Economic and Technical Determinants of Surface Irrigation Water Use in Wheat Tenancies in North Sudan

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Abstract: - Surface water in Sudan comprises mainly the River Nile and other tributaries. The River Nile, which is shared between 10 countries namely Nile Base Countries, is the primary source of water in Sudan. Irrigated wheat is grown in East, Central and of North Sudan, but the River Nile State of North Sudan offers more suitable environment for the crop production. Wheat, commonly grown in the public pump irrigated schemes where faces a manifold problem. The study investigated On-Farm Water-Use Efficiency (FWUE) for Wheat production. Systematic sampling was adopted in selecting scheme participants. CropWat4 analysis and stochastic frontier model were use in analyzing water use and efficiency in Wheat production. The research revealed that growers were over-irrigating their crop by 36%. High irrigation-water cost is the most critical production constraint. There was inefficiency in water use and the significant determinants of output of Wheat are water price and fertilizer. The inefficiency factors include farming experience, extension visits, irrigation distance and off farm income. Thus farmers were inefficient in the use of production factors as they operated below the frontier output. There is enormous potential for improvements that could lead to substantial savings in irrigation water, which in turn can be utilized to gain additional irrigated areas.

Key-Words: - wheat, irrigation, efficiency, water productivity

1 Introduction

The world's population is growing by about 80 million people a year, implying increased freshwater demand of about 64 billion cubic meters a year. Competition for water exists at all levels and is forecast to increase with demands for water in almost all countries (UN- Water Statistics, 2012). Irrigation systems for agriculture, viticulture, and residential and commercial landscapes consume enormous amounts of water resources. An effective irrigation system needs to apply the appropriate amount of water without applying too much (Fazackerley *et al*, 2011). 70% of the blue water withdrawals at global level go to irrigation. Irrigated agriculture represents 20% of the total cultivated land but contributes 40% of the total food produced worldwide (FAO, 2012). Sudan has a tropical sub-continental climate, which is characterized by a wide range of variations extending from the desert climate in the north through a belt of summer-rain climate to an equatorial climate in the extreme south. The average annual rainfall is 416 mm, but ranges between 25 mm in the dry north and over 1 600 mm in the tropical rain forests in the south. Sudan has the largest irrigated area in sub-Saharan Africa and the second largest in the whole of Africa, after Egypt. The irrigated sub-sector plays a very important role in the country's agricultural production. Although the irrigated area constitutes only about 11 percent of the total cultivated land in Sudan, it contributes more than half of the total volume of the agricultural production. Irrigated agriculture has become more and more important over the past few decades as a result of drought and rainfall variability and uncertainty. It remains a central option to boost the economy in general and increase the living standard of the majority of the population. Wheat is one of the most strategic crops in Sudan. It is Sudan's second most important cereal food in terms of consumption after sorghum. Over the past few years, wheat production, which is almost entirely irrigated, has been declining due to diminishing yields and soaring input costs. Since 1999, the Government liberalized the wheat production regime and removed all support programs. These moves have prompted many farmers to drastically reduce wheat cultivation and/or switch to more lucrative cash crops, such as vegetables and oil seeds. Gezira, White Nile, New Halfa, River Nile and Northern States are the main suppliers for irrigated wheat. The overall area under wheat in 2005/06 exceeded 290 thousand feddans (122 000) hectares (MAS, 2006). Irrigation water is an essential key for economic growth and human welfare, and for conserving ecosystems. Poor state and inadequate investment, however, are resulting in large populations not having access to the water services they need. Failure to manage water resources effectively is also resulting in increased pressure on these resources, mounting competition for their use among different economic activities, and, in some regions, conflict. The last three decades witnessed critical problems regarding water provision, distribution and utilization particularly encountered at peak demand periods that may be attributed to power failure accompanied by lack and high cost of fuel and spare parts to operate the pumps. These became common problems and were aggravated even more by the diminution of the canals carrying capacities, resulting in low productivity of crops. Faki (2004) stated that the high cost of production, coupled with low productivity and lack of a cheap source of power, has made it difficult for the farmers to realize the full potential of the State. Further, development is constrained by serious limitations on the two basic resources: land and water. Flow recession of the Nile and Atbara Rivers in August and September affect the availability of irrigation water in October through February. Requirement for irrigation water is highest through this period when winter cash crops (i.e. wheat, legumes, fodders, vegetables) are grown and require irrigation water. Economic scarcity, meanwhile, is caused by a lack of investment in water or insufficient human capacity to satisfy the demand for water. Symptoms of economic water scarcity include a lack of infrastructure, with people often having to fetch water from rivers for domestic and agricultural uses. Some 2.8 billion people currently live in water-scarce areas (Molden, 2007). According to Elsir *et al.* (2004), it has long been recognised that high production costs, low productivity and lack of a cheap source of power for water pumping hinder realisation of the full agricultural potential in River Nile State. The awareness of water use efficiency not widespread in most of the public schemes in the State; in other words there is low striving to apply the recommended standards of crop water requirements. The area that can be commanded by pumps is significantly higher than the actually cultivated one. This indicates that the capacity of those pumps was underutilized. Faki (2004) reported that in Northern Sudan the irrigation needs are designated in terms of numbers of irrigations, not actual quantities, and it is likely that reduction in amounts per irrigation or even number of irrigations may be possible without reducing yield. Surface irrigation by pumps, which dominates the RNS agricultural production systems, is regarded as having very low efficiency, leading to low FWUE in the majority of the public irrigated schemes there. Therefore, this paper examines water use and productivity of Wheat in the public irrigation schemes of the River Nile State in Sudan.

