DESIGN OF HYDRAULIC STRUCTURES FOR A SMALL-SCALE FADAMA STREAM DIVERSION IRRIGATION SCHEME AT ZUKUCHI, NIGERIA

By

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Abstract: *Traditional schemes built and operated by small holder farmers, have existed since pre-colonial times for rice production. Spontaneous development of traditional irrigation was at considerable pace without much government participation. The prevention of water to flood the area is succeeded by constructing a head-dyke in a suitable site across the swamp. The scheme is designed with two peripheral canals. Each has discharge capacity of 0.42m3/s which is capable of irrigation 5ha of rice field (10ha for the two canals), within irrigation period three hour fifty-four minutes (3hr 54mins). The designed parameters and dimensions of the canal are manning coefficient (n) is 0.03, the channel bed slope was (s) of 0.002, side slope (z) of 1: 5: 1, and total channel depth (D) 0.82m, bottom width (b) is 0.45m and top width (T) of 2.90m were calculatedfor the existing canal.*

Keywords: Canal, Fadama-Nigeria , Irrigation.

INTRODUCTION

Fadama is a Hausa word meaning low-lying area that is susceptible to seasonal flooding. Water is often available in these flood plains through the dry season either as flow in rivers, ponds in the river channel or saturated sands close to the surface. In the Northern part of Nigeria, this water has been used for many centuries for irrigation of small garden plots.

Traditional schemes built and operated by small holder farmers, have existed since pre-colonial times for rice production. In addition, Shadouf (traditional method of irrigation) was practiced along river courses or with wells in various areas of the north, mainly for vegetable and wheat cultivation. Spontaneous development of traditional irrigation was at considerable pace without much government participation. In most cases the schemes are technically defective. Importance of the contribution of these traditional schemes to the Nigeria's food supply cannot be over emphasized as there is increasing demand for its products from urban centers, possibly due to the rapid growth of urban centers as a result of rural-urban drift. This situation motivated the Nigerian government to provide technical assistance for improvement to the farming communities purposely to increase their output. The technical assistance includes improving agricultural practices, better control of the water flow and increases the area under irrigation.

The interest to develop irrigation agriculture is not limited to Nigeria, not even to the third world countries. Between 1950 and 1980 there was more or less a three-fold increase in the total area or irrigated agriculture throughout the world (Cernia, 1985). If there was any increase in food production at all, particularly in the third wor However, the ld countries, such an increase has been closely linked with the expansion of irrigated land. Development of new high yielding varieties as well as agricultural input cannot be ignored (Dhaman, 1988and Chambers 1988).The increase in irrigation activities has contributed between 50% and 60% of the massive increase in agriculture output of the developing countries from 1960 to 1980 (Ladan, 1998).

There view of irrigation schemes performance is important to the study of Nigeria large irrigation schemes. The series of drought years that hit the Sahelian zone, including Northern Nigeria, in the early seventies has induced governments in the affected area to broaden the drought-proof production base through increased emphasis on irrigated agriculture. The national development plant of Nigeria (1975 to 1980) reflected this new preoccupation with protection against droughts(World Bank Report, 1979). The crops that are commonly grown under irrigation and also the agricultural products that are most prominently feature on the Nigeria import bill are wheat, sugar and rice.

Because of the various problems encountered on the sustainability of large scale irrigation project, the Nigeria Government shifted its emphasis to small-scale irrigation development. According to preliminary estimates, these small-scale projects have potential of 8,000ha. This is far from being exhausted and could be extended to reach two million hectares. The potential use of fadama and swamp lands is not only determined by physical factors such as soil quality and water management but also by factors such as customary land titles and tenure, availability of labour and allocation of labour between rainfall and irrigation field crops. The system of land tenure, in particular the security of acquired and improved land is an important factor determining the degree of self-help farmers will offer. The amount of self-help that can be mobilized has a profound impact on project design, construction method and above all fiscal cost of projects (World Bank Report, 1979). This type of traditional small-scale irrigation development depends on readily available water resources in the form of rainfall, runoff and natural ground storage. The Guinea savannah zone of Nigeria is characterized by isolated swamps fed by rainfall only; narrow riverine swamps and large alluvial fadama flooded annually by rivers. The narrow river valleys are mostly small and interconnected and drain into the large river systems. The type of water management required for the narrow riverine swamps entails some drainage, water retention, temporary storage and redistribution of the runoff over areas wider than those normally inundated by the stream during the wet season.

