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Crop production practices at Folovhodwe, Rambuda, and Tshipise smallholder irrigation schemes at Mutale local municipality in Limpopo province of South Africa

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Abstract
The purpose of this study was to investigate crop production practices used by plot holders in Folovhodwe, Rambuda and Tshipise Irrigation Scheme at Mutale Local Municipality in Limpopo Province of South Africa. The results show that production practices used include those that promote increasing crop yield and natural resource sustainability and those that produce poor quality products that do not meet market requirements. Practices with prospects of promoting yields and natural resource sustainability were: (1) fertilizer application by majority (94.5% for Folovhodwe, 91.4% for Rambuda, and 100% for Tshipise) of plot holders, (2) some application of manure (27.8% at Folovhodwe, 43.3% at Rambuda and 76.7% at Tshipise), (3) use of crop rotation by majority of plot holders at Rambuda (70.2%) and Tshipise (53.3%), (4) control of weeds (using hand hoes) and insect pests (using pesticides), and (5) incorporation of crop residues into the soil (36.1% respondents at Folovhodwe, 62.2% at Rambuda, and 33.3% at Tshipise) contributing to soil fertility improvement. To the contrary, practices with prospects of reducing yields and natural resource sustainability were: (1) too low fertilizer application rate of 5 x 10kg =50kg (68.9% respondents at Rambuda, 100% each at the other two schemes), (2) lack of use of soil conservation practices by majority of plot holders (63% at Folovhodwe, 98.5% at Rambuda, and 53.3% at Tshipise), (3) only a few plot holders practicing fallowing (26.4% at Folovhodwe and 40.3% at Rambuda), and (4) burning of crop residues by some plot holders (37.5% at Folovhodwe, 11% at Rambuda, and 25.7% at Tshipise). In conclusion, Practices with prospects of promoting yields and natural resource sustainability should be promoted.

Keywords: Crop production practices, Mutale local municipality, smallholder irrigation scheme, plot holder, Limpopo province

Introduction

Practices in smallholder irrigation schemes (SIS) has an important role to play in promoting food security and growing the economy of rural areas. Despite the abundance of policies, programs and a burst of interventions directed at the intensification of smallholder irrigation schemes, their success in increasing food production and economic activity seems to be limited. According to World Bank (2008) [35], there are hardly cases of successful and sustainable farmer-managed smallholder irrigation schemes in Africa despite efforts by Governments, NGOs and private organizations.

According to Demeke (1998) [10], agriculture in Ethiopia is characterized by diminishing farm size, severe soil degradation, erratic rainfall, weak agricultural research and extension system, lack of financial services, imperfect agricultural markets and poor infrastructure. The situation highlighted for Ethiopia mostly also applies in South Africa, and this includes the Mutale Local Municipality in Limpopo Province (Chitja and Mabaya, 2015) [5]. According to Chitja *et al.*, (2015) [5], rural South Africa is largely patriarchal and is governed by tribal councils. The patriarchy in rural South Africa results in productive resources such as water and land being largely controlled by men (Cousins, 2007) [6].

In smallholder irrigation schemes, both land and water rights were mostly assigned to families (Tapela, 2008) [28], land rights therefore determine water rights. Unfortunately, such allocation of land and water rights were influenced by socio-economic status of recipient households. As revealed by van Koppen (1999) [33], women had limited rights to water associated with their lack of rights to land. In affirmation, Gabru (2005) [12] stated that the majority of rural women struggle to secure rights to water since they continue to be dominated by men with more rights to land. Access to and control of resources is a reflection of status, and secondary access to productive resources signals that women have a secondary status in their communities (Zwarteveen and Meinzen-Dick, 2001) [36].
In some cases, women are allocated user rights to land without rights to water (Brewster *et al.*, 2006; Tapela, 2008; van Koppen, 1999) [3, 28, 33], and such lack of water rights compromises their (women's) capacity to perform their duties. Resultantly, women use available water for multiple activities as revealed by a study in Nepal that showed that rural women used irrigation water for household chores (Zwarteveen and Meinzen-Dick, 2001, Jeckoniah *et al.*, 2012; Alkire *et al.*, 2013) [36, 14, 2]. Given the prevailing water scarcity it is possible that this could also be the case in communities with smallholder irrigation schemes in South Africa.
For smallholder irrigation schemes to be effective in promoting food security and economic development in rural areas, challenges such as those alluded to by Demeke (1998) [10] should be addressed. Successfully addressing those challenges would require assessment and strengthening of the production practices in the irrigation schemes.

Objective
The objective of this study was to investigate crop production practices used by smallholder farmers at Folovhodwe, Rambuda and Tshipise Smallholder Irrigation Schemes (SIS) in Mutale Municipality under the Limpopo Province of South Africa and to recommend necessary improvements.

Research Methodology
Description of study area
Location
The study was conducted at Folovhodwe, Rambuda and Tshipise SIS in Mutale Local Municipality under Vhembe District of Limpopo Province, South Africa (Figure 1).

