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The Necessity of Improving Agricultural Water Productivity in the Physical Water Scarcity Limpopo Province – South Africa

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Abstract: Whereas Agricultural water management broadly aims to improve the availability of water on land used for production of field and tree crops as well as livestock, Agricultural water productivity in this paper will focus on Crop per Drop approach. In general it uncovers the water productivity of agricultural water management being practiced in small scale irrigation schemes; and recommends managerial, operational and technological interventions that that can improve water productivity in the Vhembe small scale irrigation schemes.
Through pro-poor policies, the Government has established small scale irrigation schemes that provide water to land uses in the scheme. This research was carried out at the Dzindi and Palmaryville Irrigation Scheme in Vhembe district of Limpopo Province. Farmers are allocated 1.2ha plots where they grow maize and a range of vegetables throughout the year. Despite the fact that such policies that provide preferential access to water by smallholder farmers exist, the study found no evident sense of awareness to the approaching dangers of physical water scarcity in the region. This was evident in the irrigation water application systems and agronomic practices employed by the farmers. The study concluded that good management of agricultural water positively influences particularly the farm output of rural households. There is merit in imparting new knowledge and skills in order to empower formerly disadvantaged small scale farmers in these existing irrigation schemes in the region in order to improve the socio-economic performance of farming households. Based on these findings user-friendly instruction materials in local languages were produced. The material is being used to train farmers in Irrigation Management. Farmers have been modifying their water application systems and have been participating in water resource sharing and the maintenance of the infrastructure. This has reduced water use that had been the norm due to over irrigating.
Key words: Agricultural water management, agricultural water productivity, crop per drop approach, field crops, physical water scarcity small scale irrigation, tree crops.

INTRODUCTION

When the green revolution arrived in Africa, it was being championed on the factual basis that it increases labour productivity, reduces drudgery, creates employment in Agriculture and other support sectors and increases farm income. Whereas these have been realized at commercial level, it is still a dream to the small and medium scale farmers who are vital to food security status of most African countries. For the national governments, this is still work in progress of trial and error in nature given the past experience.

Poverty and unemployment in South Africa are often rural phenomena, and given that many of the rural inhabitants are linked to agricultural activities, the various Departments of Agriculture in South Africa have an important role to play in addressing the needs in rural areas (Elsenburg, 2005).

Given that the South African Government is still focused on mechanizing agriculture at both small and medium scale level, the agricultural engineers and agronomists must inform policy with research based information that will infuse the water productivity awareness in the agricultural mechanization endeavours.

Over the past few years, the concept of productivity of water in agriculture has gained ground with a shift in focus from land to water as a factor of production in agriculture owing increasing shortage of water (Kumar et al. IWMI 2008).

Generally, smallholder irrigation schemes (SIS) in South Africa have performed poorly and have not delivered on their development objectives of increasing crop production and improving rural livelihoods. Limited knowledge of irrigated crop production among farmers has been identified as one of the constraints to improved crop productivity (Fanadzo et al. 2010).

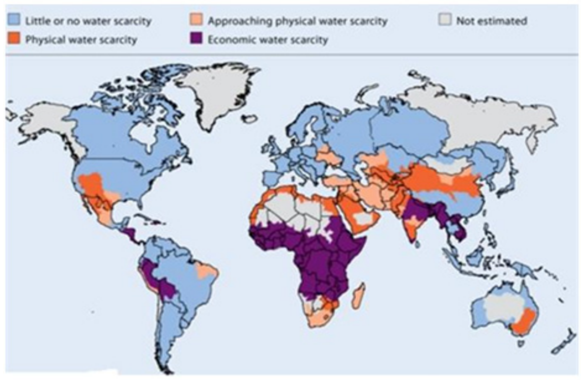
There is an important link between mechanization and water productivity. (J.F. Reid). Approximately 70 percent of withdrawals of fresh water are used for agriculture (Postel et al.1996). By 2025, 1.8 billion people are expected to be living in areas with absolute water scarcity and two-thirds of the world population will live in water-stressed areas (UN FAO 2007). Improving water management will have to be achieved by more efficient irrigation technology and higher efficiencies in whatever technologies farmers are currently using. He echoes what IWMI has been calling for, the need to dramatically improve both the efficiency and effectiveness of water use.

