Journal of Agriculture and Environment for International Development - JAEID 2018, 112 (2): 271-295
DOI: 10.12895/jaeid.20182.738

Knowledge and adoption of water use efficiency techniques among women irrigators: evidence from South Africa

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Submitted on 2018, 14 March; accepted on 2018, 22 August. Section: Research Paper

Abstract: The aim of the study was to determine the knowledge and adoption of water use efficiency techniques among women irrigators in the North West Province, South Africa. In this study, ex-post facto designed was used with a sample size of 108 farmers interviewed from the list obtained from the Department of Rural Environment and Agricultural Development (Farmer Support and Development – extension officers). Data collected were analysed using frequency counts, percentages, means, standard deviation and Probit regression model. The findings revealed that the mean age of the women irrigators was 52 years. Majority of the women had secondary level of education, married, had a mean household size of 7members, and were allocated land by tribal authorities with the assistance of the Department of Agriculture. Women irrigators in the study area were mostly aware of water use efficiency techniques such as crop rotation (93.5%), application of manure and fertilizer (92.6%) and terracing techniques (78.7%). The water use efficiency techniques adopted in the schemes are: crop rotation (78.8%), application of manure and fertilizer (78.8%) and cover crops (52.8%). The farmers were highly knowledgeable on mulching (91.7%), water harvesting (88.9%) and weed control (86.1%) while the most common constraint faced by women farmers on water use efficiency is lack of information (92.6%). Probit regression model revealed that the significant determinants for adoption of water use efficiency techniques include membership of farmers' groups, the frequency of extension visits, the existence of water tariffs, age, farm size and number of plots. The study concluded that women irrigators exhibited very low knowledge on all the water use efficiency techniques that are related to irrigation scheduling and had a low level of adoption of water use efficiency techniques. It was recommended that extension services be strengthened in order to improve the knowledge and adoption of water use efficiency techniques among the women farmers.

Key words: Water use efficiency techniques, women irrigators, Knowledge, adoption, South Africa

Introduction

South Africa is one of the driest countries in the world and obtains almost fifty percent of the mean global annual rainfall based on the per capita water availability (Schreiner *et al.*, 2010). In South Africa, about 60 percent of the areas obtains less rainfall that the required for effective crop production (De Villiers *et al.*, 2004), however, limited areas of the country receives more than 800 mm per annum (Schulze, 1997). In a water-scarce country like South Africa, there is a need to improve water use efficiency despite the decreasing demand for irrigation from 80 to about 50% in the last twenty years (De Villiers *et al.*, 2004). As the backbone of the South African economy, agriculture has been identified as one of the major sectors that can ensure the achievement of the Accelerated and Shared Growth Initiative of South Africa due to the fact that about 80% of South Africa's population depends on agriculture for their livelihood (Organization of Economic Co-operation and Development (OECD), 2006). Women play a pivotal role in agriculture as 41% are involved in agricultural production activities (Statistics South Africa (STAT SA), 2016), the non-recognition of their contribution notwithstanding. Globally, Women have always struggled to have access to productive resources such as land, inputs, financial services, technology and education (Food and Agriculture Organization (FAO), 2011) and these has tend to limit their production capacity.

Mutsvangwa and Doranalli, (2006) asserted that women play important roles in irrigation farming for empowerment and social emancipation which consequently ensures their participation in development initiatives and poverty alleviation in rural areas. Manzungu (2004) noted that increased income generation from irrigation by women has led to high confidence levels in participation in community development issues. From the educational perspective, irrigation farming also has enabled agricultural households to generate income to educate their children. Education is very important since it implies more opportunities for generating income, as well as better understanding of new and improved farming technologies (Chazovachii, 2012).

Hussain and Hanjra (2004) stated that enhancing agricultural productivity is a major strategy needed to reduce poverty among majority of the rural poor that depend directly or indirectly on agriculture such as the previously disadvantaged low-income areas of South Africa, including the North West Province. The role of water in the poverty equation is disproportionately great through impacts on other factors of food production (Hussain *et al.*, 2004). Improvement in water use efficiency enables adoption of new technologies, increased productivity, higher productivity and returns from farming, which opens up new prospects for off-farm income, improvements of livelihoods and the quality of life in rural areas (Hussain *et al.*, 2004). The productivity of water used in agriculture is important to the needs of food and environmental security. Tekana and Oladele (2011) stated that irrigation is a major technology to enhance household food security. Increasing the productivity of water to promote productivity in agriculture, reduce environmental degradation and provision of food security are critical in areas where water is a scarce resource (Rijsberman, 2001). .

The agricultural sector in South Africa faces complex series of challenges to increase food production with better quality using less water per unit of output due to the fact that South Africa is a water scarce country and water needs are above natural supply. In South Africa, water demand has increased due to population increase (Tshwene and Oladele, 2016), and the expected use of irrigated agriculture will further exacerbate this scenario to equal the demand for biomass production (Postel, 2003). Foley (2011) stated that agricultural water management is a key to enhancing food security despite the limitations posed by irrigation expansion, thus there is the need to identify and implement new techniques for water to contribute towards food security. To improve water use efficiency and ensure food security, several water use efficiency techniques have been developed and disseminated to farmers in South Africa. Singh *et al.* (2014), defines water use efficiency or productivity "as the yield of marketable crop produced per unit of water used in evapo-transpiration".

