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RESEARCH PAPER

ASSESSMENT OF THE WATER BALANCE OF THE BAREKESE RESERVOIR IN KUMASI, GHANA

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ABSTRACT
The Barekese Reservoir constructed across the Offin River provides 80% of the total public pipe borne water supplied to the Kumasi metropolis and its environs. The reservoir was designed to produce both potable water and hydropower, however, the hydropower component has not been implemented since its construction in 1971. There is also reported land cover degradation in the catchment area which has the propensity to alter the hydrologic cycle and hence runoff into the reservoir. A 10 year water balance has been assessed for the Barekese Reservoir using an integrated Remote Sensing and GIS approach for estimation of surface runoff based on Soil Conservation Service Curve Number (SCS-CN). The SCS-CN model was calibrated against observed discharges recorded at Offinso located 10.3km upstream from Barekese and the result of the calibration used to simulate runoff into the reservoir. The SCS-CN model produced an R^2 value of 0.84 and an efficiency of 82.68%. Monthly observed reservoir levels were used for the calibration and validation of the water balance model. The water balance model produced an R^2 value of 0.84 and an efficiency of 81.9%. The monthly water budget revealed that total catchment runoff and direct precipitation respectively constituted 94.32% and 5.68% of the inflows while spilled water, water withdrawal and evaporation respectively amounted to 72.19%, 20.85% and 6.96% of the outflows. This result reveals that the reservoir is being underutilized. The current average production of treated water is 109,000m^3/day but the reservoir can safely yield the design capacity of 220,000m^3/day and an additional average hydropower of 368.6kW in six months during the rainy season provided the economic analysis for the hydropower generation is found to be justifiable.

Keywords: *Water balance, Barekese Reservoir, SCS-CN model, Offinso, Hydropower*

INTRODUCTION
The anthropogenic disturbance of the water cycle through agriculture, deforestation and urbanization can cause considerable changes in the fluxes of runoff, groundwater table, base flow and sediment erosion (Vörösmarty and

Sahagian, 2000; Sumarauw and Ohgushi, 2012). The Barekese Reservoir provides about 80% of the total public pipe borne water supplied to the Kumasi metropolis and its environs (Kumasi *et al*., 2009). The reservoir has a 15-metre high, 600-metre long earth-filled dam built across the Offin River between 1967 and 1971 (Maoulidi, 2010). The characteristics of the reservoir are summarized in Table 1.

The Barekese Catchment area is currently being degraded as a result of anthropogenic activities (Kumasi *et al*., 2009, Boakye *et al*., 2008). According to Boakye *et al*. (2008), the trend of land use and land cover changes detected in the Barekese catchment area has potential consequences on the catchment characteristics and hydrology since land cover is a function of rainfall regime, soil conditions, geomorphology and the hydrologic cycle as a whole. These anthropogenic activities are likely to alter the water cycle and hence the runoff and sediment deposition. In spite of the key role that the Barekese Reservoir plays in the socio-economic development of the Kumasi Metropolis, the water balance of the reservoir has not been assessed to aid in the management of the water resource in the face of increasing anthropogenic threats as observed by Kumasi *et al*. (2009) and Boakye *et al*. (2008).

The reservoir was designed as a multipurpose reservoir to provide both potable water and hydropower but the hydropower potential has not been utilized. This is partly because there was no economic justification for additional expenditure on a power plant due to the low electricity tariffs and the availability of enough hydropower from Akosombo at the time of construction and hence, the hydropower phase was not implemented (Dernedde and Ofosu-Ahenkorah, 2002).

The country is currently being plagued with frequent power outages causing the country to lose between 2% to 6% of Gross Domestic Product (GDP) annually (Acheampong and Ankrah, 2014). In a bid to deal with the prevailing power interruptions in the country, the country has resorted to thermal power genera-

Table 1: Reservoir characteristics

Reservoir Characteristics	
Catchment area	906 (km^2)
Reservoir Capacity	
Gross (G)	35.3 million m^3
Dead Water (DW)	1.55 million m^3
Design Useable (DU = G-DW)	33.75 million m^3
Current Capacity	24.6 million m^3
Earthfill Embankment Crest Level	223.69masl
Earthfill Embankment Crest Length	526m
Spillway Length	77m
Earthfill Embankment Crest Width	6m
Height of Dam (max above river bed level)	18.5m
Height of Dam (max above foundation level)	21.5m
Spillway Crest Level	220.9 masl
Normal Retention Water Level	220.9 masl
Maximum Flood Water Level	222.4 masl

Source: (Hooijer and Track, 2009)

tion which is also far expensive compared to hydropower generation. Mini-hydro power generation for rural electrification has been recommended by many authors including Miller *et al.* (2011) and Arthur (2014) as a means to alleviate the prevailing power crises. Approximately 70 sites, with a total potential of 800 MW, have been identified for small hydropower generation in Ghana; however, none of these sites have been utilized up-to-date (Miller *et al.*, 2011). The implementation of the mini-hydropower facility at the Barekese Headworks could serve as a boost to catalyze the implementation of similar projects in other potential sites in the country. Mini-hydropower facilities generally result in rapid socio-economic development of surrounding communities.

Water balance analysis is a highly effective tool that relates local climate, geological, hydrological and land use conditions to the quantity of water available for groundwater recharge and surface runoff (Adie *et al*., 2012).

This study assesses the water balance of the Barekese Reservoir to aid efficient planning, management and decision making on the use of water in the reservoir. The output of the water balance provided an opportunity for the assessment of the hydropower potential of the reservoir. In this regard, the paper highlights how the water balance model could be used to optimize the benefits from a multi-purpose reservoir using the Barekese Reservoir as a case study.