2 Methodology

Study Area: The River Nile State is considered as one of the least developing States in the country, although, with its relatively cooler weather and fertile alluvial soils, has a comparative advantages over other parts of the country in producing relatively high-value crops (wheat, faba beans, citruses, mangos, dates, certain spices and medical plants). Wheat is ranked at the top of the major winter food crops in the State; the average cultivated area under wheat for last decade is estimated at 75,434 feddans. The State accommodates three types of pump-irrigated schemes namely, private, cooperative and public schemes with different production-relation systems. The optimum time for wheat planting is November and temperatures during this period remained cooler than average. In almost all wheat growing areas, the bulk of plantings occur on time. The effectiveness of irrigation is determined by the availability and supply of fuel for pump irrigation and the degree of siltation in canals for larger schemes.

2.1 Sampling and Data Collection

Stratified random sampling was employed in selecting 70 respondents for the study, forming about 2.3% of Elzeidab scheme's tenants. The cost route approach was adopted in collecting data for the 2005/2006 season. Data collection involved personal interviews and the use of structured questionnaire.

2.1.1 Data Analysis

Data analysis involved descriptive techniques and the use of CropWat4 software program for assessing crop water requirement. Water use efficiency was analyzed by applying the stochastic frontier model.

2.2 Economics of Wheat Production

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Gross Margin Analysis (GMA) was employed to determine the economics of Wheat production. The gross, which is calculated as gross revenue less variable costs forms a good indicator of how profitable a firm is at the most fundamental level. The general mathematical form for the gross margin analysis used to calculate the gross margin as follow:

$$GM = GR - TVC \quad \text{------ 1}$$

Where:
GM: gross margin of each crop per fed in SD.
GR: gross revenue of each crop per fed in SD.
TVC: total variable cost per fed in SD.