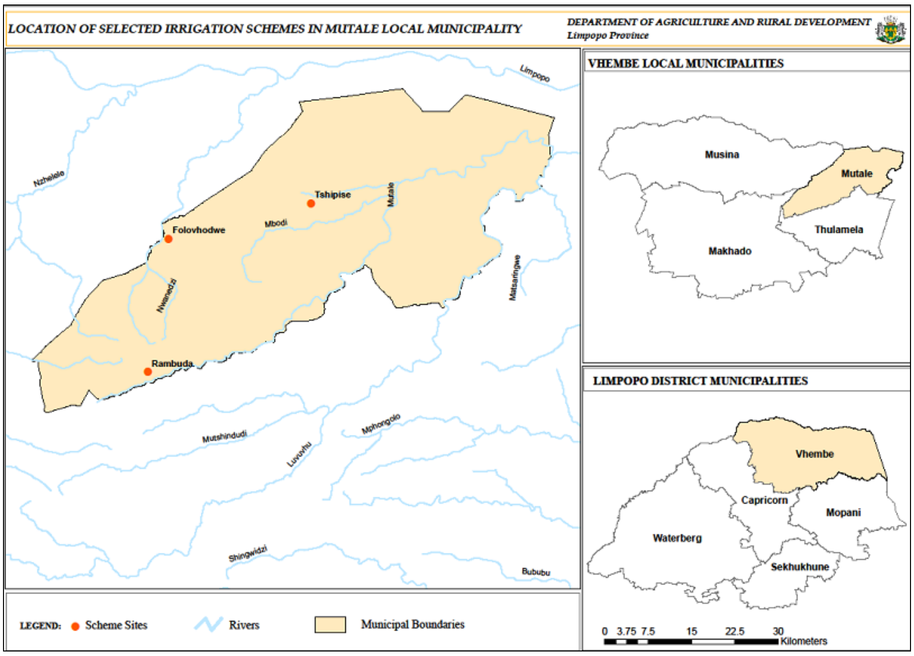

Fig 1: Location of Folovhodwe, Rambuda and Tshipise Irrigation Schemes in Mutale Local Municipality under Vhembe District of Limpopo Province, South Africa

Folovhodwe SIS is supplied with irrigation water by the Nwanedi River and is located on 22° 34' 67" S and 30^0 25' 62" E. Rambuda SIS is supplied by the Mutale River and is located on 22°47'15"S latitude and 30°27'5"E longitude while Tshipise SIS is supplied by the Tshipise River (that forms a confluence with the Mutale and Mbodi river system) and is located on 22°31 39"S and 30°40'38"E.

Climate and soil condition
The climate and soil condition in a cropping land tend to influence the production practices used by the farmer and should therefore be properly described.

Rainfall
Mutale Local Municipality receives an average of 515mm of rain per annum with more than 80% of the rainfall occurring between October and March (Tshikolomo, 2012) [27]. According to Tshikolomo (2012) [29], most of the rainfall occurs in January and February with the wettest month being February with a monthly precipitation of 105 mm.
Rainfall increase is followed by increases in stream flow and dam storage volume with a lag of about two months (Tshikolomo *et al.*, 2012) [30], and this influences the prospects of availability of irrigation water for the SIS. As stated by Tshikolomo *et al.* (2012) [30], the ability of a dam to supply water for different uses is dependent on its water gain and loss and these are influenced by the amount of rainfall it receives. The water gains are inputs (rainfall and inflows) while the losses are outputs (evaporation, abstractions, and outflows), and these result in a fluctuations of soil moisture storage.

Temperature
The monthly distribution of average daily maximum temperatures shows that the average midday temperatures for

Mutale Local Municipality range from 22.1 °C in June to 29.2 °C in January. The area is coldest during July when the temperature drops to 7.7 °C on average during the night (Mpandeli *et al.*, 2006) [21].

Temperature has a strong influence on the quantity of water loss through evapotranspiration (ET) with high temperature resulting in high ET. The annual ET for Mutale Municipality is estimated at 1475 mm (Mpandeli *et al.*, 2006; Tshikolomo, 2012) [21, 30]. Accordingly, the highest ET was reported for the hot months of December (166 mm) and January (161 mm) with the lowest ET stated for the cold months of June (74 mm) and July (82 mm).

Soils

At Rambuda SIS, soils were described as deep and well drained with small portions of moderately drained soils in some places (Nethononda *et al.*, 2013) [23]. At the Folovhodwe and Tshipise SIS, the soils were regarded very susceptible to erosion, and plots were reportedly affected by sheet erosion and by gully erosion, and floods recurred roughly on a ten-year basis (Lahiff, 2000 [15]; Chitja, *et al.*, 2015) [4].

