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Water use productivity and food security among smallholder homestead food gardening and irrigation crop farmers in North West province, South Africa

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Abstract: The study analysed water use productivity among smallholder homestead food gardening and irrigation crop farmers in the North West province, South Africa due to the fact that home gardening and irrigation constitute the most important rural development investment strategies that can have direct impact on poverty alleviation and food security. Using a large sample size technique of $n \geq 30$, 160 gardeners were selected for the study. Data was collected using a structured questionnaire and subjected to analysis using SPSS. Frequency counts and percentages were used to describe demographics. Multiple regressions were also used to identify determinants. Majority (68%) of the home gardeners have high water use productivity while 74% of those with high water use productivity are food secure. Five out of sixteen variables were significant, with three being significant at 5% ($t = -2.443$, $p = .016$), social participation ($t = 2.599$, $p = .010$), marketing outlets ($t = 2.810$, $p = .006$), while two variables were significant at 10% (home food security ($t = -1.777$, $p = .078$) and attitude ($t = -1.727$, $p = .086$). The study concludes with the need to incorporate the significant factors affecting water use productivity into food security policy agenda.

Keywords: water use productivity, water use efficiency, food security, smallholder, homestead garden, irrigation, South Africa

Introduction

Agriculture is the backbone of the South African economy, such that about 80% of South Africa's population depends on agriculture for their livelihood thus, economic growth and poverty alleviation are factors linked to increased productivity and incomes from agriculture. In addition, agriculture is identified as one of the major sectors that can ensure the achievement of the Accelerated and Shared Growth

Initiative of South Africa (ASGI-SA). Moreover, agricultural growth improves employment for poor rural people, increases the demand for consumer goods and services and stimulates growth in the nonfarm economy (OECD, 2006). The agriculture sector in South Africa faces a complex series of challenges to produce more food of better quality while using less water per unit of output because South Africa is a water scarce country as the demand for water is in excess of the supply by natural water sources in the country. Similarly, the challenges of scarce water and food insecurity have been aggravated by climate change.

According to Brauman *et al.* (2013) agricultural water use is perceived as the main factor behind increasing water scarcity with the rapid growth of agricultural water use based on the availability of large quantities of low-cost water. Water availability for agriculture is increasingly constrained as irrigated agriculture accounts for about 70% (2,850 km^3 per year) of the freshwater withdrawals in the world, and up to 85% in emerging and least developed countries. In addition rain-fed agriculture uses 6,400 km3 per year (Tilman *et al.,* 2011). Agriculture is the largest freshwater user, accounting for almost 100 percent of the global consumptive water footprint (Hoekstra and Mekonnen, 2012); 70% of withdrawals from rivers, lakes and aquifers and more than 90% in some developing countries with rain-fed agriculture covering 80% of the world's cultivated land, which is responsible for about two-thirds of crop production (UNESCO, 2014).

Presently, water use has been growing at more than twice the rate of population increase. It is expected that the amount of water withdrawn by irrigated agriculture will increase by 11% by 2050 to match the demand for biomass production (Postel, 2003). Foley *et al.* (2011) stated that agricultural water management is central to reducing the risk of food insecurity however, the limits of the model of expansionary irrigation have been reached, stressing the need to identify and implement new instruments in the contribution of water towards food security. The understanding of the magnitude of water consumption is important in a water scare scenario for evaluation and decision-making on the efficiency of water use. The reduction of the amount of water required for crop production and increasing water productivity are important strategies for achieving food security and water sustainability as demand for both increases (Brauman *et al.,* 2013). To improve water use efficiency and ensure food security, the concept of home gardening was explored in South Africa.

A home garden is a small system of household plant production (Tewabech and Ephrem 2014) and an unpopular aged-long food security strategy (Zwarteveen, 1997) partly because of its wide variety of produce and its informal nature. Home gardening has become an important part of cultural heritage (Akosa, 2011) which denotes specific farming practices at different localities. It is therefore inappropriate to ascribe definite and effective cultural practices to the management, siting and ownership of home gardening because home gardening has been a way of life for centuries (United

Nation, 2010). Home gardening has contributed to food security in many ways, such as direct access to a diversity of nutritionally rich foods, increased purchasing power from savings on food bills and income from the sale of garden products, and fall-back food provision during seasonal lean periods (Bongiwa and Obi 2015).

