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Full Length Research Paper

Analyzing wastewater use possibilities: Prospects of garden irrigation in the Middle Olifants sub-basin

N. S. Molepo*, A. Belete and J. J. Hlongwane

Department of Agricultural Economics, University of Limpopo, P. Bag X1106, Sovenga 0727, South Africa.

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The purpose of the study is to analyze the relevance of wastewater as one possibility to deal with the scarce water situation in the Middle Olifants Sub-basin. The Middle Olifants sub-basin is the third most water stressed sub-basin in South Africa. It is an arid and semi-arid region which includes different water user groups like growing industrial zones, large and small-scale farming with irrigation activities. The study used stratified random sampling technique due to the fact that some households use wastewater and others do not use wastewater. The analysis using both descriptive statistics and logistic regression model revealed that there are several socio-economic factors (for example, education level, water source, water quantity, availability of garden, etc.) that affect the usage of wastewater for agricultural purposes. This implies that the Department of Water and Forestry and other private institutions need to raise the public awareness campaign in the communities in order to encourage people to use the wastewater efficiently so that fresh water could be conserved. Policies on wastewater use have tended to focus on treatment before use and the implementation of strict regulations. In South Africa clear policy guidelines on how to optimize the benefits and minimize the risks of this practice are lacking.

Key words: Wastewater, Middle Olifants, logistic regression, households.

INTRODUCTION

Growing demands for freshwater resources in water scarce countries such as South Africa, pressure on the agricultural sector to give up part of its allocation to prime use sectors such as households and industries increases. The use of wastewater in irrigation could become important to supplement supply and also to increase efficiency in water use (World Bank, 2005). The Middle Olifants sub-basin is the third most water stressed sub-basin in South Africa. The sub-basin comprises of arid and semi-arid region which includes different water user groups like growing industrial zones, large and small-scale farming with irrigation activities. The usage of wastewater in Middle Olifants increases household food security. Households in the rural areas use treated and untreated wastewater for growing cash crops, lawn, landscaping and horticultural plants. This is done for multiple reasons such as water scarcity, reliability of wastewater supply, nutrient value of water, etc. (Tewari, 1998).

According to Speelman et al. (2005), semi-arid North West of South Africa experience water scarcity, which makes wastewater use one possible way of improving efficiency and holding great potential for saving valuable freshwater resources. Local socio-economic conditions and culture are also factors that influence the choice of crops that farmers or household irrigate.

Most vegetables irrigated with wastewater in Pakistan are eaten cooked, whereas in Dakar, most are normally eaten raw (Faruqui and Jayyousi, 2002). Additionally, the rationale for using wastewater varies enormously in different contexts. In Tunisia, many farmers would be unable to earn a livelihood without using wastewater – they have no other choice. In other cases, for example, in Vietnam, two different scenarios can occur in some cases, farmers may inadvertently use wastewater even when they do have an adequate supply of water, because of unplanned discharge

*Corresponding author. E-mail: solmol@webmail.co.za Tel: +2772 776 2190.

Abbreviations: CMAs, Catchment Management Agencies; **DWAF,** Department of Water and Forestry.

into natural water courses and canals, while in others, wastewater may be deliberately pumped into irrigation canals by authorities, when there is inadequate water at the tail-end of irrigation schemes (Faruqui and Jayyousi, 2002).

According to Strauss and Blumenthal (1990), Mexico has a highly developed system of physical and organizational infrastructure catering for wastewater use in a number of areas. Six irrigation districts manage the distribution of wastewater and surface runoff from urban areas and plans are developed for wastewater use in eleven more districts. During the dry season, irrigation water in the valley is exclusively wastewater and most is used without passing through impoundment reservoirs. However, crop restriction is enforced by the irrigation district, with lettuce, cabbage, beet, coriander, radish, carrot, spinach and parsley being specifically excluded. Maize, beans, chilli and green tomatoes, the staple food in the area are not restricted and neither is alfalfa.

