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Irrigation Development: A Food Security and Household Income Perspective

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1. Introduction

Rukuni, *et al,* (2006) posit that irrigation development represents the most important interface between water and land resources. Barau *et, al* (1999) stress greater emphasis on irrigation development as a means of increasing food and raw material production as well as promoting rural development. Similarly, (Hussain, *et, al,* undated) point out that agricultural water/irrigation has been regarded as a powerful factor for providing food security, protection against adverse drought conditions, increased prospects for employment and stable income, and greater opportunity for multiple cropping and crop diversification.

Furthermore, (Hussain *et., al,* undated) posit that access to reliable irrigation can enable farmers to adopt new technologies and intensify cultivation, leading to increased productivity, overall higher production, and greater returns from farming. This, in turn, opens up new employment opportunities, both on-farm and off-farm, and can improve income, livelihoods, and the quality of life in rural areas. Generally, access to good irrigation allows poor people to increase their production and income, and enhances opportunities to diversify their income base, reducing vulnerability caused by the seasonality of agricultural production as well as external shocks. Thus, access to good irrigation has the potential to contribute to poverty reduction and the movement of people from ill-being to well-being (Hussain *et, al,* undated).

Peacock (1995) defines food security as having adequate means of procuring one's basic food needs either by growing, manufacturing, mining or trading. Rukuni, *et, al* (1990) define food security as a situation where all individuals in a population can produce or procure enough food for an active and healthy life. Eicher & Staatz (1985) defined food security as a situation where all individuals in a population have access to a nutritionally adequate diet. The food security equation (Rukuni & Benstern, 1987) has two interrelated components: food availability and food accessibility. Food availability is whereby there is the availability of food through food production, storage or trade. Food accessibility is defined as the ability of the household to acquire food through production, purchases in the market from income earned or transfers.

For instance, Rukuni, *et, al* (1990) state that the largest number of food insecure households in Zimbabwe lives in natural regions IV and V, and accessing food through dry land production

has been unsuccessful for most communal households given the prevailing agro-ecological factors for these regions. Populations have poor access to food because they generally lack the purchasing power that would otherwise enable them to purchase foodstuffs which they cannot cultivate. Furthermore, the incidence of food insecurity in the communal areas is largely caused by the agro ecological conditions beyond the farmers' control, high consumer prices for staple grain which erodes the household disposable income and the constraints they face in diversifying cropping patterns into higher valued cash crops.

The population densities in these natural regions IV and V have long exceeded the carrying capacity of the land, consequently leading to severe degradations of land resources in many areas, thus compromising on the efforts by smallholder farmers to break through the food insecurity trap. There are also high temperatures, lowest agricultural activities and highest incidences of agricultural failure due to frequent incidence of drought and low rainfall. The major limiting factor for the successful cultivation of crops in these regions is low rainfall and high incidence of drought. The low rainfall averages 600mm per annum, which is lower than the crop requirements for most food crops. Rukuni *et al* (1990) advocated for the need to integrate rural development interventions so as to do away with higher incidences of transitory and chronic food insecurity in smallholder communal farming areas.

Manzungu & van der Zaag (1996) postulate that one of the strategies to reduce the incidence of food insecurity in smallholder communal areas which was also advocated for by the aid organisations, policymakers, academics and lay people is a production technology appropriate for low rainfall environments. The technology is in the form of smallholder irrigation schemes. Development of smallholder irrigation schemes increases the potential for more production by counteracting mid-season dry spells and some periodic dry spells. This means that the household can grow crops more than once a year in low risk associated areas than under the rain fed production. Increased production ensures high food availability at the household level due to intensification of crop production. Intensified crop production ensures increased incomes; hence, household can purchase food, ensuring household access to food.

In this light, the Zimbabwe/European Union Micro-Project Programme (ZIM/EU MPP) has funded smallholder irrigation schemes since 1982 in Zimbabwe, but had not done any "in-depth" evaluation of the viability and impacts of these irrigation schemes, to find out whether they serve the purpose for which they were intended to and justify continued implementation of these schemes. The major objective of this study was to evaluate the impact of ZIM/EU funded irrigation projects on famers' income and food security level at Mopane Irrigation Scheme in Zvishavane District. The impact evaluation study was to justify or reform further support and investment in smallholder irrigation schemes. The study assessed the impacts on household food security and income level on a comparative analysis of irrigators and non-irrigators, and mainly looks at level of food security and incomes for both categories.

2. Literature review

2.1 Food security

Anderson (1988) points out that food insecurity may be chronic or transitory. Chronic food insecurity refers to extreme food insecurity when there is a continuously inadequate food caused by the inability to acquire food. Transitory food insecurity is whereby a household experiences a temporary decline in access to adequate food. Transitory food insecurity

emanates as a result of instability in food prices, food production or people's income. In its worst form, it produces famine.

Jayne (1994) further identifies groups most vulnerable to chronic and transitory food insecurity and these include asset-poor rural people in rural and resettlement areas that farm but are often net purchasers of food. This group is said to lack the resources to produce enough income to buy their residual food requirements and this group includes female households and households in war-torn and environmentally disrupted areas, urban households with unemployed or more frequently underemployed family members. These groups typically have low levels of income and the landless labourers.

Rukuni, *et, al* (1990) argue that food security status among the households differs due to great variation in household s' resources and the ability to shift their resources into growth sectors with specific capital and climatic or infrastructure requirements. As a result, most smallholders in the semi-arid communal areas of natural region IV and V are not producing enough grain to meet the annual household demand. The existing literature suggests that the establishment of smallholder irrigation schemes has the potential of ensuring food security in the communal areas. Literature has also proposed different views regarding the possible impact of smallholder irrigation on food security in the communal lands.