The objective of this work is to advance planting dates by early irrigation practice, to provide supplementary irrigation during dry spells of the wet season, to increase the potential cultivable area, to improve the field water management and also to improve the agricultural practices. The study area is located in at Zukuchi near the Zukuchi stream located in Shiroro Local Government area in the Guinea Savannah zone of Nigeria.

MATERIALS AND METHODS

The concept of a water control system is to prevent the Fadama to be flooded. The water should be controlled and directed to the field whenever it is required. Big floods should be taken away through a floodway (drain) and every field should have access in both the water supply and drain system.The prevention of water to flood the area is succeeded by constructing a head-dyke in a suitable site across the swamp. Two peripheral canals constructed along the edges (sides) of the swamp will supply water to the entire field through special outlets. A drain excavated in the middle of the swamp will take care of the peak flows and of the water draining from the paddles.

Design Data

The major crop grown in the area is rice which covers over 20 hectares of from land. The crop water requirement will be calculated for raining the Blanny-Morin Nigeria method. The effective rooting depth of rice given as 0.6m (Varshney et al, 1982). The soil type of field is clay loam whose water holding capacity is 150mm/m Doorenbos & Pruitt,(1984). The readily available soil water that is fraction of total available soil water permitting unrestricted evapo-transpiration and/or crop growth is given as 0.40. The depth of irrigation application losses is calculated as

$$d = \frac{(pS_a)}{E_a} (\ mm\ ) \qquad (1)$$

Where d = depth of irrigation application (mm), P is the production of available soil water permitting unrestricted evapo-transpiration fraction, Sa is the total available soil water (mm/m) in the soil depth, D is the rooting depth (m) and Ea is the application efficiency fraction. The frequency of irrigation (ıı) was calculated using

$$f_i = \frac{(pS_a)\ D}{ET_c} (\ days\ ) \qquad (2)$$

Where ETc is the crop evapo-transpiration (mm). The volume of water (V) required for each irrigation of the 20hectare field is calculated for using

$$V = g.t = \frac{10}{E_a}(pS_a)DA\left(m^3\right) \qquad (3)$$

Where V is the volume of water (m3), g = stream size (m3/s) t is the supply duration (seconds)while A is the acreage of the land (ha). The time of irrigation application is given as

$$T_i = \frac{d_i}{s_i}\left(hour\right) \qquad (4)$$

Where Ti is the time application in hour, di is the depth of irrigation application in mm and ıı as the soil water intake rate in (mm/hr). Considering the basin method of water application, Dooren Bos and Pruitt, (1984) suggests that the water should be applied within 40% of the time necessary for the required depth of water to enter the soil.

Channel Cross Sectional Design.

Putting the roughness of coefficient (n) for earth into consideration a straight and uniform channel will be 0.03 (Vipond and Stanly, 1974). If the channel side slope (z) is ratio of 1.5to 1 for clay loam and the design bed slope (s) is 0.002. The channel cross-section can be designed using equation 5

$$\frac{Q_n}{S^{\frac{1}{2}}} = AR^{2/3} \qquad (5)$$

Where Q is the design stream size in (m3/s), n is the roughness of coefficient, S is the channel bed slope fraction, A is the channel cross-sectional area (m3), and R is the hydraulic radius (m).The trapezoidal section is calculated for using

$$R = \frac{A}{P} = \frac{(b + zd)d}{b + 2d\sqrt{z^2 + 1}} (m) \qquad (6)$$

Where $A = (b + zd)d \quad (m^2)$ (7) and

$$P = b + 2d\sqrt{z^2 + 1} \quad (m) \qquad (8)$$

B is the channel bottom width (m), d is the channel water depth (m), Z is channel side slope, P is wetted perimeter of the channel (m) and R is the hydraulic radius (m).