RESEARCH METHODOLOGY

Study area

The Barekese Reservoir is located 19 km North-West of Kumasi between $06^{o}51.11'$ N; $010^{o}42.10'$ W and $06^{o}50'$ N; $010^{o}39.88'$ W on the Offin River in the Ashanti Region. Fig. 1 shows the location of the reservoir, dam and the catchment area with River Offin drainage network.

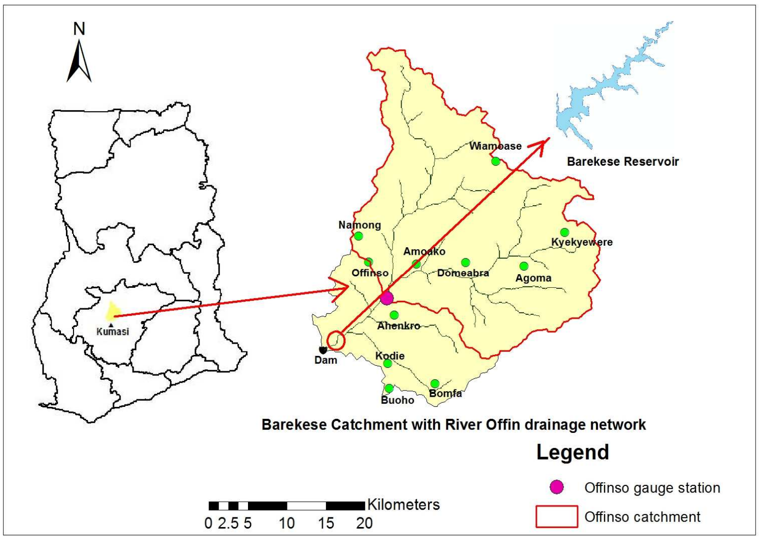

Fig. 1: Location of Barekese Reservoir, dam and catchment area with River Offin drainage network

The Barekese Reservoir lies within the River Offin Basin. The area has a semi-humid tropical climate with two rainy seasons: the main season from April to July and the minor season from September to October. The mean annual rainfall in the basin is about 1,368mm. The maximum temperature ranges between 30.2^{o}C to 31.5^{o}C whilst the mean minimum temperature ranges between 21.1^{o}C to 22.1^{o}C. The average relative humidity in the area is about 79% (Gyampoh *et al*., 2009, Turner *et al*., 1996).

The geology of the Barekese catchment area consist of Upper Voltain and Dahomeyan. The Upper Voltain underlie 3% of the area and consists mainly of sandstone while Dahomeyan underlie 97% of the area and consists of granitoid undifferentiated. The geology of the catchment area shown on Fig. 2 was prepared from a shapefile of the geology of Ghana produced by the Geological Survey Department of Ghana.

The basin lies in a moist semi-deciduous forest region. The area is characterized by plant species of the *Celtis-Triplochiton Association*. The vegetation in the catchment area is predominantly forest and this provides livelihood for the rural communities through subsistence farming. Fuel wood reserves and plantation have been established to protect the Barekese Reservoir (Adu, 1992, Turner *et al*., 1996, Gyampoh *et al*., 2009).

Much of the soil in the Ashanti Region consists of acrisols with some nitisols, leptosol, gleysols and fluvisols. They are developed in the weathering products of phyllites, schists, granites, sandstones, peneplain drifts and in terrace alluvia on gently undulating to strongly rolling topography. The texture of these soils varies according to the nature of the parent material (Adu, 1992).

The Offin River has several tributaries. Some of the streams often dry out during the dry

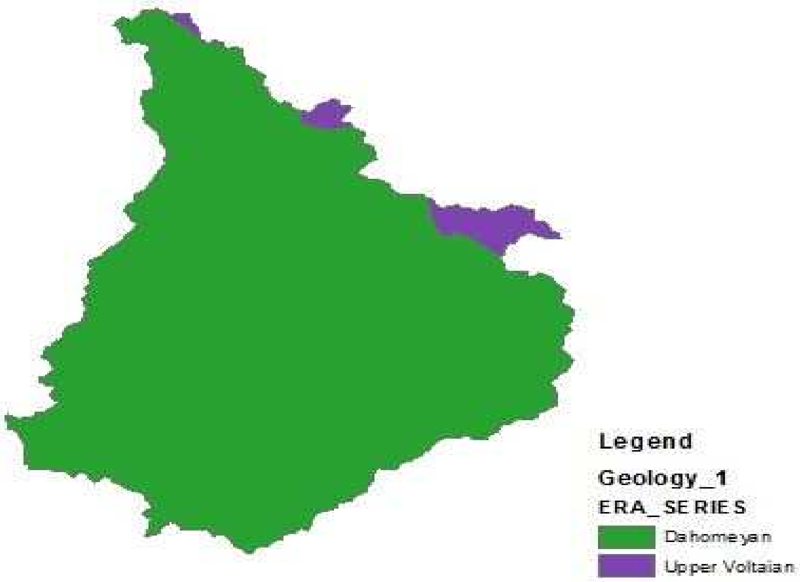

Fig. 2: The geology of Barekese catchment

season and fluctuate in water level during the rainy season. River Offin after Barekese joins the Upper Tano River along the Yenahin Range Watershed (Adu, 1992). The drainage network of River Offin at Barekese catchment area is shown in Fig. 1.