The wastewater use is defined as the usage of water for a second time (for example, flushing toilets, irrigating fruit trees and crops). Wastewater could be used to substitute other better-quality water sources for irrigating crops. The usage of wastewater for irrigating vegetable crops has important health implications for stakeholders (households, farmers, produce vendors and consumers) in wastewater-irrigated areas (Bartone, 1991).

Water must be guaranteed for all, especially to meet the basic human needs of poor people in rural areas who have been disadvantaged for so long. In the Middle Olifants sub-basin, water cannot be simply allocated to meet the increased demand from agriculture, industry and other productive sectors. Responsibility for decision-making in respect of water allocations were decentralized to the level of the future Catchment Management Agencies (CMAs). Water demand management, especially in the agricultural sector, which is the biggest user, is one of the possible solutions being considered by the South African Department of Water Affairs and Forestry (Thobani, 1995). In addition to conserving highly treated and expensive drinking water, wastewater use reduces the release of nutrient-rich wastewater into environmentally stressed streams and rivers (Bouwer, 1991).

The deliberate use of wastewater should be in compliance with applicable rules for a beneficial purpose (landscape irrigation, agricultural irrigation, aesthetic uses, ground water recharge, industrial uses, and fire protection). The most common reasons for establishing a wastewater use programme is to identify new water sources for increased water demand and to find economical ways to meet increasingly more stringent discharge standards (Dixon et al., 1994).

Wastewater use could be grouped into the following categories: Urban use – the irrigation of public parks, school yards, highway medians, and residential land-scapes, as well as for fire protection and toilet flushing in commercial and industrial buildings; and also agricultural use on irrigation of non-food crops, such as fodder and fiber, commercial nurseries and pasture (Farid et al., 1993).

Overview of the Middle Olifants sub-basin of South Africa

The Middle Olifants is one of the four sub-basins of the Olifants basin. With a population of about 3.4 million, most (67%) of the people in the Olifants basin are living in the rural areas with rudimentary or no formal domestic water supply and sanitation system (DWAF, 2003b). The Olifants basin get water from Letaba, Inkomati, Usutu to Mhlatuze, and the upper Vaal basins while it transfers water to Limpopo, Crocodile West and Marico basins. The rainfall is strongly seasonal and occurs mainly in summer. The mining sector is of paramount importance with 200 active mines like gold, platinum, tin and coal. Surface water is the important source of water while ground water also plays a significant role by contributing 16% of the whole Olifants water (Whittington and Boland, 2007).

According to Perret (2002), the population of the Middle Olifants sub-area is largely underdeveloped with scattered rural settlements. The Middle Olifants population account for close to 60% of the total population of the whole basin. The predominant land use is agriculture with extensive irrigation taking place from Loskop Dam. There are a number of platinum and chrome mines being developed in the Middle Olifants sub-area. The mines have increased the water requirements in the area both due to direct water use and the influx of people into the area to work on the new mines and also due to the new mining operations being established in the Dilokong Corridor.

Constraints faced by people in the Middle Olifants sub-basin

The major problem faced by people in rural areas of the Middle Olifants sub-basin is inadequate access to basic water (DWAF, 2003a). Water consumption is often constrained to 25 litres per day and per capita; this is hardly enough for drinking, cooking, hygiene and washing (Backeberg and Groenewald, 1995). Households cannot use their basic water for crop irrigation; this is because most of the areas in the Middle Olifants sub-basin experience water scarcity.

Most livelihood activities depend on the availability of water. However, in many semi-arid and arid areas of the Middle Olifants, freshwater is a scarce resource although Olifants River is a perennial. Water for irrigation is also required for the long dry season (Mara and Cairncross, 1989).