2.3. Calculation of irrigation water-use efficiency (WUE) for wheat

Assessment of water use under full irrigation provides important indicators for WUE in Wheat production. According to the International Center for Agricultural Research the in dry Areas (ICARDA) (2001) the concept of on-farm water use efficiency (FWUE) was developed to address this complex situation at the farm level. FWUE is defined as the ratio of the required irrigation water to produce a specific output level to the actual amount of water applied by farmers. Based on this definition, FWUE may take the value of less, equal or greater than one (< , > or = 1). Where, a value less than one implies that farmers over-irrigate their crops, while a value greater than one implies that farmers under-irrigate their crops. However, if the value of the calculated FWUE is equal to one, it means that farmers are fully efficient in using irrigation water because the required and applied amounts of water are equal, as shown in the following form:

$$FWUE = WR/ WA * 100 \quad \text{------ 2}$$

Where:
WR: is the amount of water required (m^3) by the crop to produce a certain level of crop production.
WA: is the amount of water actually applied (m^3) by farmers to produce that level of crop production.

2.4 Stochastic frontier production model specification

The Stochastic Frontier Analysis (SFA) investigates farm specific determinants of productivity. The model computes efficiency values as indicators of productivity and determinants of efficiency. This approach was adopted to determine the effect of irrigation water use by farmers on the output of Wheat.

A general stochastic production frontier model can be given by:

$$\ln q_j = f(\ln x) + v_j - u_j \quad \text{----- 3}$$

Where q_j is the output produced by firm j, x is a vector of factor inputs, v_j is the stochastic (white noise) error term and u_j is a one-sided error representing the technical inefficiency of firm j. Both v_j and u_j are assumed to be independently and identically distributed (iid) with variance σ_v^2 and σ_u^2 respectively.

Given that the production of each firm j can be estimated as:

$$\ln\hat{q}_j = f(\ln x) - u_j \quad \text{------ 4}$$

While the efficient level of production (i.e. no inefficiency) is defined as:

$$\ln q^* = f(\ln x) \quad \text{------ 5}$$

Then technical efficiency (TE) can be given by:

$$\ln TE_j = \ln\hat{q}_j - \ln q^* = -u_j \quad \text{----- 6}$$

Hence,

$$TE_j = e^{-u_j} \quad \text{----- 7}$$

Equation (7) and is constrained to be between zero and one in value. If u_j equals zero, then TE equals one, and production is said to be technically efficient. Technical efficiency of the *j*th firm is therefore a relative measure of its output as a proportion of the corresponding frontier output. A firm is technically efficient if its output level is on the frontier, which implies that q/q* equals one in value.

One aim in SFA is to explain inefficiency/efficiency in terms of exogenous determinants, (Kumbhakar and Lovell, 2000) summarized some models to explain inefficiency/efficiency of a producer. The generalized efficiency equation is given as:

$$U_i = g\,(zi;\,\gamma) + \varepsilon i \quad \text{----- 8}$$

3 Results and Discussion

Socio-demographic characteristics of tenants in area of the study were unveiled that: the average age of surveyed respondents in the scheme was 40 years old, while the average size of family's surveyed tenants ranged from 1 to 15 persons. The study revealed that all surveyed respondent were educated as well as males. Farming experience of tenants estimated at 20 years on the average, while the average farm size in the scheme was varied from 1 to 28 feddan per farm household (one feddan equal 0.42 hectare). The average distance from tenant's residence to their farms location was about 2.7 km. The research found that the farming system of Elzeidab scheme is dominated by Wheat production which occupied for 25% of the total planted land.

3.1 Elzeidab irrigation-water costs

Sudan is generally self-sufficient in basic foods, albeit with important inter-annual and geographical variations, and with wide regional and household disparities in food security prevailing across the country (FAO, 2005). The major hindrances that face high crop productivity and incomes are higher marketing margins on agricultural products and an inadequate allocation of budgetary resources and of the scarce foreign exchange earnings. As a result, the manner of low input/low-productivity model of production continues to prevail, and small farmers' incomes remain depressed. In the wake of the food shortages experienced in the 1980s, a high priority has been given by the Government to produce food crops particularly cereal and legumes. This has resulted in large expansions in sorghum and wheat areas and output. Much of this has been at the expense of the main cash crop, cotton, with production declining by more than 40 percent since the mid-1980s. The State Ministry of Agriculture (MAS) (2006) reported that irrigation water costs for the scheme are broadly differentiated into fixed and variable costs (see Figure 1).

