses. Weija dam (Greater Accra Region) also serves a multipurpose use of urban water supply for Accra and irrigation for the urban market. Tono is the single largest facility constructed for irrigation in Ghana and located in the Upper East Region. Other notable facilities constructed for irrigation include Dawhenya (Greater Accra Region) and Bontanga (Northern Region). The technical features of some of these dams are shown in Table 2.

Table 2. Technical features of some irrigation dams in Ghana

Description	Unit	Specification			
		Bontanga	Dawhenya	Tono	Weija
Type of dam		earthfill	earthfill	earthfill	earthfill
Elevation of the crest of dam	m	128.58	14.8	182.57	17.07
Volume of dam	m^3	na	na	na	260,100
Length of dam	m	1,900	915	3,471	374.90
Crest width	m	5	5	na	na
Length of emergency spillway	m	60.5	na	60.0	39.1
Elevation of the top of spillway					
• drop inlet spillway	m	122.58	na	na	na
• emergency spillway	m	124.05	11.65	179.22	3.36
Maximum reservoir surface area	$10^6\ m^2$	7.7	2.50	18.6	15.24
Maximum water surface elevation	m	122.58	5.8	179.22	7.62
Minimum water surface elevation	m	116.74	2.3	172.47	14.33
Maximum reservoir storage	$10^6\ m^3$	25.0	5.8	93	116.04
Maximum safe storage	$10^6\ m^3$	20.0	4.6	83	na
Spilling capacity at maximum water elevation					
• drop inlet spillway	m^3/s	85.0	na	na	na
• emergency spillway	m^3/s	103.0	118.5	500.0	na

Source: Compiled by Agodzo (1998) from GIDA sources; na - not available or not applicable

Irrigation dams in Ghana have been used mainly in rice and vegetable production. Recently, commercial irrigation activities have sprung up where such water facilities are used for growing fruits and other horticultural crops for export, thus generating jobs and income in crop production. The embankment and catchment protection has been a major problem regarding the management of the dams and reservoirs in Ghana. Larger dams can be disruptive to the surrounding ecosystem, both upstream and downstream. In northern Ghana especially, the problem of reservoir siltation limits the benefits from the reservoirs. In the Upper East Region, crocodiles which are considered sacred and protected animals, live in about 27 reservoirs and often make burrows in the dam walls, thus weakening such structures and making them vulnerable to failure during floods (Mbinji, 2010). Structural failures also occur due to poor design and construction.

There are a number of small irrigation dams in northern Ghana with lengths ranging between 400 and 1000 m with command areas usually up to about 10 ha. With a large number of registered beneficiaries on such projects, land holding per farmer is usually very small**.** Small reservoirs are always in high demand in the three northern regions. With over 270 reservoirs as presented in Table 3, their surface areas range from a little over 1 ha to 1800 ha. Average storage capacity ranges from 85 km^3 for those in the Upper West Region to 1,600 km^3 in the Upper East Region.

Table 3. Small reservoirs in the northern savannah area

Region	No. of reservoirs	Total area of reservoirs (ha)	Reservoir area ranges (Mean area in brackets) (ha)	Total volume of reservoirs ($km^{3)}$ (Mean in brackets)
Upper East	174	3481	1.05-1813 (20)	277,552 (1,600)
Upper West	112	637	1.06-51.98 (5.68)	9,500 (85)
Northern	102	1558	1.05-776 (15.3)	80,500 (788)

Source: Kizito 2011; cited by Svendsen et al, 2011.

These reservoirs serve as an important source for irrigation water and have been found to have little impact on the flow regime of the White Volta River (Hagan, 2007). The reservoirs are often within closed basins with minimum or no surface water discharge during the dry season (Bharati et. al., 2008). They allow for storage of water during the rainy season, with storage being released for dry season farming as well as recharge for local groundwater systems. They also serve as animal watering points.

IV. OTHER ISSUES

Improving cost-effectiveness of irrigation dams:

Irrigation systems design and construction, including dams, have come under criticism because of poor quality of work. Considering the huge investments involved, the argument is that the civil works do not give value for money. Only two things can be done with a structurally-defective dam. It can be repaired if the defect is minor. But if the defect is major, the cost of repairing it may be equivalent to constructing a new dam. The facility could be abandoned but in the northern Ghana environment where water is in high demand, any pool of water behind such defective dams could still attract multiple uses. Increasing the value generated by water use and decreasing associated costs requires interventions and understanding that looks beyond the direct value of agricultural produce, including livelihood and ecological benefits and costs. Strengthening the planning, design and construction supervision capabilities of GIDA and other service providers will further improve cost-effectiveness of irrigation dams in Ghana. This will require the development of irrigation design and practice standards for Ghana and the enforcement of such standards. This will also enforce the multiple use concepts of water facilities through appropriate design adaptations.