The purpose of the study

The purpose of the study is to analyze the relevance of wastewater as one possibility to deal with the scarce water situation in the Middle Olifants Sub-basin. Wastewater needs to be studied as a natural capital sustaining the means of living in arid and semi-arid as well as drought-prone areas. Although the use of wastewater is likely to become increasingly important as a combined strategy for water conservation and pollution prevention, management of this resource is in the hands of local farmers and municipalities. There seems to be little awareness about the importance of wastewater use among local municipalities in the Middle Olifants sub-basin.

MATERIALS AND METHODS

The method used to collect data was household interviews. The data was collected in three district municipalities of the Middle Olifants sub-basin (Polokwane, Lepelle-Nkumpi and Makhuduthamaga). From the three district municipalities the following villages are chosen: Mashushu, Mapagane, Ga-Moila, Matshelapata, Setaseng, Feke, Tjatjaneng, Ga-Malaka, Botshabelo and Mankotsane. The reason of choosing these ten villages is that fresh water is the scarcest resource and people are traveling long distance to fetch water from the rivers.

All data collected were based on the wastewater usage and water related matters. The usage of wastewater in the basin is regarded as the possible solution to deal with scarce water and thereby to solve water related problems. This view is strong in the area since farmer's production of food crops for subsistance as well as selling surpluses to neighbours entirely depend on the availability of water.

Sampling procedure

The study used stratified random sampling technique due to the fact that some households use wastewater and others do not use wastewater. A sample of 150 households was used in this study, because of limited time and also resources make it difficult to collect the data all over the Middle Olifants. This was done in all the areas where the survey was conducted in order to avoid sampling bias.

Data analysis

Descriptive statistics were used to provide simple summaries of the variables considered for the study. To analyze the data logistic regression model is used. The logistic regression was necessary to estimate the probability that households use wastewater for the second time (irrigation of crops). It was also be used to determine the percent of variance in the dependent variable explained by the independents and shows the impact of independent variables on the dependent variable.

The advantages and limitations of logistic regression model

Logistic regression has been widely used in the financial service industry for credit scoring models. It is the best suited model needed in the prediction scenarios, despite its advantages in easy interpretation and low computing cost, logistic regression is under the criticism of failure to model the nonlinear features of the predictor's effect on the dependent variable. Modern statistical techniques such as Neural Network and Projection Pursuit Regression have been proven successful in the nonlinear modeling. However, this success comes with the price of interpretability. Logistic regression is the best for predictions and also when the dependent variable is categorical; meaning that usage of it in this study is relevant. The logistic regression is thus necessary to estimate the probability that households use wastewater in the Middle Olifants sub-basin for garden purposes. It is also used to determine the percent of variance in the dependent variable explained by the independents and shows the impact of independent variables on the dependent variable.

Logistic regression is a widely used tool for the statistical analysis of observed proportions or rates. Until recently, however, this capability has not been available to the survey data analyst due to the fact that standard logistic regression methods are inappropriate for the analysis of data arising from a complex sample design. The distributional assumptions required for logistic regression model are violated when applying the method to complex survey data involving stratification and clustering. Several articles appearing recently in the literature have proposed design effect adjustments that could be incorporated into standard categorical data analysis programs.

The relationship between the probability of Y = 1 and the explanatory variables are determined through the logit function and that is the natural logarithm of odds of Y = 1. This assumes a linear relation between the log of odds and independent variables (Shields, 1991). The analysis in this study focuses on the probabilities that households use wastewater in the Middle Olifants sub-basin of South Africa. The logistic regression model is based on the probability that Y equals to one ($P=P_1$). The value of Y is assumed to depend on the value of X_1 ....X_k. The logit model representing the relationship of Y and X is given by:

General model

$$\text{Log}\,[p/(1-p)] = \beta_0 + \beta_1X_1 + \beta_2X_2 + \ldots\ldots\ldots + \beta_KX_K$$

Where: P = Predicted probability that Y equals to one (dependent variables); B_0 …... β_K = Estimated parameters; X_1 ….. X_K = Independent variables

