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Full Length Research Paper

Performance evaluation of Badeggi irrigation scheme, Niger State Nigeria, using efficiency techniques

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This study was conducted to evaluate the performance of Badeggi irrigation scheme using efficiency techniques, performance indicators such as conveyance efficiency, application efficiency and system efficiency are considered to give the overall irrigation efficiency. The overall activities around the scheme site were investigated using field observation, interviewing the beneficiary farmers, also discharge measurement in the canals, institutional and support services were investigated. The results obtained showed that overall scheme efficiency is 26% and average efficiencies were; conveyance efficiency 44%, application efficiency 80%, storage efficiency 29%, distribution efficiency 79%, system efficiency 56%, project efficiency 44% and economic efficiency 40%. Only 14,064 bags of un-threshed rice is achieved annually against 35,160 bags expected per season. The competition between irrigated and rain feed crops was usually a setback for the scheme and only one crop of rice can be grown instead of two rice cropping per season. Organizing awareness campaigns among farmers on how to utilize the available resources (land and water) in a way to agree with the recommended standard of practice was recommended.

Key words: Application Efficiency, Conveyance Efficiency, Salinization and Irrigation.

INTRODUCTION

Irrigation is a primary agricultural factor in most countries of the world today, if those countries are to meet the increasing demand for food and fibre. Precipitation is no longer a dependable source alone in agricultural production even in regions that were not classified as arid based on climate change. Any irrigation system invariably contribute to enhance crop production and increased farm income to the rural households and it provides cyclical development in different sectors of the economy as a whole (Raghava, *et al* 2011). Developing countries have made huge investments in infrastructure for irrigation in form of irrigation schemes over the last half century, realising its importance for food production for growing population. This investment, together with improved crop production technologies such as use of fertilizers, hybrid varieties, plant protection technologies etc, has enabled many countries to move towards achieving self-sufficiency in food production. Nevertheless there is also a perception that many irrigation schemes do not perform to expectations or achieve the goals. (Gorantiwar and Smont, 2005).

Many irrigation schemes in Nigeria are performing inefficiently, poor management by the government and users of those irrigation institutions, have reduce the efficiency levels of those schemes. Performance of many irrigation systems is significantly below their potential due to a number of shortcomings, including poor design, construction, operation and maintenance (Belgin *et al*., 2009). Irrigation is of major importance to many countries of the world today mostly developing countries. It is important in terms of agricultural production and food supply, the income of rural people and public investment for rural development. However there is wide spread of dissatisfaction with the performance of irrigation projects in developing countries. Continuously monitoring the Performance of a given irrigation system enables to know

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whether the targets and objectives are being met or not. It also provides system managers, farmers, policy makers a better understanding of how a system operates. It helps to identify alternatives that may be both effective and feasible in improving system performance to achieve maximum efficiency (Behailu *et al 2004*).

As world population is increasing, irrigation agriculture is needed to play a primary role in food security of the world future. Therefore, it is necessary to evaluate the efficiency levels of irrigation schemes to find ways of improving food production. Precise evaluation of irrigation scheme performance and ability to sustain it in Nigeria is fettered by inadequate and unreliable irrigation statistics. Performance evaluation is the most practical tool to assess the success of any changes in irrigation management. That is why; performance evaluation studies have gained significance since the early 2000s. It also facilitates the determination of possible problems and thus, improves the performance of irrigation schemes (Belgin *et al*., 2009). Deteriorating efficiency over the years will reduce the performance of the irrigation schemes over this period. Hence thought, the efficiency is related to the maintenance of the physical infrastructure of the water distribution network that, needs to be evaluated as performance of irrigation scheme when it is in actual operation. This helps to show the causes of performance deviation from the desired standard (Gorantiwar and Smont 2005). The performance of a farm irrigation system is determined by the efficiency with which water is diverted, conveyed, and applied, and by the adequacy and uniformity of application in each field on the farm. Consequently, optimal water use efficiency in any irrigation system depends on maximizing water use efficiency, maintaining good water quality and preventing salinization of irrigation water and these require improved quality and reliable water delivery to the field (Burt and Styles, 1999). This study, performance evaluation of Badeggi irrigation scheme, was assessed using conventional methods of irrigation efficiency with the following performance indicators conveyance efficiency, system efficiency and application efficiency. Conveyance Efficiency (*E*c) means the percent of the water reaching the field plot on the basis of water diverted and is calculated as *E*c = (water reached to the plot) × 100/(water diverted from the source) For the whole command area of a watercourse, average *E*c can be computed as:

