An Assessment of the Reliability and Adequacy of Irrigation Water in Small Holder Irrigation Schemes

Case Study: Exchange Irrigation Scheme In Kwekwe, Midlands, Zimbabwe

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Abstract: ***Zimbabwe irrigation schemes were designed with the main aim of improving the living standards and to promote sustainable development of rural communities. Years after the implementation of these irrigation schemes most of them are now operating far below their expected performance with aging and deterioration of equipment ranging among the most prominent challenges. The present study investigates the performance of the water supply systems of Exchange Irrigation Scheme of Kwekwe District Zimbabwe. The main aim is to determine the reliability and adequacy levels of water delivered by the irrigation water supply system in meeting the irrigation water needs for the scheme during the period of 2013 to 2017. Values of crop water requirements were estimated using CROPWAT model. Levels of reliability were quantified using the RWS index. The study observed that the system is continuously failing to meet the irrigation water demand with only 2013 receiving enough water to match the water demand and from the overall monthly averages irrigation water needs and irrigation water applied for the periods of 2013 – 2017 the system only managed to deliver adequate water for only three months that is February, March and June. The RWS index indicated that the irrigation scheme water supply system was unreliable in 2016 and 2017whith reliability levels of 78% and 72% respectively which are below the RWS index threshold.***

Keywords: Reliability, Adequacy, Small Scale Irrigation Schemes, Irrigation Water Management

1. Introduction

Improving agriculture productivity through smallholder irrigation schemes is one of the key strategies for alleviating poverty and improving the livelihoods of rural communities. In Zimbabwe the majority of the poor communities depend directly or indirectly on agriculture. Most of Zimbabwe agriculture productive land approximately 80% is located in semi-arid regions of the country [1].

Rainfall in the arid and semi-arid regions is too erratic and unreliable for dryland farming, making supplementary irrigation necessary for successful agriculture. Irrigation, therefore, acts as a mitigating measure against droughts and mid-season dry spells, which enables irrigators to grow crops throughout the year and intensify production. Irrigation development has played a significant role in agricultural expansion throughout the world. Irrigation development provides an opportunity for intensive land exploitation to boost agriculture production

Irrigation has historically been a chief factor for rising crop productivity. It raises the productivity of land directly by providing adequate water supply to raise the yield per hectare per crop and by allowing a second crop to be grown during the dry season when yields are potentially higher [2]

Around 1980 the government of Zimbabwe introduced communal irrigation projects in most semi arid regions of the country. The major thrust of this effort has been to raise the living standards and sustainable development of rural households through improved food security, higher incomes and better employment opportunities amid recurring droughts. So, the government of Zimbabwe's objective for irrigation development was to guarantee food security through increased crop production [1], [3]

Decades down the line the majority of these irrigation schemes gradually became a pale shadow of themselves with wear and tear of equipment ranging among the most prominent challenges [4]. Most of these schemes are now operating far below their anticipated capacity. Years of neglect and mismanagement have seen these once vibrant schemes becoming grounded with very little farming activities [5].

Zimbabwe irrigation schemes have largely been unsuccessful in meeting their main goals to improve rural livelihoods and sustainable crop production for food security and poverty alleviation [6]. The underperformance of Zimbabwe smallholder irrigation schemes, just like in most developing countries, is largely a result of complex interrelated factors, such as low technical capacity, poor institutional arrangements and uncoordinated market linkages [7].

Agriculture productivity in Zimbabwe has been affected by factors such as inadequate inputs; inaccessible markets; unreliable and inadequate water delivery, due to weak water governance institutions; weak market integration; significant degradation and abandonment of irrigated land, including substandard infrastructure; and government policies on land tenure that do not support a conducive environment for the successful operation of irrigation schemes [8]. This paper examines the reliability and adequacy level attained in supplying irrigation water to Exchange Irrigation Scheme which is one of the smallholder irrigation schemes in Zimbabwe.

1.2 Study area

The study was carried out at Exchange Irrigation Scheme in Silobela, which is an agriculture village in Kwekwe district in the Midlands province of Zimbabwe (Figure 1). It is located about 60 kilometers North West of Kwekwe town, 80 kilometers northwest of Gweru town. The area is located on international grid reference 18º59¹South and 29º18¹.It is communally owned with the management help from AGRITEX officers. The scheme is about 168.8 hectares and accommodates about 410 farmers. The scheme is flood irrigated; the water is supplied by the Zimbabwe National Water Authority (ZINWA) from the Exchange dam.