Specific model

$$\text{WTRUSEP} = \beta_0 + \beta_1\text{EDUCLVL} + \beta_2\text{WATSOU} + \beta_3\text{WTRBORD} + \beta_4\text{WTRSBFN} + \beta_5\text{QUANINY} + \beta_6\text{WATUFSIA} + \beta_7\text{GARDOIRR} + \beta_8\text{RELIBFWS} + \beta_9\text{ HHLDGWNP} + \beta_{10}\text{PBHWTRC} + \beta_{11}\text{IMPORTUWI} + \beta_{12}\text{HHLDEXP} + \beta_{13}\text{WTRSTOR} + \beta_{14}\text{ WATSOCE} + U_i$$

These independent variables and their units of measurements are described in Table 1.

RESULTS AND DISCUSSION

The findings from the descriptive statistics reveal that level of wastewater usage possibilities in the Middle Olifants sub-basin varies among the three district municipalities. Furthermore, the possibilities of using wastewater depend on several factors. Table 2 shows that the households in the Middle Olifants use wastewater and this is perhaps due to the fact that lots of people do travel long distance to fetch water from the unreliable water sources, such as rivers, public stand pipes, spring, etc.

Table 1. Variables, description and units of measurement.

Variable	Description	Unit
Dependent variable		
WTRUSEP	1 if households use the wastewater, 0 otherwise	Dummy
Independent variable		
EDUCLVL	1 if the household has primary education, 0 otherwise	Dummy
WATSOU	1 if public stand pipe is the source of water for household, 0 otherwise	Dummy
WTRBORD	1 if member of the household is affected by water borne disease, 0 otherwise	Dummy
WTRSBFN	1 if household sell/buy water to/from neighbours, 0 otherwise	Dummy
QUANINY	1 if the household expect the quantity of water to increase for the coming years, 0 otherwise	Dummy
WATUFSIA	1 if household use water from the source to cook, 0 otherwise	Dummy
GARDOIRR	1 if household is having garden or irrigated field, 0 otherwise	Dummy
RELIBFWS	1 if water from the source is reliable for most of the days, 0 otherwise	Dummy
HHLDGWNP	1 if the household is able to get all it needs for all normal household purposes, 0 otherwise	Dummy
PBHWTRC	1 if electric/motor pump is used to collect water from public borehole/well, 0 otherwise	Dummy
IMPORTUWI	1 if household knows the importance of using wastewater for irrigation, 0 otherwise	Dummy
HHLDEXP	1 if household expenditures are less than R1 000 per months, 0 otherwise	Dummy
WTRSTOR	1 if household use tanks to store water, 0 otherwise	Dummy
WATSOCE	1 if public stand pipe is the source of water for the household, 0 otherwise	Dummy

Results of the logistic regression analysis

In this section a brief discussion on the results from the logistic regression analysis is made. As can be seen from Table 3 below there are a number of socio-economic factors that affect the wastewater use possibilities for agricultural production purpose in the Middle Olifants sub-basin. More specifically the factors that have positive relationship between the wastewater use possibility and socio-economic factors are education level, water borne diseases, household expenditure as well as availability of water storage facilities.

Higher values mean that the observed result was more likely to occur under the null hypothesis (over 50%). The principal assumption on which the loglikelihood ratio is based is that there are socio-economic factors that affect the wastewater use in the Middle Olifants sub-basin. The observed results support the expectation in the sense

Table 2. Descriptive of socio-economic factors.