*E*c = *Q*d − *C*SL × *L*av 100
*Q*d × 100 (4.13)

Where

*E*c is the conveyance efficiency in percent,
*Q*d is the pump discharge in cumec (m3/s).
*C*SL is the average steady state conveyance loss (m3/s)/100 m
*L*av is the average channel length of the field plots (m)

Application efficiency defined by different researchers varies slightly in the expression (Solomon, 1988; Burt *et al*., 1997; Heermann *et al*., 1990). In broad term, application efficiency is the percentage of water delivered to the field that is ready for crop use. As the application efficiency is a measure of how efficiently water has been applied to the root zone of the crop, this parameter relates the total volume of water applied by the irrigation system to the volume of water that has been added to the root zone and is available for use by the crop. Thus, the application efficiency (*E*a) is calculated as (Wingginton and Raine, 2001): *E*a = (irrigation water available to the crop) × 100/(water delivered to the field) where Irrigation water available to the crop = root zone soil moisture after irrigation – root zone soil moisture prior to irrigation Water delivered to the field = flow meter reading or nozzle flow rate.

The measurement of conventional irrigation efficiency parameters are difficult and time consuming. Therefore, rare measurements of irrigation efficiency exist based on physical measurement of the factors affecting irrigation efficiency (Machibya, *et al,* 2003). To achieve a significant success in any irrigation project small or big scale. Performance evaluation should be a tool to periodically access the efficiency of the project by the management. Gorantiwar and Smont, (2005) concluded that efficiency is important in two ways. Firstly, appropriate optimum allocation plans cannot be developed if proper consideration is not given to efficiency. Inaccurate or simplified estimate also have a major influence on other performance parameters such as productivity, adequacy, equity and reliability. Secondly, the inspection of efficiencies over space and time at different levels enables the irrigation authorities to learn which part of the scheme is inefficient, where it is inefficient and how it is deteriorating

Inappropriate management of irrigation scheme might lead to environmental problems such as high water table and poor drainage and thus salinization and pollution in addition to low quality of water. Assessing the performance of irrigated agriculture is necessary in order to evaluate the impact of agricultural and hydrological interventions (Ingle *et al, 2015*). Increase in the population around the scheme site have raised the demand of water for the purpose of drinking, industries, and recreation, this has a negative effect on the irrigation water demand and quality. Therefore, utilizing the available water resources for efficient irrigation purpose to enhance the crop production has become a top consideration for Baddegi Irrigation Scheme.

AIMS AND OBJECTIVES OF THE STUDY

The objectives of this study performance assessment is to measure, through consistently applied standards, various factors that indicate either by comparison across systems (whether a system is performing 'well' or 'badly' in a relative sense) or by a system-specific analysis to see how the system is operating in relation to its own objectives. In general, evaluation helps to identify problems and the measures required to correct them. Thus, this study aimed at

- Improving irrigation performance
- Improving management practices
- Improving sustainability of irrigated agriculture

MATERIAL AND METHODS

Study area

Badeggi irrigation scheme is located at about 15 km east of Bida town, Niger state, on the right bank flood plain of the River Gbako, a tributary to the River Niger. The dam is a concrete type 10 m long and 12 m high, the scheme has gross command area [GCA] of 879 hectares. Part of scheme is being use by N.C.R.I, the source of water supply to the scheme is River Mussa, which is perennial. The area lies on (Lat. 9^0, 45N, Long 06^0, 07E, 70.5m above sea level) in the Southern Guinea Savannah Ecological Zone of Nigeria.

The climate condition of the area is essentially the same as typical as of the middle belt of Nigeria with high temperature and excessive humidity during the most part of year, normal rainfall ranges between 1100 mm and 1200 mm. Rainfall normally occurs between the months of April to October, the peak rainfall is recorded during the month of August. Humidity is generally high throughout the year and varies from a minimum of 51 % to maximum of 87 %. The prevailing climatic condition largely determines both, the available water resources and the crop water requirements in any season.

Land use cropping pattern

The general land use system is communal, where it is the jurisdiction of the village head to allocate the farm land to interested farmers according to the size of the family and influence. The farm size ranges from 2 – 5 hectares. Each farmer must pay to the village head produce or cash at the end of every farming season as a tax for using the land. However, the area under Badeggi irrigation scheme is controlled and allocated by the authority of Niger state Agricultural Development Project.

Generally, the main types of crops produced in the area are Rice, Maize, Sugar Cane, Guinea Corn and Vegetables like Tomatoes, Pepper etc, but specifically rice is cultivated in larger quantity therefore the cropping pattern considered is limited to Rice. Water supply system is on continues basis, the discharge in the canal system is adjusted to the irrigation requirement; the supply is distributed within the system proportionally to the hectare served.

