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Siltation of the Reservoir of Vea Irrigation Dam in the Bongo District of the Upper East Region, Ghana

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ABSTRACT

The Vea Irrigation Dam was constructed in 1980 to promote the production of food crops in the dry harmattan season. Thirty three years after construction, this study was conducted to assess the level of siltation in the reservoir and farming practices that impacts siltation within the catchment. Ten soil profiles, five on either banks of the reservoir and each of surface dimensions 1.2 m x 1.2 m were dug in the reservoir 30 m away from the water to ascertain the depth of soil sediments. Average depth of sediments was multiplied by the area of reservoir to obtain the volume of deposited sediments, from which annual depositions were estimated. Eighty (80) farmers in the four fringe communities within the catchment (Vea, Gowrie, Kunkua, and Kuyelingo) were purposively sampled and interviewed. At an average depth of 1.1 m, total deposit of about 140000 m^3 of sediments into the reservoir should be a cause for concern. Conventional tillage and continuous grazing, practiced by majority of farmers along the steep slope of the dam's upstream have direct influence on erosion and hence siltation of the reservoir. High intensity rainfall with high kinetic energies, recorded in the months of June, July, August and September results in considerable level of detachment of the already erodible soil aggregates, which contributes to erosion and subsequent siltation of the reservoir. Whilst vegetative cover reduces direct impact of rain drops, these are scanty and scattered: exposing the bare soil to erosion. In order to save the dam and its reservoir from short lifespan as a result of massive siltation, soil conservation measures, and Best Agricultural Management Practices on watersheds are recommended to local farmers within the catchment area.

Keywords: *Reservoir siltation, sediments, watershed, erosion, and irrigation***.**

1. INTRODUCTION

A dam is an impervious or fairly impervious barrier, a hydraulic structure constructed across a natural river so that an artificial reservoir is formed on its up-stream side to store water [10].

In the rural and subsistence based northern Guinea Savannah zone of Ghana, dams are the main sources of water for watering cattle and for small-scale irrigation during the long harmattan dry season (November- March). They also provide water for watering of animals and for domestic activities [11].

Deposition of soil materials into dams reduces the capacity of the reservoir, impacting negatively on the shelf life of reservoirs and pose serious threats to livelihoods that depend on it. Excessive rates of sediment deposition in storage reservoirs, canals and laterals decrease the useful life of the dam's project and increase the cost of maintenance [3]. Sediments found in irrigation water clog intake screens and pumps, fill channels, reduce reservoir capacity and useful life or deposit soil materials on crop lands [3].
Deposition of soil material into reservoirs come about through intense soil erosion, winning of sand and gravel, surface mining and other activities such as bush burning and deforestation. These render the soil surface bare to direct impact of rain. Intensive rainfall, coupled with large quantities of individual rainfall events, causes considerable runoff, which further lead to high sediment concentration in irrigation dams [12]. Bad farming methods such as farming closer to river banks, farming along the slope, and destruction of the vegetation cover contribute to the accelerated levels of particulate transport into reservoirs.

The Vea Irrigation Dam is one of the oldest dams in the Upper East Region of Ghana. Constructed in 1980, it was aimed to promote irrigation farming during the dry season

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to ensure food security, alleviate poverty and provide potable water to the surrounding communities.

Thirty three years down the lane, no desiltation has been carried out on the dam. Several patches of sediment islands can be seen in the reservoir, particularly during the dry season. The reservoir gets filled very early in the rainy season but reduces quickly at the onset of the dry season, which suggests a shallow reservoir with indication of siltation.

Noting the consequences to local livelihoods, this study was carried out to assess the level of siltation in the dam's reservoir and to identify the causes and effects of siltation on the rural livelihoods. Pragmatic measures on how to manage the dam's watershed to reduce siltation are also discussed.