Research design

The study followed a mixed approach that combined quantitative and qualitative approaches. Quantitative approach is an enquiry based on testing a theory made up of variables, measured with numbers, and analyzed using statistical procedures (Creswell, 2003; Leedy and Ormrod, 2010) [8, 37]. On the other hand, qualitative approach is an enquiry process of comprehending a social problem based on building a holistic picture formed with words, and entails reporting detailed views of informants (Lincoln and Guba, 1985; Creswell, 2003) [18, 8].

As affirmed by Tshikolomo (2012) [29], quantitative and qualitative approaches may be mutually inclusive and complementary and may therefore be used together as a mixed approach. The mixed approach as employed in this study entailed production of knowledge through collection and analysis of data using statistical procedures (quantitative) and interpretation of such information based on detailed views of informants and with requisite insight of their experiences (qualitative).

Research designs are techniques for collecting, analyzing, interpreting and reporting data (Mouton, 2001) [22] and provide guidelines to be followed in addressing research problems (Welman *et al.*, 2005) [34].

Sample frame and Sampling procedure

Sample representativeness is a requirement for research results to be credible and trustworthy (Leedy and Ormrod, 2010) [37] and can only be achieved if a sample frame is born in mind (Welman *et al.*, 2005) [34]. As stated by Welman *et al.*, (2005) [34], a sample frame is a complete list in which each unit of analysis is mentioned only once. For the purpose of this study, the sample frame was mainly described in three levels: (1) local municipalities, (2) SIS, and (3) plot holders.

Of the 25 local municipalities in the Limpopo Province, Mutale was purposively sampled for ease of access by the researcher as he resides in this municipality, and based on the fact that the majority of the irrigation schemes fall within the Mutale Local Municipality. In the selected Mutale Local Municipality, only three SIS were found to be in operational condition, namely: Folovhodwe, Rambuda and Tshipise, and those were all included in the study. These were the schemes in which plot holders relied on common supply of irrigation water. Within the three SIS included in the study, plot holders were sampled for interviews using a structured questionnaire (Table 1).

Table 1: Sample frame and selected sample of plot holders in Folovhodwe, Rambuda and Tshipise Smallholder Irrigation Schemes in Mutale Local Municipality under Vhembe District of Limpopo Province, South Africa

Name of Smallholder Irrigation Scheme	Sample frame	Sample	Sample as % of sample frame
Folovhodwe	112	73	65.2
Rambuda	96	67	69.8
Tshipise	30	30	100.0
Total	238	170	71.4

Random sampling was used to select plot holders from the sample frame so that by studying the sample, the results obtained may be generalized to the population from which the sample had been chosen (Leedy and Ormrod, 2010) [37]. Seven in ten (71.4%) plot holders in all the three SIS were sampled for the study, and this is more than double the 32% minimum sample size proposed by Stoker (1985) [27] for a population of 200 units.

Data collection and analysis

Data was obtained through: (1) review of literature that presented mainly qualitative information from scientific journals, books and reports, (2) interviews of sampled plot holders using a structure questionnaire that contained mainly closed-ended questions associated with quantitative data (Hurmerinta-Peltomaki and Nummela 2006) [13], (3) observations to confirm irrigation systems, types of crops, types of weeds, pests and diseases and management practices used; and (4) interpersonal communication with relevant officers in government departments, NGOs, and academic as well as research institutions. The questionnaire used for interviews included questions on thematic issues such as soil fertility management, crop rotation, irrigation management, and crop pest and disease management.

Quantitative data was captured and analysed using the SAS package (SAS Institute Inc. 2009) [25]. Simple frequency tables of occurrence were generated in each class of demographic variables utilizing one-way tables. The quantitative data was summarized and discussed based on objective interpretations (Lee 1999; Leedy and Ormrod 2010) [16, 37]. Qualitative data was summarized based on its content and main themes addressed, and was discussed based on subjective interpretations.

Results and Discussion

Adoption of crop production practices is dependent on the need to maintain or increase yields and is therefore influenced by the extent to which farmers are aware of instances of yield declines or increases. Farmers with declining crop yields should be motivated to adopt better agricultural production practices to increase yields while those obtaining high yields should use better practices to maintain their high yields at the least. It is therefore necessary to establish the extent of farmer awareness of their yield trends (Table 2).

Research conducted in Mopani and Sekhukhune districts in

Limpopo Province shows maize yield for households that used fertilizer were almost double those of households that did not apply fertilizer (Siambi *et al.,* 2009) [26]. It would have been important to make comparisons between yield of crops that received manure and/or fertilizer with those that did not but the data as entered may not be flexible enough. Overall, three in four (74.7%) of the plot holders in the study SIS (Rambuda-83.6%; Folovhodwe-69.9%; and Tshipise-66.7%) were aware of the trends in their crop yields over time and reported a decline. Such declines in yields are evident of poor plot holder performance in SIS (Crosby *et al.,* 2000) [9] and are associated with use of poor crop production practices. There are several reasons why some of plot holders received poor crop yields and this include: (a) Use of poor quality seeds, (b) Poor soil status in those areas, (c) Incorrect agricultural practices, (d) High climatic variability and change.