METHODOLOGY

The methods used consisted of direct field observation which was conducted during 2013-14 cropping season. Discussions with a large number of stakeholders who were directly involve in the scheme, such as farmers, staff of Niger state Agricultural Development Project, staff of National Cereal Research Institute Badeggi and operator of the dam [water distributor]. A comprehensive methodology has been proposed by Bos (1997) and Micheal (1978) for evaluating the efficiency at different levels in the irrigation scheme. The efficiencies used in this study are as follows;

Water conveyance efficiency (Ec) % =Wf/Wd × 100

Wf=Water delivered to the irrigation plot at field supply channel
Wd=Water delivered from the source
Water application efficiency (E_a) %=Ws/Wf × 100
Ws=Water stored in the root zone of the plant
Wf=Water delivered to the field at field supply channel

Water storage efficiency (Es)%=Ws/Wn × 100

Ws=Water stored in the root zone during irrigation
Wn=Water need in the root zone prior to irrigation

Water distribution efficiency (Ed) % = (1 – y/d-) x 100

d- = average depth of water stored along the run during the irrigation
y- = average numerical deviation from d-Project efficiency = it is the % irrigation water that is stored in the soil and available for consumptive use by crops. It is measured at the point of diversion from the canal or the main source of supply.
Economic (Irrigation efficiency) = the ratio of the total production (net or gross [profit) attained with the operating irrigation system, compared to the total productive expected under ideal conditions.
Three efficiency indicators are considered to give the overall scheme efficiency (Magayane *et al 2003*).
Measurement of flows was conducted using floating method, the following materials were used.

a. Measuring tape 5m long.
b. Simple wooden stakes.
c. Stopwatch.
d. Floating stick.

The time of float travel, the stream bed width, the surface water width, and water depth were measured severally

Table 1. The détermination of efficience of the irrigation scheme.

Channel	Velocity	Area	Discharge
Main	0.6330m/sec	1.0352m^2	0.655m^3/sec
Field Channel 1	0.5834m/sec	0.455 m^2	0.265 m^3/sec
Field Channel 2	0.6072m/sec	0.458 m^2	0.278 m^3/sec
Field Channel 3	0.5950m/sec	0.458 m^2	0.278 m^3/sec
Field Channel 4	0.5834m/sec	0.424 m^2	0.247 m^3/sec
Field Channel 5	0.5509m/sec	0.458 m^2	0.252 m^3/sec
Field Channel 6	0.561m/sec	0.632 m^2	0.355 m^3/sec
Field Channel 7	0.5950m/sec	0.603 m^2	0.359 m^3/sec
Field Channel 8	0.6072m/sec	0.477 m^2	0.290 m^3/sec

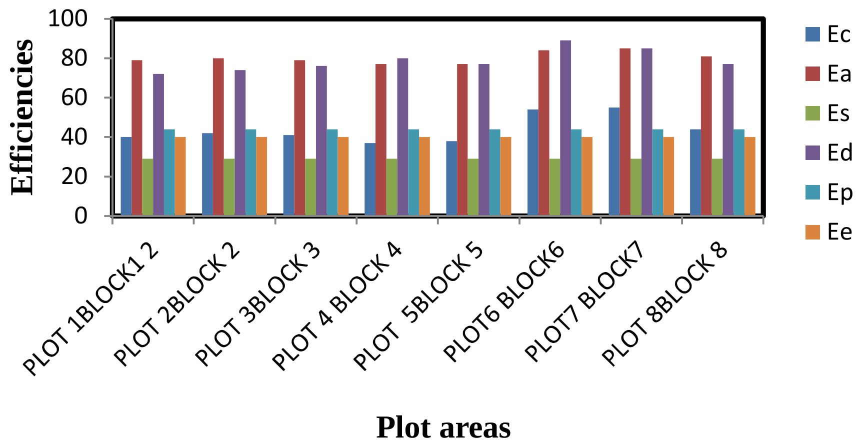

Figure 2: Efficiencies of plots in blocks at the irrigation area.

(four times) in order to determine the average. To calculate the average area of the stream cross-section (A), the average flow velocity (V), the discharge (Q) the following formula was used.

