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DISSERTATION

**THE ECONOMIC IMPACT AND PERFORMANCE OF IRRIGATION IN
ZIMBABWE**

**Submitted by
Godswill Makombe
Department of Agricultural and Resource Economics**

**In partial fulfillment of the requirements
for the degree of Doctor of Philosophy
Colorado State University
Fort Collins, Colorado
Fall, 2000**

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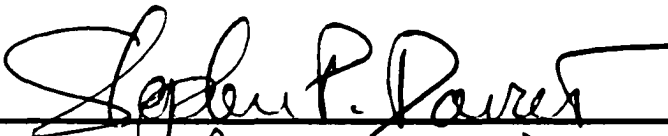
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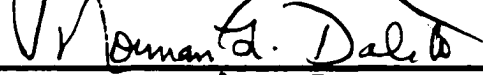
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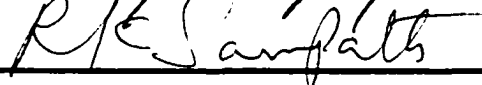
WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY GODSWILL MAKOMBE ENTITLED THE ECONOMIC IMPACT AND PERFORMANCE OF IRRIGATION IN ZIMBABWE BE ACCEPTED AS FULFILLING IN PART THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

Committee on Graduate Work

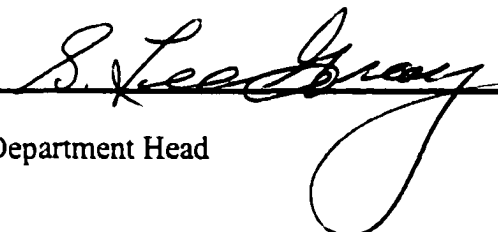








Advisor



Department Head

ABSTRACT OF DISSERTATION

THE ECONOMIC IMPACTS AND PERFORMANCE OF IRRIGATION IN ZIMBABWE

This dissertation addresses some issues concerning the performance of irrigation in Zimbabwe. Experts agree that there are many places in the world, Zimbabwe included, where food supply could better match demand through increased production. One way of increasing food production is through the development of water resources for irrigation.

In this study the benefits of irrigation are estimated for maize production in Zimbabwe. A Marshallian partial equilibrium analysis is used to estimate the net benefits for consumers and producers in maize production. The study concludes that the net benefits are high for a strategy that pursues the development of smallholder irrigation as opposed to one that develops large-scale commercial systems.

Smallholder irrigation performance in Zimbabwe is assessed in terms of water management and financial performance. The conclusion from the study suggests that smallholder irrigation is a viable development alternative. Smallholder irrigation is defined as the formal systems namely the government managed Agritex systems, the farmer managed community systems and the parastatal supported ARDA outgrowers.

This study compares the performance of the formal systems themselves and then the formal systems are compared to the informal *bani* system. Because of lack of data the ARDA systems are only included in very few of the analyses. The informal *bani* system is discouraged by the government through statutory instruments.

The main conclusions from the performance of the formal systems is that the farmer managed community system outperforms the government managed system in terms of water management and financial performance. To this extent, the government should utilize the farmer-managed model for further smallholder irrigation development.

The study also concludes that the informal *bani* system, which is discouraged by the government, can achieve the objectives of irrigation in much the same way, if not better than the formal systems. However, since there is legislation that discourages the utilization of this resource, it is recommended that the government reviews the legislation, in light of contemporary knowledge, in order to allow this apparently valuable resource to contribute to agricultural development in Zimbabwe.

Godswill Makombe
Department of Agricultural
and Resource Economics
Colorado State University
Fort Collins, CO 80523
Fall, 2000

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DEDICATION

To my father who did not live long enough to see me through my studies in Fort Collins. To my mom for never ending encouragement. To my wife Farai for support. To my son Kuku who one day will understand why I needed those afternoon “naps”. To the rest of my family (*in the African context*) which I share much love and happiness with. To those in Fort Collins who made my stay unforgettable. ” To my son Tino for the observation that: “*Baba mama* is your friend.” and for the reminder that: “*Baba*, there is a baby in your big *tummy*.” I hope that, like good, wine my friendship with “*mama*” gets better with time, and Tino, I **promise** to work on my exercise schedule as soon as this work is done, hopefully giving a new lease of life to “the baby” in my big *tummy* and to myself.

