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THE HYDRAULICALLY ASSISTED BATHYMETRY MODELING OF EFFECT OF WEATHER ON RESERVOIR WATER LEVEL

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Abstract: Life on Earth depends on water, yet water resources are severely stressed by the rapid growth of the human population and activities. The exploration and monitoring of water resources is a prerequisite for water accessibility and rational use and management. Surface water systems can be mapped using multispectral, digital image sensors and some other models. Therefore, this study analysed the effects of weather variations on the water level of Eleyele reservoir for a period of 32 years (1984, 2000, 2016 at 16 years interval) using the hydraulically assisted bathymetry model. Rainfall and temperature data were statistically analyzed using IDRISI Selva 17.0. The result of the weather variation shows 94% regression value between rainfall and temperature as they increased drastically in 2016.Hydraulically Assisted Bathymetry (HAB) model developed and used for estimating stream water depths showed open water area decreased from 122.73 ha to 101.55 ha and from 101.55 ha to 61.74 ha between years 1984 and 2000, and 2000 to 2016 respectively. In addition, the HAB model showed that between 1984 and 2016, the depth of the dam along the cross-section reduced by 0.2 m at the deepest part of the reservoir. This study established that reserved forest zone suffered degradation with a noticeable increase in encroachment on the dam level. This approach can be used to model the impact of weather variations on the water level of dam / reservoirs.
Keywords: weather; bathymetry modeling; reservoir; water level

INTRODUCTION

Water resource is a key factor in many economic activities ranging from agriculture to industrial production. Water is one of the most precious natural resources, which support human health, economic development and ecological diversity. It is the most valuable and vital resource for sustenance of life and for any developmental activity (Mishra, 2013). In Nigeria, as in any other African developing countries, population is heavily dependent on fresh water, forests, croplands and fisheries (Homer-Dixon and Blitt, 1998). Increased demand for fresh water resources associated with these trends is expected to be especially intense in rapidly urbanizing regions (Taylor *et al.*, 2004), and in the agricultural sector in order to boost food production (Carter*et al.*, 2009; MacDonald *et al.*, 2009).

The population growth has put pressure on the Africa's environment to sustainably provide goods and services to an increasing population with the current technologies, resulting in the loss of forests, animals, plant species, land degradation, increasing water shortages and declining water quality. At present, water resources are severely stressed and particularly scarce in most parts of the world (Sharma *et al.,* 1989). In many arid and semiarid regions for example, water shortage is a major obstacle to sustainable development and poverty alleviation and the cause of serious conflicts between some countries (Asadi *et al.,* 2012).

Water shortage can be further aggravated by the global climate change that is predicted to severely affect the regions of the world. Thus, exploration, mapping, and monitoring of water resources are a prerequisite for the availability, accessibility, fair utilization, and rational management of water resources in our world today (Asadi *et al.,* 2012, Yan *et al.,* 2010).

Throughout the world, water consumption is increasing more rapidly than the human population and has raised the socioeconomic and strategic importance of water resources (Alaaddin *et al.,* 2008).With the surface water sources dwindling to meet the various demands, groundwater has become the only reliable source. The indiscriminate use of this vital natural resource is creating groundwater-mining problem, hence water resource need evaluation to meet the ever-growing needs (Mishra, 2013).