Water Balance Analysis

Model formulation of the water balance components

A generalized water balance model of a reservoir describes how water levels in a reservoir respond to various simulated inflow and outflow scenarios (Yeung, 2005). The generalized form of the model is given by:

$$\Delta S = \Sigma R(t) - \Sigma W - \Sigma S_p + \Sigma (P-E)A_s \pm G(t) \qquad (1)$$

Where ΔS is the change in the stored water volume in the reservoir, t is the time interval (monthly), ΣR is the total monthly runoff into the reservoir, ΣW is the total monthly water withdrawal, ΣS_p is the total monthly spilled water, P is the monthly rainfall onto the reservoir, E is the monthly evaporation from the reservoir surface, A_s is the surface area of the reservoir computed from the water level-area curve and G is the net monthly groundwater inflow into the reservoir.

Model reduction of the water balance components

Groundwater contribution to a reservoir over a long period is assumed to be negligible (Andreini *et al.*, 2000). Hence, the net groundwater contribution into the reservoir is considered minimal and therefore negligible ($G = 0$) relative to the other outflows and inflows. Besides, there exists no information on the net groundwater contribution into the reservoir. The simplified model then becomes:

$$\Delta S = \Sigma R(t) - \Sigma W - \Sigma S_p + \Sigma (P-E)A_s \qquad (2)$$

The components of the reservoir water balance model are shown in Fig. 3.

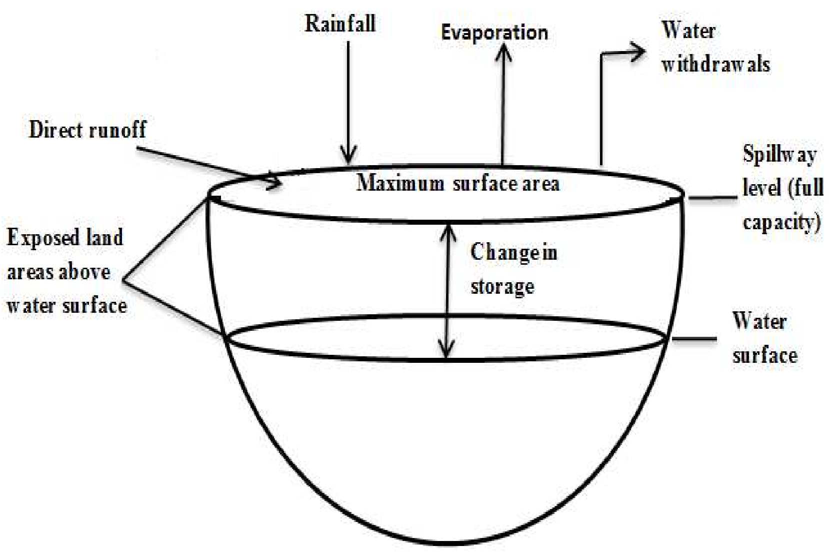

Fig. 3: Schematic view of the water budget of Barekese Reservoir (adopted from Yeung, 2005)

Determination of components of the water balance

Precipitation

The Ghana Meteorological Agency operates meteorological stations at Barekese, Offinso and Kumasi but Offinso and Barekese stations have not been operational since 2005 as a result of lack of personnel and adequate equipment. Kumasi Meteorological Station, on the other hand has up-to-date meteorological records. The monthly precipitation correlation between Kumasi and Offinso records was 0.71 for the period spanning 1990 to 2004 while the correlation between that of Kumasi and Barekese was 0.65 spanning 1993 to 2004. The absence of a very strong correlation could be attributed to inadequate monitoring of operations and records at the Offinso and Brekese meteorological stations. Under this prevailing condition, the study adopted the monthly precipitation records for Kumasi.

Catchment delineation, gauging and discharge measurement

The two catchment areas (Offinso and Barekese) were delineated in ArcGIS using SRTM DEM downloaded from GLCF at the University of Maryland, USA. The study employed the use of digitized soil map (shapefile) of Ghana produced by the Soil Research Institute of CSIR and the delineated catchment areas to prepare soil map for the catchment areas. The reclassification of the soil types into Hydrological Soil Group (HSG) was based on the FAO soil group classification as provided in Table 2.

Land cover maps for December 1986 and May 2007 were prepared using Landsat images in Erdas Imagine Software and merged with the soil maps in ArcGIS to generate curve number maps for Barekese and Offinso catchment. The unsupervised classification method was used for the land cover classification. The procedure for catchment delineation and derivation of curve number map is illustrated in Fig. 4. Since only few satellite images were used for the study, land cover change was assumed to be linear and hence the need to interpolate the land cover change for estimation of the weighted curve number for unknown periods in MS Excel. The SCS-CN relation given below was used to compute the runoff:

$$P_e = \frac{(P-0.2S)^2}{P+0.8S} \quad (3)$$

$$S(cm) = \frac{2540}{CN} - 25.4 \quad (4)$$

$$CN_w = \frac{\Sigma_{i=1}^{n} CN_i A_i}{\Sigma_{i=1}^{n} A_i} \quad (5)$$

Where P_e is the excess rain or direct runoff, S is the potential maximum retention, *CN* is the curve number. The estimation of the weighted

Table 2: Soil reclassification table

FAO Soil Class	Soil Composition	Reclassified SCS-CN HSG
Acrisols	sand, loamy sand and sandy loam soils	A
Leptosols	sandy clay loam soils	C
Lixisols	clay loam, silty clay loam, sandy clay, silty clay and clay soils	D