Exchange Irrigation Scheme is located in Agro-ecological region IV [9]. Natural region IV is located mainly in the mid-altitude areas of the country, rainfall in this region is moderate, severe midseason dry spells make it marginal for maize, tobacco and cotton, or for the enterprises based on crop production alone. The farming systems are therefore based on both livestock, production of fodder crops and cash crops [10] .The soils are mainly clay loam soils, moderately deep with inherent soil fertility [11]

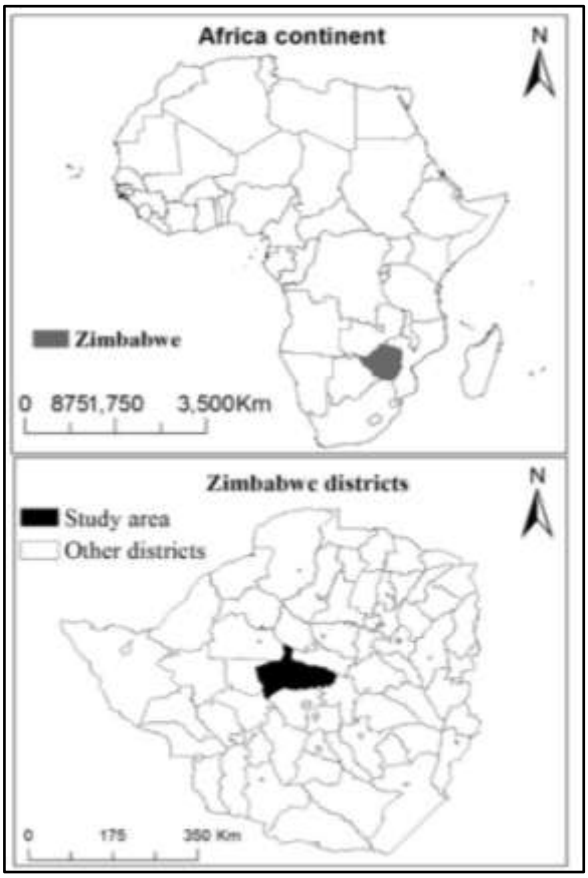

Figure 1: Location of the study area

2. Irrigation schemes management in Zimbabwe

2.1 History of Zimbabwe irrigation schemes

Irrigation schemes in Zimbabwe were launched in 1913 as a means of famine relief and subsequently to settle black farmers displaced from designated areas for white commercial farmers [12]. In 1928 the colonial government introduced a program to provide services to existing smallholder schemes and to assist in developing new schemes. This process eventually led to the wearing down of farmer involvement in planning, development and financing of smallholder schemes. Since 1928 the smallholder schemes have been heavily subsidized, from that time onwards the colonial regime kept a tight grip on smallholder irrigation schemes to an extent of laying regulations on what to plant and when to plant in other words it was responsible for the managerial role of the schemes [12].

Sikwela, (2008) also concluded that the confidence in the successes of irrigation schemes by the Zimbabwe government led to huge investment in irrigation and dam construction soon after independence [13]. The main reason for such high level of investment in irrigation development was to decrease dependency on government, improve food security and promote rural development and alleviate poverty.

Zimbabwe with most of its agriculture productive land located in semi arid regions small holder irrigation schemes becomes a key strategy in poverty alleviation and uplifting of rural communities livelihoods. Samakande, (2004) said that Smallholder irrigation worldwide can be recognized as a crucial common property reserve for the sustenance of rural livelihoods in semi-arid regions [14].

Manzungu, (2003) indicated that since the Fast Track Land Reform Program (FTLRP) was launched in 2003 irrigation functional area stands at 120,000 hectares. New entrants in the irrigation sub-sector include A1, A2 and indigenous large-scale commercial farmers, who between them now account for about 30% of the irrigated area. He also observed that about 30% of farmers in the small holder irrigation schemes lack the ability to fully utilize their irrigated plots [15].

2.2 Irrigation water management in Zimbabwe

Irrigation allows a high level of crop diversification that are not possible to achieve using rainfed agriculture [16], [17]. Crop intensification in irrigated lands enables households to cultivate during dry and rain seasons and, this will result high land augmentation effect.

