IRRIGATION PERFORMANCE IN ZIMBABWE

Published by:

IRRIGATION PERFORMANCE IN ZIMBABWE PROJECT
UNIVERSITY OF ZIMBABWE 1994
FACULTY OF AGRICULTURE
P.O. BOX MP 167, MOUNT PLEASANT
HARARE. ZIMBABWE

.SBN 0-86924-108-7

Page Layout & Typesetting:
ALPHABETICA

Origination & Printing:
The Print Shop

Citation:
Rukuni M., M. Svendsen, R.Meinzen-Dick *with* G. Makombe eds. 1994. *Irrigation Performance in Zimbabwe.* Proceedings of two workshops held in Harare and Juliasdale, Zimbabwe, 3 - 6 August, 1993. UZ/AGRITEX/IFPRI Irrigation Performance in Zimbabwe Research Project. Faculty of Agriculture. Univeristy of Zimbabwe.

CONTENTS

AGROECONOMIC PERFORMANCE OF SMALLHOLDER IRRIGATION IN ZIMBABWE

Ruth Meinzen-Dick[a], Martha Sullins[b] and Godswill Makombe[c]

INTRODUCTION

The objectives of increasing agricultural production and incomes are common to all types of irrigation in Zimbabwe, though the relative importance given to different objectives varies somewhat among irrigation system types. Many factors influence the impact of irrigation on achieving these goals, and the delivery of water from the source to the fields is only one (albeit critical) input. Seeds, fertilisers, labour, management, and other inputs also have a major impact on the level of agricultural production, while the relative prices of inputs and outputs will affect the level of farm incomes obtained from irrigated production. The structure of irrigation management in Zimbabwe acknowledges that meeting the objectives of irrigation development requires going beyond water deliveries. Whereas many countries have specialised irrigation departments that have no mandate beyond providing water to the fields, in Zimbabwe the management entities for all types of irrigation systems commercial, government, community, and informal systems are responsible for coordinating the supply of inputs and information on their schemes to increase the overall productivity of irrigated agriculture.

To understand the interaction of both farm-level and irrigation system-level factors under a given set of economic conditions, it is important to evaluate not only the hydrologic performance of the irrigation system itself, but also the performance of the irrigated agricultural system and the agricultural economic system (Small and Svendsen, 1992), as well as the role of irrigation deliveries in achieving that performance. Yet empirical measures of the agro-economic performance of smallholder irrigation systems in Africa are scarce. In reviewing the scope and potential of small-scale irrigation in sub-Saharan Africa, Adams (1990:1310) points out:

> There is nonetheless a lack of research on small-scale irrigation in Africa, whether on technical, economic, or social attributes, or on performance. Something called "small-scale irrigation" is often *assumed* to be the answer to the problem of the failure of large-scale projects, ... However, there is little hard evidence on the performance of small-scale irrigation schemes, or explicit comparisons between large-and small scale projects (emphasis in original).

[a] Research Fellow, International Food Policy Research Institute, Washington D.C.

[b] Research Assistant, International Food Policy Research Institute, Washington D.C.

[c] Lecturer, University of Zimbabwe, Department of Agricultural Economics and Extension.

This chapter examines the agroeconomic performance of different types of irrigation systems in Zimbabwe in terms of cropping patterns, yields, returns per unit of land and per unit water and farmers' orientation toward irrigation. The final section discusses the relevance of these findings for irrigation policy and management to increase agricultural production and rural incomes in Zimbabwe.

CROPPING PATTERN

While rainfed cultivation is generally restricted to the summer season in the communal areas of Zimbabwe, controlled water supplies make cultivation possible during the winter season on irrigated lands. Comparison of the cropping intensity between scheme and with dryland sites provides an indicator of the extent to which irrigation systems are intensifying cultivation. The composition of the cropping pattern, especially the proportion of area under high-value crops such as vegetables, is an important determinant of the economic performance of systems. On the other hand, cultivation of cereals (especially maize) is important for food security.

Table 5.1 presents the cropping intensity reported by sample farmers on the irrigation schemes studied during the 1990/91 summer and 1991 winter seasons. Overall, the Agritex systems had the highest proportion of farmers who reported cultivating all of their land. Agritex farmers also reported higher winter cropping intensities than those in other scheme types.[1] Cropping intensity on the dryland was fairly high in summer (91.5 percent), but dryland farmers did not cultivate their fields in winter. Like the dryland farmers surveyed, farmers on Charandura irrigation system had no winter cultivation because no irrigation water was available.

Maize was the dominant summer crop, grown on 46 to 98 percent of the area on all irrigation schemes except the ARDA schemes (Table A5). Cotton is grown on the entire irrigated area of the two sample ARDA schemes, but this cash crop was grown on only two of the Agritex schemes in very small quantities (less than 6 percent of the area on Chibuwe and Tawona). Groundnuts are the second most prevalent summer crop on Agritex and community schemes, especially on Mabodza, Chakohwa, and Mkoba, and are grown on 13.5 percent of the dryland area.

In winter, wheat is grown on both ARDA schemes, on approximately 35-40 percent of the area in Mwerahari/Sachipiri and Bangure, and on less than 7 percent of the area in Chakohwa, Tawona, and Mutambara (Table A6). Virtually all wheat production in Zimbabwe has been under large-scale irrigated conditions, and wheat production for import substitution is an important government objective.