Source: USDA Soil Conservation Service, 1972

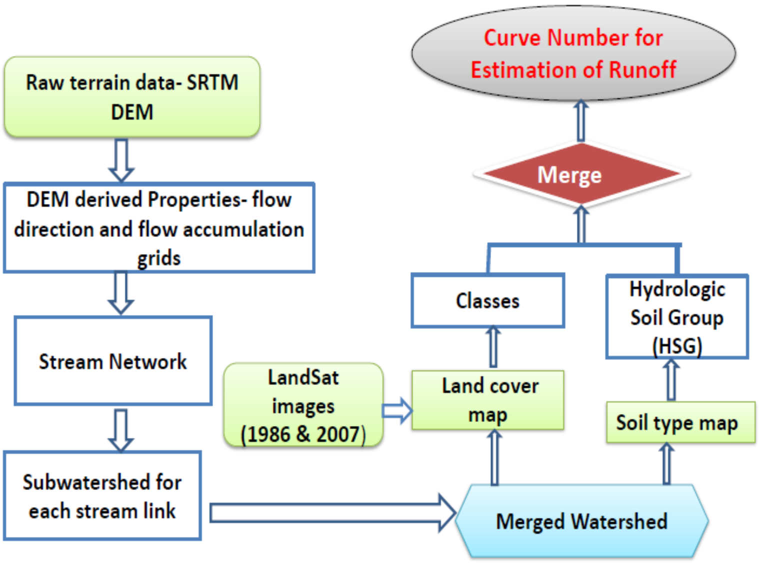

Fig. 4: Procedure for catchment delineation and derivation of curve number

CN_W value was based on the *CN* values for normal antecedent moisture conditions. CN_w is the weighted curve number, CN_i is the curve number for land cover type, A_i refers to the area with curve number CN_i whilst $\sum_{i=1}^{n} A_i$ is the total area of the catchment (Suphunvorranop, 1985, Chow *et al*., 1998, Shadeed and Almasri, 2010, Kumar *et al.*, 2010).

Runoff into the reservoir from the Barekese Catchment is only monitored at Offinso, located at 10.3km upstream from Barekese Reservoir, while the contribution from the remaining portion of the catchment area is not monitored (Fig. 1). The Offinso hydrological station is located at 06°53′N and 01°38′W. Since there is no gauge station on the reservoir, an SCS-CN rainfall-runoff model calibrated at Offinso was used to derive the monthly simulated runoff into the reservoir at Barekese. After obtaining the monthly runoffs from the SCS curve number model at Offinso Gauge Station, it was realized that the model was over-predicting the surface runoff hence the need to calibrate the model. The calibration was done by adjusting the model input parameter (weighted curve number) to ensure best simulated estimates for the observed stream flow at Offinso. In accordance with the Klemes split sample test, the first five years (2001-2005) was used for the calibration while the last five years (2006-2010) was used for the validation. The adjustment was subsequently applied to the weighted curve number estimated for the larger Barekese catchment to determine the simulated runoff into the Barekese Reservoir.

Evaporation

Evaporation from the water surface is not monitored at the headworks. The Penman method has been found suitable for evaporation estimation under any climatic conditions and for a time scale as long as one month (Kebede *et al.*, 2006). This evaporation model was therefore adopted for the study. The Penman evaporation is given by:

$$E = \frac{AH_n + E_a\gamma}{A + \gamma} \quad (6)$$

Where A is the slope of the saturation vapour pressure verses temperature curve at the mean air temperature, mm of Hg/°C , γ is the Psychrometric constant = 0.49mm of Hg/°C, H_n is the net radiation, mm of evaporable water per day, E_a is the parameter including wind velocity and saturation deficit.

$$H_n = H_a(1-r)\left(a + b\frac{n}{N}\right) - \sigma T_a^4\left(0.56 - 0.092\sqrt{e_a}\right)\left(0.1 + 0.9\frac{n}{N}\right) \quad (7)$$

Where H_a is the Incident (Extraterrestrial) solar radiation outside the atmosphere on a horizontal surface (mm of evaporable water per day), a is a constant depending on the latitude ϕ

$$a = 0.29\cos\phi \quad (8)$$

b is a constant with an average value of 0.52, n is the actual duration of bright sunshine, hrs, N is the maximum possible hours of bright sunshine (hrs), r is the reflection coefficient (albedo), σ is the Stefan-Boltman constant = 2.01×10^{-9}, is the mean air temperature in degree kelvin = 273+°C

$$E_a = 0.35\left(1 + \frac{U_2}{160}\right)(e_w - e_a) \quad (9)$$

E_a is the parameter including wind velocity and saturation deficit, U_2 is the mean wind speed at 2m above ground surface (km/day), e_w is the saturation vapour pressure at mean air temperature (mm of Hg).

$$e_w = 4.584\exp\left(\frac{17.27t}{237.3+t}\right) \text{ mm of Hg} \quad (10)$$

t is the temperature in ^oC, e_w- e_a is the vapour deficit, e_a is the actual vapour pressure

$$RH = 100\frac{e_a}{e^\circ(t)} \quad (11)$$

RH is the Relative humidity.

Meteorological data such as temperature, humidity and evaporation used to obtain the variables in the Penman Equation were obtained from Ghana Meteorological Agency, Kumasi. In situations where data such as slope of the saturation vapour pressure verses temperature curve, incident solar radiation, maximum possible hours of bright sunshine and reflection coefficient were not available, standard data from FAO Irrigation and drainage paper 56 by Allen *et al.* (1998) based on other primary meteorological data for the region were used.

Withdrawals

Information on monthly withdrawals from the reservoir was obtained from Ghana Water Company Limited (GWCL) Barekese Headworks Station, Kumasi. Withdrawals are estimates from pumping hours since there is no gauge in place for such function.

Spill

There is no monitoring of the quantity of water that leaves the spillway of the reservoir. Monthly spills were therefore estimated as excess of the storage capacity.

Hydropower generation potential of the reservoir

The hydropower potential of the reservoir was assessed as excess of the simulated discharge required to meet the design capacity of 220,000m^3/day of treated water with allowance for losses during treatment. GWCL estimates losses during treatment to be 5% of the total raw water (Antwi, 2005). The head H of the reservoir is 12m (Dernedde and Ofosu-Ahenkorah, 2002). British Hydropower Association estimates the overall system efficiency, η, to be in the range of 60%-80%. An average value of 70% was used for the computation.