Makadho (1994) states that the development of smallholder irrigation schemes dates back to 1912 and from 1912-1927 smallholders developed and managed their own irrigation schemes without government intervention. In 1928, the government took over some of the irrigation schemes when it felt that it was necessary to intervene in the development of this sector. Before independence, the majority of African smallholders in Zimbabwe were restricted to areas of poor soils and rainfall. The government therefore saw the development of irrigation schemes as a famine relief strategy.

Literature also suggests that earlier, the smallholder irrigation schemes had the assurance of food security at household level for smallholder communal farmers. The irrigation schemes did not only meet the intended objectives of increased food security, but also benefited the surrounding communities, who were not in the irrigation schemes. In concurrence, Rukuni (1984) reported that the areas that surrounded the schemes tended to provide a ready market for the food crops. The study by Rukuni (1984) showed that maize, beans, and vegetables had the greatest demand and were most prevalent on the schemes. About 70% percent of the maize sales were done locally.

A cost benefit analysis performed by Sithole (1995) indicated that irrigation increased household food security in the marginal to poor rainfall areas. The study also revealed that irrigation did not only improve the food security position of the level of the irrigators, but also the rest of the community benefited from these schemes. Sithole (1995) also revealed that the incomes of the irrigators were higher than the incomes of the non-irrigators. As a result of the higher incomes, the irrigation participants were in a position to purchase grain to satisfy household requirements to make up for any shortfall in production, as compared to non-participants. Sithole (1995) also compared the incomes and yields of the irrigators and that of the non-irrigators. Results of the study indicated that the smallholder schemes were both financially and economically viable and the

participants were able to meet both the capital and running costs of smallholder irrigation schemes.

Sithole & Testerink (1983) conducted a study in Swaziland on the cropping and food insecurity aimed at evaluating how cash cropping contributed in alleviating food insecurity in Swaziland. The results indicated that it is only with irrigation that crop production can be carried out throughout the year in Swaziland. Sithole & Testerink (1983) concluded that increased crop production can be expected to encourage the establishment of more agro-industries to process the output, thereby increasing employment opportunities and purchasing power of individuals, implying capacity to purchase grain to meet the household requirements, thus increased food security.

A study by Gittinger *et al* (1990) stated that many of the world's undernourished live in large river basins in Asia, where lack of irrigation, erosion, flooding, high salinity and poor drainage represent major obstacles to improved productivity. In the semi-arid regions of Asia and Africa, the inability to harness water effectively severely limits the strength of the growing season and when the rains occur, they often take a heavy toll in flooding and soil erosion. Thus crop yields, with the existing technology of irrigation efficiency, can be doubled and increases through better control of allocation of water.

A study by Webb (1991) in a village of Chakunda in Gambia revealed that introduction of smallholder irrigation schemes increases food consumption. Webb (1991) listed the following benefits realised by participation in irrigation schemes:

- There is increased income that was translated into a boom in expenditure, investment, construction and trade.
- Backward and forward linkages resulting from traders coming to purchase irrigation produce, in this case, rice and sell cloth, jewellery and other consumables.
- Smallholder irrigation can be a worthwhile investment in the development of marginal areas of the world, coupled with the provision of irrigation facilities to communal area farmers, thus increasing yields and ensuring food security and increasing the purchasing power of the beneficiaries due to increased incomes.

2.2 Irrigation income

An income analysis for Mzinyathini scheme, carried out by Sithole (1995), revealed that the savings per hectare per month per household was Z$931.22 in drought relief. The income analysis for different groups, the project irrigators and the non-irrigators, suggested that the irrigators were in a better position to afford enough grain to satisfy household requirements than non-irrigators.

Meinzen-Dick *et al* (1993) established that among the farmers using irrigation in the natural regions IV and V, the majority (72%) were found to be food secure and had stable incomes. The study also showed that the gross margins of irrigation schemes were significantly greater than those not using irrigation. Rukuni (1985) carried out an almost similar research study in the natural regions IV and V and he showed that investment in smallholder irrigation development can have an important effect on both rural incomes and local food supplies. The results from the study revealed that the yields achieved on smallholder schemes are higher than rainfall yields in communal areas.

2.3 Viability of smallholder irrigation schemes

A report by Southern African Development Community (1992), mentioned that most recent schemes will not cover the cost of development and operation, thus are uneconomic. The SADC report noted that despite the support from the government and a donor, formal irrigation has not been formal. This is in controversy with some literature that suggests that smallholder irrigation scheme in marginal rainfall areas can only survive when supported by government.

This was supported by Mupawose (1984), when he was advocating for reduced subsidies on smallholder irrigation. The study further highlighted that irrigation schemes have failed and some are under-utilised. He further indicated that poor management had led to a decline in yield per unit area and to an overall lack of viability of the project. He cited that this was due to lack of interest and lack of farming experience by the irrigation participants.

In an economic analysis study carried out by Webb (1991) on smallholder irrigation scheme in Gambia, it was revealed that the increased income from irrigation resulted with increased expenditure, construction, investment and trade. A cost benefit analysis carried out by Paraiwa (1975), showed that irrigation schemes can play an important role in developing a cash economy for rural communities by making it possible for viable cash income to become accessible in a fairly large number of individuals.

A study by Peacock (1995) argued that smallholder irrigation development is not necessary for food security. The research was conducted based on comparing the cost of constructing irrigation in the communal areas and the cost of food relief coming into the area. It was shown that the costs of developing irrigation were higher than the cost of providing drought relief. The study also concluded that the development of smallholder irrigation for the purpose of food security was not economically viable.