In South Africa, irrigation schemes cover about 1.3 million hectares of land were mainly located in rural areas of the former homeland to help rural farmers to improve their livelihoods. Poverty alleviation, employment and ensuring household food security in rural areas are major objectives for the establishment of smallholder irrigation schemes in South Africa (Aliber, 2003). According to Tekana and Oladele (2011) the use of irrigation contributes greatly to the improvement of rural livelihood. Small-scale farmers who are part of irrigation schemes realized an improved and increased supply of food that eventually leads them to be food secure (International Fund for Agricultural Development (IFAD), 1998). According to International Programme for Technology and Research in Irrigation Drainage (IPTRID) (1999) poverty can be reduced by giving irrigation access to both men and women. A significant difference in income and nutrition has been made in female headed household who have been given access to irrigation systems in Zimbabwe, Tanzania, Kenya and Gambia (IPTRID, 1999).

Increasing global population and demand for food are jointly stressing the need for agriculture to be a major user of water and thus the need to practice intensive agriculture such as irrigated agriculture which is more productive than rain fed agriculture (Singh and Kumar, 2009). The combination of irrigation farming and adoption of water use efficiency techniques will lead to more crops per drop of water (Singh *et al.*, 2014). It is estimated that agriculture uses almost two-thirds of South Africa's water resources, so improving the water use efficiency (WUE) without expansion can potentially contribute to water savings and food security (Jarmain *et* *al.*, 2014). The purposes of water-use efficiency are to conserve water by reducing conveyance losses either by channels lining or use of closed conduits, evaporation losses by avoiding midday sprinkling, reduced foliar interception by under-canopy; runoff and percolation losses by eliminating over-irrigation; mulching and by keeping the inter-row strips dry and applying weed control measures where needed, enhance crop growth, use of optimal timing for planting and harvesting, use optimal tillage, use appropriate pest and disease control, application of manures, practice of soil conservation for long-term sustainability, monitoring of water-table elevation and early signs of salt accumulation, and appropriate drainage and irrigation as well as, taking into consideration weather conditions and crop growth stage (FAO, 1997; NRC, 2010).

Annandale *et al.* (2011), posit that the irrigation industry as the largest user of freshwater resources in South Africa is a major determinant of achieving the country's goal of water sufficiency. Since the late 1990s, the Water Research Commission has funded research on analysis and development of irrigation-scheduling tools in South Africa , however, the adoption of these has to be determined as analysis, development and transfer do not directly translate to use by farmers which is the ultimate of technology development and dissemination processes.. There are several technologies that have been developed to improve the efficient use of water among farmers involved in irrigation farming. However, women, particularly in the study area have always been isolated from agricultural activities and information dissemination. It is important to determine how much of the techniques are known to women involved in irrigation farming, their knowledge of water use efficiency techniques and the constraints encountered in the use of these techniques. In view of these, the main objective of the study was to determine the knowledge and adoption of water use efficiency techniques among women irrigators in the North West Province. The specific objectives were to identify the personal characteristics and determine awareness, knowledge, adoption and constraints to the use of water use efficiency techniques among women farmers on irrigation schemes.

Materials and Methods

Study area

The study was conducted in the North West Province of South Africa. North West shares borders with Gauteng Province to the East, Limpopo Province to the North East, Botswana in the North, the Free State Province to the South and the Northern Cape Province to the West. The Province consists of four district municipalities and 19 local municipalities (as shown in Figure 1) and it is predominantly rural with most of the people relying on agriculture for their livelihoods (Rural Environment and Agricultural Development (READ), 2015). The North West Province has four districts, and Mahikeng is the capital city. The 2014 mid-year population estimates that there are approximately 3.67 million people residing in the Province (Statistics South Africa, 2016). Nearly 43% live in the Eastern Bojanala Platinum District Municipality and further a 24% live in Ngaka Modiri Molema District Municipality. The North West Province is rural, with 60% living in rural areas and the rest in urban areas. The climate of the Province is characterised by well-defined seasons with the rainy season occurring from October to March. The most common crops planted in the North West are maize and sunflower. In the North West Province there are several irrigation schemes that have been developed to enhance livelihood opportunities in agriculture due to the semi-arid nature of the area, but only schemes from Taung and Dinokana are operational, hence, the study focused on those two areas.

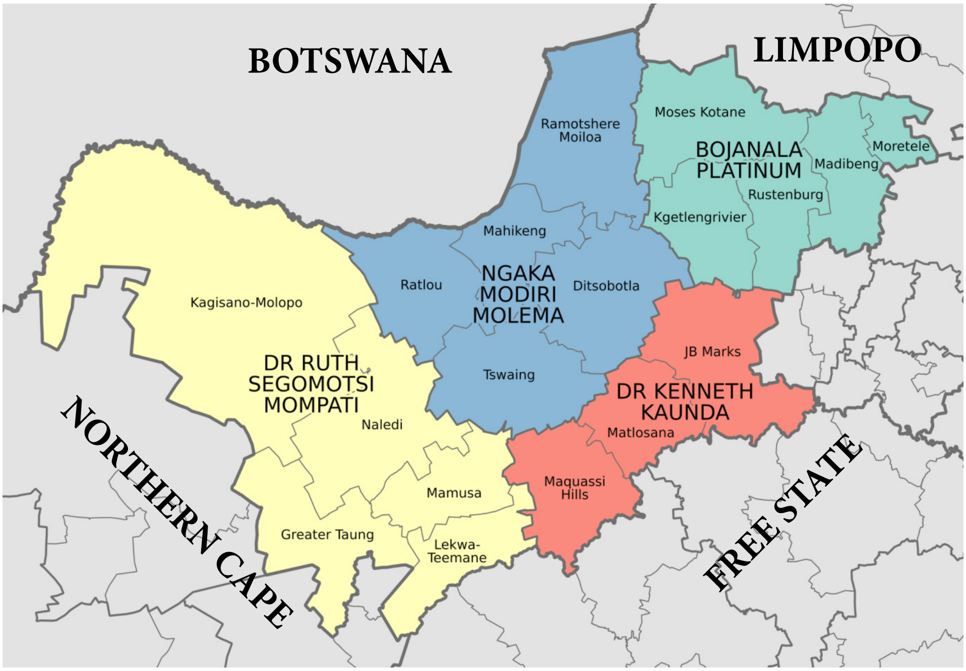

Figure 1 - Map of the North West Province showing all the Districts
Source: Wikipedia, 2016.