If, Q, is the rate of flow (m^3/s) of water that is available for hydropower generation, and the reservoir has a head, H in meters, γ is the unit weight of water and η is the overall system efficiency then:

i) Water Power Potential, $P = \gamma \times Q \times H$ (12)

ii) Power of hydropower plant, $P_H = \gamma \times Q \times H \times \eta$ (13)

RESULTS AND DISCUSIONS

Catchment areas and land cover change

The estimated area of Barekese catchment and Offinso catchment are 893.26km^2 and 685km^2 respectively. Fig. 1 illustrates the two catchment areas. The soils found on the Barekese catchment area are Acrisols, Leptosols and Lixisols with percentage area coverage of 90.96%, 5.78% and 3.26% respectively. The map showing the soil types on Barekese catchment is depicted in Fig. 5. Since few satellite images were available for this study, satellite images for 1986 and 2007 were used. Land cover maps produced for the Barekese catchment area for 1986 and 2007 using the unsupervised classification are illustrated in Figs. 6 and 7 respectively. The results of the land cover classification reveal land cover degradation in the study area. From Table 3, open forest in the Barekese catchment area has decreased significantly by 44.85% within the period from 1986 to 2007 while closed forest has increased by 3.58%. The water body has reduced by 59.10%. Farmland/grassland/shrubs, open area and settlements have appreciably increased by 29.99%, 29.79% and 48.01% respectively within the same period. The merging of the land cover map and the soil map in ArcGIS produced the curve number map for the Barekese catchment area which is illustrated in Fig. 8. The curve number map was used for the estimation of the weighted curve number for the computation of surface runoff using the SCS-CN model.

Calibration of surface runoff

Fig. 9 illustrates the calibrated and validated discharge with observed discharge. The SCS

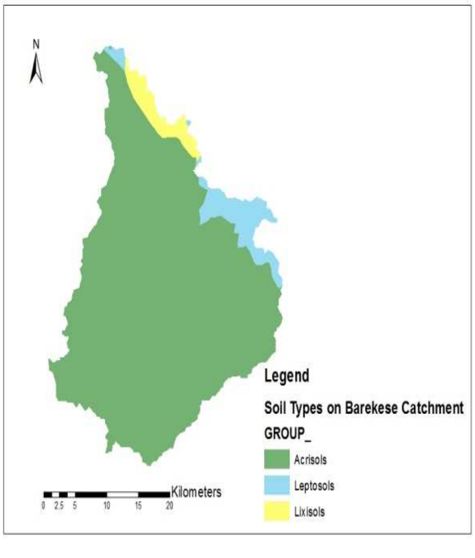

Fig. 5: Map showing the soil types on the Barekese catchment

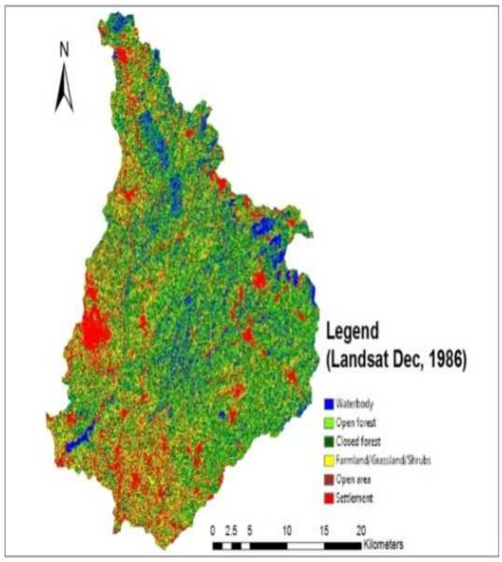

Fig. 6: Land cover map for Barekese catchment, 1986

model produced an R^2 value of 0.84 and an efficiency of 82.68%. This indicates a good performance with observed data.

Precipitation (Rainfall)

Monthly distribution of rainfall for the period of study is illustrated in Fig. 10. The catchment area falls under a region with a bimodal rainfall pattern which peaks from April to July in the major season and from September to October in the minor season. The maximum average monthly precipitation recorded in June was 204.3mm while the minimum average monthly precipitation recorded in January was 19.9mm. The mean annual precipitation was 1538.2mm.

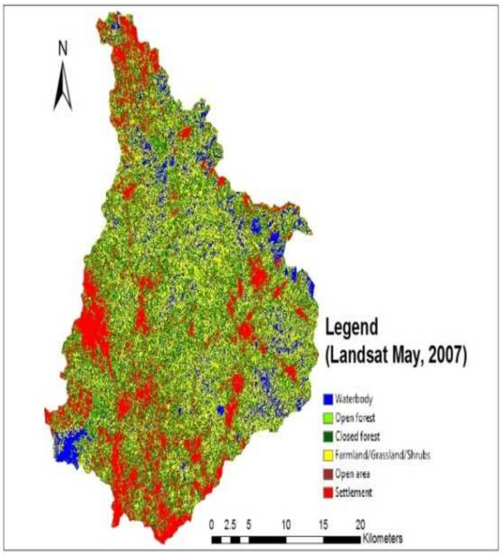

Fig. 7: Land cover map for Barekese catchment, 2007

Water Withdrawal

Monthly withdrawal for water supply from 2001 to 2010 ranged between 2,095,070m^3-2,114,596m^3 with an average of 2,104,891m^3 per month. Monthly water withdrawal from 2001 to 2010 is illustrated in Fig. 11.