2.4 Success stories of irrigation development

FAO (1997a) in a brief general overview of the smallholder irrigation sub-sector in Zimbabwe concluded that smallholder irrigation has brought success stories to farmers. The following observations were made; smallholder farmers are now able to grow high value crops both for the local and export markets, thus effectively participating in the mainstream economy, in areas of very low rainfall, as in Natural Regions IV and V, farmers enjoy the human dignity of producing their own food instead of depending on food handouts, irrigation development has made it possible for other rural infrastructure to be developed in areas which could otherwise have remained without roads, telephones, schools and clinics, smallholder irrigators have developed a commercial mentality and crop yields and farmer incomes have gone up manifold.

Similar inferences were also highlighted in a study of an irrigation scheme in the village of Chakunda in the Gambia; Webb (1991) gave the following as some of the benefits of irrigation:

- Increased income that was translated into increased expenditure, investment, construction and trade.
- Backward and forward linkages: traders were reportedly coming to purchase irrigation produce (rice) and in turn sell cloth, jewellery and other consumer items.

- Increased material wealth. At the village level, this was in the form of construction of a large mosque built through farmers' donations and an improvement of the village clinic. At household level, increased wealth could be seen in 55 houses built in the village, fourteen with corrugated metal roofing.

2.5 Challenges and constraints

Rukuni *et al* (2006) state that a number of problems have befallen irrigation schemes that are managed by central government departments, such as poor marketing arrangements, limited access to water, inability to meet operational costs due to poor fee structures and the lack of a sense of ownership, financial viability and poor governance. Some of these problems have necessitated government transferring responsibility to farmers, who have continued to mismanage these systems, hence their dilapidation. Poor maintenance and lack of effective control over irrigation practices have resulted in the collapse of many irrigation systems.

The FAO (1997) report identified a number of constraints, which hampered smallholder irrigation development in Zimbabwe. Some these include high cost of capital investment in irrigation works considering that communal farmers are resource poor, lack of reasonably priced appropriate irrigation technology for the smallholders, shortage of human resources at both technician and farmer levels, lack of decentralized irrigation service companies to give back-up service in rural areas, poor resource base of farmers, fragmented and small size of land holdings, unsecured or lack of land titles and high interest rates.

Further to the above constraints, Gyasi *et al* (2006) state that in many countries, institutional weaknesses and performance inefficiencies of public irrigation agencies have led to high costs of development and operation of irrigation schemes. Poor maintenance and lack of effective control over irrigation practices have resulted in the collapse of many irrigation systems. The study by Gyasi *et al* (2006) concluded that collective action for the maintenance of community irrigation schemes is more likely to be problematic when the user group size is large and ethnically heterogeneous, and where the scheme is shared by several communities. Use of labour intensive techniques in the rehabilitation of irrigation schemes promotes a sense of ownership and moral responsibility that help ensure sustainability. A high quality of rehabilitation works and regular training activities also contribute to successful irrigation management by communities.

3. Study area and methodology

3.1 Study area

It is estimated that at least 60% of Zimbabwe's communal farmers live in natural regions IV and V, where food insecurity is greatest (Rukuni, 2006). These areas are not suited to intensive farming systems. The research site was selected in natural region IV, an area with relatively less rainfall of less than 500mm and poor soils. This makes vast track of land unsuitable for cash cropping. The research was based on a case study of Mopane Irrigation Scheme, located in Runde area in Zvishavane, Midlands Province. The scheme has been functional since the year 2000 and the main crops cultivated are cash crops; wheat, maize, tomatoes and onions.

3.2 Sampling methods

Primary data was used as a main source of inference, while secondary data was used as a backup to the primary data. Stratified sampling was used in which the data available was divided into two strata; irrigators and non-irrigators. From each stratum, random sampling was done to obtain thirty irrigators and thirty non-irrigators. Data collection was done through structured surveys using a full administered questionnaire. The questionnaire captured data on household characteristics, asset endowment, livestock endowment, gross margin performance, agronomic practices, off-farm income, yield of grain crop. The data was entered into the Statistical Package for Social Scientists (SPSS) for further analysis.

3.3 Analytical frameworks

3.3.1 Regression analysis

A regression model was used in the regression analysis to examine the factors that affect productivity; hence food security. The project assumed the following regression model:

$$Y = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + \alpha_4 X_4 + \alpha_5 X_5 + U_i \quad (1)$$

Y = Food Security
$\alpha_0, \alpha_1 - \alpha_5$ are model parameters
X_1 = Asset endowment
X_2 = Household size
X_3 = Off-farm income
X_4 = Area under cultivation
X_5 = Draught power ownership
U_i = Random error term

The expected results from this regression model were as follows:

- Household asset endowment positively impacts food security.
- An increase in household size increases food security.
- Off-farm income has a positive impact on food security.
- Area under cultivation positively related.
- Draught power ownership enhances food security.

3.3.2 Gross margin analysis

Gross margin analysis was the major tool, which was used in the analysis to compare the returns between the irrigators and the non-irrigators and assess the benefits of irrigation. The study looked at the agricultural performance of both the irrigators and non-irrigators at Mopane irrigation scheme. To determine any changes in the production or productivity levels and gross incomes, a comparative analysis of inter-farm was vital. Inter-farm comparative analysis compares the irrigators and non-irrigators who are located in the same geological area.

The research study therefore used a gross margin per ha analysis as an indication of plot level performance, that is, how well farmers did on their land with the resources that were available to them. According to Johnson (1991), gross margin analysis is useful for

production cycles of less than a year as this enables costs and returns to be directly linked to enterprise. Gross margin is the difference between the total sales and the variable costs.

$$\text{Gross Margin} = \text{Total Sales (Gross Income)} - \text{Variable Costs} \quad (2)$$

$$\text{Where: Gross Income} = \text{Total Volume of Output (Q)} \times \text{Price (P)} \quad (3)$$

and Variable Costs include the costs such as fertilizer, seed, crop chemicals, marketing costs, transport costs, machinery operational, labour costs, etc that would have been incurred in the production process until the produce has reached the market.