Multiple use dams:

Multiple use systems – where water serves crops, animals, fish, and domestic purposes – can increase the value derived per unit of water. Some estimates of water consumption (Table 4) for the 2010 population of cattle, sheep and goats in 23 selected countries in the Americas, Africa, Europe, Asia and the Oceania amounted to about 16.44 million m^3 per day for nearly 1.4 billion animals. The annual water consumption by the same animals for the same period works out to about 6 billion m^3. For Ghana, nearly 9.44 million animals in 2010 would have consumed up to 22 million m^3 of water. This should be equivalent to the maximum safe storage of the Bontanga reservoir in the Northern Region of Ghana. Animal production requires provision of adequate water at vantage locations for the animals and this is necessary for a good performance of the animal industry in Ghana and elsewhere. Quite often, when it comes to the construction of dams, consideration of such facilities for animals comes as after – thoughts. Direct interventions for animal watering facilities in Ghana are few and incomprehensive. The huge potentials of the animal industry cannot be achieved without adequate provision of water, where dams provide some options.

Table 4. Estimated animal water consumption for some selected countries in 2010

Region	Country	[1]Animal Population in 2010			[2]Estimated Daily water consumption (l/d)
		Cattle	Goats	Sheep	
North America	USA	92,582,400	3,000,000	5,530,000	1,790,408,128.00
	Canada	12,460,000	177,698	813,600	240,331,392.00
Europe	Germany	12,706,229	220,000	2,370,000	251,397,164.13
	UK	10,109,787	92,951	31,084,338	316,491,815.39
	France	19,597,825	1,308,239	8,446,627	410,790,204.25
	Italy	5,786,111	1,112,060	749,716	117,209,629.67
	Denmark	1,629,516	25,284	165,774	31,676,150.52
	Netherlands	3,967,599	374,184	1,116,609	81,228,525.03
	Russia	4,376,670	na	na	83,025,429.90
Africa	Burkina Faso	8,398,459	12,342,454	8,243,238	241,661,535.23
	Mali	8,794,545	12,424,345	10,038,035	256,682,038.65
	Ghana	1,448,011	4,464,338	3,530,688	59,448,872.67
	Niger	9,818,339	13,648,687	10,939,988	284,608,590.83
	Nigeria	15,270,169	101,554,113	53,566,458	910,157,389.93
	Botswana	2,651,098	884,114	186,552	54,573,993.06
	Egypt	3,417,273	na	na	64,825,668.81
	South Africa	11,547,078	5,025,607	26,575,066	345,450,761.66
South America	Argentina	50,946,937	4,295,951	14,639,217	1,042,204,066.89
	Brazil	207,271,447	8,443,293	15,197,066	4,026,500,785.59
Asia	Japan	4,376,670	na	na	83,025,429.90
	India	199,075,000	140,537,000	71,558,000	4,624,832,750.00
Oceania	Australia	27,000,000	na	67,700,000	782,990,000.00
	New Zealand	9,811,668	184,870	37,322,093	336,155,193.96
	Total	**723,042,831**	**310,115,188**	**369,773,065**	**16,435,675,516.07**

Source: [1]World Animal Health Information Database (2011); [2]Author's estimate (2012)

V. CONCLUDING REMARKS

To meet the MDGs on hunger and poverty with present practices in agriculture globally will require 9,700 cubic kilometers of agricultural evapotranspiration by 2025, up from the 6,100 used in 2005 (Molden *et al*, 2007). This will lead to more intense competition for water resources. Increasing water productivity - the agricultural output per unit of water used in agriculture - reduces the need for additional water in irrigated and rainfed systems. Water productivity is thus an appropriate response to growing water scarcity pressures including the need to free up water to sustain ecosystems and to meet the growing demands of cities and industries.

Opportunities for improving the productivity of water for crops, livestock, fisheries and forestry are many. Many farmers in developing countries could raise water productivity by choosing accepted agronomic and water management practices. Such practices can lead to water savings at farm level from 40% of the water supply to 200% in some rice based systems (Molden et al, 2007). Dams will continue to play a crucial role in water supply for multiple uses as irrigation and livestock watering and the demand will continue to grow. Improved management of such water facilities in the face of the increasing water demands cannot be taken for granted.

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