Monthly pan evaporation estimated using the Penman Evaporation Model shows a fluctuation within the period which ranged between 5.42mm per day to 4.43mm per day with an average of 4.84mm per day. The estimated monthly evaporation using Penman Evaporation Model is illustrated in Fig. 12.

Calibration and validation of the water balance model

A monthly routing of the outflows and inflows was performed using the water balance model in Microsoft Excel. There has been a reduction in reservoir capacity from an initial gross capacity of 35.3 million m^3 in 1971 to a capacity of 24.6 million m^3 in 2009 (Hooijer and Track, 2009). Volume-elevation curves for 1999 and 2009 were used because of the changing reser-

Table 3: Land cover change in the Barekese catchment area (1986-2007)

Land cover	Area in 1986 (ha)	Percentage of total area in 1986	Area in 2007 (ha)	Percentage of total area in 2007	Change in Area (ha)	Percentage change
Waterbody	5454.66	6.09	2231.01	2.49	-3223.65	-59.10
Open Forest	21278.68	23.76	11735.19	13.10	-9543.49	-44.85
Closed Forest	24810.42	27.70	25698.51	28.70	888.09	3.58
Farmland/Grassland/ Shrubs	20775.49	23.20	27005.22	30.16	6229.73	29.99
Open Area	14445.79	16.13	18749.34	20.94	4303.55	29.79
Settlement	2790.57	3.12	4130.46	4.61	1339.89	48.01

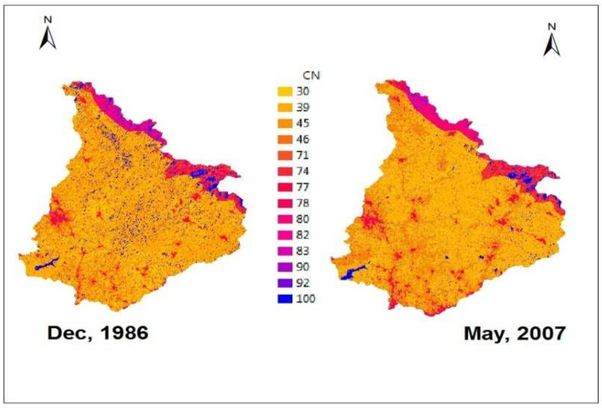

Fig. 8: Curve number map for Barekese catchment area

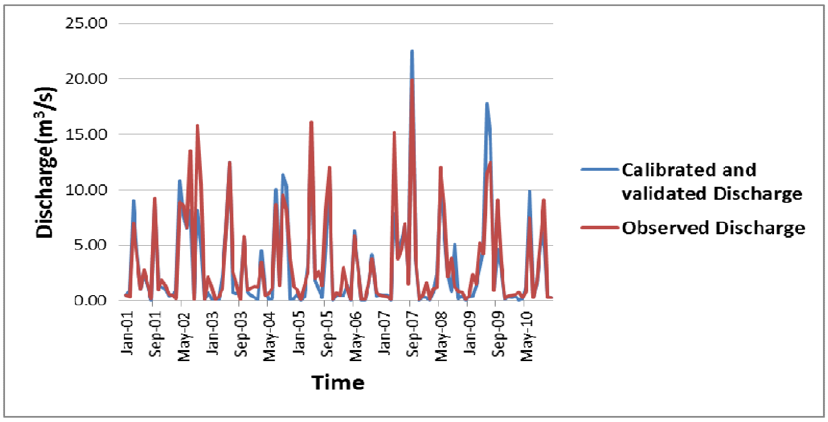

Fig. 9: Calibrated and validated discharge with observed discharge

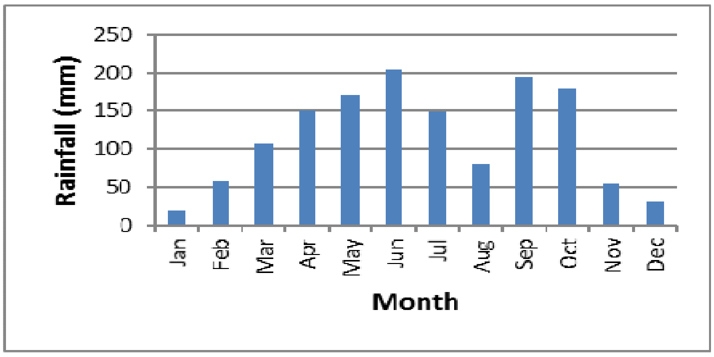

Fig. 10: Average monthly rainfall for Kumasi (2001-2010)

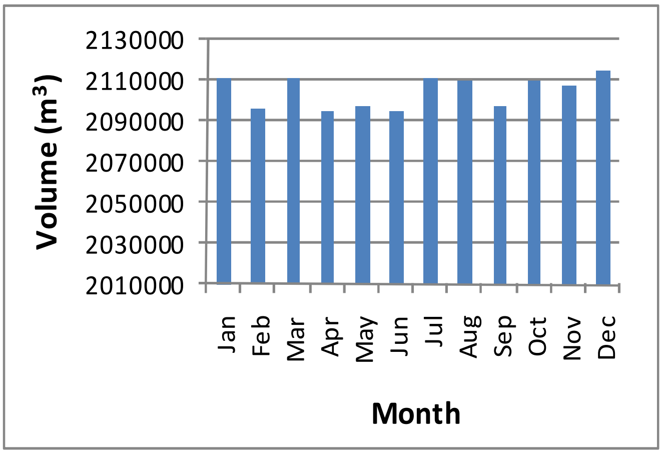

Fig. 11: Average monthly water withdrawal (2001-2010)