3.3.3 Farm income analysis

The crop incomes for the irrigators and the non-irrigators were derived through the use of gross margin analysis. Although the gross margin has two components that are income from sales and value of crops retained, crop output was evaluated using nominal prices. Individual household crop gross margin budgets were computed for both dry land and irrigated crops in the case of irrigators and only for dry-land for the non-irrigators. Since Mopane scheme is operated as a cooperative, only one whole farm budget was considered and then number of irrigators divided the profit to get the per income. The non-farm incomes were also compared. The main thrust behind this is to test the hypothesis that incomes of the irrigators in the project are greater than that of the non-irrigators. After computing the household gross margins, the first impressions were based on comparing the mean gross margins for the irrigators versus that of the non-irrigators.

3.3.4 Descriptive statistics

These were used to describe the differences between irrigation and non-irrigation households. Simple statistics like mean was employed to analyse data and yield, demographic characteristics, acreage and food availability. Also, socio-economic analysis like household size, ages, education, assets and other resources that can help in comparing the two sets of household were made use of.

4. Results and discussion

4.1 Demographic and endowment characteristics

It is vital to describe and compare household characteristics of sample households for primarily informing explanations for behavioural variability between irrigators and non-irrigators. Characteristics such as age, marital status, sex structure, employment, agricultural equipment endowment, livestock ownership, land ownership and ownership of other assets were considered important. This is because the asset base and household demographic structure of the household has implications on flexibility and capabilities with respect to crop production and consumption.

4.1.1 Demographic structure of households

Consideration of household demographic features offers one of the platforms on which to compare and explain behavioural variations relevant to this study.

Variable	Irrigators (Sample Mean)	Non-Irrigators (Sample Mean)
Household size	9.80	6.48
Males	3.44	2.28
Females	5.64	4.20
Household head's age	47	42
Total number of children	7.37	4.30
Children >15 years	4.99	3.02
Children <15 years	2.48	1.28
Total no. of adults	4.03	2.10

Source: Survey data

Table 1. Household Demographic Analysis

The results in Table 1 indicate that the average household size of irrigators is 9.80, higher than that of non-irrigators, with an average of 6.48 household members. There were more adults in the irrigator category with an average of 4.03 against non-irrigators' 2.10 adults. The irrigators' average household age is 47years 5years higher than that of non-irrigators (42). The irrigators have, on average more children than non-irrigators, 7.37 children per household as compared to 4.30 children for non-irrigators. This would suggest that irrigators might, on average, be more mature than the non-irrigators, who tend to be younger households on average.

Thus, the motive behind the irrigators participating in the irrigation scheme is to feed their larger household size. The larger household size may be giving the irrigators a comparative advantage, which is reflected in increasing returns to scale and decreasing average costs. For example, irrigators tend to have more labour in activities such as land preparation, where there is a great deal of labour needed, and also division of labour which increases the economies of scale.

4.1.2 Household land ownership

The quantity of land available per household is one of the most important constraints to production for communal farmers. Therefore, it is vital and valid to base comparison of irrigators and non-irrigators on the availability of arable land. This information is also important in that it will help in realising whether any disparities in household incomes may be accounted for by the rise in dry land holding.

Category	Average Size of Arable Dry Land	Average Size of Irrigable Land
Irrigators	2.26 ha	0.45 ha
Non-irrigators	2.09 ha	

Source: survey data

Table 2. Average cropping land area

The results in Table 2 show that irrigators have more dry-land (2.26ha) on average, compared to the non-irrigators who have 2.09 ha. Under this scenario, *ceteris paribus,*

irrigators are expected to have more output compared to non-irrigators. The fact that irrigators have more dry land can be attributed to the fact that they might have acquired pieces of land long before the non-irrigators, who later acquired smaller pieces of land later on. In addition to dry land, irrigators have 9ha of land, which converts to about 0.45ha per household. The irrigators do work as group and the production resources are pooled together for production and the whole produce is shared and marketed as a group.

4.1.3 Livestock ownership

Livestock form an important component of household food security in the communal areas. Significant differences in livestock ownership may reasonably explain differences in food security, income and agricultural technical performance between irrigators and non-irrigators as they contribute to household food availability through production, as a production asset and through household food accessibility and through income generation.

Livestock	**Irrigators**		**Non-Irrigators**	
	Sample Mean	**% Owners**	**Sample Mean**	**% Owners**
Cattle	6.04	62.8	4.80	53.2
Goats	12.84	90.3	6.20	64.2
Donkeys	3.89	68.1	1.10	44.8
Sheep	0.94	42.7	0.23	21.8
Chickens	14.29	97.8	8.26	84.3
Draught animals	7.43	78.4	3.45	61.9

Source: Survey data

Table 3. Livestock ownership

The results in Table 3 show that irrigators have more livestock compared to the non-irrigators. Irrigators own an average of 6.04 cattle against 4.80 cattle for non-irrigators with percentage ownership of 62.8% and 53.2% respectively. Irrigators also have a higher number donkey per sample household of 3.89 compared to non-irrigators who have 1.10 donkeys. Better possession of draught animals would give the irrigators a comparative advantage in timeliness of tillage activities. Thus irrigators technically perform better than the non-irrigators, thus making the irrigators less vulnerable to poverty than the non-irrigators.

4.1.4 Ownership of agricultural equipment

Ownership of agricultural implements by households influences timeliness of cultivation and therefore yields. Implements can also be hired out to earn income for the households.