Vegetable cultivation is potentially high value production, but also entails high risks. In addition to the agronomic risks of pests and susceptibility to water shortages at critical times, there are considerable marketing risks, including price fluctuations and the difficulty of getting produce to market in good condition, since transportation is limited on many schemes. Furthermore, formal credit sources will not provide funds for inputs in vegetable production because, unlike maize and other regulated commodities sold to the Grain Marketing Board, it is difficult to secure repayment from vegetable crops. But for those farmers who take the risks and are able to grow vegetables, the returns are potentially higher than other crops.[2]

Maize grown on many irrigation schemes can be treated as either a vegetable or grain. Early-harvested maize cobs can be sold as green mealies for a much higher price than dry cobs harvested for grain. Premium prices are paid for green maize during the Christmas season, until the period when green maize is available from dryland areas. Thus, using irrigation water to plant the crop before the rains begin can have payoffs, with less risk because the crop can always be dried and harvested as grain maize if market conditions for green maize are unfavourable.

Tomatoes, beans, cabbage, and rape or other greens are important vegetable crops. They are grown in both seasons, but are more important in winter, when there is less production of other crops. Mabodza, Tawona and Mutambara are especially notable for their tomato production, and Senkwazi and Chakohwa for beans.

The *bani* gardens exhibit the most diverse cropping patterns, with a wide variety of vegetables, bananas, sunflowers, bambara nuts, and some sugarcane. Small plots of rice are grown on land which is too wet for other crops, and raised beds are used to provide proper water control for other vegetables. No central manager or committee sets cropping patterns or water allocation on the gardens, so individual farmers are able to choose their own crops.

Dryland production includes several crops not found on irrigation systems. Maize and groundnuts accounted for 75 percent of Charandura dryland farmers' holdings in summer, but they also grew small areas of rapoko, bambara nuts and sunflower. Dryland sample farmers in Chakohwa, a drier natural region, planted drought-tolerant sorghum on half of their land, while maize was restricted to 18 percent, with 11 percent groundnuts, 6 percent bambara nuts and 5 percent sunflower.

AGROECONOMIC RETURNS TO IRRIGATION: YIELDS AND CROP BUDGETS

While cropping patterns provide an indicator of production patterns, the area planted alone tells little about the productivity of irrigation systems. Yield (defined as output per unit land) is perhaps the most commonly cited indicator of the agricultural productivity of irrigation systems.

The analysis of cropping patterns and crop yields indicated the choices farmers made, based upon input and output prices and the availability of necessary factors of production. Crop budgets go one step further, to indicate the returns generated by these choices. An analysis of crop budgets is useful in comparing the cash return to certain crops across irrigation scheme types, as well as with dryland agriculture. Summing the gross margins for all crops gives the gross crop income, which can be used to evaluate the contribution of the gross margin in covering the farmer's fixed costs for crop production, but should not be interpreted as a measure of whole farm profitability (Dillon and Hardaker, 1984).

Crop budgets for the sample were computed using data on gross value of output and total variable costs for each crop, by plot and season. Gross value of output was computed using the prices for which farmers reported selling their output. All output prices were adjusted to the farm-gate (net of transportation costs). Where farmers reported no marketed output, and thus no output prices, scheme-level average output prices were used. The total variable costs per crop were computed for all inputs used in the production of that crop, according to the unit and price reported by the farmer. Water charges were not included in the variable costs, because comparable data were not available on farmers' cost of irrigation across system types.[3] Gross value of output minus the total variable costs were calculated as the returns to family labour, capital, land and water.

Before discussing the results on yields and returns to irrigation, one important caveat is necessary. Considerable caution should be used in interpreting the per hectare yields and returns, especially for *bani* schemes and others with very small holding sizes. It is difficult for farmers to recall output levels and prices of mixed crops, and the task is made more difficult for vegetable crops with multiple harvests. Small errors in farmers' recall of inputs or outputs, or in the area cultivated are magnified when extrapolated to a per hectare basis. For the *bani* gardens, aerial photos and geographic information systems was used to develop relatively accurate measures of total garden size, but the proportion of the gardens under each crop was estimated by visual inspection and pacing on the ground. With many small beds of different vegetables, the potential for error is quite high. Because of this inherent measurement problem in dealing with micro scale garden production, the yields and gross margins should be regarded as indicative, rather than absolute, and caution should be used in projecting to larger holding sizes.

Maize

With 4.5 tonnes per hectare, Mwerahari/ Sachipiri had the highest maize yields. Schemes producing maize yields in the 3 to 4 tonne range were found among both Agritex (Mondi Mataga and Senkwazi) and community systems (Bangure and Mkoba), but most systems averaged 2 to 3 tonnes per hectare. Maize yields on all irrigation systems except Charandura were significantly higher than dryland yields, which averaged less than 0.5 tonnes per ha (including numerous plots which failed). With no irrigation water available, Charandura irrigation system yields (averaging 485 kg per ha) and crop failure rates were comparable to the dryland sites. Table A7 presents average yield and production information (in grain equivalents) for maize on sample irrigation systems.

Crop failure, as well as low yields, accompanies inadequate water supplies. Over 60 percent of maize plots were reported as having no output in Charandura irrigation system and Chakohwa dryland sites. The only other locations with reported crop failure for maize were Chibuwe, Mutambara, and Mbiru with 15 to 16 percent of plots, and Maboleni, Dufuya and Charandura dryland, with 4 to 6 percent of maize plots. Such crop failures are more serious than low yields, because the value of all inputs is lost.

The garden farmers use significantly lower levels of nitrogen, phosphorous, and potassium fertiliser than Agritex or community systems. *Bani* gardeners may use relatively low levels of chemical fertiliser for several reasons. First, there is a lower availability of credit and extension advice on such systems. Second, garden irrigators may concentrate their inputs and resources on higher-value vegetable production. Finally, the response to chemical inputs may not be as great in garden production. With no phosphatic or potassium fertilisers, and less than 10 per ha of nitrogen, fertiliser inputs on the dryland sites are significantly less than on all types of irrigation systems, including garden systems.