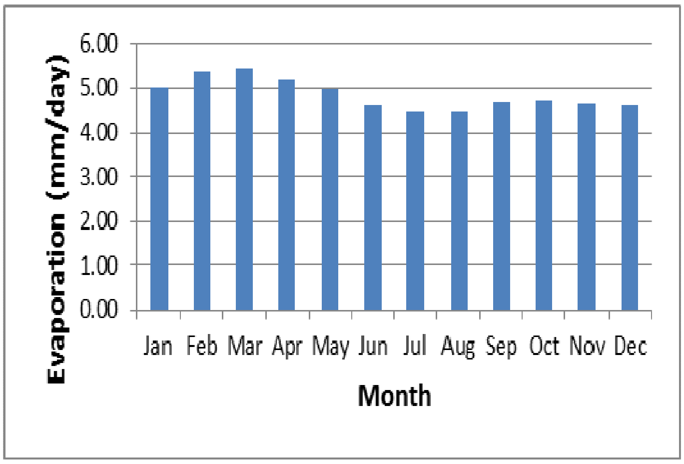

Fig. 12: Estimated average monthly evaporation for Kumasi using the Penman Evaporation Model (2001-2010)

voir storage as a result of sedimentation activities with time. The estimated reservoir capacity for the period 2001-2005 using Brune's and Brown's approach was generally comparable with storage capacity from the volume-elevation curve for 1999 and hence the curve was used for the calibration period (2001-2005) and that for 2009 fitted well for the validation period (2006-2010). Literature on Brune's and Brown's approach for estimation of reservoir capacity is found in Jothiprakash and Garg (2008) and Adwubi *et al.* (2009). Elevation 220.9 m.a.s.l. is the spillway crest level and hence considered as spill level in the simulation. It was realized that the simulated reservoir levels were generally slightly lower than

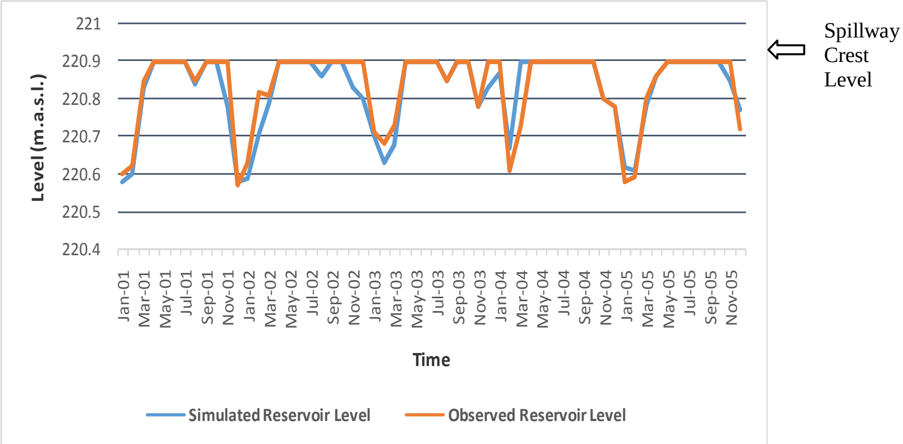

Fig. 13: Simulated and observed reservoir levels for the calibration period (2001-2005)

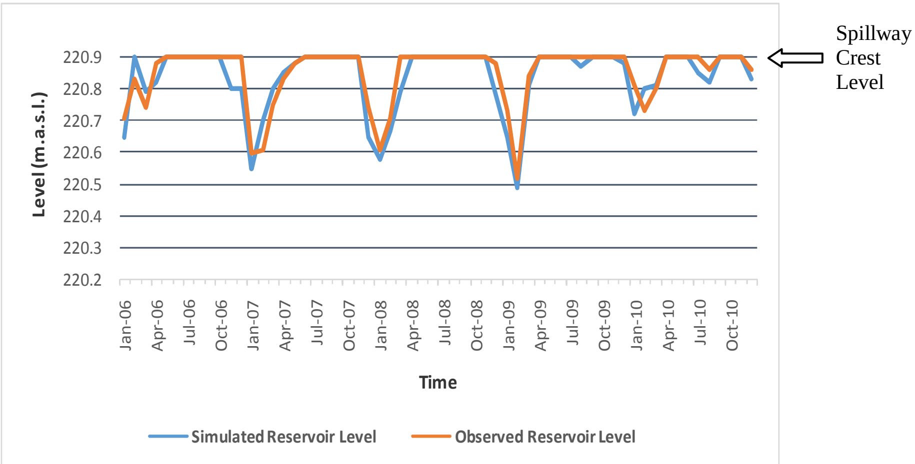

Fig. 14: Simulated and observed reservoir levels for the validation period (2006-2010)

the observed reservoir levels hence the need to adjust other inputs of the water balance model in order to simulate as close as possible to the observed reservoir levels.

Calibration involved adjusting correction coefficients associated with precipitation, evaporation and withdrawal by try-and-error method to fit simulated reservoir volumes to observed reservoir volumes. After calibration, the water balance model had R^2 of 0.86 and an efficiency of 84.8%. Fig. 13 illustrates the simulated and observed reservoir levels for the calibration period (2001-2005). The calibrated model was used to simulate runoff over an independent period outside the calibration period. The validated model has R^2 of 0.83 and an efficiency of 78.2%. Fig. 14 illustrates the simulated and observed reservoir levels for the validation period (2006-2010). The performance of the water balance model is provided in Table 4. The water balance model produced an R^2 of 0.84 and an efficiency of 81.9% for the entire period (2001-2010). The overall performance of the water balance could be described as being satisfactory. There exists a strong correlation between the measured and simulated reservoir levels.