— Models and Selection Scenario

Six watershed models were used to simulate hydrology and water quality among these, SWAT and HSPF was the most common, both utilized by three studies. The array of models suggests that no singular watershed model is appropriate for assessing cumulative impacts, and other factors may drive model selection. Butcher *et al.,* (2010) utilized both SWAT and HSPF, and selected them based on the requirements that a model be process-based, dynamic with daily time steps, able to simulate water quality, widely used and accepted, in the public domain and with an existing GIS interface. Thus, their rationale was in part mechanistic and in part based on ease of access. Praskievicz and Chang (2011) chose WinHSPF because it is one of the most commonly used public domain modeling systems with a large user community and abundant technical support, and because it is able to simulate water quality. The use of various watershed models allows researchers to examine their relative strengths and weaknesses. Butcher *et al.,* (2010) found that HSPF was better able to replicate observations during calibration and validation, but SWAT simulations of watershed response to changing conditions were more robust. All climate models were based on General Circulation Models (GCMs), although studies used varying GCMs from different sources. Nearly all studies relied on emissions scenarios developed in the United Nations Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios (SRES) to drive the GCMs, but they differed in the number of emissions scenarios they used. Nelson *et al.*, (2009) tested the A2 and B2 scenarios, representing mid-high and mid-low emissions, respectively. Both Viger*et al.* (2011) and Tu (2009) tested three scenarios, B1, A1B and A2, representing increasing emissions levels with B1 as the "best case" and A2 as the "worst case" in their analyses.

Franczyk and Chang (2009) relied on the A1B scenario, and Wilson and Weng (2011) and Praskievicz and Chang (2011) on the A1B and the B1 scenarios. Butcher *et al.,* (2010) relied only on the A2 scenario. Scenario selection reflects a choice by the researchers regarding the context of the results. Researchers using multiple scenarios sought to capture the variability implicit in the scenarios by including a range. Franczyk and Chang (2009) used the A1B scenario because it was the "middle of the road scenario", while Butcher *et al.*, (2010) used the A2 scenario because it was the "pessimistic" scenario. Only Tong *et al.*, (2012) did not rely on a climate model or SRES scenarios, and instead developed four hypothetical scenarios.

The use of these hypothetical allowed the authors to examine a range of responses, but may have limited practical application as the results are not predicted changes and cannot capture seasonal variability. Models often used for land use include FORE-SCE (Viger *et al.*, 2011), IDRISI (Wilson and Weng, 2011; Tong *et al.,* 2012) and a linear regression extrapolating historical land use trends (Tu, 2009). GIS are capable of managing large amounts of spatially related information, providing the ability to integrate multiple layers of information and to derive additional information (Arshad, 2008).

Krishnamurthy (1996) and Ramaraju (2006) used Remote Sensing and GIS techniques for water exploration and identification of artificial recharge zones.The studymodeled the Effect of weather on Eleyele reservoir (Dam) water levelby analysing the rainfall and temperature pattern within the study area for 32years and using hydraulically assisted bathymetry model to determine the water level.

MATERIALS AND METHODS

— The Study Area

Eleyele Dam covers the water storage area itself plus a strip of dry land surrounding the reservoir and varying in width from 30.48 m – 365.76m. It is located in Ibadan North West Local Government Area of Oyo State and lies within latitude 7°30' – 7°45' N and longitude 3°55' – 3°88' E. The area elevation is relatively low ranging between 100-150m above sea level and surrounded by quartz-ridge hills toward the downstream section where the Eleyele dam barrage is located.

The reservoir was made by damming River Ona with a total area of 526.0921 hectares and situated within the lower boundary of Guinea Savanna vegetation belt having the combination of equatorial and tropical hinterland climate (Akingbogun *et al.*, 2012). Figure 1 shows the Map of Ibadan showing the location of Eleyele Reservoir.

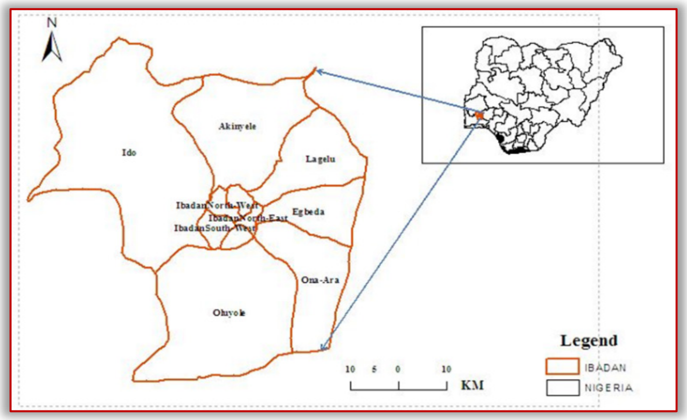


Figure: 1: Map of Ibadan showing the location of Eleyele Dam (Source: FRIN, 2016)

— Methods employed

This study employed GIS and Remote Sensing and the general procedure used in this study are described. Several data sets are prepared as inputs to the ArcGIS and IDRISI softwares.