The results in Table 4 indicate that irrigators are better endowed with agricultural implements than non-irrigators. This implies that irrigators are wealthier than non-irrigators. However the most important tools on the farm are the plough and the hoe. Farmers often can do without such implements as scotch carts, harrows, cultivators and wheelbarrows. Since irrigators have more draught animals, it is logical and unsurprising

that they also have more agricultural implements lime cultivators and scotch carts. This gives irrigators a comparative advantage in crop production in form of more timeliness in land preparation and other tillage practices. More often, the plough is used in place of a cultivator, which explains the very low number of cultivators in the two samples.

Type of implement	Irrigators		Non-irrigators	
	Sample Mean	% Owners	Sample Mean	% owners
Plough	1.46	94.7	0.96	76.3
Hoe	6.12	100	4.31	100
Wheelbarrow	2.87	78.5	1.07	66.7
Scotch cart	0.15	69.7	0.09	44.0
Harrow	0.12	23.5	0.06	16.7
Cultivator	0.23	12.6	0.11	11.2

Source: Survey data

Table 4. Agricultural equipment endowment

4.1.5 Household housing

Two types of housing structures are dealt with in this study and these are traditional and modern houses. A traditional house is taken to be a structure, which is usually round with walls, made from mud poles or farm bricks and thatched with grass, and normally one roomed. A modern house is taken to be a rectangular structure made from farm bricks or cement bricks, zinc or asbestos roofed and constitute one or more rooms.

Structure	Irrigators		Non-irrigators	
	Sample Mean	% Owners	Sample Mean	% Owners
Traditional houses	2.28	100	1.97	94..3
Modern houses	1.20	78.4	1.48	88.7

Source: Survey data

Table 5. Average number of types of housing structures of households

The results in Table 5 indicate that all irrigating households had at least one traditional house. However, non-irrigators have on average more modern houses as compared to irrigators. Also, more non-irrigators have modern houses than irrigators. The difference in modern housing may be due to the fact that since more non-irrigator household heads stay outside the village working mostly in towns or near towns, they might be bringing home the types of houses they see in towns.

4.1.6 Place of residence of household head

The place of residence of household head often indicates the opportunity cost of being in the village than anywhere else. In this case, the number of heads staying in the village may explain incentives attached to remaining in the village.

Place of residence	Irrigators %	Non-irrigators %
Village	56.7	43.3
Town	21.5	47.4
Other	12.8	9.3
Total	100	100

Source: Survey data

Table 6. Place of residence of household head

The results in Table 6 indicate that 47.4% of non-irrigators household heads stay away from the village, or employed somewhere outside the village than the non-irrigators who only constitute 21.5% who are in towns. This can be attributed to the fact that some non-irrigators get engaged in employment as mine workers at Shabanie Mine and other surrounding mines in Zvishavane. The higher opportunity cost associated with leaving the village and the irrigation scheme is higher than that of staying in the village, thus the irrigators are left with no other incentive other than that of staying in the village.

4.1.7 Household off-farm employment

Employment is defined as the number of able bodied people who are willing to work and can find a job. Table 4.7 below shows the employment status of household members.

Employment status	Irrigators	Non-Irrigators
No. employed off-farm	0.63	1.49
% with no member in regular employment (locally or elsewhere)	59.4	30
% with at least one member in regular employment	40.6	70

Source: survey data

Table 7. Employment status: irrigators and non-irrigators

Table 7 shows that on average, 1.49 of non-irrigators are employed off-farm as compared to 0.63 for irrigators. Off-farm employment generally indicate access to off-farm income particularly remittances. Again, 70% of the non-irrigators had at least one member in regular employment, as opposed to 40.6% of irrigators. This can be attributed to the fact that, as seen in the analysis above, more non-irrigators are employed in Zvishavane and other surrounding areas, while the irrigators see that it is more profitable to stay at the schemes, the reason why they constitute only 40.6% in regular employment.

5. Agricultural productivity

This subsection compares the technical performance and farm incomes to test the hypothesis that irrigators are better agriculturalists and earn more income than non-irrigators using the Gross Margin Analysis.

5.1 Land productivity

On average irrigators have more dry land an average of 2.26ha, 0.17ha higher than non-irrigators'. It is therefore expected that irrigators have more output than non-irrigators. The difference in land allocation may be explained by the efforts of irrigators seeking to meet the grain requirements of their larger households. Millet was more popular with irrigators for the purpose of beer brewing which was not so popular with non-irrigating younger women. Most land was devoted to sorghum among non-irrigators, which illustrates the lack of rainfall and risk of crop failure inherent in the Natural Region IV where Mopane scheme lies.

5.2 Dry-land production

The main source of livelihood for the farmers in Mopane area is the sale of crops. The incomes are represented in the form of gross margins, which are the incomes remaining after deducting the variable costs from the whole farm gross income.

$$\text{Gross Margin} = \text{Gross Income} - \text{Variable Costs} \quad (4)$$

Household Production Parameter	Price (US$/t)	IRRIGATORS			NON-IRRIGATORS		
		Ave Area (Ha)	Ave Yield (Ton/ha)	GI/Crop (US$/ha)	Ave Area (Ha)	Ave Yield (Ton/ha)	GI/Crop (US$/ha)
Maize (ton)	109.10	0.64	3.500	381.85	0.59	3.230	352.39
Sorghum (ton)	563.64	0.77	0.376	211.93	0.83	0.418	235.60
G/nuts (ton)	181.82	0.43	0.466	84.73	0.36	0.353	64.18
Millet (ton)	256.97	0.42	0.351	90.20	0.31	0.311	79.92
Total Av. Area (ha)		2.26			2.09		
Total GI (US$)				768.70			732.09
GI/Ha (US$)				340.13			350.28
GI/Household (US$)				11.34			10.80

Source: survey data

Table 8. Gross incomes: irrigators and non-irrigators

Maize is the most important cereal crop grown in Zimbabwe. At Mopane irrigation scheme, the crop ranks first in number of producers. As observed in the table above, there is a high yield in maize for irrigators, an average of 3.50 ton/ha, as compared to an average of 3.23 ton/ha for non-irrigators. This might be due to the fact that the irrigators, as seen in the former empirical comparative analysis, are better asset endowed than the non-irrigators, thus they perform technically better in dry land production.