The importance of mechanization is underlined by the fact that tillage influences crop growth and yields by changing soil structure and moisture removal patterns over the growing season. Soil structure and moisture removal changes are dependent on soil properties, types of tillage and climatic conditions. Moisture is usually the limiting crop yield factor (L. Papworth, 2004).

Small-scale irrigation farming is envisaged to play a progressively larger role in rural development and to help reduce some inequalities in South Africa's space economy. Since the late 1990s, the government has aimed to 'revitalise' government-owned small-scale irrigation schemes, many located in former homelands (Tapela, 2008).

The importance of smallholder irrigation schemes in South Africa arises primarily from their location in the former homelands, which continue to be poverty nodes. In these areas, irrigated farming has the potential to contribute significantly to food security and income of participating homesteads and to create employment, both directly and through forward and backward linkages to primary production (W van Averbeke et al. 2010).

However, the above is in danger due to the fact that South Africa is one of the areas facing physical water scarcity. Fig. 1



Source: http://maps.grida.no/go/graphic

Figure 1. Areas of physical and economic water scarcity

Some researchers attribute poor performance of many SIS in SA to socio-economic, political, climatic, and design factors while others have indicated that farmer practices may actually be constraining performance, identifying low yields as evidence of poor farmer performance (Averbeke, 2012). At Large both cropping intensity and yields in Canal irrigation schemes are low, with farmers attributing low crop performance indices to lack of adequate tillage services, fertiliser, seed, chemicals and irrigation equipment (Fanadzo et al.2010). Using optimum tillage or no tillage and managing equipment traffic patterns are two good practices of appropriate soil management that can improve soil physical properties so that soil water availability is maximized. Certain tillage methods will create a better environment for water to enter the soil and be available to, or reached by, the plant roots. (Meijer et.al).

The key issue here is using the research based knowhow, and cropping skills, in other words that is a combination of right tilllage, right overall mechanization and the right irrigation.

MATERIALS and METHOD

The indicators used widely for the assessment of furrow irrigation systems performance are the application efficiency, Ea (%), and the distribution uniformity, DU (%). DU characterizes the irrigation system whereas Ea is a management performance indicator (Pereira and Trout, 1999; Pereira *et al.*, 2002; Gonçalves et.el.).

In this study both the application efficiency, Ea (%), and the distribution uniformity, DU (%) were used to quantitatively assess the distribution performance of the irrigation system (Horst et al. 2005).

$$E_a = \frac{Z_{req}}{D} \times 100\% \qquad (1)$$

$$DU = \frac{Z_{lq}}{Z_{avg}} \times 100\% \qquad (2)$$

where

Z_{req} = the average depth (mm) required to refill the root zone in the quarter of the field having higher soil water deficit;

D = the average water depth (mm) applied to the irrigated area;

Z_{lq} = the average low quarter depth of water infiltrated in the field (mm); and

Z_{avg} =- the average depth of water infiltrated in the whole irrigated area (mm).

Water conveyance efficiency (Ec)

$$Ec = \frac{Q_{Dci}}{Q_{Ctf}} \times 100 \qquad (3)$$

where

Q_{Dci} = water delivered to field and

Q_{Ctf} = water delivered from source.

Procedures that were used to quantify the uniformity of irrigation furrows are those that have been established and standardised (ASAE EP419.1).

Evaluation of the social-economic and cropping component the Dzindi and Palmaryville irrigation scheme

Structure and sampling procedure

The study was conducted in the Vhembe and Sekhukhune Districts. The two districts were originally designed to be pilot areas of the Limpopo Agribusiness Academy (LADA). The main phase of the study was a structured questionnaire survey instituted over a strategically calculated sample size.

The proposed sample size was arrived at using the sampling theory. Total sample size was determined by the following formula:

$$n = k\frac{z^2 p(1-p)}{d^2} \qquad (4)$$

$$=3x\frac{(1.645)^2 x0.33(1-0.33)}{0.05^2} = 705$$

where

n desired sample size

k number of stages of sampling (i.e. 3-stage cluster sampling, in this case: female/young and other headed households)

z standard normal deviation (1.96 for 95% confidence level, 1.645 for 90% confidence)

p proportion of target population estimated to have characteristic (since no estimate is available, we use 0.33)

q 1-p

d degree of accuracy required (usually 0.05, as here, or 0.02 for greater significance)

The figure of 705 households was rounded up to 720

Development of learning materials

Based on the observations in the field, training materials for mechanizing agriculture in Small Irrigation Schemes to enhance water productivity were developed, namely Farm Mechanization and Irrigation Management. The experiential learning theory was used Figure 2.