Home gardening has the potential to improve the consumption of vegetables and fruits, improve child health care and nutrition, and improve household food security and income as well as women empowerment. It is believed that it also provides practical experience in food production and natural resource management. Through enhancing food nutrition and security, home gardening contributes to the alleviation of health and social impact of diseases. Effective home gardening in semi-arid areas like the North West province in South Africa needs an improved understanding of key factors impacting on land and water productivity which are imperative for a better informed and decision-making as well. The productivity of water used in agriculture is essential to meet the goals of food and environmental security. One of the technologies considered important in terms of ensuring household food security is through irrigation practice (Kahinda *et al.*, 2008). Increasing the productivity of water is critical in areas where water is a scarce resource since it promotes productivity in agriculture and plays a pivotal role in reducing environmental degradation and provision of food security (Molebatsi *et al.,* 2010). Anecdotal evidences suggest that water use efficiency and productivity were higher with home garden than other irrigation schemes

Molden *et al.* (2007) define water use productivity as the physical mass of production measured against depleted or available water. They further indicate that productivity of water can be related to the economic value of the produce per unit volume of water. Brauman *et al.* (2013) evaluated the use of water resources for food production through food produced (kcal) per unit of water (l) consumed. Crop water productivity is defined as food (edible) kilocalories produced per litre of evapotranspiration, evaluated separately for rainfed and irrigated crops (Tilman *et al.,* 2011, Seo and Mendelsohn 2008).

Abdullaev *et al*. (2003) maintain that there are indicators that determine water productivity such as produce obtained, agricultural operations, climatic conditions, soil standards and water supply rate. If there is enough water supply rate, farmers are likely to produce more due to abundant water resources. The formulae below shows how water productivity is calculated:

$$\mathrm{WP} = \frac{outpt}{Q}$$

Where WP is water use productivity (kgm^{-3}), output is quantity harvested in kg and Q is the amount of water used per cubic meter.

Despite the importance of home garden, emphasis in agriculture has been placed in large scale irrigation in terms of water use and production. In most studies, focus has usually shifted away from water use productivity in home gardening. The main objective of the study was to analyse water use productivity among smallholder homestead food gardening and irrigation crop farming in the North West province, South Africa. The specific objectives were to: identify the personal characteristics of rural small farmers engaged in home gardening and irrigation crop farming; determine the level of water use efficiency in home gardening; ascertain the level of returns of water use in home gardening; and determine the impact of home gardening and irrigation crop farming on household food security. Significant relationship between farmers' personal characteristics, farm characteristics and water use productivity in home gardening and irrigation crop farming were explored.

Methodology

The study was conducted in four districts of the North West province (Bojanala Platinum, Ngaka Modiri Molema, Dr Kenneth Kaunda and Dr Ruth Mompati). According to the North West Parks Board, the surface area of the North West province of South Africa is 118,797 sq km (45,869 sq miles). It shares the international border with Botswana, within the country it shares margins on the south with provinces of Free State, Northern Cape, and on the northeast and east by the Limpopo Province and Gauteng. Temperatures range from 17^{o} to 31 ^{o}C (62^{o} to 88 ^{o}F) in the summer and from 3 to 21^{o}C (37^{o} to 70 ^{o}F) in the winter. Annual rainfall totals about 360 mm, with almost all of it falling during the summer months, between October and April.

The research design used in this study was descriptive and quantitative. Bless and Higson-Smith (2000) define this approach as a study concerned about the condition that exists, processes that are prevailing, developments that are ongoing and trends that are developing. This study focuses on water use productivity in homestead home gardening in the North West province. Furthermore, the approach was used to identify personal characteristics, water access, and educational level of farmers as well as farmers' perceptions towards water use productivity in home gardening. The sample was drawn from all households engaged in home gardening, especially participants who were willing to participate. A recognisance survey by the authors revealed that the homestead gardeners ranges from 100 to 250 per district. A large sampling technique by (Kerlinger and Lee, 2000) of $n \geq 30$ was applied in order to select the farmers since the number of gardeners is not evenly distributed within the province. A total of 160 gardeners were selected for the study representing 40 per district. Data was collected through a structured questionnaire which was developed based on the objectives and review of the relevant literature.