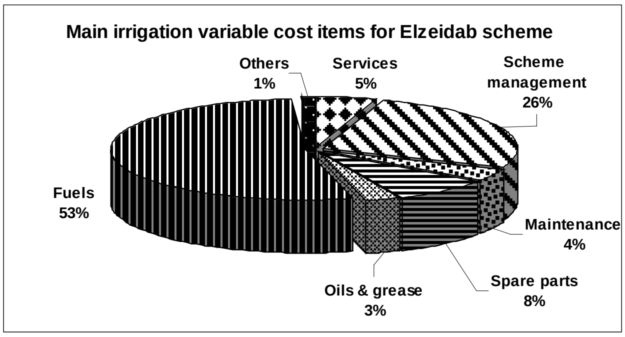

Fig. 1: the irrigation cost components in percentage

Irrigation costs are mainly based on variable costs as elaborated in figure 1, while department of irrigation of MAS often ignores the fixed costs of irrigation. The annual running expenses comprise fuel (diesel), oil (engine, gearbox), grease, spare parts, maintenance, staff salaries and allowances (management expenses), services and others. The analysis unveiled that the fuels component amounted about SD 116,422,848 constituting the highest component of the cost of irrigation forming 53% of the total irrigation costs. Irrigation-water cost is invariably considered as the most critical farm production constraint on account of the high cost of irrigation water pumping from the River Nile. Figure 2 represents the detailed illustration of disaggregated production costs and depicts the cost components in a sequence of the seasonal crop production operations.

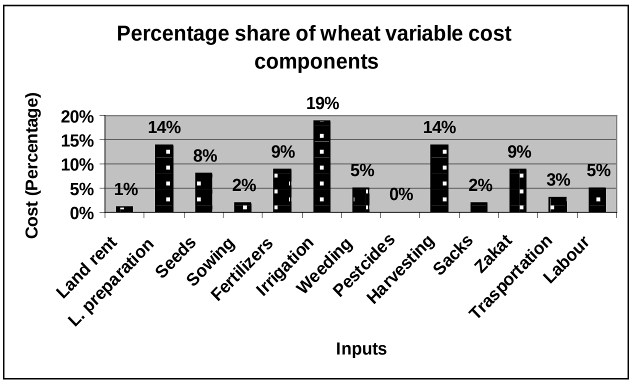

Fig. 2: Share percentages of wheat variable cost components

The 13 cost components shown in Figure 2 add up to SD 70054 as the total cost of production. The irrigation-cost component formed the highest cost item accounting for 19% of total production cost. Wheat growers in the scheme pay the cost of this item at a fixed rate to the scheme administration at the end of the season.

3.2 Gross Margin Analysis

According to the survey results, wheat production costs were less than its gross returns resulting in a positive gross margin of SD 4295 as shown in Table 1. The Table also shows that, although the gross margin of wheat was positive sign, but it was nevertheless low, especially if the forgone opportunities of using winter land and water resources are considered, given wider range of winter crops that can be produced. One reason for lower gross margin might be low productivity coupled with the increasing input prices that faced in the RNS in the last decade. According to this fact, unfortunately, wheat crop could be assessed as infeasible crop in North Sudan unless improvements are made.