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Chapter 1

Introduction

1.1 World food situation

There is huge disparity between growth in world food production and population. A significant proportion of the world's population suffers from undernourishment and many people die of malnutrition. Between 1972 and 1992, approximately 200 million people starved to death or died of hunger related diseases. Between 800 million and 1.2 billion people in the world are undernourished. Undernourishment, however, sometimes results from factors that are not related to food production, but many developing countries cannot produce enough food to feed their populations. (Hrein and Feltz, 1998)

Many of the developing countries in Africa are unable to produce enough food for their populations. There is, therefore, very little disagreement among experts that Africa needs to increase agricultural production and enhance food security especially Sub Saharan Africa. One serious constraint to increasing food production in this region has been the lack of development of the available water resources. Less than 15 percent of the region's irrigation potential has been developed (Rosegrant and Perez 1995). This is especially problematic in semi-arid areas, where low rainfall limits production, and recurring droughts precipitate periodic food crises. Irrigation development can go a long

way to alleviate some of Africa's food problems because it produces on average two and a half times more per hectare than non-irrigated production (Hren and Felts, 1998).

Table 1.1 shows FAO estimates of the development of irrigation in Africa relative to the world (Rydzewski, 1990). Even though most people depend on agriculture in Africa, agricultural land use is still less than 40 percent of total potential. Africa has the lowest irrigated area as a percentage of cultivated area and the lowest harvested area under irrigation as a percentage of total harvested area compared to the regions listed in Table 1.1. These statistics indicate that Africa still has the potential to increase agricultural activity and food production.

One reason for the limited irrigation development has been general pessimism regarding the performance of irrigation systems in Africa. Most of the systems have had financial, management and environmental sustainability problems. The costs of infrastructural development for conventional irrigation systems are often high and managerial capacity needs to be developed, especially in comparison to Asia, where irrigation has played a major developmental role (Adams, 1992). Instead of relying on "conventional", large-scale irrigation development, smallholder irrigation systems under farmer management may provide a more feasible alternative (Adams 1992, Rydzewski, 1990). However, this may well be an overgeneralization given the fact that for smallholder irrigation systems, some characteristics are very site specific leading to different performance (Rydzewski, 1990).

Table 1.1. Agriculture and irrigation in Africa relative to the world

Agricultural land use as a percentage of total potential					
	Total	Africa	Near East	Far East	Latin America
1974-76	40	30	63.5	79	25
1990	45	34.5	65.5	83.5	33.5
2000	49	37	67	86.5	38
Irrigated area as a percentage of cultivated area					
1974-76	13	1.5	23	22.5	7
1990	15	2	25	29	7
2000	16	2	26	32	7
Harvested area under irrigation as a percentage of total harvested area					
1974-76	18.5	3	30	25.5	10.5
1990	23	3.5	34.5	35.5	10
2000	24	4	37	38.5	10

Source: Rydzewski (1990)

The size of irrigation projects has also been a debatable concept. In India, projects are classified as major, medium and minor depending on cost, whereas the FAO classifies those projects greater than 500 ha in area as large, between 50 ha and 500 ha as medium and less than 50 ha as small, irrespective of cost (Rydzewski, 1990). In this study smallholder projects neither refer to costs, nor size but to the land holding of a farmer. A project is classified as smallholder if land holding is less than 10 ha irrespective of cost and or total project size.

1.2 Irrigation in Africa

According to FAO 1995 estimates for Africa as a whole, 85 percent of water withdrawals are used in irrigation as opposed to the other major water uses namely communities (domestic) and industry (FAO, 1995). Figure 1.1 shows water withdrawal as a percentage of renewable water resources in Africa. The arid regions of the north account for more than half of agricultural withdrawals on the African continent.

Several estimates of irrigation potential have been put forward and these have significant differences. However, it is established that about 60 percent of irrigation potential in Africa is concentrated in seven countries; namely Angola, Sudan, Egypt, The Republic of the Congo (formerly Zaire), Ethiopia, Mozambique and Nigeria (FAO, 1995). The FAO defines water managed areas as: "The land on which water is used for the purpose of agricultural production..." (FAO, 1995, pp 9). Using this definition, there are about 14.3 million ha of water-managed areas in Africa. Figure 1.2 shows how unevenly the water-managed areas are distributed in Africa. Egypt, Sudan, South Africa, Morocco and Madagascar cover about 19 percent of Africa but account for about 60 percent of the water managed areas. In the African water managed areas, surface irrigation is the most widely used technique (FAO, 1995).