Although maize yields on garden systems are not higher than on other types of systems, the reported value of output per hectare is significantly higher on garden system than on either Agritex or community systems (Z$ 3,733 on garden systems, compared to an average of less than Z$1,000 per ha on Agritex and community system). This is because garden systems are able to sell more of the maize as green mealies, rather than as lower-priced grain maize. The higher value of output on garden systems, combined with a substantially lower level of chemical input use, result in significantly higher gross margins for maize on this type of system. Conversely, despite yields that averaged over 1.75 tonnes, low reported prices combined with moderate input costs produced gross returns of less than Z$ 150 per ha on Mabodza and Chibuwe. The value of output did not cover the input costs on Charandura irrigation and Chakohwa dryland, so the average gross margins for maize were negative in these sites.

Wheat

The question of whether smallholders can significantly contribute to increasing wheat production is important for Zimbabwe, where wheat is a major wage good that can only be grown during the dry winter season under irrigation. The country's wheat requirements are predominantly met by irrigation on large-scale commercial farms. If smallholder irrigation schemes could produce wheat it would expand the base for national production and offer smallholder producers an alternative winter crop. In the present sample, wheat was grown on both of the ARDA systems, three of the Agritex systems, and two community systems. With yields averaging 4.3 tonnes per ha, wheat productivity per unit land was significantly higher on the ARDA schemes than on the Agritex and community systems. The Agritex yields averaging 2.1 tonnes were significantly higher than those on community schemes which averaged 0.7 tonnes (Table A8). The difference in yields on ARDA versus Agritex and community schemes is not solely attributable to a lower level of inputs on smallholder systems,[1] but may be due to different water management or cultivation practices. In particular, ARDA systems use overhead sprinklers with mechanised land preparation and harvesting, while farmers on Agritex and community systems use open channels with draft plowing and manual harvesting.

Farmers on Tawona reported a higher value of output per unit area than on other schemes because of higher yields than other Agritex and community schemes (2.9 tonnes per ha, compared to 1.5 tonnes for Mwerahari/Sachipiri, and less than 1 tonne on other schemes), combined with a higher reported price per unit output. Overall, the per ha value of output was significantly higher than on community schemes. After deducting cash outlays, the gross margins (returns to land, water, family labour, and capital) were over Z$1,000 per ha on both ARDA systems, Mwerahari/Sachipiri, and Tawona, but, on average farmers on Mutambara lost money in wheat production. The gross margin per ha was significantly higher on Agritex systems than on either ARDA or community systems. Fixed costs and water charges, which are higher on ARDA schemes (averaging Z$ 1,700 per ha for wheat on Middle Sabi, and Z$ 635 per ha on Chisumbanje), further reduce the profitability of wheat cultivation for ARDA farmers, and enhance the comparative advantage of Agritex systems (especially Tawona) with respect to income generation.

What does this imply about the potential for smallholder irrigated production of wheat? Certainly Mutambara does not have a comparative advantage in wheat production. With a negative average gross margin, wheat production on this scheme does not compete with other systems than can produce wheat with gross margins over Z$,1000 per ha, nor with the alternative winter crops of tomatoes, which had average gross margins of Z$,1920 per ha on Mutambara. The returns on wheat on Bangure and Chakohwa are less than Z$1,000 per ha, but higher, on average, than the alternate winter crops of tomatoes and beans on those schemes. Gross margins for wheat production on

Chakohwa and Tawona are competitive with those of ARDA system, but the sample size of wheat plots is so small that such returns cannot be extrapolated to larger areas. Despite the significantly lower yields on Agritex than ARDA schemes, wheat production could be profitable for smallholders, particularly if the differential access to and use of inputs, advice on wheat production, and output markets were addressed.

Other Crops
Table A9 shows that for summer groundnuts, farmers on community schemes received the highest average gross margins per hectare (Z$2,805), while dryland farmers had the lowest average margins for that crop (Z$ 79). On the garden schemes, groundnuts were grown only in Maboleni, with relatively high average gross margins (Z$1,093). Groundnut gross margins on Agritex schemes (Z$ 767) were intermediate but higher than those received for maize (Z$ 529).

Cotton is grown primarily on the ARDA schemes, and on two Agritex schemes. Average gross margins per hectare for cotton were similar on the two ARDA schemes (with an average of Z$1,339), but returns to Agritex farmers appear to be highly variable, particularly on Chibuwe where the relative water supply for summer was low (Chapter 4).

Tomatoes have higher average gross returns in the summer than any other major crop on Agritex, community, and garden systems, but the sample of farmers growing summer tomatoes is too small for generalisation. Tomatoes are grown on more plots in winter, with average returns of approximately Z$,1 500 for Agritex, Z$2,000 for community, and Z$3,800 on garden systems. Across all schemes, the gross returns were highly variable. While part of the variability may be due to problems inherent in measuring output from horticultural crops which are harvested throughout the season, marketing problems and price fluctuations make returns to tomato production variable for farmers.

Beans also provided highly variable returns per hectare, and farmers received much lower gross returns during the summer season, except in Mondi Mataga and Maboleni. For all schemes, gross returns for beans in summer averaged Z$ 110, compared to Z$,1 685 during the winter.

MARKETING OF AGRICULTURAL PRODUCTION

Farmers generated surplus production for sale from their irrigated plots in both the summer and winter seasons, while their dryland holdings produced little marketed output (see Table A10). In summer, small amounts of dryland produce are sold only on Mabodza, Mondi Mataga and Mwerahari/Sachipiri (Agritex schemes), and Maboleni and Mushimbo garden schemes. Dryland sample farmers use their output primarily for domestic consumption, with only Charandura dryland farmers selling any of their production (an average of 3 percent).