According to Grafton and Hussey (2011), water management is an activity of planning, developing, distributing and managing the optimum use of water [18]. It include, better water supply, sustainability of the water source, improved crop yields, efficient water uses which facilitate equitable distribution of water, lower water charges, saving in time and energy, reuse and safe disposal of water and the reduction of pollution to the environment which all contribute to an improved quality of life for the rural and urban communities.

Water management is becoming a critical constraint in Zimbabwe, water resources, which until quite recently were considered cheap and plentiful, are now fully recognized to be scarce and valuable [19].Pazvakavambwa found out that one additional cubic meter of water (irrigation and rainfall) can give an added 1.5 kg of maize.

Samakande, (2004) suggested that it is important to note that Zimbabwe has taken steps to address the water challenges, the major highlight include the water reforms that began in the mid 1990`s which culminated in the promulgation of the water act and the Zimbabwe water authority act which provided for sustainable water resources management [14]. The country has also put place a policy frame work towards integrated water resources management which aims at striking balance between land and water and environmental aspects with human development needs.

Ascertain water use especially at field level have revealed gross over application in most surface Irrigation schemes, [19], [20]. The low application efficiency in the range 26-30% recorded by Senzanje et al, (2003) were attributed mainly due to poor water management practices. Samakande, Senzanje and Manzungu recognized smallholder irrigation as sustenance of rural livelihoods in Zimbabwe whereby 70% of the population live in rural areas characterized by low and unpredictable rainfall. Their paper looked at field water management on crop performance at Gudyanga and Chakohwa irrigation schemes in Manicaland.

2.3 Irrigation water reliability

Most authors have proposed indicators to measure irrigation system performance. Adequacy focus with water supply to the crop relative to its demand and reliability is a measure of how closely actual performance matches expected performance. Abernethy (1986) defined reliability as deliveries according to some schedule and according to him, unreliable water supplies are undesirable to a system's overall health [21]. The successful results of the allocation plans depend on reliable supply. Gorantiwar et al, (2005) concluded that water is delivered to the farmers in accordance with the schedules prepared during the planning process; the supply is considered to be reliable [22].This expectation can be real or perceived. Real (technical) reliability measures focus on the frequency which target levels are achieved, perceived reliability measures focus on people's perceptions, and are thus difficult to quantify.

Molden and Gates, (1990) also measured the temporal variability of the supply in their set of performance indicators. The authors proposed the coefficient of variation over a region (R) of actual amount delivered (Qd) against amount required (Qr) as a performance indicator to assess reliability [23]

$$\text{Irrigationwaterreliabilty} = \frac{\text{Qd}}{\text{Qr}}$$

The reasons attributed to the unreliable irrigation water supply are mainly due to technical and managerial in efficiency [23]. Some of the problems are as a result of power cuts, poor canal maintenance; unexpected demands arise from sectors other than irrigation, inappropriate consideration of the capacity of the water distribution system, canal breakage and theft and management capacity or capability of the irrigation organization to deliver the scheduled supply.

In Zimbabwe, water supply systems for smallholder irrigation schemes were generally designed so that adequate water is available 90 % of the times [24]. Reliability levels of 80 to 90 % are sometimes used by large-scale commercial farmers when deciding to develop their own irrigation systems [25].

Makadho**,** 1999 suggested the use of relative water supply index in the assessment of the adequacy and reliability of irrigation water supply [26]. He said that to determine whether water supply is adequate or not the comparison can be made between amount of water available at the field level (Sj) with the volumes of water demand (Dj) for crop production during the study period.

Relative water supply index [26]

$$\text{RWS} = \frac{\text{S}}{\text{D}}$$

Where
RWS …….Relative water supply
S…………Is water supplied
D…………Demand

Water deficit is when Sj < Dj and when RWS RWS figure of 80% denotes minimum requirements below which significant yield reduction occur [26], [27]. The ratio provides the relative abundance or scarcity of water in the field by matching water available to the farmers with that which is actually needed by the farmers.

3. Material and Methods

3.1 Procedure

The methods used include secondary data, case study approach and comparative analysis. For data collection the researcher used key- informant interviews, semi-structured interviews, documentary review and discussions.

CLIMWAT was used to generate the climatic data that was used in CROPWAT 8.0. CROPWAT 8.0 was then used to estimate the crop water needs and the irrigation water needs for the scheme. For data analysis and data presentation Microsoft Excel analysis tool was used.