Table 2: Plot holder awareness of yield trends in Folovhodwe, Rambuda and Tshipise Smallholder Irrigation Schemes in Mutale Local Municipality under Vhembe District of Limpopo Province, South Africa

Name of scheme	Aware of trend, yield declines		Not aware of trend	
	No	%	No	%
Overall	127	74,7	43	25,3
Folovhodwe	51	69,9	22	30,1
Rambuda	56	83,6	11	16,4
Tshipise	20	66,7	10	33,3

With continued declines, maize grain yields would understandably be averaging less than 3 t/ha^{-1} recorded on several schemes (Van Averbeke *et al.,* 1998; Machete *et al.,* 2004; Van Averbeke, 2008; Mnkeni *et al.,* 2010) [32, 19, 31, 20]. One in four (25.3%) of the farmers were not even aware of whether their crop yields were increasing or decreasing, and those would not know whether to change their production practices or not.

With majority of plot holders having reported declines in their crop yields, an investigation of the crop production practices used in the selected SIS became more justifiable. Production practices of importance include soil fertility management (with a focus on use of both chemical fertilizers and manures), cropping systems, irrigation water management as well as crop pest and disease management.

Soil fertility management

According to Siambi *et al.,* (2009) [26], soil fertility management has emerged over the past years to be the main management constraint responsible for the very poor yields obtained in Africa. The Insiza and Gwanda districts in Zimbabwe had the largest proportion of area planted to maize and had high proportions of households that used manure in the 2004/05 season. Insiza District had a higher proportion (58.3%) of households that used manure in the 2004/05 season followed by Gwanda (31.6%) (Siambi *et al.,* 2009) [26].

Proper management of soil fertility is important for good crop yields to be obtained. The proper management of soil fertility entails understanding crop nutrient requirement for target yields to be realized. Soil analysis should be conducted to determine existing nutrient status and subsequently to decide whether to apply fertilizers or not. Among the commonly used fertilizers for crop farming are chemical fertilizers and manures. As was highlighted by Siambi *et al.,* (2009) [26], Mopani and Sekhukhune districts had a higher proportion of household not aware of where to source information on soil fertility management. The national extension service was cited in both districts as a source of information on soil fertility management. Non-governmental organizations were identified as another source of information. For example, studies done in Zimbabwe in Matobo district had the highest proportion of households citing NGOs as a source of information on maintaining soil fertility. Other farmers were cited by a significant proportion of households in both South Africa and Zimbabwe as sources of information on soil fertility management (Siambi *et al.,* 2009) [26].

Use of chemical fertilizers

The focus of the study was to assess the extent and correctness of use of chemical fertilizers in the selected SIS as these have strong influence on crop yields. Accordingly, issues of soil sampling and fertilizer application (or lack thereof) were important (Table 3). Studies conducted in Mopani and Sekhukhune districts, generally show significant proportion of households were aware of the use of mineral fertilizers in managing soil fertility. Mopani district in South Africa had the least (34.7%) number of households that were aware of the use of mineral fertilizers in managing soil fertility. Insiza, Gwanda and Matobo in Zimbabwe had the highest proportion of households (more than 90%) aware of the use of mineral fertilizers in managing soil fertility. Despite the high levels of awareness on mineral fertilizer use the proportion of households that have used fertilizer at least once remain limited. Sekhukhune had the highest proportion (50.4%) of households that have tried mineral fertilizer at least once. It also had the highest proportion (20%) of households that used mineral fertilizers in the 2004/05 season (Siambi *et al.,* 2009) [26]. The plot holders in the SIS under study did not know how to conduct soil sampling (98.6% for Folovhodwe and 100% each for Rambuda and Tshipise). Accordingly, no soil samples were taken except for only 1.5% of plot holders reported to have taken soil samples at Rambuda SIS. The findings regarding soil sampling suggest that the plot holders did not have information on nutrient contents of their soils. The majority of the farmers (94.5% for Folovhodwe, 91.4% for Rambuda, and 100% for Tshipise) reported, however, that they applied fertilizers. The results further show that the majority of the farmers (90.1% at Folovhodwe SIS, 95.1% at Rambuda SIS, and 80% at Tshipise SIS) used fertilizer mixtures together with Limestone Ammonium Nitrate (LAN). The fertilizers were reported to have been applied at three different times, and most plot holders applied two weeks after planting at Folovhodwe (47.4% of respondents, during planting at Rambuda (46.9%) and before planting at Tshipise (45.5%).