— Data acquisition

Quick Bird/ Google Earth images for the delineation of the study area and Weather parameters.

— Data preparation

Eleyele basin images are covered by path 191 and rows 55. A supervised classifier (parallelepiped classification) was used to stratify the images.

— Cross-Classification Analysis

Categories of image 2000 were compared with those of 2016 and tabulation of the number of cells in each combination was produced. Cross classification was performed using CROSSTAB module in IDRISI. It performs an analysis that compares images containing categorical variables of two types which are hard classification in which all pixels in the maps have complete membership to exactly one category. CROSSTAB outputs a cross-classification image and table. The cross-tabulation output is a tabular matrix that shows the number of pixels that correspond to each combination of categories in the two images being compared. CROSSTAB expresses the tabular matrix in terms of the proportion of the total number of pixels. CROSSTAB gives summary statistics, such as the Cramer's V and Kappa (IDRISI manual, 2012).

The first of these measures is CRAMER'S V, a correlation co-efficient between the images that ranges from 0.0 indicating no correlation to 1.0 indicating perfect correlation. A chi-square statistics is output along with the appropriate degree of freedom (df 6) and the significance of the Cramer's V was tested. If the chi-square is significant, so it is Cramer's V. Since the 2 images have exactly the same number of categories, another measure of association called Kappa was produced, which is an Index of Agreement for each category.

— The hydraulically assisted bathymetry model

For this study, a remote sensing model named the model hydraulically assisted bathymetry (HAB) model (Mark *et al*, 2005) was used for estimating stream water depths without the use of ground crews was adopted. The models is based on simple concepts of open-channel flow and require only slope data for the stream bed and discharge data from a nearby gaging station at the time of image collection. HAB model does not require ground data on depths or water optics thus removing logistical obstacles associated with field surveys and radiometric calibration and enable depth estimates using historical and modern photos and digital data. This model utilized Beer–Lambert law, which describes the exponential absorption of light in water columns where scattering is minimal:

$$I = I_o e^{-BD} \quad (1)$$

where: e is the base of natural logs,

I is the intensity of light at some depth,

I_o is the intensity of light immediately prior to entering the water column, is a constant indicating the strength of absorption per unit depth, and

D is the distance that the light passes through water (Denny, 2003).

In most images, intensity (I) is unknown for each pixel, so that the digital numbervalue (DN) is substituted into Eq. (2), and the distance of light passage is identified as the depth of water:

$$DN = DN_0 e^{-\beta . D} \quad (2)$$

To solve for depth, rearrange Equation 2:

$$DN = \ln(DN/DN_0)/\text{-}\beta \quad (3)$$

The value DN_omust be equal to the DN of the riverbed when any significant water depth does not cover it (Mark et al., 2005). To estimate DN_o, the DN value of the dry shore material adjacent to the river was used, since the same material that makes up the majority of the wetted riverbed pixels as in the absence of field measurements, is initially unknown. Using the same cross-section, we then reiterated Eq. (3) with different values until estimated discharge equaled the known stream discharge of 3.4m3/s for the HAB derivation, which occurred at =0.652 m. A final value was determined and substituted into Eq. (3) to determine the depth of the Dam, The resulting HAB equation for predicting depth was:

$$D = \frac{\ln\left(\frac{DN}{51}\right)}{0.652} \quad (4)$$

Change in water level map was carried out in order to determine the status of the dam. The thematic map of the study years was extracted by Boolean operation. The outputs were transformed into vector layers for overlay operation in order to display changes and locations over the years.