However, there is a low yield of sorghum for the irrigators of 0,376 ton/ha, against 0,418 ton/ha for the non-irrigators. The irrigators grossed an average income of US$768.70 against

US$732.09 for non-irrigators from sorghum. Sorghum has better tolerance to dry conditions than maize, so non-irrigators generally devote more area to it, as a hedging strategy against food shortages.

Groundnuts yield is high within the irrigators, an average of 0,466 ton/ha compared to 0,353 ton/ha realised by the non-irrigators. This can be attributed to the fact that irrigators devote more land to its production than non-irrigators do. The difference in hectarage devoted to the crop may be explained by several factors, which include household size, total arable dry land and labour availability among others. As seen from the empirical analysis, irrigators had a comparative advantage in all of the factors above.

Irrigators have higher yields for millet of 0.351ton/ha than non-irrigators' 0.311ton/ha. It was envisaged, from informal interviews, that most irrigators are interested in income from millet through beer brewing. It was mostly older women who were interested in beer brewing, which may explain why the younger non-irrigating women were less into the crop than irrigators were. Irrigators, as seen previously, allocate more land on average for millet production than non-irrigators do. The lower yields for non-irrigators can be attributed to poor timing of cultivation activities by non-irrigators.

Crop	**Total Average Costs (US$)**	
	Irrigators	**Non-Irrigators**
Maize (US$)	109.77	75.64
Sorghum (US$)	35.39	36.61
G/nuts (US$)	17.48	11.45
Millet (US$)	19.88	30.79
Total Var. Costs (US$)	**182.82**	**154.49**

Source: Survey data

Table 9. Average total costs: dry-land production

Comparing the cost outlays for crop production between irrigators and non-irrigators, irrigators had significantly higher total variable costs of US$182.82 than non-irrigators' US$154.49, as shown in Table 9. It is believed that as a result of significantly higher use of variable inputs, compounded by more access to draught power and agricultural implements, irrigators had significantly higher output per ha than non-irrigators. This explains why irrigators seem to have a higher average gross margin than of non-irrigators as shown in the table 10 below.

Parameter	**Irrigators**	**Non-irrigators**
Gross Income (US$)	768.70	732.09
Total Variable Costs (US$)	182.82	154.49
Gross Margin (US$)	**585.88**	**29,223.36**
Average Gross Margin (US$)	**19.53**	**19.25**

Source: Survey data

Table 10. Gross margin analysis: dry-land production

5.3 Irrigation productivity

Mopane irrigation scheme produces crops during winter and summer. Total area for cropping amounts to 9ha of land. In winter, crops grown were maize, tomatoes, onions, and cabbage. Table 11 shows the hectarage allocated to each crop, average yield, price/ton, and gross income yielded, total costs in irrigation, the gross margin and the gross margin per household. Crops are grown collectively and the profits shared equally among the members.

Crop	Total Arable (ha)	Average Yield (Ton/ha)	Price of output (US$/ton)	Gross income (US$/ha)	Total Cost (US$/ha)	Gross Margin (US$)	Gross Margin/ha (US$)	Per Gross Margin (US$)
Maize	4	2.25	109.09	245.45	166.92	78.84	19.71	0.65
Tomatoes	2	4	181.82	727.27	295.10	432.17	216.08	108.04
Onion	1	0.86	96.97	83.39	16.50	66.89	66.89	66.89
Cabbage	2	2.4	121.21	290.91	78.90	212.01	106.00	56.00
Totals	**9**			**1347.03**	**557.12**	**789.91**	**408.69**	**230.98**

Source: Survey data

Table 11. Gross Income, Average Total Costs and Gross Margin for Irrigation

Overall, higher costs were incurred in the scheme's crop production than in dry-land production, which were US$182.82 in dry land against US$557.12 for irrigation. This can be attributed to the fact that irrigators have more income to meet these expenses and costs than the non-irrigators.

Maize is given the greatest hectarage in the irrigation scheme. An average yield of 2.25t/ha was obtained for maize. However, maize has a dry-land gross margin of US$381.85, higher than US$245.45 for irrigation. Other gross margins for other crops grown in the scheme were much higher than dry land gross margins for both irrigators and non-irrigators, indicating increased crop incomes for irrigators than non-irrigators. Main reasons for the higher yields of crops are: availability of water for irrigation during the dry season; access to water to counteract mid season dry spells, ability to extend the growing season, more agricultural implements and draught power; increased use of production inputs like fertilizer, economies of scale in resource use, for example, labour specialisation and access to technical advice from the Agricultural Research and Extension (AREX) personnel.

From table 8, it is observed that irrigators' average dry-land crop gross income per household is US$11.34, higher than non-irrigators' US$10.80. From the irrigation schemes, the gross income per participant is US$230.98 as shown in Table 11. In this respect, the irrigation scheme yields additional income for irrigators than what non-irrigators are getting from dry land farming.