Research design and sampling technique

The research design used in this study was ex-post facto which is trying to explain the present adoption decisions with past factors experienced by the women irrigators. Cohen, Marion and Morison (2000) maintained that an ex-post facto experiment begins with groups that are already different in some respect and searches in retrospect for factors that brought about these differences. This study focused on knowledge and adoption of water use efficiency techniques among women irrigators in the North West Province. The population of the study was made up of women farmers in Rethuseng (30), Bosele (20), Ipelegeng (20), Tshidiso (20), Tshenolo (10), Reaitlhoma (10) and Zeerust (40) irrigation schemes in the North West province. According to READ (2015), there are 150 women involved in irrigation farming in the above irrigation schemes.

Different proportions of samples were taken from each of the schemes. In essence each scheme was stratum from which random sampling took place. Through the use of the Roasoft sample size calculator, a sample size of 108 farmers was selected. The irrigation schemes covered were: Rethuseng; Bosele; Ipelegeng; Tshidiso; Tshenolo; Reaitlhoma; and Zeerust. A structured questionnaire was operationalized based on the objectives of this study for the data collection process. The questionnaire was divided into sections on personal characteristics, awareness, knowledge adoption and constraints to the use of water use efficiency techniques among women farmers. The questionnaire was subjected to face validity by experts on agricultural extension, consisting of lecturers in Agricultural Extension, Community and Managers with long years of working experience in the Rural, Environment and Agricultural Development Department as well as research dependents. To determine the reliability of the questionnaire, a pre-test was carried out among women on the irrigation scheme in Taung (Rethuseng). A split half technique was used to determine the reliability which gave 0.85 as the alpha co-efficient.

Data analysis

Data were sorted and analysed through the Statistical Package for the Social Sciences (SPSS 21.0). Descriptive statistic such as frequency, percentages and mean were used to describe all the variables of the study while the Probit regression model was used to quantify factors that determine the adoption of water use efficiency techniques due to the dichotomous nature of the dependent variable, this is in line Omotayo (2017). More so, the justification for using the Probit model over the logit model was due to its ability to constrain the utility value of the decision to join the variable to lie within 0 and 1, and its ability to resolve the problem of heteroscedasticity (Asante *et al.*, 2011). Adoption of water use efficiency techniques (Y) was captured as a dummy variable with the value of 1 assigned to a farmer who is adopting and 0 for otherwise. The probit model is specified as follows

$$Z_k = \beta_0 + \beta_k \sum_{i=1}^{n} \mathrm{J}_k + \mu_k \quad 1)$$

$$Z_k = \beta_0 + \beta_1 \mathrm{J}_1 + \beta_2 \mathrm{J}_2 + \beta_3 \mathrm{J}_3 + \beta_4 \mathrm{J}_4 + \beta_5 \mathrm{J}_5 + \beta_6 \mathrm{J}_6 + \beta_7 \mathrm{J}_7 + \beta_n \mathrm{J}_n + \mu_k \quad 2)$$

Where Z_k is the dichotomous (binary) dependent variable indicating the adoption of water use efficiency techniques measured as 1 if farmers adopt and 0 if otherwise.
B_0 and β_k are the parameters of the estimates,
n = number of variables
J_k = the independent variables used in the study which include J_1 = Age, J_2 = Farming experience, J_3 = Marital status, J_4 = Educational level, J_5 = Knowledge, J_6 = Land ownership, J_7 = awareness, etc.
μ_k = error term.

Results and Discussion

Socio-economic profiles of the women irrigators in the irrigation schemes

The results of the personal characteristics of women irrigators from Table 1 revealed that majority (92.6%) of the women irrigators were above 40 years of age with a mean age of 52 years. This may be attributed to the observable trend of rural young people migrating to urban areas in search of other jobs aside farming because of their negative perception leaving the older women to farming activities. This is in consonance with South African Confederation of Agricultural Unions (SACAU) (2013) who reported that Africa's agriculture is predominantly carried out by the old and retired people in rural areas as young people seek better opportunities in urban areas and their surroundings. Also, about 41.7 percent of the women irrigators are married. This is in line with Adeniyi *et al*. (2016), who reported a similar trend among women farmers in Nigeria. Furthermore, 42.7% of the women had 1-3 dependents and the mean household size was 7 persons. Majority (80.6%) of the respondents didn't go beyond secondary education this might be due to the traditionally prevalent trend in the rural areas where parents with limited resources would choose to educate male children than females on the grounds that girls would be given out for marriage. Table 1 further reveals that majority (88.9%) of the land allocated to the women is by the tribal authority and more than half (54.0%) of women irrigators are members of famers' groups. In terms of contact with extension agents, majority (81.5%) of the women stated that they had contact, however, it is worthy of note that only a few (49.1%) of these women have regular contact with extension officers revealing the need for improvement in extension services been rendered to farmers in the area. Table 1 also shows that majority of the women irrigators pay utility fees such as water rates, (77.8%) and electricity (54.6%) while more than half (56.6%) of them majorly practised mono cropping system on their farms.