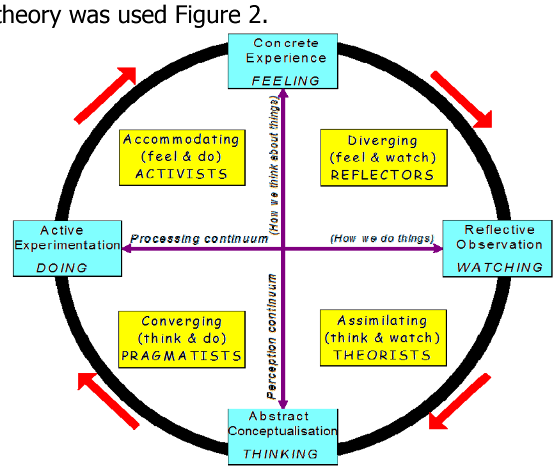


Figure 2. Kolb's cycle of experiential learning (source: https://www.google.cz/search?q=experiential+learning+theory)

To determine command area water reception, the Float Method was used to measure the flow rate at the weir diversion/canal uptake point. Data is given in Table 1.

Table 1. Captured data to determine canal flow late

Captured Parameter		
Parameter	Location	
	At canal take off	At distributary canal inlet
Canal cross sectional area, A (m^2)	0.092	0.064
Canal length covered by float, L_f (m)	3	3
Time taken by leaf float to cover L_f, t_L (sec)	12.47	14.21
Computed data		
Velocity = (distance / time) x 0.8 (m/s)	0.192	0.169
Flow rate Using continuity equation: Q = AV (m^3/s)	0.018	0.011

RESULTS and DISCUSSION

It was vital to asses the physical, cropping and social-economical components of this irrigation scheme as a unit in order to understand how the scarcy water that the government is providing to the community is being translated into yields to uplift welfare of these communities. Farmers at the Dzindi and Palmaryville irrigation schemes use shortfurrow water application system. Water for the two schemes is abstracted from the same river. Palmaryville is close to the source of water whereas the Dzindi scheme's water distribution box is about 21 km from the water abstraction point.

The Canal irrigation system performance indicators are poor. The physical inspection of the infrastructure discovered cracks in the main and field plot distribution canals. Reduction in flow rates due to seepages was very prevalent.

Conveyance and Uniformity coefficients

Using computed data from the table 1, water conveyance efficiency, $\boldsymbol{E_c}$ was determined

$$E_c = \frac{Q_{Dci}}{Q_{Ctf}} \times 100 = 0.011 / 0.018 \times 100$$

$$= 61.11\ \%$$

This almost 39% loss of irrigation water in transit can be attributed to the poor condition of the irrigation infrastructure as shown in Figure 3. This was discovered during the physical inspection of the irrigation infrastructure.

Figure 3. Irrigation water leasing through a cracked delivery canal lining

Evaluation of physical component of the irrigation system was calculated based on data from field characteristics and field measurements.

Table 2. System performance evaluation for Dzindi canal irrigation scheme

Water delivery parameters			Field captured parameters					
Computed flow rate at canal take off/weir diversion point m^3/s	Computed flow rate at field plot inlet m^3/s		Nr. of observations	Avg. amount of infiltrated water mm	Low quarter avg. mm	Total deviation m^3	Water stored in root zone m^3	Water diverted to irrigated plot m^3
0.018	0.011		10	72.29	46.12	133.80	3.42	5.79
Performance indicators								
Conveyance efficiency							61.11%	
Distribution uniformity							63.80%	
Water application efficiency							58.72%	

There are huge irrigation water losses arising from deep percolation as manifested by the low water application efficiency of 58.72% (Table 2).

The crop is not only being deprived of more than 41% of irrigation water that is being delivered, but the deep percolation is leaching the much needed nutrients beyond the reach of the plant root system. The low distribution uniformity that stands at 63.80% seems to be one of the causes of the low yields of maize. The yield in the study area was found to be 1t/ha compared to the province's potential yield of 9 to 12 t·ha^{-1} possible under irrigation (Figure 4). Maize is the main crop of choice by many farmers as reported in Figure 6.