Hence $$AR^{2/3} = \frac{\left[(b + zd)d\right]^{5/3}}{\left[b + \left(2d\sqrt{z^2 + 1}\right)\right]^{2/3}} \qquad (9)$$

To provide allowance for the freeboard (F) is determined using the formula in equation 10

$$F = cy \qquad (10)$$

Where F is the free board (m), C is coefficient, 0.46 for canals up to 0.7 m3/s add Y = is the depth of water flow.

$$\text{Channel depth } (D) = d + f \qquad (11)$$

$$\text{Channel top width } (T) = b + 2DZ \quad (m) \qquad (12)$$

Canal water control structure design.

At the beginning of the canal, a water control structure is provided to prevent high flows and damages on the canal, A simple and contracted rectangular weir capacity is determined by rise of the shelters. The weir capacity is determined by use of equation 13.

$$Q = 1.86\left(L - 0.2H\right)H^{3/2} \qquad (13)$$

Where Q is the flow rate (m3/s), L is the length (m). The length therefore of crest can be determined from equation 13 as

$$L = \frac{Q}{1.86\left(H\right)^{3/2}} + 0.2H \qquad (14)$$

Pipe Outlet Design.

Pipe outlets are installed in the canals at certain intervals in order to get water out of the canal to the field. The interval depends on the topography, nature of swamp and field boundaries. The pipe outlet is the simplest and cheapest which can operate with a very small head. Selecting a 7.62cm (3") diameter PVC pipe, its discharge flowing out freely can be determined using equation is (Sarrides, 1981).

$$Q = AC\sqrt{2gh} \qquad (15)$$

Where Q is the discharge water (m3/s), A is the cross sectional area of the pipe (m2), g is the acceleration due to gravity which is 9.81m/s2, c is the coefficient of discharge and it is the pressure head over the centre of the pipe (m).

Head Dyke Design:

This is a water control structure usually of rectangular weir type equipped with wooden shutters (planks) for regulating the water level behind the pool, It consists of the crest apron, cutoff and using.

Crest Design:

A low crest level of a flux bat a discharge perimeter is proposed. Effort was made to avoid too deep water over the crest, which may result in an increased height of gates, thickness of floor and cost of super structure above floor level. In view of this, the proposed height of water over the weir is 0.45m. The overall length of the weir can be determined using sharp crest weir head-dyke formula in equation 16 (Varshney et al, 1982).

$$Q = 1.84(L - 0.1\,n)H^{3/2}H \qquad (16)$$

Where Q is the discharge of the stream flow (mz/s), L is the total clear water way (m), n is the number of end constructions and it is the head over the crest (m).

$$L = \left[\frac{Q}{1.84\,(H)^{3/2}} \right] + 0.1nH \qquad (17)$$

The stream flow discharge Q is determined based on the runoff estimation of water shed of the stream calculated from topographical map and rainfall of the area using equation 18

$$Q = \frac{CIA}{36} \qquad (18)$$

Where estimation of water flow (m3/s), C is the dimension less runoff coefficient, I is the intensity of stream of design return period and duration equal to the time of concentration for the catchment concerned (cm1h) and A is the catchment a area (ha).

Apron and cut-off design.

Provision of apron along a water course is to protect the structure from erosion problems due to waterfall and the consequent damage on the structure. Further more, it gives stability to structure against over farming moments while cut-off protects the structure against underneath water piping and erosion and gives stability against upward pressure. Length the apron is designed using equation 19 (Varshney et al 1982).

$$GE = \frac{H}{d\pi\sqrt{\lambda}} \qquad (19)$$

Where GE is the exit gradient, it is the maximum static head (m) and d is the down stream depth of cut-off (m).