In an attempt to understand the practices by farmers, the researcher accessed documentary evidence in form of books used for recording yields, cropping programs, climatic data, water reports and other relevant records. The documents were collected from the Irrigation Scheme offices, AGRITEX offices and Midlands Province Irrigation Department (MPID). These records definitely provided a proposal from which critical issues on water management were explored.

The information on Allocated water (AW) and Requested water (RW) was acquired from the records that were provided by the Irrigation Scheme management committee and the Midlands Province Irrigation Department (MPID).

The researcher used monthly data for 2013-2017 cropping seasons.

Rainfall data was compiled from the rainfall record books at the scheme, which were made from monthly rainfalls that were determined by a standard rain gauge graduated to the nearest millimeter. Rainfall readings were taken after every rainfall event and recorded in the rainfall record book this was done throughout the season. The researcher used the collected data on rainfall from the year 2013-2017.

CLIMWAT was used to determine the average climatic conditions for Kwekwe district (min temp, max temp, humidity, wind, sun, radiation and evapo-transpiration). The climatic data from CLIMWAT was then exported to CROPWAT which is a decision support system developed by the Land and Water Development Division of FAO for planning and management of irrigation.

CROPWAT was used to calculate the seasonal crop water needs and the crop irrigation water need of the scheme. CROPWAT 8.0 uses Penman Monteith method which is recommended by FAO. It provides a standard to which evapo-transpiration at different periods of the year or in other regions can be compared, and evapotranspiration of other crops can be related [28].CROPWAT was used as a practical tool to carry out standard calculations for reference evapotranspiration, crop water requirements and crop irrigation requirements, and more specifically the design and water management of the irrigation scheme.

On the reliability assessment the researcher used relative water supply index (RWS) proposed by Makadho(1999). To determine whether water supply was adequacy or not, a comparison was made between each year`s total amount of water available at the field level (Sj) with the year`s total volume demanded (Dj) for crop production during 2013 to 2017 seasons. The scheme efficiencies ware assumed to be still according to the Department off irrigation standard that is, field application efficiency 60%, field canal efficiency 92% and water conveyance efficiency 92%. The overall irrigation efficiency was then considered to be 50%.

Relative Water Supply Index (RWS)

$$RWS = \frac{S}{D}$$

Where
RWS …….. Relative water supply
S…………... Is water supply
D……………Is water demand

Water is considered to be unreliable when S<D and If RWS< 0.8

4. Results and Discussion

4.1 Irrigation water supply and demand

The graph below shows the water supplied and water demanded by Exchange Irrigation Scheme from 2013 to 2017.

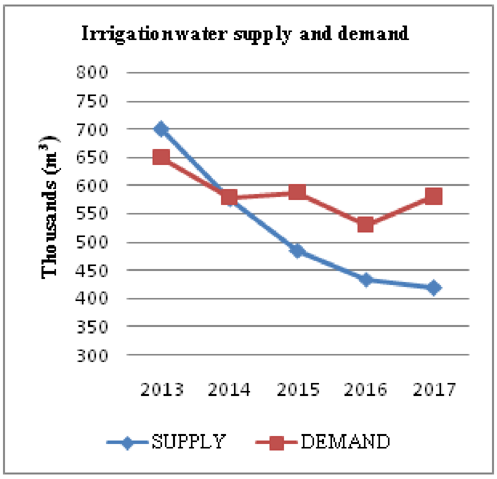

Figure 2: Irrigation water supply and demand

From the graph its showing that the water supply system is continuously failing to meet the irrigation water demand. During the time of study Exchange Irrigation Scheme water supply only managed to meet the water demand on only one year that is in 2013. The graph is showing that the water supply is continuously dropping from 2013 and it is failing to meet the scheme irrigation water demand. The discussion with farmers also showed that the scheme has been poor with the crop yields being far below the expected yields. Incomes have been too low to sustain the day to day living of the participants. This poor performance has been directly due to numerous technical and planning related problems. Frequent pump breakdowns as the whole of 2016 the scheme operated with only two pumps instead of three pumps. The scheme faces delays in repairing of the pump whenever it breaks down and electricity is sometimes disconnected due to non-payment of the bills.

So, we can conclude that the reason why water supply is not adequate to satisfy water demand for Exchange Irrigation Scheme is not due to the low dam levels, but rather technical and managerial problems within the scheme. [9], [29] also made the same conclusion in their researches that the failure of smallholder schemes in Africa is mainly because of substandard infrastructure, unclear irrigation scheduling and inefficient water use.