With regards to fertilizer application methods, some plot holders used broadcasting (37.5% at Folovhodwe, 30.3% at Rambuda, and 20.8% at Tshipise SIS) that could be less efficient as some fertilizers might be inaccessible for uptake by crop plants. It was pleasing to note that the rest of plot holders used the more targeted methods of band, row and whole placement likely to be more efficient. Even without soil analysis, the generic fertilizer recommendation for less demanding irrigated crops such as maize is 4 x 50 kg of 2:3:2(30) plus 1 x 50 kg LAN (ARC, 1999) [1]. The maximum fertilizer application rate of 5 x 10 kg (=50 kg) reported by plot holders at the study SIS (68.9% at Rambuda, 100% each at the other two SIS) was far less than the generic recommendation, and this may have been influenced by lack of fertilizer recommendations and unaffordable prices of fertilizers as confirmed by majority of the plot holders (97.2% at Folovhodwe, 71.2% at Rambuda, and 60% at Tshipise SIS).

Table 3: Soil fertility issues and fertilizer application practices in Folovhodwe, Rambuda and Tshipise Smallholder Irrigation Schemes in Mutale Local Municipality under Vhembe District of Limpopo Province, South Africa

Parameter	Response	Folovhodwe SIS (%)	Rambuda SIS (%)	Tshipise SIS (%)
[N]		[73]	[67]	[30]
Know how to sample soil	Yes	1,4	0,0	0,0
	No	98.6	100,0	100,0
Soil samples were taken	Yes	0,0	1.5	0,0
	No	100,0	98.5	100,0
Fertilizers were applied	Yes	94.5	91.4	100,0
	No	5.5	8.6	0,0
Fertilizers often used	Fertilizer mixture only	0,0	1,6	3,3
	LAN only	0,0	1,6	16,7
	Fertilizer mixture + LAN	90,1	95,1	80,0
	Fertilizer mixture + Urea	9,9	1,6	0,0
Times of fertilizer application	Before planting	22,6	20,8	45,5
	At planting	36,1	46,9	23,6
	2 weeks after planting	47,4	32,3	30,9
Methods of application	Broadcasting	37,5	30,3	20,8
	Banding	0,0	11,1	14,6
	Row placement	56,7	47,5	60,4
	Place in planting hole	5,8	11,1	4,2
Application rate (10 kg bag/plot)	1-5 bags	100,0	68,9	100,0
	6-10 bags	0,0	31,2	0,0
Fertilizer affordability	Yes (affordable)	2,8	28,8	40,0
	No	97,2	71,2	60,0

Use of manures

According to the results generated from the research conducted in Mopani and Sekhukhune districts, households obtained information on the use of manure from various sources that included parents, other farmers and the national extension service. In South Africa, for example, most households learnt about the use of manure from other neighboring farmers and their parents (Mpandeli, *et al.*, 2006; Siambi *et al.*, 2009) [21, 26]. A limited proportion, less than 8%, of households learnt about manure use from the national extension agents. By contrast, in Zimbabwe 20 to 27% of households first learnt about manure use from the national extension service. As is the case for South Africa, most households in Zimbabwe learnt about manure from parents and fellow farmers (Siambi *et al.*, 2009) [26]. Considering the issue of unaffordability of chemical fertilizers, plot holders in SIS would likely use alternative materials such as manures. The extent of use of manure would be influenced by availability in nearby communities (Table 4).

Table 4: Manure application at Folovhodwe, Rambuda and Tshipise Smallholder Irrigation Schemes in Mutale Local Municipality under Vhembe District of Limpopo Province, South Africa

Parameter	Response	Folovhodwe SIS (%)	Rambuda SIS (%)	Tshipise SIS (%)
[N]		[73]	[67]	[30]
Manure applied in plot	Yes	27,8	43,3	76,7
	No	72,2	56,7	23,3
Source of manure	Own animals	81,0	73,3	73,9
	Neighbour / Relative	19,1	26,5	26,1
Ease of availability of manure	Yes (Easily available)	92,2	85,3	60,9
	No	7,8	14,7	39,1
Time of application of manure	Before planting	81,0	70,6	73,9
	At planting	19,1	29,4	26,1

The extent of manure application was variable across SIS with most plot holders (76.7%) having applied at Tshipise. At least seven in ten (73.3%) of the plot holders across the SIS who applied manures relied on own animals for supply of the material. The manure was therefore reported to be easily available by majority of the plot holders (92.2% at Folovhodwe, 85.3% at Rambuda, and 60.9% at Tshipise).

The majority of the respondents (81, 0% at Folovhodwe, 70.6% at Rambuda, and 73.9% at Tshipise SIS) applied manures before planting. Application of manures before planting is often a good practice as it allows time for decomposition of the materials necessary for release of nutrients (Dewes and Hunsche, 1998) [11]. As was the case with application of chemical fertilizers, the use of manures was not based on any scientific recommendation.

Soil moisture management

Effective management of soil moisture is necessary for the success of SIS. Important aspects of soil moisture management include irrigation frequency as well as use of conservation practices and conservation measures (Table 5).