Standardization of measurement units was carried out during data collection for yield of vegetables. This was based on the fact that producers, growers utilise different forms of measurement for their produce. They utilise bundles, beds and bags to estimate the size of the harvest. These types of harvests are not standardised and are based on value judgment by individuals. It was also noticed that the sizes of bundles, bags and beds vary from one area to another and depending on the type of vegetable. The weights and sizes of leaf, root and stem vegetables were not the same. To be more scientific, it was necessary to standardise all measurements. For the standardization, a scale was used to get the sum of weights for vegetables and conversions made.

Data was sorted and analysed through the Statistical Package for Social Sciences (SPSS) version 18.0. Descriptive statistic such as standard deviation, mean, frequency

Table 1 - Conversion rates in vegetables in kg.

Quantity sold / harvested	
Types of crop (in bundles)	Units (Kg)
Cabbage	2.266
Carrot	0.918
Beetroot	1.154
Tomato	0.650
Butternut	1.156
Onion	0.664
Lettuce	0.31
Cauliflower	0.584
Green beans	0.702
Green pepper	0.512
Spinach	2.011

distribution were used to describe the personal characteristics of respondent, tables, graphs and percentages were used to summarise the data and enhance the readability of the results. Multiple regression analysis was also used.

The objective on socio-economic factors affecting water use productivity by farmers was analysed using an ordinary least square (OLS) model. The OLS model for this study is specified as

$$Y_i = \alpha_0 + \alpha_1 X_{i1} + \cdots + \alpha_{25} X_{i25} + e \quad (1)$$

The specific model for this study is
Water Use Productivity (Y) = f (b_0+$b_{1,}$ (Gender of household head)+ $b_{2,}$ (Farming experience)+$b_{3,}$ (Marital status of household head)+$b_{4,}$ (Education) + $b_{5,}$ (Religious belief) +$b_{6,}$ (Land ownership) + $b_{7,}$ (Type of crop)+ b_8), (Willingness to expand)+ $b_{9,}$ (Attitude) +$b_{10,}$ (Home food security)+ $b_{11,}$ (Marketing outlets)+ $b_{12,}$ (Social participation) + *e* (error term) (2)

Table 2 - Household characteristics of home gardeners.

Variables	Frequency (%)
Gender	
Male	78(48.8)
Female	82(51.3)
Age (years)	
less than 30	7(4.4)
30-40	41(25.7)
41-50	40(25)
51-60	41(25.7)
above 60	31(19.5)
Farming experience (years)	
Less than 10	64(40)
10 to 15	46(28.8)
16 to 20	33(20.8)
Above 20	17(10.7)
Marital status	
Single	58(36.3)
Married	75(46.9)
Divorced	7(4.4)
Widowed	20(12.5)
Education	
Abet	15(9.4)
Primary	66(41.3)
Secondary	77(48.1)
Tertiary	2(1.3)
Household size (persons)	
1 to 3	72(45)
4 to 7	79(49.4)
More than 7	9(5.6)
Size of homestead food gardens (ha)	
0.1 to 1	129(80.6)
1.1 to 2	30(18.8)
2.1 to 3	1(0.6)

Results and discussion

The results on household characteristics of home gardeners are presented in Table 2. Table 2 shows that each of the age brackets of 30 and 40 years and 51 and 60 years had 25.7% of the respondents. This is a clear indication that people less than 30 years old are not involved in agriculture in home gardening. This may be attributed to the feeding lifestyles of this age category. According to ALDEP (1982), in Botswana, gardening activities are carried out by people aged between 45-75 years and the practice is more common in older neighbourhoods. Table 2 also shows that 51% of respondents are female while 48.8% are male. This shows low participation of men in home gardening. Keller (2003) stated that if women are in charge of home gardens, there is a positive likelihood that vegetables produced will be used for household consumption. The results indicate that 48.1% and 41.3% of the respondents have secondary and primary level education respectively. Table 2 further shows that 46% of farmers in homestead food gardening are married with 49.4% having household size ranging from 4 to 7 persons.