Characteristics of the Vea Irrigation Project

The dam has a catchment area of 136 km^2, maximum lake surface area of 405 hectares, maximum storage of 17 x 10^6 m^3, live storage of 16 x 10^6 m^3, dead storage of 1 x 10^6 m^3, and crest length of 1585 m. The dam has two main canals (the right bank and the left bank canals) and a spillway. The right bank canal is 9 km long and has 30 laterals that channel water from the main canals to irrigated fields. The left bank canal is 12 km long and has 31 laterals. Though it has a gross project area of 1,197 hectares, only 650 hectares is under cultivation. The project spreads through eight communities: Vea, Gowrie, Bongo Nyariga, Bolga Nyariga, Zaare, Yikine, Sumbrungu and Dindubisi.

Data Collection

Two data kinds were collected: primary and secondary. The primary data were generated through field measurements, direct field observations and interviews. The secondary data included rainfall data and data collected from the irrigation company of upper region (ICOUR) at Vea. Relevant literature on the project and activities were also obtained from ICOUR.

Field measurements

Field Measurements were done to determine the depth of sediments in the Vea reservoir. Ten soil profile pits of surface dimensions 1.2 m x 1.2 m (plate 1) were dug in the reservoir 30 m away from the water. Based on estimates of the original depth of reservoir, maximum permissible depth was 1.2 m. The soil profiles were distributed equally on both right and left banks of the reservoir. From the surface area and depth dimensions, the volume of soil material transported and deposited into the reservoir was estimated.

Plate 1: Measurement of depth of sediments in a profile pit in the Vea reservoir of Ghana

2. RESULTS AND DISCUSSION

Volume of sediments deposited in the reservoir

From the area of reservoir (4.05 x 10^6 m^2) and the average depth of deposited depths (Table 1), the estimated volume of deposited sediments was 4.5 x 10^6 m^3.

Table 1: Depths of sediments in the soil profiles dug in the reservoir of the Vea dam of northern region of Ghana

Name of soil profile	Depth of sediment (m)
A	0.9
B	1.2
C	1.1
D	1.2
E	1.2
F	1.2
G	1.1
H	1.0
I	1.1
J	0.9
Average	**1.1**

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Assuming similar annual deposition for the 33 years; average yearly sedimentation of 1.4 x 10^5 m^3 occurs in the reservoir. For the entire catchment area, this amounts to 1000 m^3/km^2/year. The estimated rate of sedimentation of the reservoir is close to the findings of [2], who described sedimentation of the Quipolly reservoir in Australia between 1941-1943 as "extraordinary" at a rate of 1140 m^3/km^2/year. At this rate of siltation, pragmatic measures: such as dredging, riparian protection and other reservoir protection measures must be carried out to curb the situation. Should annual deposition remain the same; there will be a reduction in lifespan of the Vea dam (Table 2).

Table 2: Projected volume of sedimentation in the Vea reservoir up to 93 years

Period (years)	1	**33**	**63**	93
Volume of sediments(m^3)	1.4x10^5	**4.6x10^6**	**8.8x10^6**	13.0x10^6

From the maximum storage capacity of 17 x 10^6 m^3, the Vea reservoir would be half full of sediments by the 63rd year after construction (roughly 30 years from 2013). [7] reported that the lifespan of the Magat dam, Southeast Asia's biggest multi-purpose dam was radically reduced to 36 years from an initial estimate of 50 years due to massive siltation that follows slash-and-burn farming, cage fishing and illegal tree-cutting. Similar reduction in lifespan due to siltation are reported in Taiwan [4].

Causes of Sedimentation

From the interviews with residents and farmers, a number of factors contribute to the high volume of sediments recorded in the reservoir (plate 1 and plate 2). These include:

- Poor vegetative cover and inexistence of cover crops within the watershed
- Steep slope within the watershed
- High susceptibility of soil in the watershed to erosion
- Intensive farming activities within the watershed
- High domestic and commercial gravel winning activities adjacent the reservoir
- Low level of agricultural best management practices in the Vea watershed

Plate 2: Pile of sediments in the Vea reservoir 33 years after construction

Volume of sediments in drains that feed the dam

About 6.9 x 10^6 m^3 of sediments, estimated at 2 x10^5 m^3/year of sediments are brought through the drains that feed the dam. Comparing the estimated average volume of sediments in the reservoir (4.5 x 10^6 m^3) with the volume of sediments through the drains, the difference of 2.4 x10^6 sediments that is not accounted for might have been lost from the reservoir through:

- The spillway when the dam exceeds its storage capacity and spills
- The block making activities carried out in and around the reservoir (Plate 3)
- The sand winning activities carried out in the reservoir (Plate 4)

Plate 3: Building blocks made from the sand deposited in the Vea reservoir. The blocks are later carried to construction sites where they are used in the construction of buildings

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Plate 4: Sand winning in the Vea reservoir for the purposes of construction

Factors that enhance sedimentation of the Vea dam

Intense rainfall and high erosivity

Across the catchment area, highest rainfall amounts (MMR.amt) and rainfall intensities (Rfall.Int) are generally recorded between June and September (Figure 1). These are associated with high kinetic energies that create serious runoff and erosion problems.

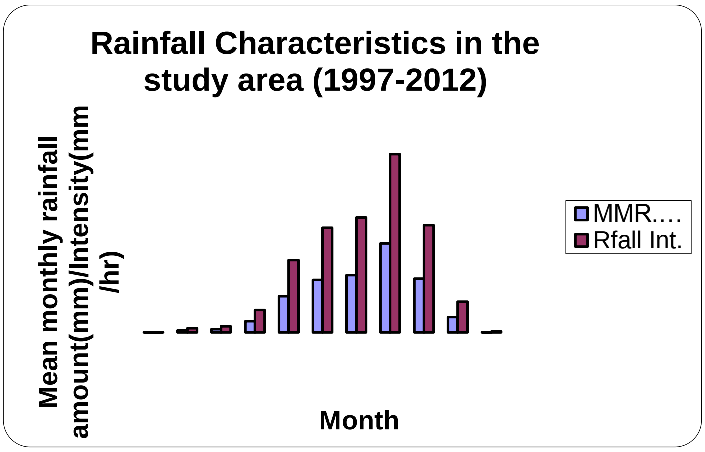

Figure 2: Rainfall characteristics in the study area from 1972 to 2012

The sharp, high-intensity rainfall peaks and rainfall amounts; coupled with a low infiltration rate and steep slopes enhance water accumulation that builds into runoff with high kinetic energies and erosion as explained by [9] and [8]. [8] indicated that rainstorms with intensity less than 25.40 mm/hr are not erosive but intensities greater than 25.40 mm/hr have the ability to detach soil particles and cause erosion. [9] also stated that erosion is mostly caused by rainfalls at intensities greater than 25 mm/hr. Rainfall intensities in June, July, August and September across the catchment area exceeds 25.40 mm/hr (Figure 2) and are therefore erosive and contributes to the sedimentation of the dam.

Low cover crops within the watershed

The vegetative cover within the watershed, especially tree cover is scanty and scattered as a result of the intensive farming activities across the area (Plate 5). Some plant species exists: including herbs of the family Rubiaceae (e.g., *Diodia scadens* Sw.) and Acanthaceae (e.g., *Monechma ciliatum* (Jacq.) Milne-Redhead).

Plate 5: Typical vegetative cover within the watershed of the Vea irrigation dam

Major grasses include those of the family Poaceae/Graminaea (e.g., *Digitaria horizontalis* Willd, *Heteropogon contortus* (L.) P. Beauv. ex Roem. & Schult, *Schizachyrium exile* (Hochst.) Pilger, *Andropogon gayanus* Kunth, and *Dactyloctenium aegyptium* P. Beauv.). Tree species include those of the family Combretaceae (e.g., *Combretum lamprocarpum* Diels, and *Terminalia avicennoides* Guill. & Perr.), Leguminosae-Mimosoideae (e.g., *Entada africana* Guill. & Perr.) and Rubiaceae (e.g., *Gardenia ternifolia* var. goetzei (Stapf & Hutch.) Verdc. (Stapf & Hutch.) Verdc.). Shrub species include the family Euphorbiaceae (e.g., *Securinega virosa* (Roxb. ex Willd.) Pax & Hoffm.), and Fabaceae (e.g., *Chamaecrista mimosoides* (Linn.) Greene). Cultivated food crops include rice (*Oryza sativa*), sorghum (*Sorghum bicolor*), millet (*Pennisetum cinereum*), groundnut (*Arachis hypogea*) and cowpea (*Vigna unguiculata* (L.) Walp.). Though some tree species like *Azadirachta indica*, *Senna siamea* and *Eucalyptus spp* are planted along the fringes of the reservoir as riparian protection against runoff, erosion and hence sedimentation; the trees are being fell for logs and firewood. The few riparian protective plants are also being cleared to make way for the winning of fine sand and gravels for construction (plates 3 and 4).