ARDA schemes are commercial farms and thus ARDA farmers marketed all of their irrigated production, except for a small proportion of wheat retained by some farmers (typically one or two 90 kg bags). As Table A10 illustrates, Agritex, community, and garden system farmers sold more of their irrigated produce in winter (29 to 62 percent) than in summer (8 to 21 percent). Senkwazi, Tawona and Mutambara farmers sold more than two-thirds of their irrigated production during the winter season (but less than one-third during the summer). Overall, farmers on the garden schemes sold the smallest proportion of their total production (an average of only 8 percent in summer and 29 percent in winter).

The data on gross margins indicate that several crops including maize, groundnuts, tomatoes, and sometimes beans, provide relatively high gross returns for farmers. However, farmers do not concentrate their income generating efforts solely on these crops. Instead the types of cash crops are very diverse across the sample irrigation schemes. Although a larger proportion of crop production is marketed in the winter, the diversity of crops marketed is greater in the summer season, and the crop composition varies across schemes (see Table A11 and A12). Maize was sold on every scheme except Mbiru, and comprised 25 to 84 percent of total marketed production where it was sold. Community farmers sold the greatest proportion of maize (79 percent of marketed production), while garden farmers sold the least (24 percent). Vegetables made up the remaining crop sales in summer, and included tomatoes, beans, cabbage, peas, okra and cucumbers.

In winter, tomatoes were the most important crop marketed on the Agritex, community and garden schemes. Tomatoes accounted for 58 percent of the gross returns received by Agritex farmer, beans provided 30 percent, and the remaining 12 percent came from wheat and other vegetables. Community farmers received 67 percent of their gross returns from tomatoes, 20 percent from beans, and 13 percent from wheat and other vegetables. Finally, garden farmers received an average of 56 percent of their gross returns from tomatoes, 11 percent from rape, and 31 percent from other vegetables. Some schemes concentrated on particular crops. On Mwerahari and Sachipiri, for example, farmers primarily sold wheat (94 percent of their gross returns from marketing) and Chakohwa farmers sold mostly beans (75 percent).

The garden systems appear to have the greates diversification of crops sold, particularly in winter when most farmers market tomatoes and a wide range of minor crops, including cabbage peas, okra, potatoes, onions, sweet potatoes and cucumbers. On the other hand, Agritex and community farmers concentrate on marketing tomatoes and beans. A greater diversity in cropping pattern allows farmers to respond to changing input and output price incentives, and to target their production towards the most remunerative crops, especially in winter when output prices are higher and more households are likely to be net food purchasers. Unfortunately, the survey output prices are not indicative of seasonal variations or product quality and therefore cannot be used to demonstrate differences in marketing access or timeliness among schemes and scheme types.

Although the extent of marketing from irrigated production was much higher than from dryland production, 80 percent of irrigated sample farmers reported having problems marketing their crops.[5] Among the problems cited were insufficient transport (56 percent), low prices (20 percent), and absence of a market (14 percent). Farmers also mentioned untimely payments for crops sold, crops spoiling before they could be marketed, lack of packaging for transport, theft and not being able to sell crops to the GMB.

Access to markets clearly differs across the sample schemes (Table A13). Sales on the schemes and to neighbours off the schemes were more important than sales at local growth points. For example, three-quarters of Mondi Mataga, Chibuwe, Mkoba and Mbiru sales were made on or near the scheme. Local mission schools and hospitals were an important market for some community systems. Only Mabodza, Senkwazi, and garden system farmers trans-ported relatively large amounts of crops to towns for sale. Maize, cotton, beans and other grains were sold to the Grain Marketing Board (GMB), but this accounted for a lower proportion of marketed output than approved buyers or others such as flour or food companies. Many farmers also cited sales to agro-processing units such as Lemco, National Foods, Blue Ribbon, Tanrose, Victoria Flour, and other wholesalers. These outlets comprised at least a quarter of all sales on Mabodza, Tawona, Mutambara and Mushimbo. Across the schemes, maize, tomatoes, and beans had wider markets, while groundnuts and other vegetables were sold primarily on or near the scheme.

While wider markets are often important for irrigated farmers' incomes, local sales from irrigation systems have important spillover effects for food security of nearby dryland farmers. Overall, 55 percent of Agritex and 52 percent of garden system plotholders reported that neighbouring dryland farmers got food from their plots. The proportion of community irrigation system farmers supplying dryland neighbours with food was even higher (65 percent). Only 4 percent of ARDA farmers reported providing food to dryland cultivators, reflecting the orientation of ARDA schemes toward commercial, rather than basic food crops. The high proportion of farmers of Agritex, community, and garden systems who regularly supply food to dryland farmers indicates that crops produced on smallholder irrigation schemes are important not only for providing food and income to plotholders, but also for increasing the availability of food for other communal farmers, especially in remote areas.

INDICATORS OF AGROECONOMIC PERFORMANCE

The incomes farmers receive from irrigation are influenced by three factors: irrigated holding size, cropping pattern on those holdings, and the gross income they receive from crop production. The first column of Tables 5.2 and 5.3 presents the total gross margin per holding averages for sample sites in summer and winter seasons, respectively. The total gross margin represents the returns received by farmers, which can then be applied to the fixed costs (including water charges) incurred for the whole farm. The gross margins per holding were significantly higher on ARDA systems than on any other system types: Z$7,366 for ARDA, compared to an average of Z$418 for Agritex, Z$143 for community, Z$435 for garden systems in summer, and Z$ 236 for dryland.[6] In winter, ARDA farmer had average gross margins of over Z$ 5,000, compared to Z$1,000 or less on all other irrigation schemes (and no production on Charandura or the dryland sites). However, the fixed costs on ARDA systems are also high, so the difference in farm profitability between system is not as great as it might appear.