From Fig. 15, it is observed that the water resource potential of the reservoir is being underutilized. From Table 5, withdrawal for water supply constituted only about 20.85% of the outflows while the amount of water spilled constituted 72.19%. The reason for the large volumes of spill could be attributed to the underutilization of the facility for water supply and hydropower. The design capacity of the Barekese Headwork for treated water production is 220,000m^3/day (Maoulidi, 2010) but the

Table 4: Performance of Barekese reservoir water balance model

Period	R^2	Efficiency (%)
Calibration (2001-2005)	0.86	84.8
Validation (2006-2010)	0.83	78.20
Entire period (2001-2010)	0.84	81.90

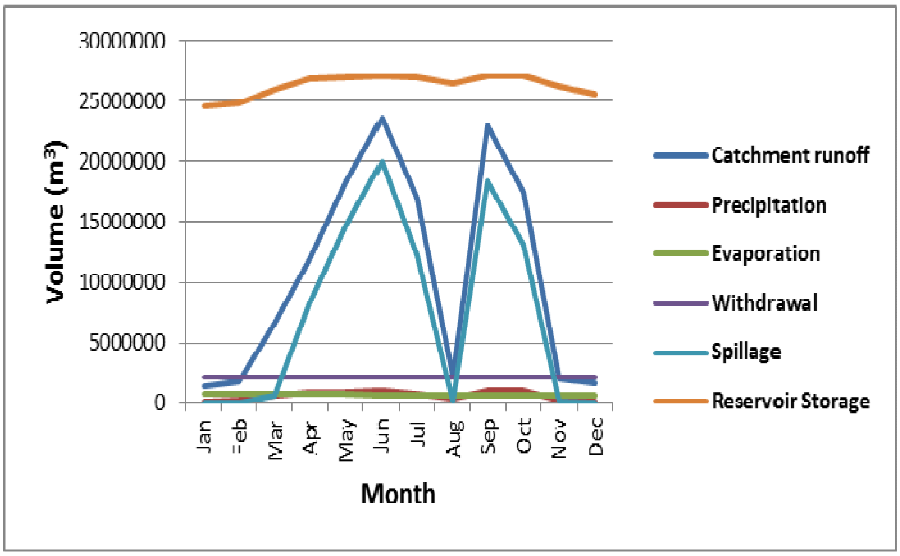

Fig. 15: Monthly reservoir volume and water budget

Table 5: Water budget of the Barekese Reservoir

Inflows		Outflows		
(percentage of total inflows)		(percentage of total outflows)		
Total runoff	Direct rainfall	Evaporation	Water withdrawals	Spill
94.32	5.68	6.96	20.85	72.19

Table 6: Monthly hydropower potential of Barekese Reservoir

Month	Water Power Potential P (kW)	Power of hydropower plant P_H (kW)
April	221.7	155.2
May	515.9	361.2
June	756.3	529.4
July	457.1	320
September	729.3	510.5
October	478.8	335.2
Average	**526.5**	**368.6**

headwork only produced about 59,392 m^3/day as at 2010 (Kuma *et al*., 2010) which is only about 27% of the design capacity. This problem of underproduction of treated water could be attributed to two main factors: inadequate power to run the pumps and inadequate expansion of the water treatment infrastructure (Maoulidi, 2010, Antwi, 2005). The current average production of treated water at the headworks is 109,000m^3/day.

Besides, the availability of facilities such as a penstock, a platform for the installation of a power generation turbine and excess water in the rainy season indicates the feasibility of operating a mini hydropower plant in the rainy season. GWCL could therefore consider the following options in order to maximize the water resource potential:

- Expanding the available facilities to treat more water for consumption
- Operating a mini hydro plant which could operate for six months of the year i.e. from April to July and from September to October.

From Table 6, the average monthly Water Power Potential, $\boldsymbol{P}$ and Power of Hydropower Plant, $\boldsymbol{P_H}$, in the months of operation are 526.5kW and 368.6kW respectively. According to Arthur (2014) a typical 60 kW small-scale hydropower plant could serve about 365 household with an average of 5 persons per household. Therefore, from computation using the 368.6kW power of the hydroplant at Barekese, the facility could serve about 2,242 household in the rainy season if implemented. In view of this, such a facility that generates electricity from excess water that would have otherwise been spilled will go a long way to add some amount of power to the national grid.

CONCLUSION AND RECOMMENDATIONS

In this study, the assessment of the water balance of the Barekese Reservoir was performed using an integrated Remote Sensing and GIS approach for estimation of surface runoff based on SCS curve numbers.

Total watershed runoff and direct precipitation respectively constituted 94.32% and 5.68% of the inflows while spilled water, water withdrawal and evaporation respectively constituted 72.19%, 20.85% and 6.96% of the outflows. The current average production of treated water is 109,000m^3/day but the reservoir can safely yield the design capacity of 220,000m^3/day and an additional average hydropower of 368.6kW in the rainy season. GWCL can maximize the water resource potential of the Barekese Reservoir by the implementation of the following options:

I. Expansion of facilities at the headworks to increase water supply

II. Operation of a mini hydro plant during the rainy season. This however should be subjected to economic analysis since the hydrological analysis is positive in the rainy season.

The power generation from the facility would alleviate the burden imposed on surrounding communities by the prevailing intermittent power outages in the country. Operation of the facility would also lead to the rapid socio-economic development of the area.

There is observed increasing degradation of the vegetative land cover in the Barekese Catchment area. Between 1986 and 2007, the open forest has reduced by 44.9% while farmlands have increased by 30%. Intensive education of the inhabitants and collaborative work among stakeholders is required to address the rate of forest degradation in the catchment area.

The Meteorological Stations at Offinso and Barekese should be reopened and furnished with the requisite equipment and personnel to enhance research study in the area. The spill from the reservoir should be monitored by setting up a hydrological gauge station downstream of the Barekese Dam or by periodic measurement of the head over the spillway.

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