Table 1 Gross margin analysis of wheat in Elzeidab scheme

Production cost (SD/feddan)	70054
Average yield (kg/feddan.)	676
Average price (SD/kg)	110
Gross return (SD/feddan.)	74349
Gross marginal revenue (SD/feddan.)	4295

Source: Field survey, 2006

3.3 Irrigation water use efficiency

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When agricultural water is used effectively and safely, production and crop yield are positively affected. A decrease in applied water can cause production and yield to decrease. Management strategies are the most important way to improve agricultural water use and maintain optimal production and yield. The key is to implement management strategies that improve water use efficiency without decreasing yield. Some examples include improved irrigation scheduling and crop specific irrigation management. These strategies allow for the conservation of water and energy, and decrease grower's costs. Total water withdrawal in the Sudan was estimated at 37 km^3 for the year 2000. The largest water user by far was agriculture with 36 km^3. Municipalities and industry accounted for withdrawals of 0.99 km^3 and 0.26 km^3 respectively. Water used in Sudan derives almost exclusively from surface water resources. Groundwater is used only in very limited areas, and mainly for municipal water supply (FAO, 2005). FWUE of wheat crop was estimated at two levels, one per watering and the other per season. The study revealed that the average applied irrigation water per season for the crop was found to be 3756 m^3/ feddan as illustrated in Table 2.

Table 2 Assessment of FWUE per watering and per season for wheat
Source: Field survey, 2006

The analysis revealed that the total applied water for wheat is not high if compared to some seasonal crops in the scheme which consume relatively high amounts. For instance, onions, vegetables and potatoes are high water-demanding crops among their growing seasons that extend over about 141, 130 and 110 days, respectively. The estimated FWUE of Elzeidab scheme of RNS indicated to a wide technological gap between the required utilization (WR) and actual water application (WA) for wheat and other crops (see Figure 3). The Figure also shows that farmers within the surveyed sample over-irrigated their entire field crops.

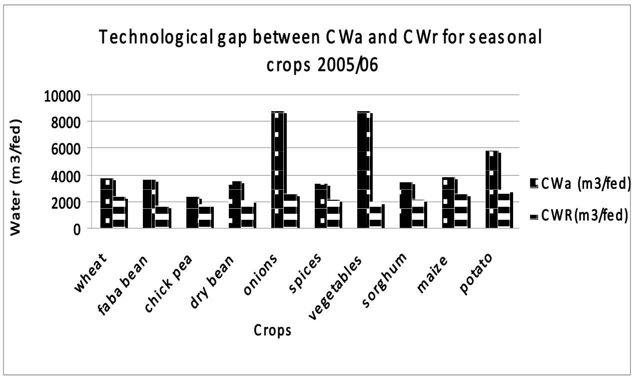

Fig. 3: Physical gabs between CWA and CWR for the surveyed tenants

The average cultivated farm area in area of the study was estimated as 6.0149 feddan per tenancy, while the average area of cultivated wheat was found to be as 3.672 feddan, or 61% of the total cultivated farm area. The research revealed that Wheat growers in the scheme exceeded the crop water requirements by 41% per watering and 64% for the whole season, suggesting the need for improving the FWUE. Further, the study quantified the amount of water supplied by the scheme and the quantity required for

Crop	CWa (m^3/fed)	FWUE watering	Over-irrigation %	FWUE -season	Over-irrigation %
Wheat	3756	0.41	59	0.64	36

Wheat production as depicted in Table 3. The average amount of water available to the total cultivated farm area was 28573 m^3; while the average quantity of crop water requirements was 13432 m^3, indication surplus water of 15141 m^3, which is sufficient for supplying expected extensions in irrigated areas derived at 6.779 feddan or 112% of the total cultivated area of tenancy.

Table 3 Physical gap between the CWA and CWR for the cultivated area of farm compared to wheat area

category	Av. cultivated area (fed)	CWA (m3)	CWR (m3)	irrigation gap (m3)	Expected extension area (fed)	Expected extension area (%)
Farm size 8.509 fed.	6.0149	28573	13432	15140.59	6.779	112
Wheat	3.672	13792	8800	4991.72	2.083	57

Source: Field survey

Table 3 also illustrates the average amount of water available to wheat within the farm amounting to 13792 m^3. The average quantities of crop water requirements were 8800 m^3 with an estimated surplus water of 4992 m^3; sufficient for a possible extension in irrigated area of 2.083 fed equal equivalent to 57% of cultivated area.