Wing wall and Embankment.

The purpose of a providing a wing wall is to guide the flow of stream through the weir structure. Its length depends on the length of apron. Embankment is provided to protect fadama area to be flooded and at the same time it forms a pool of water behind, which creates the head for water to flow in the canal designed.

Drainage canal design.

The purpose of the drain is to take care of the excess water during floods and take away drained or out flood from the crop field. The designed slope of the fadama which also include drain capacity such as the design peak flood and the drains from the crops calculated using equation18.

RESULT AND DISCUSSION.

Presently on the study area, it was discovered that the planting time depends on the availability of water. When the flow is too little it runs in the existing course of the steam or in the lower points of the fadama. This makes impossible the timely planting of the enter area and10 by that time all the fadama area is covered with water. The flow is increased considerably in short time and farmers are unable to plant the rest of the swamp due to high level of water. They home to wait until the water depth is reduced to the normal level that will allow crops to be planted. However it may be too late to plant and if the farmer proceeds to plant, the water may be reduced considerably and insufficient to meet the demand at the growth stage.

Due to lack of water control, the benefits of fertilizer and herbicide application are not derived as most of it is washed off by flood. Poor crop performance was observed especially around the edge of the fadama where water could not reach and the crop suffers from water shortage. As the water depth in the fadama varies considerably and no control of water, adoption of improved high yielding varieties that require certain control level of water because difficult. Farmers are therefore restricted to specific varieties that are low yielding. Due to buck of control water flow, the cultivation is restricted to the immediate narrow strips of fadama along the stream thereby abandoning a reasonable size of potential cultivable area.

The scheme is designed with two peripheral canals. Each has discharge capacity of 0.42m3/s which is capable of irrigation 5ha of rice field (10ha for the two canals), within irrigation period three hour fifty-four minutes (3hr 54mins). The designed parameters and dimensions of the canal are manning coefficient (n) is 0.03, the channel bed slope was (s) of 0.002, side slope (z) of 1: 5: 1, and total channel depth (D) 0.82m, bottom width (b) is 0.45m and top width (T) of 2.90m were calculated for the existing canal. The canal water control structure comprising rectangular weir device and shutter, and pipe outlet were incorporated into the canals for regulating the flow in the canal and to deliver water to the field respectively. The designed head-dyke had two days of 1.30m wide capable of over-spilling 1.30m3/s flood and impound the stream flow if the shutter, are closed to a level of 0.45m high at over it's the normal level. This 11impounded water level provides adequate head of water to flow into the canals to the field safely without erosion hazard. The apron, cut-off stilling basin wings and embankment were designed accordingly to protect the head-dyke. The drainage canals were designed with a discharge capacity of 1.69m3/s to collect and dispose excess water form the paddy and overlie watershed.The irrigation system designed can be operated with a rotational system to irrigate 10ha field pershift. Two shift are required to complete irrigation of the entire project area for a period of 3.54hours. Also continuous supply of the system can be used to irrigate the field for a period of 7hours. Frequency of irrigation is 4days with 36mm net depth of water application. The field will be irrigated using basin application method. The field is to be prepared by contouring the basin where necessary so that during irrigation upper reach basin overtop id to supply the down one and the excess overflow to the drain.

CONCLUSION.

The study has presented the development of an irrigation scheme to ensure that maximum benefit is derived from it. The existing situation of the scheme hampers remarkably the exploitation of the fadama for agricultural purposes by the farming communities of Zukuchi. Therefore, the limited available fadama requires judicious use through appropriate technology if the inhabitants are to achieve their rice production goal by increasing their output per unit area. The appropriate technology consists of design and construction of a weir structure across the stream, canals and water control structures at the periphery of the fadama, the drain along the stream water course, and on farm field preparation purposely to direct and regulate the water flow over the fadama area. This will facilitate improved agricultural practices that will increase the output per unit area.

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