RESULTS AND DISCUSSION

— Temperature and Rainfall Pattern in the Study Area

The temperature and rainfall distribution pattern of the study area over the study period were presented in Figures 1, 2 and 3 depicting the high temperature in the study area leading to reduction in the water volume in the reservoir. Also, Figure 4 indicates a strong relationship between rainfall and temperature with a regression value of 94%. Both rainfall and temperature graphs show that rainfall and temperature increased drastically in 2016. This resulting to vegetation loss and may contribute to evaporation of the dam and transpiration the surrounding ecological features.

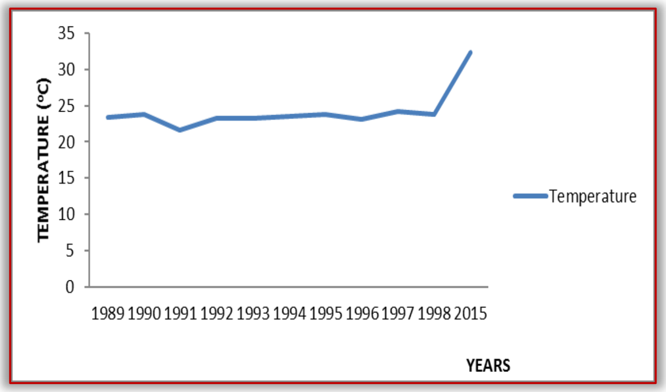


Figure 1: Temperature Pattern for Eleyele Water Dam

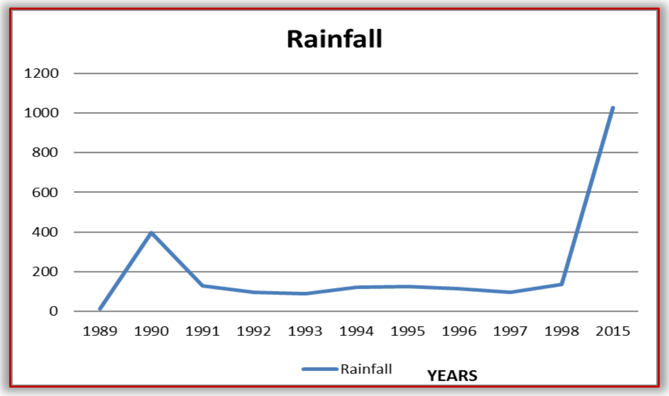


Figure 2: Rainfall Pattern for Eleyele Water Dam

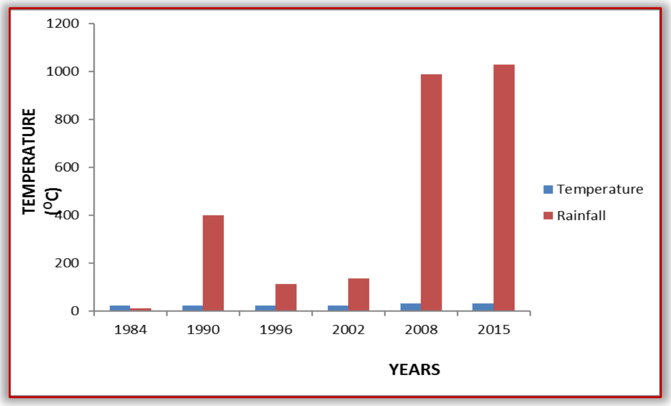


Figure 3: Rainfall and Temperature pattern for Eleyele Water Dam

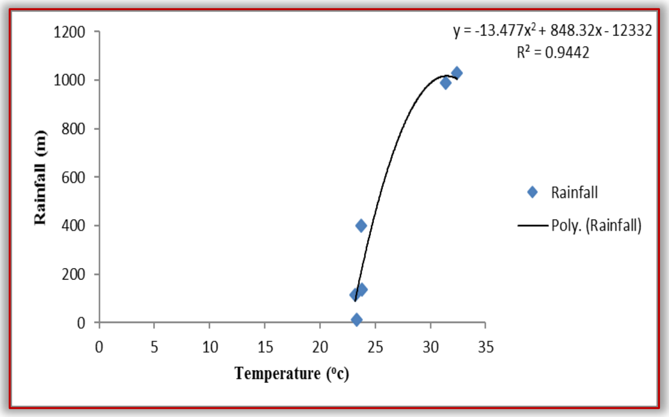


Figure 4: The relationship between rainfall and temperature

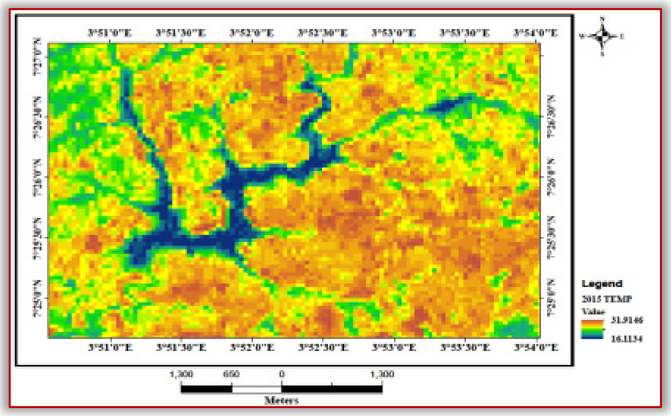


Figure 5: Surface temperature image

Figure 5 shows temperature distribution of the study area as at 2016 in pixels (30m x 30 m). The surface teperature map revealed that built up land has the highest temperature while the water body has the lowest temperature.

Table 1: Water area distribution pattern between 1984 and 2016

Category	1984		2000		2016	
	Hectares	%	Hectares	%	Hectares	%
Open Water	122.74	3.14	101.55	2.59	61.74	1.58 54.54,1.39

Table 2: Markov: 2000/2016 Transition Probability of Water areachanges

LULC	Built Up	Open Water	Vegetation Cover
Open Water	0.5794	0.0472	0.3734