Table 1 - Personal characteristics of women irrigators (n=108)

VARIABLES	FREQUENCY (%)	MEAN
Age		
Less than 40 years	8 (7.4)	
40-50	25 (23.2)	52 years
51-60	28 (25.9)	
Above 60 years	47 (43.5)	
Marital status		
Single	34 (31.5)	
Married	45 (41.7)	
Widowed	13 (12.0)	
Divorced	16 (14.8)	
Number of dependents		
1 - 3	46 (42.7)	
4 – 6	39 (36.1)	5 persons
7 – 9	20 (18.5)	
10 – 13	3 (2.7)	
Number of members in household		
1 – 3	6 (5.6)	
4 – 6	46 (42.6	
7 – 9	33 (30.6)	7 persons
10 – 12	18 (16.6)	
Above 12	5 (4.6)	
Highest level of education		
Primary	7 (6.5)	
Secondary	87 (80.6)	
High school	3 (2.8)	
Non-formal education	11 (10.2)	
Land tenure status		
Personal / inherited	12 (11.1)	
Allocation	96 (88.9)	
Farm size		
Less than 8	24 (22.2)	
8 – 10	52 (48.1)	
Above 10	32 (29.7)	
Number of plots		
Less than 10	78(72.2)	
10	1(0.9)	
Above 10	29(26.9)	

Table 1 - Continued

VARIABLES	FREQUENCY (%)	MEAN
Location of plots in one area		
Yes	107 (99.0)	
No	1 (0.9)	
Members of farmers' group		
Yes	58 (53.7)	
No	50 (46.7)	
Contact with Extension Agent		
Yes	88 (81.5)	
No	20 (18.5)	
Frequency of extension visits		
Rarely	30 (27.8)	
Occasionally	53 (49.1)	
Regularly	25 (23.1)	
Extension Agency		
Government Parastatals	104 (96.3)	
Non-Government Parastatals	4 (3.7)	
Sources of labour		
Self	85 (78.7)	
Family	3 (2.8)	
Hired	20 (18.5)	
Farming experience		
1 – 10	29 (26.9)	
11 – 20	26 (24.1)	
21 – 30	27 (25.1)	
31 - 40	17 (15.8)	
Above 41	9 (8.3)	
Number of years in irrigation scheme		
1 – 10	33 (30.6)	
11 – 20	31 (28.0)	
21 – 30	23 (21.3)	
31 – 40	15 (13.9)	
Above 40	6 (5.6)	
Water rate		
Yes	84 (77.8)	
No	24 (22.2)	
Existence of water tariffs		
Yes	40 (37.0)	
No	68 (63.0)	

Table 1 - Continued

Variables	Frequency (%)	Mean
Electricity for water pumping		
Yes	59 (54.6)	
No	49 (45.4)	
Cropping systems		
Mono cropping system	61 (56.6)	
Double cropping system	6 (5.6)	
Multiple cropping	26 (24.1)	
Mixed cropping	11 (10.2)	
Crop livestock integration	4 (3.7)	

Awareness of water use efficiency techniques among women irrigators

The result in table 2 presents the awareness of water use efficiency techniques among women irrigators in the North West Province. From a list of 20 techniques it was revealed that the women irrigators were aware of about half of them, prominent among which were crop rotation techniques (93.5%), application of manure and green manure and fertilizer (92.6%) and the terracing technique (78.7%). This agrees with the report of Christensen *et al*. (2012) who stated that globally, crop rotation was a common agronomic practice that has wide range of awareness and utilization. He stated that it helps to replenish soil nutrients and break diseases and pest cycles thus leading to higher crop yields. Also, Al-Turbank (1999) reported that terracing, also known as staircase farming, is one of the oldest water diversion and soil management system in the world. The ancient traditional system of terracing was found to be the solution for growing crops on steep slopes and preventing erosion, as well as allowing efficient use of water.

Table 2 Awareness of water use efficiency techniques (n=108)

Techniques	Yes	No
Reduced tillage	61(56.5)	47(43.5)
Mulching	63(58.3)	45(41.7)
Intercropping	78(72.2)	30(27.8)
Use of drought resistant varieties	53(39.1)	55(49.1)
Furrow irrigated raised bed (FIRB) planting	67(62.0)	41(38.0)
Use of cover crop	80(74.1)	28(25.9)

Tab. 2- continued

Techniques	Yes	No
Rain water harvest	77(71.3)	31(23.7)
Drip irrigation system	75(69.4)	33(30.6)
Relay cropping	44(40.7)	64(59.3)
Crop rotation	101(93.5)	7(6.5)
Application of manure and green manure and fertilizer	100(92.6)	8(7.4)
Contour farming	48(44.4)	60(55.6)
Terracing	85(78.7)	23(21.3)
Deficit and supplemental irrigation	41(38.0)	67(62.0)
Micro-irrigation methods	45(41.7)	63(58.3)
Reduced conveyance losses by lining channels or closed conduits	13(12.0)	95(88.0)
Reduce runoff and percolation losses due to over irrigation	13(12.0)	95(88.0)
Crop density improvement	18(16.7)	90(83.3)
Reduced direct evaporation during irrigation by avoiding midday sprinkling	36(33.3)	72(66.7)
Use of lysimeters	5(4.6)	103(95.4)

*Figures in parentheses are percentages

Adoption of water use efficiency techniques

The findings in Table 3 show the adoption of water use efficiency techniques among women irrigators in the North West Province. It was revealed that the adoption of water use efficiency techniques among women farmers in the area was still very low as only 4 out of the 20 techniques was prominently adopted. The adopted techniques include crop rotation (78.8%), application of manure and green manure and fertilizer (78.8%), use of cover crops (52.8%) and reduced tillage (64.8%) while the least adopted techniques are terracing (3.7%) and crop density improvement (5.6%). The low level of adoption of terracing in the area is due to the fact that the farmers believe that terracing helps to reduce erosion, trap and hold rain water, enhances water saturation and is much more applicable for steep surfaces and the North West province unlike some other provinces is prominently made up of flat landscapes hence the lower level of adoption. The high level of adoption of cover crops and crop rotation in the area provides the farmers with a lot of potential opportunities for sustainable soil health and nutrient management. Chaney and Mayse (1997) also stated that the adoption of these techniques have several important implications for controlling pest and diseases.