Table 5: Soil moisture management practices in Smallholder Irrigation Schemes in Mutale Local Municipality, Vhembe District, Limpopo Province of South Africa

Parameter	Response	Folovhodwe SIS (%)	Rambuda SIS (%)	Tshipise SIS (%)
[N]		[73]	[67]	[30]
Irrigation frequency	Once in ≤ 1 week	100,0	100,0	100,0
	Once in > 1 week	0,0	0,0	0,0
Use of soil conservation practices	Yes	37,0	1,5	46,7
	No	63,0	98,5	53,3
Used conservation measures	Stone bunds	32,6	-	46,7
	Sand bags	6,5	-	30,0
	Mulching	30,4	-	23,3
	Terracing	28,3	-	0,0
Crop failure related to irrigation issues	Yes	84,9	73,1	76,7
	No	15,1	26,9	23,3
Specific reasons for crop failure	Water shortage	46,5	65,3	76,3
	Disease infection	22,8	4,2	0,0
	Infrastructure failure	29,8	27,3	23,7
	Flooding & erosion	0,9	2,8	0,0
	Others	2,2	-	0,0

All plot holders in the study SIS reported that they irrigated once in a period of at most one week, implying that there might be cases where irrigation was done more frequently than once weekly. The farmers probably irrigated once weekly in cases where the supply of water did not allow for more frequent irrigation. The majority of plot holders (63% at Folovhodwe, 98.5% at Rambuda, and 53.3% at Tshipise SIS) did not use soil conservation practices, and this could have resulted in high rates of soil moisture loss which would require frequent irrigation for high crop yields to be obtained. With the prospects of less frequent irrigation, low crop yields would be obtained, hence the assertion by three in four respondents that their crop yields were declining (Table 6). Where soil conservation was practiced, various measures were reported for Folovhodwe and Tshipise SIS, and those were stone bunds, sand bags, mulching, and terracing. The fact that the majority of plot holders did not practice soil conservation probably contributed to crop failure related to irrigation as reported by majority of respondents (84.9% at Folovhodwe, 73.1% at Rambuda, and 76.7% at Tshipise). The prospect of lack of soil conservation being a major cause of crop failure was affirmed by the fact that most plot holders (46.5% at Folovhodwe, 65.3% at Rambuda, and 76.3% at Tshipise SIS) regarded water shortage to be cause of the crop failure.

Cropping systems

The types of cropping systems used in SIS determine the prospects for success of the schemes. Common cropping systems include crop rotation, intercropping, and fallowing.

Table 6: Cropping systems used in three Smallholder Irrigation Schemes in Mutale Local Municipality, Vhembe District, Limpopo Province of South Africa

Parameter	Response	Folovhodwe SIS (%)	Rambuda SIS (%)	Tshipise SIS (%)
[N]		[73]	[67]	[30]
Crop rotation practiced	Yes	12,5	70,2	53,3
	No	87,5	29,9	46,7
Reasons for not rotating	Never heard of it	85,5	100,0	100,0
	Not like it	14,5	0,0	0,0
Intercropping practiced	Yes	9,9	14,9	40,0
	No	90,1	85,1	60,0
Reasons for not intercropping	Never heard of it	7,9	20,0	0,0
	Not like it	92,4	63,6	100,0
	Crops not do well	0,0	16,4	0,0
Fallowing practiced	Yes	26,4	40,3	73,3
	No	73,6	59,7	26,7
Reasons for not fallowing	Never heard of it	25,0	26,8	50,0
	Land is scarce	75,0	73,2	50,0
Length of fallow period	3-6 months	44,4	61,5	77,3
	7-12 months	38,9	30,8	13,6
	>12 months	16,7	7,7	9,1

An investigation of the extent of use of the cropping systems in the SIS was therefore important (Table 6). Crop rotation was used by majority of plot holders at Rambuda (70.2%) and Tshipise (53.3%) SIS. As for Folovhodwe SIS, only one in ten (12.5%) plot holders used crop rotation, majority (85.5%) of those who did not use it revealed they had never heard of it while some clearly indicated that they just did not like crop rotation. The plot holders who rotated their crops are likely to be more successful than their counterparts. Majority of the plot holders in the SIS under study (90.1% at Folovhodwe, 85.1% at Rambuda, and 60% at Tshipise) did not practice intercropping, and majority of those plot holders (92.4% at Folovhodwe, 63.6% at Rambuda, and 100% at Tshipise) just did not like this cropping system. Fallowing was commonly practiced only at Tshipise (73.3% plot holders) with fewer plot holders practicing it at Folovhodwe (26.4%) and Rammbuda (40.3%). Land scarcity was cited as the main reason for not practicing fallowing (cited by 75% of respondents at Folovhodwe, 73.2% at Rambuda, and 50% at Tshipise SIS). The plot holders who practiced fallowing mostly did so for shorter periods of 3-6 months, and this was revealed by 44.4% of respondents at Folovhodwe, 61.5% at Rambuda, and 77.3% at Tshipise.