3.4 Economic and technical productivity per unit water for wheat

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Fifty years ago, the common perception was that water was an infinite resource. At this time, there was fewer than half of the current number of people on the planet. People were not as wealthy as today, consumed fewer calories and ate less meat, so less water was needed to produce their food. They required a third of the volume of water we presently take from rivers. Today, the competition for water resources is much more intense. To avoid a global water crisis, farmers will have to strive to increase productivity to meet growing demands for food, while industry and cities find ways to use water more efficiently (Chartres, 2010). Cropping pattern is also one of the most important parameters involved in irrigation command areas. It is directly related to the productivity of irrigation systems and greatly contributes to improved soil and water utilization. Crop planning in irrigated agriculture has traditionally been based on the concept of maximization of net benefit (Montazar *et al*, 2011). According to the International Center for Agricultural Research the in dry Areas (ICARDA) research on WUE, water productivity is defined as the ratio of crop production (kg) to the unit of water used (m^3) or as the amount of food produced per unit volume of water used. There are several different ways of expressing water productivity such as pure physical productivity, combined physical and economic productivity. Determination of productivity per unit water of wheat here was assessed for both economic and physical productivity of water. Water productivity in monetary terms in (m^3/SD) of output per cubic meter of water as depicted in Table 4, it provides an important indicator of water productivity. From Table 4, water productivity of wheat in monetary term was only 3.619 SD/m^3, while it was 5.452 SD/m^3 for spices.

Table 4 Determination of wheat productivity per unit water in monetary terms in Elzeidab scheme

Crops	Water price (SD)	Water amount (m^3/fed)	Water productivity (SD/m^3)
Wheat	13592.59	3756.00	3.619

Source: Field survey

On the other hand, physical (or technical) water productivity that measures kg of output per m^3 of water was only 0.180 kg/m^3, which very low when compared to water productivity for potatoes derived at 0.680 kg/m^3 in the area of study (Table 5). Hence water productivity in technical or economic terms have important considerations for the assessment of crops produced in the irrigated subsector.

Table 5 Determination of wheat productivity per unit water in physical terms in Elzeidab scheme

Crops	Yield (kg)	Amount of water (m^3/fed)	Productivity per unit water (kg/m^3)
Wheat in the scheme	676	3756	0.180

Source: Field survey, 2006

3.5 Determinants of efficiency in wheat

The frontier result of the determination of efficiency is shown in table 6.The model statistics estimated are all valid. The value of gamma (g) indicates the proportion of variation in the model that is due to capacity production factors included in the model. The value is relatively high, 0.75 percent and is statistically significant at one percent. The implication is that most of the variables included in the model are necessary in accounting for the output of Wheat in Sudan. The generalized likelihood ratio statistic (also known as the LR test) is high 14.62 which led us to conclude that the production frontier is identical to the production function. The results obtained are valid and not spurious. Water price for irrigation and fertilizer are the significant determinants of output of Wheat. While water price is negative and significant at 1 percent, fertilizer is a positive determinant of output and is significant at 5 percent. Previous studies by Amaza (2000), Adeoti

Table 6 Results from maximum likelihood estimation

Production factors	Coefficient	t-value
Constant (βo)	5.397***	8.30
Land (β_1)	-0.031	-1.26
Seed (β_2)	0.005	0.47
Water Price (β_3)	-0.051***	-3.740
Capital (β_4)	-0.026	-0.08
Fertilizer (β_5)	0.001**	2.21
Animal Power (β_6)	0.001	1.51
Labour cost (β_7)	0.001	1.12
Efficiency factors		