Table 3 - Adoption of water use efficiency techniques (n=108)

ITEMS	YES*(%)	NO (%)
Crop rotation	85(78.8)	23(21.3)
Application of manure and green manure and fertilizer	85(78.8)	23(21.3)
Use of cover crop	57(52.8)	51(47.2)
Reduced tillage	70(64.8)	38(35.2)
Use of drought-resistant varieties	29(26.9)	79(73.1)
Intercropping	27(25.0)	81(75.0)
Reduce direct evaporation during irrigation by avoiding midday sprinkling	27(25.00	81(75.0)
Rain water harvest	24(22.2)	84(77.8)
Mulching	24(22.2)	84(77.8)
Relay cropping	23(21.3)	85(78.7)
Drip irrigation system	22(20.4)	86(79.6)
Furrow irrigated raised bed (FIRB) planting	21(19.4)	87(80.6)
Contour farming	17(15.7)	91(84.3)
Deficit and supplemental irrigation	16(14.8)	92(85.2)
Micro irrigation methods	15(13.9)	93(86.1)
Use of lysimeters	11(10.2)	97(89.8)
Reduced conveyance losses by lining channels or closed conduits	9(8.3)	99(91.7)
Reduce runoff and percolation losses due to over irrigation	9(8.3)	99(91.7)
Crop density improvement	6(5.6)	102(94.4)
Terracing	4(3.7)	104(96.3)

*Figures in parentheses are percentages

Knowledge of water use efficiency among women irrigators

The results from Table 4 reveal the knowledge of the women irrigators on the effect of the utilization of water use efficiency techniques in the North West Province. From a list of 60 knowledge test items rated on True (2) and False (1) scale, the Women irrigators exhibited varying degrees of knowledge on water use efficiency techniques. Prominent items where they were highly knowledgeable were mulching prevents evaporation of moisture (91.7%) and mulching improves water use efficiency (89.8%); water harvest concentrates water flow and storage (88.9%), water harvest improves water use efficiency (87%), weeds compete with crops for soil nutrients, water and light (86%), weed control improves water use efficiency (84.3%). Schonbeck (2015) stated that mulching contributes to weed management in organic crops by reducing weed seed germination, blocking the growth of weed, and favouring the crop by conserving soil moisture and sometimes, by moderating soil temperature. The results however further reveals that the women irrigators exhibited low level of knowledge on all water use efficiency techniques closely related to irrigation scheduling. The reason for the low knowledge could be due to the fact that women irrigators lack information about these models. WRC (2008) also maintain that small-scale farmers do not have access to expensive monitoring equipment, computers and internet access on irrigation scheduling

Table 4 - Knowledge of effect of techniques on water use efficiency

Knowledge Statements	Yes (%)	No (%)
Micro irrigation (drip irrigation) as the applied irrigation is directly targeted to the roots zone rather than being lost as soil evaporation and or deep drainage.	89(82.4)	19(17.6)
Micro irrigation will improve water use efficiency.	94(87.0)	14(13.0)
Water harvest is the collective name for a range of technologies that aim to concentrate water flows and storage.	96(88.9)	12(11.1)
Water harvest will improve water use efficiency.	94(87.0)	14(13.0)
Tillage influences crop yields and water use efficiency.	61(56.5)	47(43.5)
Mulching will prevent evaporation of moisture	99(91.7)	9(8.3)
Mulching will improve water use efficiency	97(89.8)	11(10.2)
Intercropping is cultivation of two or more crops simultaneously on the same field	94(87.0)	14(13.0)
The total water used in intercropping makes water use efficiency higher	78(72.2)	30(27.8)
Weeds compete with crops for soil nutrients, water and light.	93(86.1)	15(13.9)
Weed control will improve water efficiency.	91(84.3)	17(15.7)
Contour farming involves ploughing, planting and weeding along the contour.	40(37.0)	68(63.0)
These contour lines create a water break which reduces the formation of rills and gullies during times of heavy water run-off; which is a major cause of soil erosion.	35(32.4)	73(67.6)
Contour farming will improve water use efficiency.	34(31.5)	74(68.5)
Anti-transparent are materials or chemicals used to reduce transpiration.	60(55.6)	48(44.4)
Anti-transparent methods will improve water use efficiency.	63(58.3)	45(41.7)
Common water erosion control measures comprise of stone bunds, stones lines, micro-catchments and rows of trees or perennial grasses.	74(68.5)	34(31.5)