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The role of vegetative/plant cover in reducing erosion in an area cannot be over-emphasized [9]. It protects the soil from direct impact of raindrop and reduces the velocity of runoff and hence erosion. If the ground is protected by any kind of vegetative cover, it absorbs the impact of the raindrops and the water reaching the ground surface no longer has the force to dislodge the soil particles. The scanty and scattered vegetative cover of the watershed with relatively large bare ground, particularly during the dry season as a result of indiscriminate burning as revealed from the study has rendered the land highly susceptible to high risk of erosion. This phenomenon has contributed to the high rate of erosion in the watershed, which consequently deposited about 1000 m^3/km^2/year of sediments into the reservoir within the 33 years period. The direct impact of the high intensity raindrops, rainfall amount, and kinetic energies recorded annually in the study area are poorly intercepted and has led to the current poor state of the dam.

Farmer practices and their implication on the watershed of the Vea irrigation dam

About 98% of farmers within the watershed practice conventional tillage which involves the use of mouldboard ploughs, disc ploughs and disc/tine harrows used to till the land for crop cultivation. This practice is not best for watersheds. It tends to pulverize the soil near the surface and create a compacted layer below the ploughed depth, which reduces infiltration and results in increased runoff and erosion and hence silting-up reservoirs. [9] indicated that conservation tillage such as zero tillage and minimum tillage reduce soil erosion from farmlands and are therefore best for watersheds. Besides the conventional tillage, farmers close to the reservoir ploughed along the slope instead of across the slope (plate 6). This practice enhances erosion and increase sedimentation of the reservoir.

Plate 6: Ploughing along the slope near the reservoir

Livestock grazing on the watershed is also high with 90% of the farmers practicing continuous grazing. This could lead to overgrazing and therefore little or no protection of riparian areas of the reservoir. Rotation grazing and forage harvesting and management could be practiced.

Field observations reveal that farmers on the watershed reserve only few trees in strategic points on their farmlands to provide shade, where they can rest during farming activities. Trees play a very crucial role in the protection of farmlands from torrential storms and/ or wind, thus serving as wind breaks/shelter belt. It is in this light that [5] indicated that a strip of uncut and un-cleared vegetation or trees should be left on farmlands of watersheds and that cultivation and other farming practices need be carried out with minimum disturbance. Generally, it is known that gravel or sand winning is an activity that involves stripping the soil of the vegetation cover and top-soil to a consistency that allows for continuous excavation. In that regard, activities such as tree felling for logs and firewood, gravel and sand winning, block and brick molding; practiced within the watershed poses erosion threats to the reservoir. Tree and shrub species planted specifically as riparian protection are those being cleared to make way for the winning and molding activities. Some of the molded bricks are not conveyed early and when it rains they are washed directly into the reservoir.

Burning was also observed within the watershed (Plate 7). Farmers burn off litter and crop residues on their farmlands, particularly during the period prior to the onset of the rainy season, as part of land preparation for planting [6].

Plate 7: Burnt riparian protection plants within the Vea watershed

This practice leaves the ground bare and renders it highly susceptible to erosion during runoff and subsequent increased sedimentation of the reservoir. Some *Panicum maximum* (vetiver grasses), which were planted as riparian protection are being burnt by the livestock keepers to make way for the regeneration of fresh foliage for their animals to graze. Burning of farmlands and forestlands can result in drastic increase in sedimentation of adjacent reservoirs. [1] estimated that, the total sediment in the Creek dam, whose catchment was burnt was 1000 times greater than it was before fire under humid tropical conditions. Such large increases in sediment load were, however, not reported after burning because of the more rapid re-growth of vegetation.