Water area distribution pattern between 1984 and 2016 in the dam is shown in Table 1, while Table 2 shows the 2000/2016 Markov Transition Probability of Water area changes From Table 2, it is clear that the water body is endangered as a result of negative influence human activities depicting serious threat faced by Eleyele in future due to anthropogenic activities as in indicated in decrease in open water rate from 2.59% to 1.58%.

— Cross Tabulation Operation

The results of cross tabulation are in Table 3 listing the total as well as several measures of association between the images. The cramer's value of46% indicates an extremely good relationship indicating that the two variables are measuring the same concept.

Table 3: Cross-tabulation of 2000 (columns) against 2015 (rows)

Categories	1	2	3	Total
0	176	0	785	961
1	10609	4	16019	26632
2	0	534	216	750
3	944	860	18873	20677
Total	11729	1398	35893	49020

Chi Square =21190.02539, df = 6, P-Level = 0.0000, Cramer's V =0.4649

Table 4: Proportional Cross tabulation

Categories	1	2	3	Total
0	0.0036	0.0000	0.0160	0.0196
1	0.2164	0.0001	0.3268	0.5433
2	0.0000	0.0109	0.0044	0.0153
3	0.0193	0.0175	0.3850	0.4218
Total	0.2393	0.0285	0.7322	1.0000

Overall Kappa = 0.3086

— Changes in water level of the DAM

Change in water level map was carried out in order to determine the status of the dam as extracted from the thematic maps of the study years using Boolean operation. The outputs were transformed into vector layers for overlay operation. The overlay vectors layer is shown in Figure 6 depicting the changes and change locations from 1984 to 2016 and readings summarized in Figure 7. The estimated discharge equaled the known stream discharge at = 0.652 m and the calculated depth along the examined cross section of the Eleyele Dam between 1984 and 2016 using equation 4 and result to 0.2 m.