5.4 Non-farm income

Assessing non-farm income is also important to investigate ways households supplement their income from crops. From the previous empirical analysis, it was shown that there were more non-irrigators than irrigators who stayed away from the village, employed somewhere outside the village and in Zvishavane. Though irrigators have, in terms of crop incomes

outperformed non-irrigators, they might be more successful in other areas like off-farm work. As a result, there is need to evaluate and compare non-farm income of the two categories. An attempt was made to cover a number of income-earning activities in the area.

Source of Income	Irrigators		Non-irrigators	
	Mean (US$)	% of Total Income	Mean (US$)	% of Total Income
Remittances	21.88	10.0%	55.15	28.5%
Hiring out family labour	29.82	14.7%	26.73	13.8%
Hiring out agric implements	24.85	11.4%	5.33	2.8%
Sale of livestock	22.30	10.2%	14.55	7.5%
Building activities	32.12	14.7%	46.73	24.1%
Beer brewery	16.36	7.5%	12.42	6.4%
Cross Boarder	30.30	13.9%	17.58	9.1%
Shop business	40.48	18.6%	15.09	7.8%
Totals	**218.12**	**100%**	**193.58**	**100%**

Source: survey data

Table 12. Other sources of household income

Table 12 above examines the other sources of income besides cropping. Remittances were vital in non-irrigators with 28.5% contribution to total income, compared to 10.0% for irrigators. This is because more members from non-irrigating households are in regular employment as previously shown in Table 7. The highest income earner to irrigators is shop business, representing a contribution of 18.6% compared to 7.8% for non-irrigators. However, building activities tend to contribute significantly to both irrigators and non irrigators, with a contribution of 14.7% and 24.1% respectively.

Irrigators have more income on average, (US$218.12) against US$193.58 for non-irrigators. This can be attributed to the fact that irrigators have more livestock, which they sell as reflected by a proportion of 10.2% for irrigators compared to 7.5% for non-irrigators, and more agricultural implements, which they hire out. The larger size of the irrigators also gives them the opportunity of hiring out family labour which also contributes to the average income for irrigators as compared to non-irrigators.

Some females, from both categories are also involved in trading activities where they go to countries like South Africa where they buy other goods for resale. This contributes significantly to both the incomes of both, though female irrigators gross more from such activities. It is also important to say that since irrigating households are bigger and older they have greater division of labour and diversified off-farm income sources. This confirms that income of irrigators is greater than that of non-irrigators since the irrigators have more income in dry land and irrigation activities as compared to the non-irrigators.

5.6 Regression analysis results

Applying the regression model, the econometric results are presented as in Table 13 below. The dependent variable is food security. The estimates indicate essentially in accordance with the hypothesis that the irrigators are more food secure as compared to the non-

irrigators. The variables in the model that affect household food security include household size, sex of household head, off-farm income, area under cultivation and draught power ownership. Each parameter estimate measures the relationship or contribution of each variable to the food security level per household.

Independent Variable	Parameter Estimate	T- value	Significance
Intercept (constant)	- 45.326	- 0.429	0.528
Household size	88.423	2.914	0.107*
Household asset endowment	- 31.853	- 1.495	0.163
Off-farm income	5.265	2.480	0.14*
Area under cultivation	0.839	3.486	0.0485*
Draught power ownership	9.202	2.146	0.058**
Random error term	86.574		

Source: survey data

Table 13. Regression analysis model and the estimates

$R^2 = 0.718$ Adjusted $R^2 = 0.641$

* - indicate significance at the 5% level
** - indicate significance at the 5% and 10% level

The results indicate R^2 is 0.718, implying a degree of 71.8% relationship among the independent variable. The adjusted R^2 shows that 64.1% of the variables can explain the model and the higher the adjusted R^2, the more significant the model. Therefore, the variables can significantly explain the model.

Household size, as can be seen Table 13 is significant at the 5% level and the positive coefficient indicates that there is a positive relationship between food security and household size. It was observed in the previous analysis that irrigators were seen to have a higher household size on average than the non-irrigators. This explains why food security increases with an increase in household size since more labour will be available to work in the irrigation and dry land plots, including hiring out labour and raise income to purchase more food. This supports the hypothesis that irrigators are more food secure and higher incomes compared to non-irrigators.

Off-farm income is also significant at the 5% significant level and the coefficient is positive. This indicates that an increase in off-farm income leads to an increase in the food security. As previously observed in the preliminary analysis of the study, the irrigators had more off-farm income than non-irrigators, thus it can be concluded that they are more food secure than the non-irrigators. This again supports the hypothesis that irrigators are more food secure than non-irrigators.

The area under cultivation is also seen to positively affect household food security. This is shown by a positive coefficient in the model. This means that as area under irrigation increases, household food security also increases. It is also, at the 5% significance level true that irrigators are more food secure compared to non-irrigators. This is because the irrigators were seen to own, on average more land than non-irrigators did, coupled with

that from irrigation. This can be attributed to the fact that they can produce more per given area, thus boosting their food production for the family.

Draught power is also another variable that is seen to positively affect the level of household food security. This is significant at the 5% level and can safely support the hypothesis that irrigators are more food secure since they were seen to have more draught power on average than non-irrigators. As a result, they engage in timeliness ploughing, thus aiding in boosting output production.

6. Conclusions

6.1 Socio-economic characteristics of the household

Irrigators were found to be larger households and older than non-irrigating households. Non-irrigators had more members in regular employment than irrigators, suggesting more income to non-irrigators from remittances. Irrigators have more livestock on average than non-irrigators. On agricultural equipment, irrigators were better endowed than non-irrigators were. On housing, non-irrigators' houses were more modern as compared to those of irrigators. Finally, irrigators had more land than non-irrigators suggesting increased production of more food from dry land cropping than non-irrigators. Non-irrigators seem to be more into off-farm regular employment than irrigators.