Table 4 - continued

Knowledge Statements	Yes (%)	No (%)
Relay cropping is the growing of two or more crops on the same field with the planting of a second crop after the first one has completed its development.	51(47.2)	57(52.8)
Relay cropping allows both crops to share a portion of the growing season, increasing solar radiation and heat availability.	53(49.1)	55(50.9)
Relay cropping will improve water use efficiency.	44(40.7)	64(59.3)
The growing of different crops in succession on a piece of land to avoid exhausting the soil and to control weeds, pests and diseases.	50(46.3)	58(53.7)
Supplemental is the addition of small amounts of water to essentially rainfed crops during critical periods (water stress) to provide sufficient moisture.	52(48.1)	56(51.9)
Supplemental irrigation will increase water use efficiency.	46(42.6)	62(57.4)
Crop rotation is the growing of different crops in succession on a piece of land to avoid exhausting the soil and to control weeds, pests and diseases.	65(60.2)	43(39.8)
Crop rotation will improve water use efficiency.	67(62.0)	41(38.0)
Conveyance loss: water that is lost in transit from a pipe, canal, or ditch by leakage or evaporation.	38(35.2)	70(64.8)
Reduced conveyance losses by lining channels or closed conduits will improve water use efficiency.	37(34.3)	71(65.7)
Percolation losses: The movement of water by gravity downward through the soil profile beyond the root zone, this water is not used by plants.	27(25.0)	25.0)
Reduction of runoff and percolation losses improves water use efficiency.	34(31.5)	74(68.5)
Planting or crop density refers to the spacing of plants when "planting" in the soil or other potting medium.	30(27.8)	78(72.2)
Crop density will improve water use efficiency.	23(21.3)	85(78.7)
Lysimeter is a measuring device which can be used to measure the amount of actual evapo-transpiration released by plants.	15(13.9)	93(86.1)
The use of Lysimeter as a preventative toll, is very familiar to those working to protect our groundwater resources.	15(13.9)	93(86.1)
Eddy covariance technique: It is used to estimate momentum, heat, water vapours, carbon dioxide and methane fluxes.	6(5.6)	102(94.4)
Eddy covariance technique will improve water use efficiency.	5(4.6)	103(95.4)

Table 4 - continued

Knowledge Statements	Yes (%)	No (%)
The Bowen ration is the mathematical method used to calculate heat lost/ gained.	3(2.8)	105(97.2)
Bowen ration will improve water use efficiency.	2(1.9)	106(98.1)
Use of surface renewal: evaluate the influence of water stress on the relationship between evapo-transpiration and water status indicators.	5(4.6)	103(95.4)
The use of surface renewal will improve water efficiency.	5(4.6)	103(95.4)
Soil water balance is a user-friendly irrigation scheduling model, it performs the calculation of the water balance and crop growth using three units, namely; weather, soil and crop.	9(8.3)	99(91.7)
Soil water balance will improve water use efficiency.	8(7.4)	100(92.6)
SAPWAT: It is to determine water and irrigation requirements of crops with the objectives of contributing towards efficient utilisation of water in agriculture.	4(3.7)	104(96.3)
BEWAB irrigation scheduling programme assists on how much water should be applied throughout the season and when to apply it.	4(3.7)	104(96.3)
The Canesim system has a single layer soil water balance and simulates crop transpiration, evaporation from the soil, deep drainage and run-off.	4(3.7)	104(96.3)
The Canesim system will improve water use efficiency.	3(2.8)	105(97.2)
PAWC: It determines irrigation frequency, which influences water use efficiency, distribution canal capacity and surface water logging.	4(3.7)	104(96.3)
Profile Available Water Capacity (PAWC) will improve water efficiency.	3(2.8)	105(97.2)
Pre-Programmed Deficit Irrigation: It can maximise crop water productivity instead of maximising the harvest per unit of land.	4(3.7)	104(96.3)
Pre-Programmed Deficit Irrigation will improve water use efficiency.	3(2.8)	105(97.2)
WFD: It is basically a switch which alerts the irrigator that a front of a given strength has passed a given depth in the soil.	2(1.9)	106(98.1)
Wetting front detector (WFD) will improve water use efficiency.	4(3.7)	104(96.3)
Tensiometers: It is an instrument used to determine matric water potential.	4(3.7)	104(96.3)

Table 4 - continued

Knowledge Statements	Yes (%)	No (%)
Tensiometers will improve water use efficiency.	4(3.7)	104(96.3)
PUTU: Is used to determine irrigation requirements, optimising irrigation water use and identifying drought mitigation crop production strategies.	4(3.7)	104(96.3)
PUTU irrigation computer model will improve water use efficiency.	4(3.7)	104(96.3)
CERES: Stimulates biomass accumulation based on light interception, partitioning of accumulated biomass to leaves, stems, roots, environmental stress and soil water balance.	3(2.8)	105(97.2)
CERES-maize model will improve water use efficiency.	3(2.8)	105(97.2)
CROPGRO: Predicts phenology, growth, senescence and nitrogen accumulation in locations that represent different scenario of environmental and agronomic management.	3(2.8)	105(97.2)
CROPGRO will improve water use efficiency.	3(2.8)	105(97.2)

*Figures in parentheses are percentage

Constraints to the adoption of water use efficiency techniques

Table 5 presents the constraints faced by women irrigators with regard to the adoption of water use efficiency techniques on a 2 point scale of Yes (2) or No (1). The most common constraints faced are: lack of information (92.6%); high input costs (94.4%); and low level of technical knowledge about the use of water efficiency (88.9%). The least prominent constraints are: land litigation (35.2%); poor planning of planting time (40.7%); and poor crop selection (48.1). According to Afful and Lategan (2014), public extension service is the dominant source of production information. However, extension agents do not transfer relevant information such as water use efficiency techniques; hence the reason why the respondents indicated that the worst constraint been faced was the lack of information. Stevens (2006) stated that many irrigation scheduling consultants and extension officers operating as knowledge support systems to farmers, are not properly trained in irrigation management and equipped to fulfil this responsibility of transferring relevant information to farmers (such as water use efficiency techniques).