While the gross margin per holding provides an indicator of how well irrigation systems perform in terms of increasing gross crop incomes per family , it tells little about the efficiency of land and water resource use in creating those incomes. Total crop income may be higher on some schemes simply because farmers are allotted larger holdings, and not because those holdings are used productively. Even returns per unit area do not control for different levels of water supplied. To account for differential resource endowments, especially of land and water, the gross margin per unit area and per unit of water supplied to the irrigation system were calculated.

Productivity per Unit Land

Tables 5.2 and 5.3 present values for two alternative measures of gross margins per unit area as indicators of irrigation performance: per hectare actually cropped, and per hectare of total holdings (or command area). The first measure of gross margins per unit area can be taken as an indicator of plot level performance: how well farmers did on the land they cultivated, with the water that was available to them. The second measure of gross returns per unit area takes into account the production over the entire potential command area, and is thus a better measure of the performance of the scheme as a whole. Gross margins on the area cropped (first definition) are likely to be higher if scheme managers or farmers decide to restrict cultivation to only part of the potential command, but provide a high relative water supply to that area. However, under this scenario the gross margins over the entire area (second definition) might be lower than if the water was spread more thinly and the entire command area was served.

When one controls for differences in holding sizes and cropped area, the gross margins per unit area cultivated on garden systems (over Z$3,000 per ha per season) are significantly higher than on all other types of systems in both seasons (Tables 5.2 and 5.3). Community systems had significantly higher gross margins per ha cropped than Agritex or ARDA systems in winter, although ARDA gross margins per ha were significantly higher than Agritex, community or dryland in summer. Individually, Mkoba, Senkwazi, and Tawona schemes had relatively high gross margins per cultivated hectare in both seasons.

The summer cotton crop is more profitable for ARDA farmers than winter season wheat production, but on most other systems, the gross margins per cropped hectare are higher in winter than summer. Several factors contribute to higher gross margins in winter. Where irrigation water is available, crop physiological responses are higher in the dry season than in the rainy season, which has more cloudy days. The higher proportion of vegetable production also offers higher returns in winter, and the lack of rainfed production in winter raises prices for irrigated output.

Gross margins per total holding (or total command area) control for cropping intensity. This indicator of performance has lower values than the gross margins per unit of cultivated area wherever water is concentrated on some of the area and other land is left fallow. The effect is more marked in winter (when more schemes leave land fallow) than in summer (when most of the command area is cultivated). The difference between the two indicators is greatest on Mwerahari/Sachipiri and the garden systems, especially in winter.

Even controlling for cropping intensity, the gross margins per total command area are significantly higher for garden systems than any other types of schemes in each season. ARDA average gross margins per ha command area are significantly higher than Agritex, community, and dryland sites in summer, but significantly lower than community and Agritex in winter.

Productivity per Unit Water

The gross margin per unit of water gives an indicator of the efficiency of water use in terms of financial returns to the input. This measure is calculated by dividing the gross margin by the average water available on the scheme, including rainfall and irrigation supplies (see Chapter 3).[7] The fourth column of Tables 5.2 and 5.3 reports average gross margins per hectare-meter (ha-m) of water for sample smallholder irrigation systems (water data were not available for ARDA and dryland sites, nor for Mondi Mataga).

This measure assumes that the same amount was delivered to the entire cultivated area, an assumption which is almost never accurate. The gross margin per unit water also does not explicitly account for the timing and volume of each application. As Makadho (Chapter 4) demonstrates, water supplies are often in excess of crop demands in some periods, but inadequate in other periods, even if total water availability is high. Poor spatial or temporal distribution of water (providing excessive amounts in one area or period and shortages in others) is likely to reduce average gross returns per unit of water over the scheme as a whole.

While in many cases the output per hectare of land and per hectare-meter of water are of similar magnitude, a comparison of the four indicators for Bangure illustrates the value of examining returns to water. In winter, average gross margins per holding on Bangure are among the lowest of any schemes. Controlling for the very small holding sizes and cropped area on Bangure gives gross margins that are 3 times higher per ha of holding, and 4 times higher per ha cropped than the gross margins per plotholder. Bangure's gross margins per ha are thus comparable to the average gross margins per ha on Agritex systems in summer, though still much lower than the Agritex average for winter. But as Makadho (Chapter 4) shows, Bangure had a very low water supply, particularly in winter. Of the water available, very little was wasted through poorly timed delivered. Taking these factors and the cropping patterns into account, the gross margins per unit water on Bangure are among the highest of any scheme, particularly in winter.

Overall, gross margins per unit water were approximately the same on Agritex and community schemes, though in both cases the values for winter were twice as high as for summer (Z$ 775 in summer, Z$1,511 per ha-m in winter on the Agritex system, compared to Z$ 615 in summer and Z$1,591 in winter on community systems). Thus, if smallholder irrigation schemes are able to store water and carry it over from the wet to the dry season, they can double the value of that water's use in production.[8]

The garden systems had significantly higher returns per unit water than either Agritex or community systems. With gross margins per ha-m of Z$1,744 in summer and Z$3,138 in winter, the average productivity per unit of water on *bani* gardens was twice as high as on Agritex and community systems, even using the most conservative calculation, with total water available on the *bani*[9] as the denominator. This gives the returns per unit water if the gardens took up all of the available rainfall and groundwater. However, *bani* gardens do not take up all of the available water, and any excess is available elsewhere. The only water used by garden systems is the amount of crop evapotranspiration. Using this as the denominator would show even greater returns per unit water on the *bani*.[10]

The high value and intensive cultivation of garden system is clearly a factor in their performance, but the type of irrigation also contributes. As Andreini (1993) shows, much of the water is distributed by sub-irrigation on the *banis*, which produces low evaporation losses. Less than 20 percent of crop evapotranspiration is met by surface irrigation, and much of that is lifted and carried directly to plants. This uses less water and has lower transmission losses than application from open channels, hoses, or siphons. Thus, both the farm-level profitability and the technical efficiency of water resource use on garden systems are very high.