6.2 Impact on food security

The study has presented some evidence to show that irrigators produce more food than non-irrigators. The output of irrigators from dry-land and irrigation is greater than non-irrigators' output from dry land production. The irrigators were also seen to have more dry-land on average, coupled with that from irrigation as compared to non-irrigators. As a result, they had more crop output compared to the non-irrigators. This ensures availability of food for them. From the gross margin analysis, it was seen that irrigators had more crop income, and coupled with non-farm income, they have more disposable income, which they can use for purchasing household food requirements which cannot be locally produced.

The irrigation scheme has also been seen as a source of food where non-irrigators would buy the produce like cabbage, tomatoes and onions. Thus, irrigators have more disposable income as compared to non-irrigators. More income implies a much better security position for irrigators giving them the opportunity to purchase more nutritious foods. As was observed, the farmers grow cabbages, onions and tomatoes and these crops do help in relieving malnutrition. Thus, the hypothesis that irrigation increases the food security level in the communal areas is therefore accepted, provided that food markets are available.

6.3 Impact on farm incomes

It has been shown from the study that irrigation increases the incomes of the smallholder irrigation farmers through crop incomes. This was done on a comparative analysis scenario where the gross margins from dry land for both the irrigators and non-irrigators were computed. The larger contribution of income from irrigation has evidenced that the irrigation

scheme increased the incomes of irrigators substantially, and was largely responsible for the significant difference in the income levels between both categories. Higher incomes improve the standard of living; hence irrigation improved the welfare of irrigators.

The evidence supports the hypothesis that irrigators have more income as compared to non-irrigators. An analysis of other sources of income was conducted and showed a higher off-farm income for irrigators than of the non-irrigators'.

6.4 Technical performance

Smallholder irrigation schemes increase agricultural productivity. Irrigators were seen to perform better than non-irrigators. This is attributed to the fact that irrigators are better factor endowed, had more draught power and labour force. This means they practiced timeliness agricultural activities, thus increasing agricultural productivity. Irrigators also have better access to extension services through AREX personnel who constantly disseminate information to them, unlike non-irrigators who often meet him after a long period. Thus, we fail to reject the hypothesis that irrigators are better agricultural performers than non-irrigators.

7. Policy insights

Irrigation, as has been established from this study, positively impacts on the irrigators through improving household food security and income, hence standard of living for the irrigators. As a result, ZIM/EU MPP, together with the government and private sectors, should be encouraged to invest more in smallholder agriculture. Increases in the incomes realised from irrigation scheme contributes to the Gross Domestic Product, which is an aspect of economic growth. Hence, irrigation contributes to economic growth of the nation.

The irrigation scheme was seen to make a positive contribution to household food security, thus, it is a way of ensuring that people have access to adequate, nutritious food in their homes. This improves on the standards of living of the rural poor.

8. Recommendations

The study shows that smallholder irrigation can make a significant contribution towards poverty alleviation, increased incomes and food security. As such, ZIM/EU MPP and other donor NGOs should continue and be encouraged to support smallholder irrigation scheme investments. This should spread to all areas in the country, especially to those communal areas where rainfall is erratic. This will ensure food security, increased incomes, improved standards of living and employment creation for the rural population.

Governments, public and private institutions and non-governmental organisations are recommended to work together defining and implementing comprehensive strategies for smallholder irrigation development especially in the smallholder communal areas so as to ensure food security and employment to the rural population. There is need to formulate a comprehensive strategy to promote small-scale irrigation, including the accessibility of appropriate and affordable technology.

Such a strategy should include the following components:

- Review existing regulations and policies that influence small-scale irrigation.
- Define the role of government institutions, private sector and non-governmental organizations (NGOs) in promoting the adoption of improved irrigation technologies by small farmers. The private sector and NGOs should be encouraged to participate. However, it is recognized that government should play an active part in the identification and development of appropriate technologies and in the wider issues of rural infrastructural development so as to encourage expansion of smallholder irrigation projects.
- Encourage private investment in irrigation through provision of credit and financial incentives targeted to smallholder irrigation.
- The local rural district councils should make sure that they get in touch with NGOs, like ZIM/EU MPP and the donor community willing to take part in establishment and development of smallholder irrigation schemes, leading to self-sufficiency and food security.

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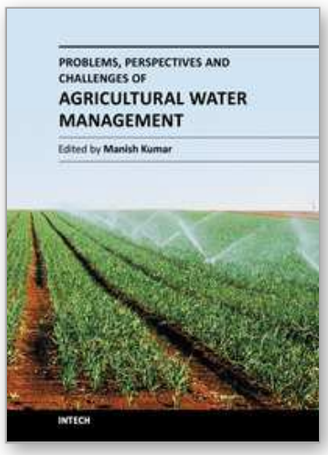
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Problems, Perspectives and Challenges of Agricultural Water Management

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Food security emerged as an issue in the first decade of the 21st Century, questioning the sustainability of the human race, which is inevitably related directly to the agricultural water management that has multifaceted dimensions and requires interdisciplinary expertise in order to be dealt with. The purpose of this book is to bring together and integrate the subject matter that deals with the equity, profitability and irrigation water pricing; modelling, monitoring and assessment techniques; sustainable irrigation development and management, and strategies for irrigation water supply and conservation in a single text. The book is divided into four sections and is intended to be a comprehensive reference for students, professionals and researchers working on various aspects of agricultural water management. The book seeks its impact from the diverse nature of content revealing situations from different continents (Australia, USA, Asia, Europe and Africa). Various case studies have been discussed in the chapters to present a general scenario of the problem, perspective and challenges of irrigation water use.

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