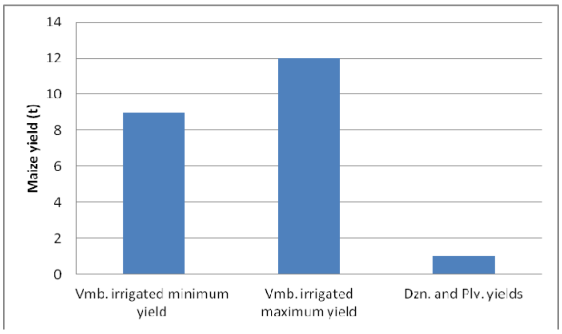


Figure 4. Maize yields obtained in study area compared to yields on irrigated commercial farms in the area.

For maize production in the region, the DU values should be at least 70%. When we consider that this is a sample of the 300 000 Limpopo provinces' farmers that occupy on average 2 ha per farmer that translates into 600 000 ha in the province. Their average 1.0 t·ha^{-1} grain yield, is only 8 to 11% of the potential of 9 to 12 t·ha^{-1} possible under irrigation at commercial level in the province. Production losses therfore, amount to a minimum of 4 800 000 tonnes (Figure 5)! And, this is despite the government's effort to provide water, land, mechanization and agricultural inputs.

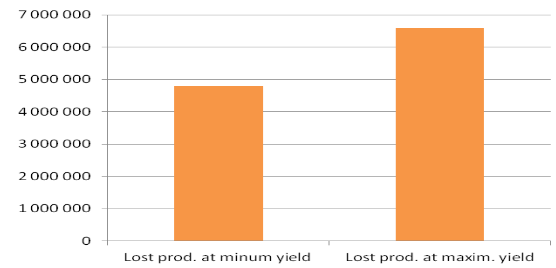


Figure 5. Lost production on 600 000 ha occupied by SmallSacle farmers in the province in tonnes.

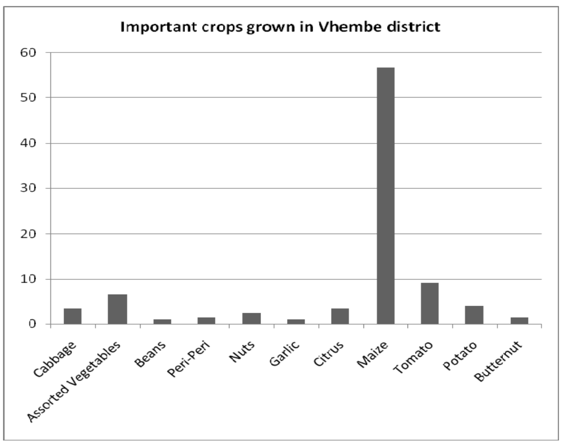


Figure 6. Crops nominated by more than 1% of respondents to be most important in Vhembe district

The Social beneficiation component Evaluation results

The average age of the farming community in the two irrigation schemes is alarming (figure 7). The average age was found to be 56 years. The young and the youth are attracted to other industries other than agriculture.

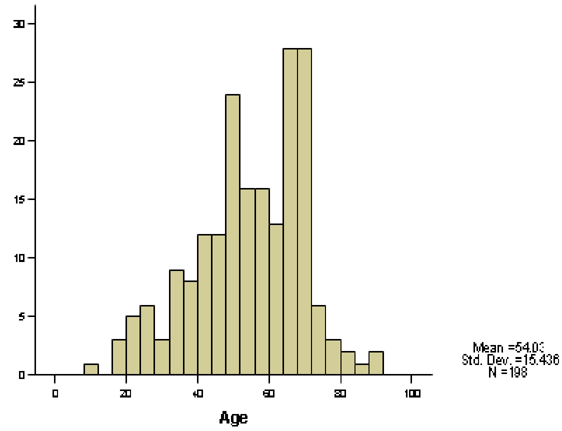


Figure 7. Age distribution of Vhembe farming community

Findings presented in Figure 8 are striking. Despite the national government deliberate policy of promoting food security and improved livelihoods through investing in these irrigation schemes – irrigation schemes revatilization with a view of increasing productivity and empowering the farming community, the study found that the majority of the farming community depends on social grants.