Table 2 shows that 80.6% of the respondents indicated garden sizes ranging from 0.1-1 hectares while 0.6% have garden sizes larger than 2 hectares. Mayori (2009) found that home gardens were mainly carried out in areas of between 152-520 m^2. National Gardening Association (2009) reported that the median global garden size is 8.9m^2 and the average food garden size is 55.7 m^2. Teitelbaum and Beckley (2006) found that the average size of home gardens range from about 500 m^2 to more than 2,500 m^2 (a quarter of a hectare), but in extreme cases, home gardens are as small as 20 m^2 and as large as 10,000 m^2. According to Barlow and van Dijk (2013) in Kwazulu Natal, South Africa, garden sizes is generally enough to ensure household food security but not enough for them to be viable commercially. Similarly, 78.8% of respondents indicated in Table 2 that 1to 3 of their households members are active in homestead gardening.

The results in Table 3 show that 50% of respondents use communal land for gardening while 49% of respondents use their personal land. Only one percent of respondents use leased land for production. Land security is often seen as a

Table 3 - Land ownership and cropping system of farmers engaged in home gardening.

LAND OWNERSHIP	YES	NO
Own land	79(49.4)	81(50.63)
Communal land	80(50)	80(50)
Leased land	1(0.6)	159(99.4)
Land reform	0(0)	160(100)
Rent	0(0)	160(100)
Cropping system		
Mono cropping	42(26.3)	118(73.4)
Double cropping	3(1.9)	157(98.1)
Mixed cropping	99(61.9)	61(38.1)
Crop livestock integration	0(0)	160(100)

Table 4 - Quantity of vegetables harvested, consumed and sold by respondents.

	Quantity harvested		Quantity consumed*		Quantity sold*	
Vegetables	Less than 400kg	400 kg and above	Less than 400kg	400 kg and above	Less than 400kg	400kg and above
Spinach	96(60)	64(40)	37(23.1)	7(4.4)	59(36.9)	57(35.6)
Cabbage	101(63.1)	59(36.9)	42(26.3)	46(28.8)	59(36.9)	13(8.1)
Carrot	128(80)	46(28.8)	82(51.3)	40(25)	46(28.8)	6(3.8)
Beetroot	121(75.6)	41(25.6)	82(51.3)	35(21.9)	39(24.4)	6(3.8)
Tomatoes	143(89.4)	19(11.9)	93(58.1)	15(9.4)	50(31.3)	4(2.5)
butternut	141(88.1)	19(11.9)	124(77.5)	11(6.9)	17(10.6)	8(5.0)
Onion	148(92.5)	18(11.3)	130(81.3)	10(6.3)	18(11.3)	8(5.0)
Green beans	154(96.3)	6(3.8)	130(81.3)	4(2.5)	24(15)	2(1.3)
Green Pepper	160(100)	0(0)	20(12.5)	0(0)	140(87.5)	0(0)

*Subset of quantity harvested

precondition for intensifying agricultural production. According to Bembridge (2000), insecure land limits farmers' incentive in making long-term development investments on their land. Farmers feel that for them to be more productive, they should have land ownership rights so that they can rent or sell their land at any time and also for their children to be able to inherit the land. Baiyegunhi and Makwangude (2013) also suggests that communal ownership would promote productivity.

Table 4 shows the distribution of respondents in terms of quantity of vegetables harvested, consumed (per season) and sold. The quantity harvested for each vegetable was dichotomised based on into less than 400 kg and 400 and above due to the overall average score of the yield obtained by the farmers. All the farmers produced green pepper although at a yield lower than 400 kg, however it is a major crop for sale as 87.5% of the respondents sold their produce. All other vegetables shows trend of high yield among the respondents and high consumption and less proportion for sale. This may be attributed to the fact that the home garden are primarily for household food security. Spinach is considered as the favourite crop for many customers within the range of home gardeners. Production of butternut is not as common as other vegetables however, beans is more labour intensive, an indication that most gardeners are not interested in planting beans.