Crop pest and disease management: Effective management of crop pests and diseases is critical for the success of SIS. Common crop pests to be effectively managed include plant pests (weeds) and insect pests.

Weed management

Weeds compete with crop plants for moisture, nutrients and sunlight, hence the importance of their investigation to determine the prospects of success of SIS (Table 7).

Table 7: Weed occurrence and their management in three Smallholder Irrigation Schemes in Mutale Local Municipality, Vhembe District, Limpopo Province of South Africa

Parameter	Response	Folovhodwe SIS (%)	Rambuda SIS (%)	Tshipise SIS (%)
Occurrence of weeds	Yes	68.5	76.1	83.3
	No	31.5	23.9	16.7
Common weeds	Yellow nutsedge	31.4	16.7	71.4
	Kweek grass	27.5	11.9	19.1
	Black jack	13.7	19.1	4.8
	Mexican poppy	17.7	21.4	0.0
	Common buffalo grass	7.8	7.1	0.0
Control methods	Hand hoe	100.0	100.0	100.0

The majority of plot holders (68.5% at Folovhodwe, 76.1% at Rambuda, and 83.3% at Tshipise) agreed to have problem of weeds in their plots. Problematic weed species as cited by various numbers plot holders were yellow nut sedge, Kweek grass, black jack, Mexican poppy, and common buffalo grass. All plot holders (100%) used hand hoe as their main instrument to control weeds. The reason could be because the hand hoe was cheaper to buy. With the use of hand hoes, it would be expected for plot holders to have invested a lot of their time on weeding.

Insect pest management

Insect pests damage crop plants mainly through direct feeding on plant parts, and the type of damage is related to the type of mouth parts of the insect pest (Cranshaw, 2004; Pedigo and Rice, 2006) [7, 24]. The majority of plot holders at Rambuda (64.2%) and Tshipise SIS (73.3%) had problems of pests in their plots while fewer (46.6%) plot holders had the problems at Folovhodwe (Table 8).

Table 8: Insect pest occurrence and their management in three Smallholder Irrigation Schemes in Mutale Local Municipality, Vhembe District, Limpopo Province of South Africa

Parameter	Response	Folovhodwe SIS (%)	Rambuda SIS (%)	Tshipise SIS (%)
Occurrence of insect pests	Yes	46,6	64,2	73,3
	No	53,4	35,8	26,7
Common insect pests	Beetle	20,0	16,2	16,7
	Maize stalk borer	53,3	54,0	55,6
	Locust	26,7	24,3	22,7
Control method	Chemical	100,0	100,0	95,5
	Indigenous knowledge	0,0	0,0	4,6

The common insect pests were maize stalk borer (reported by 53.3% of respondents at Folovhodwe, 54% at Rambuda and 55.6% at Tshipise SIS) followed by locusts (26.7% at Folovhodwe, 24.3% at Rambuda, and 22.7% at Tshipise) and least beetle (20% at Folovhodwe, 16.2% at Rambuda and 16.7% at Tshipise). Almost all the plot holders relied on chemical control methods for management of the insect pests, and control effectiveness would depend on the respondents' affordability of the pesticides and the correctness of their use.

Disease management

Plant diseases are an important constraint to crop yield and quality, and are caused by pathogens that may be fungal, bacterial, viral, and/or nematodes. It was observed that nine in ten plot holders at the SIS under study (93.2% at Folovhodwe, 89.6% at Rambuda, and 90% at Tshipise) did not have problems of crop diseases (Table 9).

The climate of Mutale Municipality is fairly arid, and this could be cause for plant diseases to be less problematic, more so those caused by fungi. The plot holders who indicated having problems of crop diseases in their plots revealed maize streak virus to be their main problem (60% at Folovhodwe and 100% at Tshipise). Where crop diseases were identified as problems, various control methods were used at different schemes. Majority of plot holders used indigenous knowledge at Folovhodwe (60% of respondents) and Tshipise (66.7%) while about nine in ten (85.7%) used chemical control at Rambuda SIS.

Table 9: Disease occurrence and their management in three Smallholder Irrigation Schemes in Mutale Local Municipality, Vhembe District, Limpopo Province of South Africa

Parameter	Response	Folovhodwe SIS (%)	Rambuda SIS (%)	Tshipise SIS (%)
[N]		[73]	[67]	[30]
Was there any disease in your plot?	Yes	6.8	10.4	10.0
	No	93.2	89.6	90.0
What were the major diseases?	Maize streak virus	60.0	28.6	100.0
	Powdery mildew	40.0	42.9	0.0
Methods used to control the diseases	Indigenous knowledge	60.0	14,29	66.7
	Chemical	40.0	85.71	33.3

Crop residue management

Effective management of crop residues influences the success of production practices and is therefore important for sustainable crop production.