PRODUCTIVITY AND HOLDING SIZE

The relationship between farm size and productivity has been the subject of an extensive body of literature in many countries. While there may be increasing returns to scale on larger farms, especially with "lumpy" investments such as draft animals or machinery, small farms are often found to make more productive use of the land, through higher cropping intensities and greater use of family labour (Berry and Cline 1979). Rukuni's (1984) study of Nyanyadzi, Sanyati, and Makonese in Manicaland found that crop choice was more restricted on smaller irrigated holdings, although farmers on the "comma hectare" scheme in that study (Makonese) were more likely to grow high-value crops of green maize and tomatoes than were farmers on the other systems.

Similarly in a study of the Agritex-managed Nyanyadzi irrigation system, Tiffen (1990) points out that the smaller the holding size, the more important it is for farmers to grow high-value crops, if the irrigated land is to support a household. However, the Nyanyadzi study also found that farmers with the largest irrigated holdings (1.6 ha) were able to put more of their land into high-value crops (tomatoes, summer vegetables, and cotton), because those crops require larger amounts of working capital which farmers with large holdings could more easily afford.

The issue of determining the appropriate holding size for irrigation scheme farmers is of considerable concern for smallholder irrigation development. The government wants to provide access to irrigation to as many households as possible, but also ensure that farmers on irrigation schemes will be oriented toward irrigated production, and devote sufficient time and management effort to ensure that the irrigation system resources are used effectively. The former objective is met by allocating as small a plot size as possible, while the latter is often presumed to require plots large enough to generate relatively high income levels without

The empirical evidence from the present study suggests that, within the smallholder irrigation sector, smaller holdings are more productive than larger ones in terms of both land and water resource use. Table 5.4 presents the average gross margins per hectare of total holding and per hectare-meter of water by holding size for Agritex, community, and garden systems.[11] The financial returns per unit land and per unit water are generally highest for the smallest holding size category (less than 0.25 ha).

In summer, Agritex farmers with 0.25 to 0.49 ha had the highest average gross margins per ha (Z$1,045) or per ha-m (Z$1,109), significantly higher than all categories with more than 0.5 ha. Those with 1.50 to 1.99 ha had significantly lower gross margins per ha (Z$ 97) and per ha-m(Z$ 59) in summer. The average Agritex financial returns in winter on holdings of less than 0.25 ha were significantly higher per unit land than for all other size categories (which were all less than Z$1,600 per ha), and significantly higher per unit water (Z$2,430 per ha-m) than for the holdings of 1 to 2 ha (which were less than Z$ 410 per ha-m). Among community systems, summer gross margins per unit land and water were significantly higher for holdings of less than 0.25 ha than for the 0.50 to 0.99 ha holdings. In winter, gross margins per unit land and water were significantly higher for holdings of less than 0.5 ha than for those of 0.50 to 1.50 ha.

Although the garden systems have significantly higher financial returns per unit land and water than other system types overall, there is little difference in productivity by holding size among the garden plots. Most garden holdings are small (90 percent are less than 0.5 ha, and 9 percent are less than 1 ha). Within this limite range of holding sizes in the garden systen differences in gross margins per unit land an per unit water are not significant at the 0.0

The inverse relationship between holding size and productivity of land and water resources in smallholder irrigation systems merits further investigation of several issues, including the contribution of higher cropping intensity, cropping pattern, and intensity of management and input use (particularly labour inputs). However, results from this study do indicate that farmers with larger holding sizes may not use irrigation resources as effectively as those with smaller holdings. In the following section we examine the degree to which holding size affects farmers' orientation toward irrigation, and the premise that large holding sizes are needed to increase farmers' orientation toward irrigated production.

HOLDING SIZE AND DEPENDENCE ON IRRIGATION

Farmers with larger irrigated holdings are more likely to depend on irrigated production for their income, but even among sample plotholders with less than 0.25 ha of irrigated land, 49 percent reported irrigated land as the major source of income (Table 5.5).

Of those with irrigated holdings of 0.25 to 0.5 ha, 72 percent reported irrigated land as their major source of income, and over 83 percent of farmers with 0.5 ha or more reported primary dependence on irrigation for income. A similar pattern is found for dependence on irrigation for household food. Thus, holding sizes of at least 0.25 to 0.5 ha are likely to provide the primary source of income and food for households. That does not, however mean that irrigation will be the sole source of income generation, even with large holding sizes. Even with irrigated holdings of over 3.5 ha, many Chisumbanje farmers continue to be very involved in dryland and garden cultivation for food production, and 20 percent have off-farm activities.