Variable	Wastewater use possibilities (%)			
	Lepelle-Nkumpi	Makhuduthamaga	Polokwane	Average
	41.1	65.0	45.0	48.7
EDULVL%	31.4	35.0	30.0	32.0
WATSOU%	74.3	0	100	61.3
WTRBORD%	8.6	2.5	5.0	6.0
WTRSBFN%	0	25.0	22.5	12.7
QUANINY%	38.6	10.0	75.0	40.7
WATUFSIA%	47.1	75.0	35.0	51.3
GARDOIRR%	82.9	42.5	30.0	58.0
RELIBFWS%	58.6	12.5	37.5	32.0
HHLDGWNP%	51.4	97.5	92.5	22.7
PBHWTRC%	78.6	0	100	63.3
IMPORTUWI%	61.4	47.5	35.0	50.7
HHLDEXP%	97.1	95.0	87.5	94.0
WTRSTOR%	20.0	7.5	10.0	14.0
WATSOCE%	71.4	0	97.5	59.3

Source: Field survey (2008).

Table 3. Logistic regression results.

Variable	Co-efficient	SE	Wald statistics	Significance
EDULVL	1.050**	0.332	10.029	0.002
WATSOU	- 2.777*	1.387	4.007	0.045
WTRBORD	2.907*	1.208	5.792	0.016
WTRSBFN	1.359	0.928	2.142	0.143
QUANINY	0.488	0.618	0.624	0.430
WATUFSIA	- 0.038	0.307	0.016	0.900
GARDOIRR	0.055	0.714	0.006	0.939
RELIBFWS	0.935*	0.430	4.730	0.030
HHLDGWNP	1.939**	0.681	8.101	0.004
PBHWTRC	4.686**	1.741	7.239	0.007
IMPORTUWI	4.115***	0.809	25.867	0.000
HHLDEXP	1.570	1.190	1.742	0.187
WTRSTOR	0.144	0.267	0.292	0.589
WATSOCE	1.096	1.081	1.027	0.311
Constant	- 19.900***	5.238	14.436	0.000
- 2 Log likelihood			99.963	
Pseudo R square			68%	
% cases correctly predicted			51.4%	
Chi – square			10.85	

***, **, * represent significance at 1%, 5% and 10%, respectively.

that there are socio-economic factors such as education level and water source that affect the utilization of wastewater. The loglikelihood ratio accepts the null hypothesis, which revealed in the Middle Olifants sub-basin utilization of wastewater is affected by socio-economic factors.

If R^2 is greater than 0.50 it implies that the null hypothesis should accepted, since 50% of the variance is explained by all the variables used. The value of R^2 is 0.68, which implies that the independent variables included in the model explain about 68% of the variation in the wastewater use in the Middle Olifants sub-basin.

There are variables in the model which are significant and showed a positive impact on the wastewater use possibilities.

There are probabilities of wastewater usage in the Middle Olifants sub-basin since the average value is 48.7%, meaning that households are adopting the method of conserving scarce fresh and using wastewater to perform other beneficial activities. This implies that there are households who know the importance of using wastewater.

Conclusion

The findings from the descriptive statistics shows the usage of wastewater in the Middle Olifants is increasing (± 48.7%), while most people have garden in their yards and this implies that there are households who are using scarce fresh water to irrigate crops in the gardens. This implies that the Department of Water and Forestry (DWAF) and other private institutions need to raise the public awareness campaign in the communities in order to encourage people to use the wastewater efficiently so that fresh water could be conserved. The action would definitely help to ease the problem of scarcity of water in the area.

Planned use of wastewater that seeks to maintain the benefits and minimize the risks would require an integrated approach. Key to the success of endeavours to make the transition to planned strategic reuse programmes are a coherent legal and institutional framework with formal mechanisms to coordinate the actions of multiple government authorities, conversion of farmers towards more appropriate practices for wastewater use, public awareness campaigns to establish social acceptability for reuse, and consistent government and civil society commitment over the long term with the realization that there are no immediate solutions.

Policies on wastewater use in South Africa have tended to focus on treatment before use and the implementation of strict regulations. Clear policy guidelines on how to optimize the benefits and minimize the risks of this practice are lacking. Also a better estimate of the extent of wastewater irrigation is needed before the reality of its use can become an agenda item for policy and decision-makers.

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