4.2 Irrigation water applied against irrigation water need

The graph below represents the average irrigation water needs and irrigation water applied during the time of study (2013-2017)

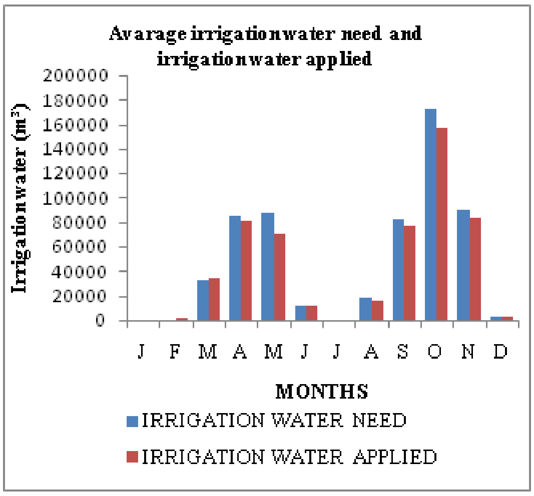

Figure 3: Irrigation water applied against irrigation water need

From the overall average irrigation water needs and irrigation water applied for the periods of 2013 – 2017 we can see that the Irrigation Scheme water supply system is failing to meet the irrigation water needs for the scheme. The scheme water supply system only managed to meet the irrigation water need only for three months that is March, February and June with the rest of the year having irrigation water deficit. These results can be ascribed to substandard in the technical and managerial decisions. The scheme experience power cuts and frequent pump breakdown which are having impact on the efficiency of the irrigation water supply system.

4.3 Irrigation relative water supply

The graph below shows the reliability levels in percentages for Exchange Irrigation Scheme from the year 2013 to 2017.

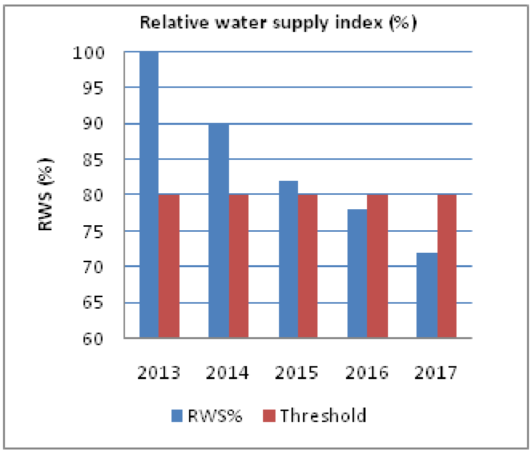

Figure 4: Irrigation relative water supply

The researcher used the Relative Water Supply Index (RWS) as proposed by Makadho, 1999 to determine the water reliability of the Irrigation Scheme water supply system [26]. RWS index states that the water system is only reliable when the water supply is more or equal to water demanded or when the RWS index value is greater than 80%. From this research the Exchange Irrigation Scheme water supply was only reliable during 2008, 2009 and 2010 with 100%, 98%, 82% RWS index values respectively. The last two years of the research the scheme RWS index indicated that the scheme water supply was not reliable with 78% and 72 % RWS index respectively.

5. Conclusion and Recommendations

The study revealed that the irrigation water supply system for Exchange Irrigation Scheme of Kwekwe District is failing to meet the crop irrigation water needs and this has affected the water reliability of the whole irrigation scheme. The scheme water supply system is unreliable and this is affecting the crop production and the livelihoods of the farmers. The performance of the Irrigation Scheme is significantly below its potential due to number of shortcomings, such as poor management, poor operations and maintenance.

As a country Zimbabwe needs rehabilitation program to counteract deterioration and poor performance of irrigation schemes, especially now when the country is experiencing the effects of climate change and variability. There is a need for improved planning, operation and sustainable and integrated water resources management. Also, he government need to upgrade farmer's knowledge on water and crop management for the better and sustainable development of the agriculture based communities. The government must concentrate on essential needs that are related to water management, education and improvement of WMC and IMC members. Smallholder irrigation schemes need capacity building in water management in all its aspects that is in design, operation and maintenance, integration with water management, the environment and health.

Further more for significant water savings to be achieved there is a need of improvement or substitution of the flood irrigation which have low efficient (less than 75 % efficient) with more efficient irrigation methods such as conventional (75 %) sprinkler centre pivot (80 %), micro-jet (85 %) and drip (90 %) irrigation methods.

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