A = (a+b)h/2
V = L/T
Q = VA (m^3/s)

RESULT AND DISCUSSION

In the determination of efficiency of the irrigation scheme a plot was selected randomly from the eight blocks of the scheme and their efficiencies evaluated with an average. The existing depth and width of the channels are used in the determination of the areas of the channels; an average of three trials of velocities was conducted. The followings were equally obtained, runoff losses in the field equal to 1200m^3, water stored in the root zone during irrigation equal to 480m^3, and water needed in the root zone prior to irrigation equal to 1680m^3. Average efficiencies obtained are conveyance efficiency = 44%, application efficiency = 80%, storage efficiency = 29%, distribution efficiency = 79%, system efficiency =56%, project efficiency = 44% and economic efficiency = 40%. (table 1)

Lack of operation autonomy and little sense of ownership on the part of the beneficiaries are common problems in the majority of small-scale irrigation scheme. However no comprehensive studies have been conducted to explore the cause of these unsuccessful irrigation efforts and to generate potential solutions to improve the overall efficiencies of the irrigation scheme with the user communities (Melisew, 2012)**.**

The low conveyance efficiency (44%) obtained was as a result of inadequate water management practices around the scheme site, in using bare hands to clear the channels some designed works becomes faulty or damaged which permit loss of large amount of water, the degree of land preparation and lack of skills or carelessness of some farmers enhance the decrease in the conveyance efficiency. Since every farmer is aware of the effect in poor application of irrigation water, they spend much time and effort to ensure proper application of water. The storage efficiency is very poor; it was observed that the soil at the project site was mainly sandy loam which has a low water holding capacity, excessive seepage loss form part of the problems. About 1680mm of water needed by rice 1200mm (70%) was

Table 2: Planting time of major crops in 2013/2014.

	Guinea corn	Millet	Mellon	Ground nut	Maize	Rice
Before April	19	16	24	14	18	0
First half of April	17	24	24	26	14	0
Second half of April	12	20	12	16	8	0
First half of May	26	24	29	29	34	2
Second half of May	8	2	3	7	3	6
First half of June	8	3	5	6	15	11
Second half of June	5	9	5	0	15	11
First half of July	4	2	0	0	0	15
Second half of July	0	0	0	1	0	18
First half of August	0	0	0	0	0	16
Second half of August	0	0	0	0	0	21
Total	99	100	92	99	107	98

lost through deep percolation. Effective water distribution was obtainable because of good canal layout, each plot in blocks were given adequate time to receive water (figure 1). Poor management of available water for irrigation both at system and farm levels has led to a range of problems and further aggravated water availability and has reduced the benefit of irrigation investments [FAO, 1996].

Activities upstream of river Mussa caused low supply of water from the river during the dry season and this has a great effect on the average project efficiency which is 44 percent, other factor is the inability of the farmers to cultivate rice during the peak of raining season, much of the time is expended on upland cropping, table 2. Economic efficiency of the irrigation scheme is 40 percent, almost all the farmers cultivating at the scheme site has upland cropping as their priority before the end of May every year and at this period about 50 percent of the upland crops has been planted. Thus, it is only after sowing and weeding of upland crops that the farmers comes to prepare land for rice while the probability of having more than 75mm of rain still to fall is less than 50 percent. Therefore only one crop of rice can be grown instead of two rice cropping per season. The competition between irrigated and rain feed crops is usually a setback for economic Efficiency of any irrigation scheme if the farmers don’t have the knowledge or scale of preference for rain feed and irrigated cropping. It often happens that at the peak of labour requirement for rice (nursery preparation, land preparation and transplanting) lots of time was devoted to rain feed crops on the upland fields.

Under ideal conditions (proper water management, pest control and two cropping time per season) the expected un-thresh rice production at Badeggi irrigation scheme is 35160 bags but only 14064 bags of un-thresh rice is achieved, about 60 percent is lost to poor water management strategies and other related problems. Underutilization of the scheme cannot be disconnected from the failure of the farmers to master the techniques of double cropping system and lack of managerial and technical experience in irrigation scheduling, drainage and irrigated crop production by the staff of the management authority.

CONCLUSION AND RECOMMENDATIONS

From the study, the existing performance of Badeggi irrigation scheme using efficiency and agricultural practices indicators, the results obtained showed values of outputs are below the recommended standard of practices. To overcome lower efficiencies, repairs of the broken canals, continue clearing and lining of the field channels are desirable to solving the problems associated with seepage. Establishing of water users association and training on water use practices will improve the efficiency of the scheme; to further improve the output irrigated crops should be given much attention and adherence to cropping time table. Organizing awareness campaigns among farmers on how to utilize the available resources (land and water) in a way to agree with the recommended practices will help in identifying alternatives, which may be both effective and feasible in improving system performance to achieved maximum efficiency

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