In Table 5, majority of respondents (99.4%) do not use wells for irrigation with only 1% using wells.86.9% of gardeners stated that they do not use rain water tanks for irrigation. This means that they do not have storage facilities for water as tanks may be too expensive to install. Only 13.1% of respondents use rain water tanks. Rain

Table 5 - Sources of water for and methods of irrigation in homestead food gardens.

Source of water for irrigation		
	No	Yes
Tap	87 (54.4)	73 (45.6)
Well	159 (99.4)	1 (0.6)
Rain water tanks	139 (86.9)	21 (13.1)
Rain water harvesting	113 (70.6)	47 (29.4)
Spring	159 (99.4)	1 (0.6)
Borehole	61 (38.1)	99 (61.9)
Irrigation Methods		
Bucket/watering cans	50 (31.3)	110 (68.8)
Furrow	117(73.1)	43 (26.9)
canal	54 (33.8)	106 (66.3)

water harvesting is only done by 29.4% of respondent. The findings by WHO and UNICEF (2006) indicate that communities relying on wells as source of water tend to be poor and live in environments with associated high health risks and therefore, majority do not opt to use wells as a source of water for irrigation.

Table 5 indicates that 54.4% of respondents do not use tap water for irrigation. This may be due to the fact that they will be subjected to pay for water usage and at some point, it becomes expensive. Moreover, they are not producing enough for sale. Only 45.6% admitted to be using tap water for irrigation purposes. According to DWAF (1997, 2013), water users in South Africa, will not be billed by the Department if they are schedule 1 user in terms of the National Water Act (Act no 36 of 1998). These are non-commercial uses of water including domestic use, small-scale gardening and the watering of livestock. Such use will not invite tariffs for the water and the water will be supplied to water service providers free of charge but some government officials insist that those who use water for agricultural purposes must pay.

Table 5 shows that 68.8% are using watering cans/ bucket, while other use canals (66.3%). The size of the farm and level of irrigation technology applied could be responsible for the high proportion of people using watering cans and canals. According to Giddings (2004) , most farmers prefer using irrigation methods which use less labour requires less maintenance required, that can allow easy establishment and maintenance of crops and is also suitable to most soil types.

Table 6 shows water use productivity among home gardeners which was expressed as a ratio of quantity harvested for each of the vegetables and the quantity of water used. Water use was estimated by measuring the average rate of flow to determine the quantity released to the farms for furrow and canal irrigation techniques and volume and number of watering cans for those using watering cans. Cabbage has the highest

Table 6 - Water use productivity among home gardeners.

VEGETABLES	QUANTITY HARVESTED Kg (Mean)	TOTAL WATER USE WATER CUBIC (m^3)	WATER PRODUCTIVITY (kgm^{-3})
Spinach	90680.8	78.848	11.5
Cabbage	104236	38.532	27.1
Carrot	29541.24	40.29	7.3
Beetroot	29496.24	31.995	9.2
Tomatoes	19172.556	31.505	6.1
Potatoes	500	0.765	6.5
Butternut	12837.38	13.335	9.6
Onion	19591.3864	25.087	7.8
Green beans	3545.1	5.55	6.4
Green pepper	819.2	2.78	2.9

Table 7 - Cross-tabulation of water use productivity and food security status of farmers.

	High WUP	Low WUP	Total
Not food secured	28	25	53
Food secured	80	27	107
Total	108	52	160

χ^2= 7.75, df=1 p = 0.005

water use productivity (27 kgm^{-3}). This is followed by Spinach (11.5 kgm^{-3}) and butternut (29.6 kgm^{-3}). This may be because of the respondents mastering the production and water management for these vegetables. Green beans and green pepper has the lowest water use productivity with (6.4 kgm^{-3}) and (2.9 kgm^{-3}) respectively. This implies that the conversion of water to yield for these vegetables are low under a ceteris paribus condition.