The results showed that urban growth (anthropogenic factors) within the study area imposes a lot of pressure on the reservoir. Between 1984 and 2016, the depth of the reservoir reduced significantly. In addition, the reserved forest zone has suffered degradation seriously and if the trend continues, the encroachment will further reduce the reservoir area and the surrounding reserved forest will disappear. By projection, the reservoir area will reduce by 1% (39.08 ha) of the total area considered for the study area by the year 2032.The combined influence of climate and human activities effect the land use, which also affect the water levels in the dam over 32 the years and this, confirms the findings of Viger *et al.*,(2011); Wilson and Weng (2011) and Tong *et al.*,(2012) on the use of regression models on the on land use trends impacts.

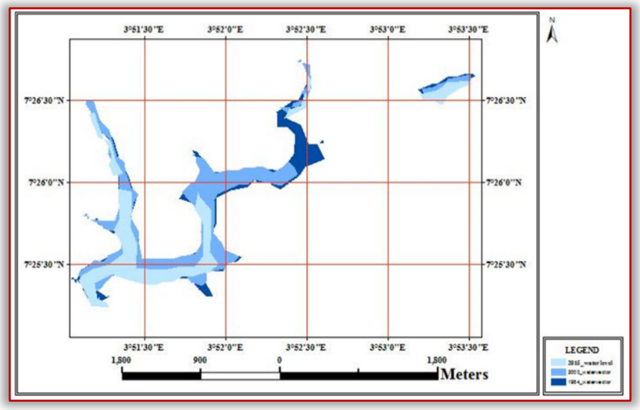
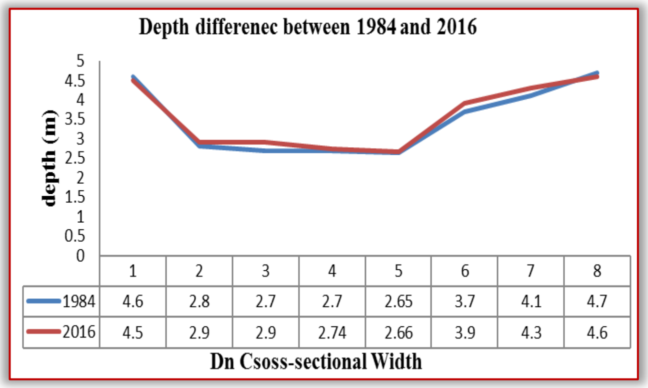


Figure 6: 1984/2000/2016 Water Level of Eleyele Dam



	1	2	3	4	5	6	7	8
1984	4.6	2.8	2.7	2.7	2.65	3.7	4.1	4.7
2016	4.5	2.9	2.9	2.74	2.66	3.9	4.3	4.6

Figure 7: Dam water level

CONCLUSIONS

The effect of weather on Eleyele reservoir (Dam) water level was analysed using rainfall and temperature pattern within the study area and dam water levels determined within 32 years (1984-2016) with the aid of GIS analytical functions.

The results showed that urban growth (anthropogenic factors) within the study area imposes a lot of pressure on the reservoir as there was reduction in the reservoir depth significantly between study periods. With the results of this study, image cross-sections can be used to better representatives of the stream or river. As a result of the long term effect on the water resources in the area, government should evacuate the inhabitants of Eleyele watershed, who had converted the watershed to commercial and residential zone in order to reduce the deforestation of the riparian vegetation observed to have suffered serious decay between 1984 and 2016 as uncontrolled anthropogenic activities around the dam contributed to the water level / depth decrease of the dam. The dam profile also reveals that surface filling may be a factor for the rise of the surrounding continent.

The regression analysis showed strong relationship between temperature and rainfall. Checkmating the activities of man, which have been observed, in the course of the study, as the major cause of forest degradation around the dam would save the environment from effects of climate change. Such development could also facilitate immensely evapo-transpiration of the dam.

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