Irrigated holding size is not the only factor which determines the degree of dependence on irrigation. The amount of dryland and rainfall available for unirrigated production, together with household characteristics, are also likely to have an influence. Table 5.6 presents results of a logistic regression model for the probability that irrigation would be the primary source of income, as a function of irrigated and dryland holding size, average rainfall, and plotholders' gender and literacy.[12]

The model is:

probability (IRRINC) = FN (TOTALHA, DRYFARM, FARMSIZE, READ, AVERAIN) GENDER

where:

IRRINC	=	Depends primarily on irrigated land for household income
TOTALHA	=	Total irrigated holding, in ha
DRYFARM	=	Total dryland holding, in ha
FARMSIZE	=	Household size
GENDER	=	Dummy variable for female plotholder
READ	=	Dummy variable for literacy
AVERAIN	=	Average annual rainfall, in mm

The model predicts 83.5 percent of the cases correctly. The amount of irrigated area has a strong positive effect on the probability that plotholders will report irrigated production as their primary source of income, while the size of dryland holding and average rainfall have significant negative effects. This is not surprising, because irrigation is more important in drier areas. The magnitude of the coefficients indicates that a unit of irrigated land has a stronger effect in determining farmers' dependence on irrigation than an equivalent unit of dryland. Plotholders who have larger households are significantly more likely to depend on irrigation, as are female plotholders and those who are literate. The effect of family size may be due to the greater availability of household labour for irrigation activities. Literate plotholders may be more able to adapt to new production practices under irrigation. These results indicate that policies which allocate irrigated plots larger than 0.25 ha, and give priority to literate women with large families and little dryland, are most likely to foster schemes in which farmers concentrate on irrigated production. However, only small increments of irrigated land are needed to provide the primary source of income for smallholders.

CONCLUSIONS

The analysis of the agroeconomic performance of the four types of irrigation systems in this study show that irrigated production allows a higher cropping intensity, reduces crop failure rates, and is more profitable for farmers than dryland production. By making winter cultivation possible, irrigation systems provide a source of incomes and food during the dry season when rainfed cultivation is not possible in most communal areas. Irrigated production also has greater market linkages than rainfed production, both in terms of input use and sale of output.

Beyond this, it is difficult to draw definitive conclusions about which types of irrigation systems perform best because such assessments depend on the measure of performance used. The choice of scheme management, holding size, and even cropping pattern depends on which objectives are considered most important in irrigation development. ARDA systems perform much better than other types in terms of raising wheat yields and the gross margins of plotholders (though not necessarily farm incomes, after fixed costs are deducted). Garden systems perform poorly according to those criteria, but when the differential endowments of land and water resources of sample systems are considered, the gross margins per hectare of land or hectare-meter of water are highest on garden systems.

There is a direct trade-off between the objectives of raising incomes from irrigation enough to provide "full time occupation and resources independent of dryland agriculture" (DERUDE, 1983:4), and providing supple-mental income and food security to as many households as possible. Making farmers independent of dryland generally requires larger irrigated holdings, while providing supplemental resources to a greater number of farmers is best achieved by providing supplemental resources to a greater number of farmers who would continue to cultivate dryland. The analysis of farmers' reported primary source of income shows that, while farmers with larger holdings are more likely to report dependence on irrigation, even relatively small amounts of irrigated land can provide a major source of household income. The analysis of returns to land and water resources indicates that financial returns to resource use provide an additional factor in favour of small holding sizes, because they are more intensively cultivated.[13]

In identifying the holding size required to meet scheme objectives, one must also recognise the relationship between scheme size and irrigated holding size, and its role in determining farmers' potential income sources. Among sample systems, the correlation coefficient between average holding size and scheme command area was 0.69. On a small scheme it is possible to allocate fractional-hectare plots and expect that tenants can still have access to dryland. But on a large scheme, if average irrigated holdings are a fraction of a hectare, the number of tenants becomes very large. This not only increases scheme management problems, but also makes it very unlikely that irrigators can have dryland holdings within commuting distance of their irrigated land. Many of the larger schemes are located in the Sabi Valley, where the concentration of irrigation schemes and the dry natural region make it even more unlikely that smallholder irrigators would be able to find sufficient dryland to supplement their income from irrigation.

Large-scale systems face greater management complexity in delivering water to meet crop requirements over a large area. This is compounded if farmers choose diverse cropping patterns with staggered planting dates. As a result, relatively uniform cropping patterns are often imposed on larger Agritex schemes, which may have a negative impact on output markets for farmers. By contrast, small-scale systems with high performance in terms of returns to land and water (such as Mkoba or the *bani* gardens) are characterised by a management-intensive system of diverse cropping patterns and planting dates, which prevents production from flooding the local market.

Larger schemes, particularly those with uniform cropping patterns, have particular marketing difficulties because production is likely to exceed local demand during certain periods. This is less of a problem for non-perishable crops that can be stored and marketed throughout the year, or transported out of the local area more easily, but poses greater constraints to producing and marketing more perishable crops (especially horticultural production and green maize). Arrangements with agro-processing units or other marketing agents to buy on the scheme offer potential solutions to this problem, but several Agritex officers reported difficulties with establishing or maintaining such contractual arrangements.

Decisions regarding crop choice allow scheme managers to target agricultural production resources on achieving one or more objectives for irrigated agriculture. Therefore, the role of horticultural production in income generation and food security should be carefully studied on each scheme. For example, if a scheme's primary objective is to increase household incomes, horticultural crops may offer higher gross margins than traditional grain crops. However, since the returns to horticultural crops are quite variable, intensifying their cultivation may jeopardise food security and income stabilisation on schemes where these are important objectives. In areas where the risks to increasing horticultural crop production are too great, irrigated maize cultivation offers a compromise between the high margins of horticultural production, and production stability and food security, along with increased control over the timing of crop marketing. If water is available to start the crop before the rains, the output can be sold as green mealies at a relatively high price, but if water shortages or other factors intervene, a grain crop can still be harvested and sold.

In order for Agritex-managed irrigation schemes to increase their returns to land and water resources, changes in management patterns may be required to allow more mixed cropping patterns, with multiple crops at different stages. This may, in turn, involve farmer participation in making decisions on cropping and water delivery patterns. While this increases the difficulty in delivering water to meet crop water requirements, it may be better to have slightly lower water delivered for low-value crops.

The assessment of the role of smallholder irrigation in Zimbabwe should include garden irrigation on *banis*. This would, in turn, require reconsidering the current effective ban on *bani* cultivation in light of new evidence on the hydrologic and environmental aspects of *bani* use (Andreini 1993), and the high returns to land and water resources use in garden irrigation.