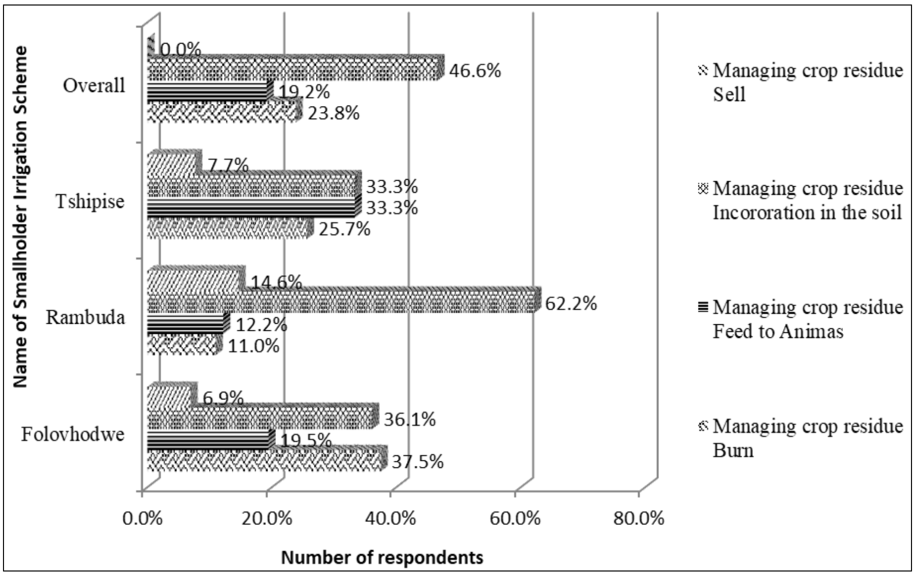

Fig 2: Crop residue management in three Smallholder Irrigation Schemes in Mutale Local Municipality, Vhembe District, Limpopo Province of South Africa

For instance, incorporation of the residues in the soil promotes decomposition and release of mineral nutrients that contributes to soil fertility while leaving them on the soil surface promotes formation of an organic mulch that reduces moisture loss and allows for insect pests and disease pathogens to survive through cropping seasons. Plot holders in study SIS managed crop residues in various ways (Figure 2). As revealed by various numbers of respondents, crop residues were managed through incorporation into the soil (36.1% at Folovhodwe, 62.2% at Rambuda, and 33.3% at Tshipise SIS), feeding to animals (19.5% at Folovhodwe, 12.2% at Rambuda, and 33.3% at Tshipise SIS), and burning (37.5% at Folovhodwe, 11% at Rambuda, and 25.7% at Tshipise SIS). Very few plot holders sold their crop residues.

Conclusion and Recommendations

Production practices used by plot holders in the irrigation schemes under study included those that promoted increased crop yield and natural resource sustainability and those with possible counter effects. Practices with prospects of promoting yields and natural resource sustainability were: (1) fertilizer application by majority (94.5% for Folovhodwe, 91.4% for Rambuda, and 100% for Tshipise) of plot holders and use of targeted band, row, and hole placement by combined majority of plot holders, (2) manure application, mostly at Tshipise (76.7%), and the application of these organic material before planting (80.9% at Folovhodwe, 70.6% at Rambuda, and 73.9% at Tshipise SIS) that allowed time for decomposition that is necessary for release of nutrients, (3) use of crop rotation by majority of plot holders at Rambuda (70.2%) and Tshipise (53.3%) SIS, (4) plot holders controlled weeds (using hand hoes) and insect pests (using pesticides) reported to be problematic with diseases revealed less problematic, and (5) incorporation of crop residues into the soil, mostly at Rambuda (62.2%) contributing to soil fertility improvement.

To the contrary, practices with prospects of reducing yields and natural resource sustainability were: (1) fertilizer application rate of 5 x 10 kg (= 50 kg) reported by plot holders (68.9% at Rambuda, 100% each at the other two SIS) far less than the generic recommendation, probably due to unaffordable prices of fertilizers as confirmed by majority of respondents (97.2% at Folovhodwe, 71.2% at Rambuda, and 60% at Tshipise SIS), (2) lack of use of soil conservation practices by majority of plot holders (63% at Folovhodwe, 98.5% at Rambuda, and 53.3% at Tshipise SIS), (3) only a few plot holders practicing fallowing, mainly at Folovhodwe (26.4%) and Rambuda (40.3%) with land scarcity cited as the main reason for not practicing fallowing (75% of respondents at Folovhodwe, 73.2% at Rambuda), (4) burning of crop residues by some plot holders (37.5% at Folovhodwe, 11% at Rambuda, and 25.7% at Tshipise SIS) burned their crop residues releasing carbon (CO_2) carbon sequestrated in organic materials into the atmosphere.

Practices with prospects of promoting yields and natural resource sustainability should be promoted while those reducing yields and natural resource sustainability should be prohibited.

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