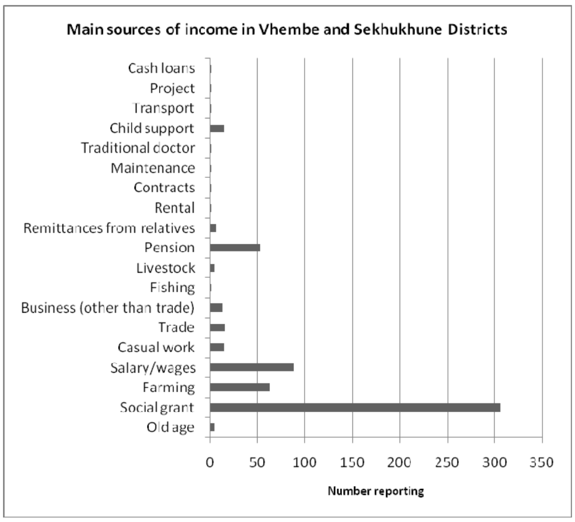


Figure 8. Source of income

Through interviews with farmers and the extension officer whose office is at Dzindi, it was found that the extension office lacked capacity to support farmers.

Based on the findings which indicated that a technology gap existed, learning materials were tailored to the needs of these farming communities, designed and produced. Figure 9 gives the concept that was used to develop the learning material. The material are in the local language of the farmers, they depict the environment in which the farmers practice their agriculture and therefore farmers identify with the problems and issues in these learning material; and farmers are proactive in applying solutions that were developed with their full participation. The material is also being used in farmer training centres to train farmers in order to equip them with skills that will promote water productivity.

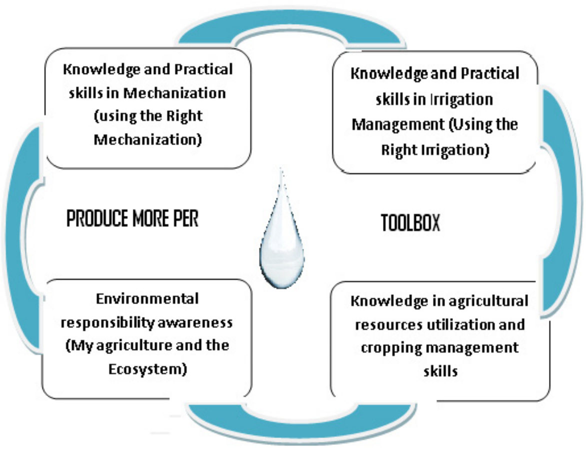


Figure 9. Learning materials concept.

Government policy and the right to water are likely to be enhanced given the discussions on Hydraulic property rights creation, (the process of establishing recognized claims to water of a certain quality and quantity on a particular site at certain timings, making investments in physical infrastructure to abstract, store and/or convey water, and thus create use value of water, is the single most important ground for vesting claims to water). That said, however, the issue that must be addressed is water use productivity. How can farmers produce more per drop in view of the indications that by 2025 water demand in South Africa will outstrip supply?

CONCLUSIONS

The following were concluded from the study:

- The furrow irrigation systems being practiced in the majority of Canal irrigation schemes in Limpopo Province are unsustainable. Their water productivity levels are very poor.
- The Distribution Uniformity and application efficiency of the Irrigation System are lower than the recommended values; and negatively impacting on yield.
- The maintenance of the infrastructure is very poor. Physical inspection uncovered cracked canals, evidence of seepage and plant growth in water conveyance system. All these have negative impact on irrigation water conveyance.
- The yield rates are very low. The 1t per ha for maize is almost 8 times lower than what is obtained on irrigated commercial farms.
- There is need to upscale water productivity by using the right mechanization, the right irrigation and researched methods for utilizing agricultural resources. This will guarantee a sustainable cohabitance of agriculture and the ecosystem.
- There is "double spending" by the government. The government has invested in the SIS, helped revamp them through Rehabilitation, continues to pay extension officials and yet the major source of income for farmers in SIS are social grants from the government.
- Farmers are willing to better their agricultural practices by applying technologies that have been developed with their full participation. This is because it is about them and it is their solution.

At the time when the nation is struggling with how to balance water allocation (industry, energy, environmental use and domestic use) and has also embarked on land redistribution, its ever increasing social grant budget will soon become unsustainable.

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