3. CONCLUSION

Thirty three years after the construction of the Vea dam for purposes of irrigation in the dry season, fish farming, and domestic water supply; an annual siltation rate of 1000 m^3/km^2/year in the reservoir should be a course for concern as this drastically reduces the reservoir's storage capacity and its expected lifespan; which will impact negatively on the socio-economic activities of local inhabitants.

Basic management practices can be adopted to resolve the siltation rate and sedimentation. Vegetative cover, especially the tree cover within the catchment is scanty and scattered as a result of intensive farming, and burning of riparian vegetation. Tree species which were planted at the edges of the reservoir as riparian protection against runoff, erosion and sedimentation are fell by the people around the reservoir for logs and firewood. These few riparian protective plants are also being cleared to make way for the winning of sand and gravel. The poor state of vegetation within the watershed has exposed the already highly susceptible erosive soils to particle dislodgement due to the direct impact of raindrops, which also comes with high intensities and kinetic energies. Agricultural practices within the Vea watershed do not also meet the standards of Agricultural Best Management Practices on watersheds. About 98% of farmers within the watershed practice conventional tillage, which tends to pulverize the soil near the surface and create a compacted layer below the ploughed depth which reduces infiltration and results in increased runoff, erosion and reservoir siltation. Poor grazing management, including continuous grazing which is practiced by 90% of livestock keepers exposes the bare land to direct raindrops: especially in the months of June, July, August and September when the rainfall is at its peak with high intensities. These facilitate high rate of soil particles detachment, runoff, erosion and subsequently siltation of the reservoir.

To enhance reservoir storage capacity and reduce siltation, trees and erosion resistant grasses should be planted as riparian protection against erosion. Generally, the Vea dam need be desilted. A regular and intensified extension educational programme for farmers in the surrounding communities about Agricultural Best Management Practices on watersheds including: conservation tillage (zero and minimum tillage), proper grazing management (rotation grazing), and undertaking farming activities further away from the reservoir, should be organized.

REFERENCES

[1] **Boughton, W. C., (1970).** Effects of Land Management on Quality and Quantity of Available Water. A Review of Australian Water Resource. Water Resource Council Research Project 68/2, Report 120. Mainly Vale, University of New South Wales.

[2] **Chanson, P. H., James, D. P., (1999).** Extreme Reservoir Siltation: A Case Study Rapid Reservoir Sedimentation in Australia. http:/water.wikia.com/wiki/Dam, accessed on 12/05/2013

[3] **Hagan, R. M., Haise, H. R., Edmister, T., W., (1967*).*** Irrigation of Agricultural Lands. Pp. 53, 63

[4] **Hil K., Anne M., Egger, T., Hensen T. (1996).** Erosion Control in the Tropics, 5th Edition, pp. 6-7

[5] **Jefferies, M., Mills, A., (1990).** Freshwater Ecology: Principles and applications. Behaves Press, London, pp. 285.

[6] **Kugbe, J., Fosu, M., Vlek, P.L.G. (In press).** Impact of season, fuel load and vegetation cover on fire mediated nutrient losses across savanna agro-ecosystems: the case of northern Ghana. Nutrient Cycling in Agroecosystems. DOI: 10.1007/s10705-014-9635-8

[7] **Lagasca, C. (2005)**. Siltation, Illegal Tree-Cutting Imperil Isabela's Magat Dam. http:/www.philstar.com/nation/301856/siltation-illegal-tree-cutting, accessed on 5/3/2009

[8] **Lal R., (1990**). Soil Erosion in the Tropics: Principles and Management. McGraw-Hill,Inc., USA, pp.3-5, 29-30, 35, 50.

[9] **Morgan, R. P. C., (1995).** Soil Erosion and Conservation. 2nd Edition, ELBS/Longman Group (FE) Ltd, pp. 7,11-15, 18, 26-27.

[10] **Punmia, B. C., Pande, B. B. L. (1992)**. Irrigation and Water Power Engineering. 12th Edition. LAXMI, New Delhi, India, pp. 259-264, 291, 320.

[11] **Rubin, N., Warren, W.M. (2014).** Dams in Africa: An inter-disciplinary study of man-made lakes in Africa. Routledge

[12] **Tigrek, S., Aras, T. (2011).** Reservoir sediment management. CRC Press