Education of household head (δ_1)	0.127	0.81
Household size (δ_2)	-0.129	-0.50
Farming experience (δ_3)	0.352*	1.82
Age of household head (δ_4)	-0.111	-0.29
Extension Visit/Access (δ_5)	-0.289*	-1.78
Irrigation distance (δ_6)	0.695**	2.09
Home to field distance (δ_7)	-0.409	-0.73
Off-farm Income (δ_8)	-0.624*	-1.95
sigma-squared	0.49**	2.51
Gamma (g)	0.75***	5.06
log likelihood function	-52.69	
LR test of the one-sided error	14.62	

Source: Field survey

(2001) Ogundele (2003) and Awotide (2004) also reported low elasticity for fertilizer in food crop production in Nigeria. The economic price of irrigation water is not charged and this has resulted in large volumes of water being wasted. Farmers are not charged on the basis of volume used and once they pay subject to use the way they want. Wheat growth depends on high soil fertility and as such there is heavy application of fertilizer for high productivity. Farmers enhance the productivity of land through the application of fertilizers. Four factors were significant in the inefficiency model viz farming experience, extension visits, irrigation distance and off-farm income. In the inefficiency model, a negative coefficient implies an increase in efficiency while a negative coefficient leads to reduction in efficiency other things being equal. As the farmer gets older he becomes less innovative and takes little risk. This accounts for the impact of farming experience. Extension visits impacts positively on efficiency. Farmers receive advice of modern techniques and advice about the best way to handle farm problems and availability of modern seeds and seedlings. The further away the source of irrigation, the more difficult farmers make use of the service. Farmers provide their own transport and as such when the source is far away, they spend more money on transportation and use less of services. This accounts for while distance impacts negatively on efficiency. People who earn off farm income and get remittance often do not concentrate in terms of following all the agronomic practices and this often decreases productivity hence efficiency.

3.6 Technical efficiency of wheat farmers

Irrigation development requires the mobilization of often scarce resources, including arable land, adequate water, and financial capital. Hence, it is imperative that the organization subsequently entrusted with responsibility for the completed irrigation scheme, be capable of ensuring proper management of such resources. Efficient use of these resources may be evaluated using indicators such as: cropping intensity (IC), the proportion of the area affected by damage (PSD) and relative water supply (RWS) (Dembele *et al*, 2011). The frequency distribution of the technical efficiency indices derived from the analysis of the stochastic production is provided in Table 7.

Table 7 Distribution of economic efficiency

Efficiency Range	Mean	Percentage
0.14 – 0.30	0.208	7.14
0.31 – 0.47	0.421	15.71
0.48 – 0.64	0.582	32.86
0.65 – 0.81	0.722	31.43
0.82 – 1.00	0.866	12.86
Grand Mean	0.611	

Source: Field survey, 2006

The technical efficiency of the sampled farmers was less than one (or 100%) indicating that all the Wheat farmers sampled were operating below the frontier. The best performing farm had a technical efficiency of 0.95 or 95 percent, while the least performing farm had a technical efficiency of 0.14 or 14 percent. The mean technical efficiency of the Wheat farmers was 0.61 or 61 percent. This implied that the Wheat farmers were able to obtain about 61 percent of optimal output from a given set of production inputs suggesting that there is the scope for increasing Wheat production by 39 per cent if they were to operate at the frontier or by 5 percent if all Wheat farmers would adopt the technology and production techniques currently used by the most technically efficient farmers. In general, the results suggested that the sampled farmers were fairly technically efficient.