Table 5 Constraints in using water use efficiency techniques

Constraints	YES	NO
Lack of information	100(92.6)	8(7.4)
Low level of technical knowledge	96(88.9)	12(11.1)
Lack of attention paid to environmental issues	87(80.6)	21(19.4)
No attention paid to planning of the project before production	56(51.9)	52(48.1)
High cost of inputs	102(94.4)	6(5.6)
Poor soil fertility	54(50.0)	54(50.0)
Poor crop selection	52(48.1)	56(51.9)
Poor planning of planting time	44(40.7)	64(59.3)
Poor infrastructure of irrigation system	74(68.5)	34(31.5)
Land litigation	38(35.2)	70(64.8)
Poor water supply	78(72.2)	30(27.8)
Poor water management	77(71.3)	31(28.7)
Poor government policies on irrigation/water use	64(59.3)	44(40.7)
Lack of water management skills for scheduling of labour	60(56.6)	48(44.4)
Lack of knowledge about deficit and surplus influence on crop production	64(59.3)	44(40.7)
Lack of skills on how to determine water requirements for crops	76(70.4)	32 (29.6)
Lack of skills about the proper timing of irrigation application	69(63.9)	39(36.1)
Lack of production skills	83(76.9)	25(23.1)

*Figures in parentheses are percentages

Factors influencing the adoption of water use efficiency techniques

Table 6 shows the results of factors influencing the adoption of water use efficiency techniques. The most adopted techniques were: reduced tillage; cover crops; crop rotation; and manure and fertilizer. Each of these techniques was subjected to Probit regression analysis. The results for the Probit analysis for reduced tillage revealed that the model is well fitted at 1% with a Chi-Square value of 3157, $p < 0.01$. Four variables were significant determinants for the adoption of reduced tillage as water use efficiency technique. These variables include: land tenure ($Z= -1.678$, $p < 0.093$); membership of farmer' group ($Z= - 3.104$, $p < 0.02$); frequency of extension visits (Z=

2.359, $p < 0.018$) and existence of water tariffs (Z= -2.085, $p < 0.037$). The implications of the findings are that adoption of reduced tillage has a direct relationship with frequency of extension visits i.e. an increase in the frequency of extension officers to the women farmers will increase the probability of their adoption of reduced tillage technique. On the other hand, adoption of reduced tillage technique has an inverse relationship with land tenure, membership of farmers' group and existence of water tariffs. This result agrees with the findings of Grabowski *et al*. (2016) that farmers in Eastern Zambia adopt minimum tillage because it reduces crop losses from erratic rainfall. Arslan *et al*. (2014) also stated that in Zambia, where minimum tillage has been promoted, adoption correlates spatially with higher rainfall variability, an indication that farmers use minimum tillage to reduce their vulnerability to an unpredictable climate. Ngoma *et al*. (2016) maintained that precipitation in agro-regions where farmers are located in Zambia influences the uptake and uptake intensity of minimum tillage.

In the Probit model using the adoption of cover crop technique as a dependent variable, the results reveals that the model is well fitted at 1% with Chi-Square value of 1388, $p < 0.000$. Three variables were found to be significant factors influencing the adoption of cover crops as a water use efficiency technique. These significant variables were: membership of farmers group (Z= -3.180, $p < 0.020$); frequency of extension visits (Z= 3.009, $p < 0.003$) and existence of water tariffs (Z= -1.738, $p < 0.082$). The frequency of extension visits was found to be statistically significant at 1% and had a positive coefficient implying that an increase in the frequency of visits of extension officers to the women farmers will likely increase their adoption level of the utilization of cover crop as a water use efficiency technique. On the other hand the membership of the women in farmer groups and their involvement in the payment of water tariffs has the tendency to likely reduce their adoption of cover crop technique because of the negative coefficient these parameters possess in the model. AFSA (2015) reported that farmers adopting cover crops such as *mucuna* benefited from higher maize yields as early as the second planting season. Also, Snapp *et al.* (2001) concurred by maintaining that a number of farmers with irrigation in the Northern States (California) believe that cover crops appear to perform better in irrigated systems where competition for water and nutrients is reduced.

Using the adoption of crop rotation as the dependent variable, Table 6 also revealed that the Probit model is well fit at 1% with a Chi-Square value of 2648, $p < 0.000$. Four variables were found to be significant determinants for the adoption of crop rotation as water use efficiency technique. These significant variables include: age (Z= 2.298, $p < 0.02$); membership of farmers' group (Z= -2.261, $p < 0.024$); existence of water rates (Z= -1.714, $p < 0.086$); and existence of water tariffs (Z= -3.591, $p < 0.000$). The implications of the findings are that adoption of crop rotation has a direct relationship with age. This indicates that the older the women farmers, the higher the probability of them adopting crop rotation as water use efficiency technique. On the other hand, the membership of farmers' group, existence of water rates, and existence of water tariffs has the probability to likely reduce their adoption of crop rotation as the parameters of these variables had negative coefficients with the dependent variable. This agrees with Makate *et al.* (2016) who reported that crop diversification (the practice of cultivating more than one variety of crops that belongs to the same or different species in a given area in the form of rotations and intercropping) depends on land size, farming experience, asset wealth, location, access to agricultural extension services, information on output prices, low transportation costs and general access to information. Ekepu and Tirivanhu (2016) also stated that the number of extension contacts had a positive significant effect on adoption of sorghum-legume rotations in Uganda.