Table 7 presents the results of the cross-tabulation of water use productivity and food security status of farmers. The food security status was measured using Household Food Insecurity Access Scale (HFIAS) was used. The HFIAS is used to measure the impact of food security programs on the access component of household food insecurity. The method is based on the idea that the experience of food insecurity (access) causes predictable reactions and responses that can be captured and quantified through a survey and summarized in a scale found to be universal across cultures. The HFIAS has nine questions; each of which has a recall period of four weeks (30 days) (Coates *et al.*, 2007). The total scores were pooled and the mean used as cut-off point for secured and non- secured households. From the results in Table

Table 8 - Multiple regression analysis relationship between socio-economic characteristics and water use productivity.

	B	Std. Error	BETA	T	SIG
Constant	44.841	16.798		2.669	.008
Gender of household head	-2.360	2.092	-0.089	-1.128	.261
Age of household head	-0.101	0.129	-0.100	-0.782	.436
Farming experience	0.118	0.208	0.064	0.571	.569
Marital status of household head	0.491	1.364	0.035	0.360	.719
Education	-1.759	1.678	-0.089	-1.048	.296
Religious belief	1.755	4.192	0.031	0.419	.676
Land ownership	-3.578	2.527	-1.138	-1.416	.159
Type of crop	-2.895	1.185	-0.348	-2.443	.016
Willingness to expand	1.900	5.437	0.027	0.349	.727
Attitude	-1.225	0.710	-0.485	-1.727	.086
Household food security	-1.999	1.125	-.711	-1.777	.078
Market outlet	2.377	0.846	1.118	2.810	.006
Social participation	1.849	0.712	0.398	2.599	.010
Willingness to increase plots	-.146	.118	-.152	-1.237	.218
R	0.506				
R square	0.256				
F	3.074				.
P	0.000				

7, the total water use productivity (WUP) was calculated by pooling all the scores and denominated by the types and number of vegetable produced by each farmer. The results show that there is a high relationship between water use productivity and food security. However, the size of home garden might be responsible for the group of farmers who have high water use productivity and yet food insecure. The produce and income from such category of respondents were not enough to obtain other food types. Baiyegunhi and Makwangudze (2013) reported that most households with home gardern in KwaZulu Natal province of south Africa were food secured.

The influence of socio-economic characteristics on water use productivity among homestead vegetable farmers is presented in Table 8. The independent variables were significantly related with an F value of 3.074, $P < .05$. Also, an R value of 0.506 showed that there was a strong correlation between socio-economic characteristics and water use productivity. The results further predicted 26% of the variation in water use productivity. Five out of sixteen were significant, with three variables being significant at 5% (type of crop, social participation and market outlet) while two variables were significant at 10% (food security and attitude). Significant determinants of water use productivity were types of cropping ($t = -2.443$, $p = .016$), social participation ($t = 2.599$, $P = .010$), marketing outlets ($t = 2.810$, $p = .006$), home food security, (t=-1.777, p = .078) and attitude (t = -1.727, p = .086). The results imply that the higher the attitude, marketing, home food security, social participation and type of crop, the higher the use of water productivity among farmers. However, insignificant determinants of water use productivity were farming experience (t = 0.571, p=0.569), education (t = -1.048, p = 0.296), land ownership (t = -1.416, p = 0.159) and age (t = -0.782, p = 0.436). The results imply that the lower the farming experience, education skill, land ownership and age, the lower the water productivity use among farmers.

Conclusions

Homestead food gardening plays a pivotal role in the improvement of rural household food security and is often characterised by efficient water use. This study establishes that majority of the home garden are on communal land, oriented towards subsistence agriculture, depended on underground water through the use of boreholes and were food secured. Factors such as type of crops, social participation, market outlet used, household food security status and attitude towards home garden affect water use productivity. It is therefore important that the policy drive towards food security should focus on water use efficiency and the factors that significantly affect it as found in this area of study.

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