3.7 Future Challenges

Water withdrawals are predicted to increase by 50 percent by 2025 in developing countries, and 18 percent in developed countries. Over 1.4 billion people currently live in river basins where the use of water exceeds minimum recharge levels, leading to the desiccation of rivers and depletion of groundwater. In 60 percent of European cities with more than 100,000 people, groundwater is being used at a faster rate than it can be replenished (UN-Water Statistics, 2012). World agriculture faces an enormous challenge over the next 40 years: to produce almost 50% more food up to 2030 and double production by 2050. This will probably have to be achieved with less water, mainly because of pressure from growing urbanization, industrialization and climate change. Hence, it will be important in future that farmers receive the right signals to increase water use efficiency and improve agricultural water management, especially as agriculture is the major user of water in most countries (OECD, 2013). Globally, agriculture accounts for 80–90% of all freshwater used by humans, and most of that is in crop production. In many areas, this water use is unsustainable; water supplies are also under pressure from other users and are being affected by climate change. Much effort is being made to reduce water use by crops and produce ‘more crop per drop (Morison *et al*., 2008). Agriculture can have significant impacts on the environment as it uses on average over 40% of water and land resources. The impacts occur on and off farm, including both pollution and degradation of soil, water and air. But agriculture also supplies ecosystem services, such as biodiversity, provides a sink for greenhouse gases, and contributes to flood control and the aesthetic value of landscapes (OECD, 2013). Rockström (2013) outlined a number of key challenges the world faces as it moves into the Anthropocene era in his presentation *Sustainable intensification of agricultural development: the scientific support for a new paradigm.* “The ‘3-6-9 World’ will see temperatures increase by 3 degrees, the 6^{th} mass extinction of species and a population of 9 billion by the middle of the century: a ‘planetary saturation point’ “, he argued. Climate change has affected numerous regions over the world and raises the attention of the issue of water security. Extreme weather conditions that could result in difficulties to anticipate wet or dry spells and other adverse impacts of climate change, pose major challenges to effective water resources management. The Food and Agriculture Organization of the United Nations (FAO) has estimated that by 2025, close to 1.8 billion people will be living in countries or regions with absolute water scarcity, and two-thirds of the world population could be under stress conditions (FAO,2010). River Nile State of Sudan is concerned front tremendous water management challenges due to the lack of adequate infrastructure, inadequate of public investment in infrastructure development, Lack of awareness regarding modern water conservation technologies, delay in updating agricultural system and inefficient State policies. Furthermore, rapid population growth and urbanization also exacerbate existing water security and governance issues, creating particularly negative impacts for peri-urban and rural resident.

4 Conclusion

Wheat has been a very important crop in the Sudan agricultural production system. Most of the Wheat produced is under irrigation system. Water use is critical in the production of Wheat and therefore the study investigated the efficiency of Wheat Water use in the Elzeidab scheme. A systematic procedure was adopted in selecting scheme participants and a cost route approach was adopted in data collection. Analytical procedure in studying Wheat water efficiency and productivity include gross margin analysis for profitability, CropWAT analysis for water use efficiency and the stochastic frontier analysis for the determinants of efficiency in Wheat production. The farming system of Elzeidab scheme is dominated by wheat, which accounts for 25% of the farm land. With a share of 53%, fuel was the highest single cost item of irrigation costs. On the other hand, wheat irrigation costs formed 19% of its total cost of production representing the highest category of overall variable costs. Awareness about CWR is absent among all surveyed tenants; a situation that would be attributable to limitation in extension services. The estimated FWUE indicated a wide technological gap between the CWR and the actual applied water; reaching 41% per watering and 64% for the entire season. The estimated wasted amounts of irrigation water would be sufficient for expected irrigated-area extension that is determined as 57% of the average grown area of wheat and 112% of the average cultivated area of the scheme. Water productivity of wheat crop in monetary and physical terms was generally low in the area of study when compared to some seasonal crops. Water price for irrigation and fertilizer were the significant determinants of the output of Wheat in the scheme. While the inefficiency factors are farming experience, extension visits, irrigation distance and off-farm income. The average efficiency for the scheme is 61 percent showing that farmers are producing below the frontier output level. Based on obtained results, the noted the high amount of water wastage and recommends that building capacity for huge water savings. This capacity should be utilized for expansions in uncultivated areas in the State through State intervention and adoption of participatory approaches involving scheme administrators and tenants to manage irrigation water and sensitizing to adopt modern water saving technologies.

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