Furthermore, Table 6 showed that the Probit model using the adoption of manure and fertilizer as the dependent variable was well fitted at 1% with a Chi-Square value of 1348, $p < 0.000$. Six variables were found to be factors that significantly influence the adoption of manure and fertilizer as water use efficiency technique. These variables were: age ($Z= 3.393$, $p<0.001$); farm size ($Z= - 2.140$, $p < 0.032$); number of plots ($Z= 1.893$, $p < 0.058$); membership of farmers' group ($Z= - 2.238$, $p < 0.025$); existence of water rates ($Z= - 2.216$, $p < 0.027$); and existence of water tariffs ($Z= - 4.846$, $p < 0.000$). The coefficients of the age and number of plots owned by the women farmers was positive implying a direct relationship with the dependent variable. This further indicates that the older the women farmers and the more the number of plots they own the higher the likelihood of them adopting the use of manure and fertilizer as a water use efficiency technique. On the other hand, the coefficients of farm size, membership of farmers' group, existence of water rates and existence of water tariffs was negative implying an inverse relationship with the dependent variable. This indicates that an increase in the parameters of these variables decreases the likelihood of the women farmers adopting the use of manure and fertilizer technique. Okobi and Barungi (2012) in their research stated that lack of knowledge, lack of market information and limited access to fertilizer-specific extension services were determining factors influencing the adoption of fertilizer. Also, Gelgo *et al.* (2016) stated that farm size and membership of farmers' groups positively influence the intensity of adoption of organic fertilizer. Factors influencing adoption of compost manure in Malawi as pointed out by Mustafa-Msukwa *et al.* (2011) were age, education, crop grown, source of labour, household size, head of household, marital status, field size, land ownership, knowledge, and farmer training.

Table 6 - Determinants of adoption of reduced tillage, cover crops, crop rotation, manure and fertilizers water use efficiency techniques

	Reduced tillage	Cover crops	Crop rotation	Manure and fertilizer
Parameter	Estimate (Std. Error)	Estimate (Std. Error)	Estimate (Std. Error)	Estimate (Std. Error)
Age	.001(.002)	.003(.002)	.005 (.002)**	.007(.002)***
Marital status	-.010(.027)	.028 (.026)	.010(.021)	-.020(.022)
Dependents (No)	.006(.017)	.019(.016)	.015(.014)	.007(.014)
Household size	-.019(.017)	-.024(.016)	-.011(.013)	-.021(.014)
Level of educational	.020(.015)	.020(.014)	-.015(.014)	-.016(.015)
Land tenure	-.094(.056)*	-.070(.052)	.037(.045)	-.002(.046)
Farm size	.000(.006)	-.003(.005)	-.007(.005)	-.011(.005)**
Plots (No)	.004(.007)	.008(.007)	.009(.006)	.012(.006)*
Location of plots	-.014(.015)	-.001(.014)	-.003(.015)	-.001(.015)
Membership of farmers' group	-.171(.055)**	-.121(.052)**	-.107(.047)**	-.110(.049)**
Extension contact	.034(.138)	.008(.137)	-.090(.096)	-.142(.099)
Frequency of extension contact	.129(.055)**	.162(.054)***	.031(.042)	.069(.043)
Extension agency	-.069(.179)	-.061(.182)	-.046(.121)	-.087(.125)
Sources of labour	.017(.043)	.041(.042)	.018(.034)	.019(.035)
Farming experience	.004(.004)	.002(.004)	.004(.003)	.004(.003)
Years in irrigation scheme	-.003(.004)	-.001(.004)	-.004(.003)	-.005(.003)
Non-farming activities	.046(.117)	-.081(.117)	-.006(.093)	-.020(.095)
Existence of water rates	-.046(.135)	-.056(.131)	-.187(.109)*	-.247(.111)**
Existence of water tariffs	-.214(.103)**	-.170(.098)*	-.265(.074)***	-.372(.077)***
Water security	.004(.009)	.008(.009)	.005(.007)	.005(.007)
Constraints	-.002(.009)	-.010(.008)	-.007(.007)	-.012(.008)
Knowledge of WUE	-.008(.005)	-.003(.004)	.003(.003)	.004(.003)

Table 6 - continued

	Reduced tillage	Cover crops	Crop rotation	Manure and fertilizer
Awareness of WUE	.012(.009)	.003(.009)	-.001(.007)	.009(.007)
Intercept	-.074(.763)	-.126(.718)	-.078(.640)	-.100(.656)
Chi-square	3156.752	1388.327	2648.483	1348.084
Df	77	77	77	76
Sig	.000	.000	.000	.000

Z = Estimate/Std.Error
*** 1% significant ** 5% Significant * 10% Significant

Conclusion and Recommendations

The study concluded that despite the wide range of knowledge exhibited by the women on water use efficiency, they still had low knowledge specifically on all the water use efficiency techniques that were related to irrigation scheduling. Also, the adoption level of the women on water use efficiency was still very low. The major constraints faced by women irrigators in the area on the water use efficiency techniques were lack of information, high input costs and low level of technical knowledge about the use of water use efficiency. Significant factors influencing the adoption of water use efficiency techniques include membership of famers' group, the frequency of extension visits, the existence of water tariffs, age, farm size and the number of plots owned. The study therefore recommends that extension services be strengthened in rendering more frequent and efficient services to women farmers in order to improve their knowledge on water use efficiency techniques among farmers. It is also recommended that policy makers improve the efficiency of water rates, tariffs, and electricity by introducing volumetric measurements which allow irrigators to pay only the amount in relation to the quantity of water used. There is a need for equitable distribution of water on irrigation schemes. This is particularly important for women irrigators as it will ensure the optimal use of water resources.

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