Furthermore, since recent evidence suggests that *bani* cultivation has relatively little effect on stream flow (Andreini, 1993; Faulkner and Lambert, 1991), the high value of output per unit water on the *banis* suggests that it may be more efficient to use that water on the *banis* than in conventional irrigation elsewhere. In the search for ways to improve the income, food security, and livelihoods of communal farmers, the potential for sustainable garden irrigation on *bani* resources should not be overlooked.

However, sustainable exploitation of *banis* is integral to their success, and thus should be carefully considered in any policy formulation. Current patterns, in which farmers make all investments and manage the systems themselves, are advantageous to the government because it incurs no revenue drain, and to the farmers because they are able to control their cropping patterns and water supply. The four garden systems in this study appear to have effective local management of the *bani* use, as well as effective patterns of cultivation. However, more research is needed to identify sustainable institutions and practices, assess their availability, and determine their economic and financial viability. The most important interventions to promote garden irrigation are likely to lie not in taking over existing systems, but in disseminating information of successful practices to other suitable areas, and in assisting with input and output marketing, particularly in terms of credit and transport.

Ultimately, the greatest constraints to improving and replicating the performance of *bani* gardens, as well as other types of smallholder irrigation systems in Zimbabwe, may extend beyond water supply alone. Improving irrigation performance in order to increase the financial returns to land and water resources, and improve farmers' incomes and food security, may hinge upon the development of more flexible scheme management patterns and more reliable transportation and output markets for irrigated production.

REFERENCES

Adams, W. M. 1990. How beautiful is small? Scale, control and success in Kenyan irrigation. *World Development* 18 (10): 1309-1323.

Andreini, M. 1993. The management of Dambo irrigation system in Zimbabwe. Ph.D. dissertation, Cornell University.

Berry, R. A. and W. R. Cline. 1979. *Agrarian structure and productivity in developing countries.* Baltimore: Johns Hopkins University Press.

DERUDE (Department of Rural Development), Zimbabwe. 1983. Policy paper on small scale irrigation schemes. Harare. Mimeo.

Dillon, J. L., and J. B. Hardaker. 1984. *Farm management research for small farmer development.* Food and Agriculture Organisation Agricultural Services Bulletin 41. Rome: FAO.

Faulkner, R.D. and R.A. Lambert. 1991. The effect of irrigation on dambo hydrology: A case study. *Journal of Hydrology* 123: 147-161.

Makadho, J. 1993. An analysis of water management performance in smallholder irrigation schemes in Zimbabwe. Ph.D. dissertation, University of Zimbabwe.

Rukuni, M. 1984. An analysis of economic and institutional factors affecting irrigation development in communal lands of Zimbabwe. PhD. dissertation, University of Zimbabwe.

Small, L. E. and M. Svendsen. 1992. A framework of assessing irrigation performance. IFPRI Working Paper on Irrigation Performance, No. 1. Washington, DC: International Food Policy Research Institute.

Tiffen, M. 1990. Socio-economic parameters in designing small irrigation schemes for small scale farmers: Nyanyadzi case study. Report IV: Summary and conclusion. Report OD 117. London: Overseas Development Institute.

ENDNOTES

1. Farmers' reported cropping intensities in both seasons are higher than the area reported to be irrigated by Agritex staff (see Makadho, Chapter 4). Part of the reason for this may be that there is no tenant listed for land regularly left unirrigated, so that land would be unrepresented in the sample. Also, farmers may not have reported the land left uncultivated as part of their holdings.

2. Several schemes have fewer marketing problems, either because they are located near markets, or because agro-processors or other businesses purchase vegetables directly on the scheme. Farmers in Mushimbo participate in a marketing cooperative that transports vegetables directly into Harare.

3. While ARDA farmers pay per unit water consumed and Agritex farmers were charged Z$ 145 per hectare, much of the irrigation costs on community and garden systems are in-kind or labour contributions.

4. Difference in nitrogen applications between system types are not significant, but the level of phosphorous and potassium is significantly higher on Agritex systems than on either ARDA or community systems.

5. The proportion of farmers reporting marketing problems by system type was 70 percent for ARDA, 92 percent for Agritex, and 82 percent for community, 79 percent for garden systems, and 32 percent for the dryland sample.

6. This excludes gross margins from dryland holdings for farmers on irrigation systems.

7. Gross margins per hectare-meter of water are computed as:

GM/ha-m = GM/ha / (VOLUME / CROPAREA) + RAIN)

where:

GM/ha-m	= Gross margin per hectare-meter
GM/ha	= Gross margin per hectare
VOLUME	= Volume of irrigation water supplied (in ha m)
CROPAREA	= Cropped area of command (in ha)
RAIN	= Rainfall (in meters)

8. This is based on units of water supplied to the irrigation system, and does not account for evaporation or other storage losses.

9. Calculated as watershed recharge less evapotranspiration of natural vegetation on uncultivated area of the *bani* (from Andreini 1993, Table 4.2).

10. Even this is conservative, because if gardens were not cultivated, much of the water would be consumed by evapotranspiration of natural vegetation on the *bani* (see Andreini, 1993).

11. ARDA systems are not included in this analysis because data on gross margins per unit water are missing.

12. Levels of irrigated production or gross margins are not included in this analysis because the question on dependence on irrigation was asked at the beginning of the cropping year. Hence, actual levels of productivity during the year could have influenced farmers' answers.

13. There may also be a complementarity between irrigated and dryland holdings, by which cultivation of dryland for household food consumption allows farmers to take more risks with high value irrigated crops, while those with only irrigated land must ensure household food security on their irrigated land alone.