Figure 1.3 shows water-managed areas as a percentage of irrigation potential. This figure clearly shows the relationship between climate and use of water for irrigation. The highest proportions of irrigation development relative to potential are in the semi-arid

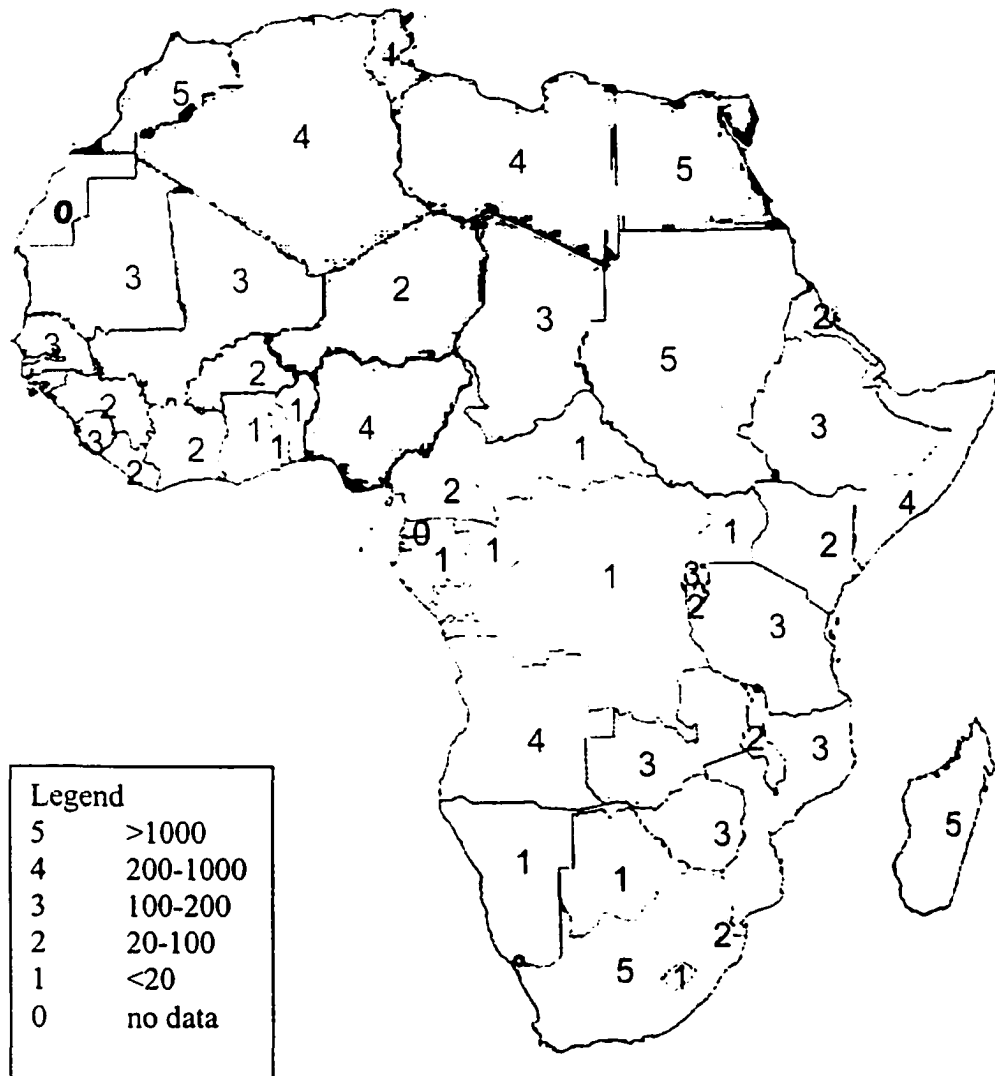


Figure 1.2: Water managed areas ('000 ha)
Source: FAO (1995)

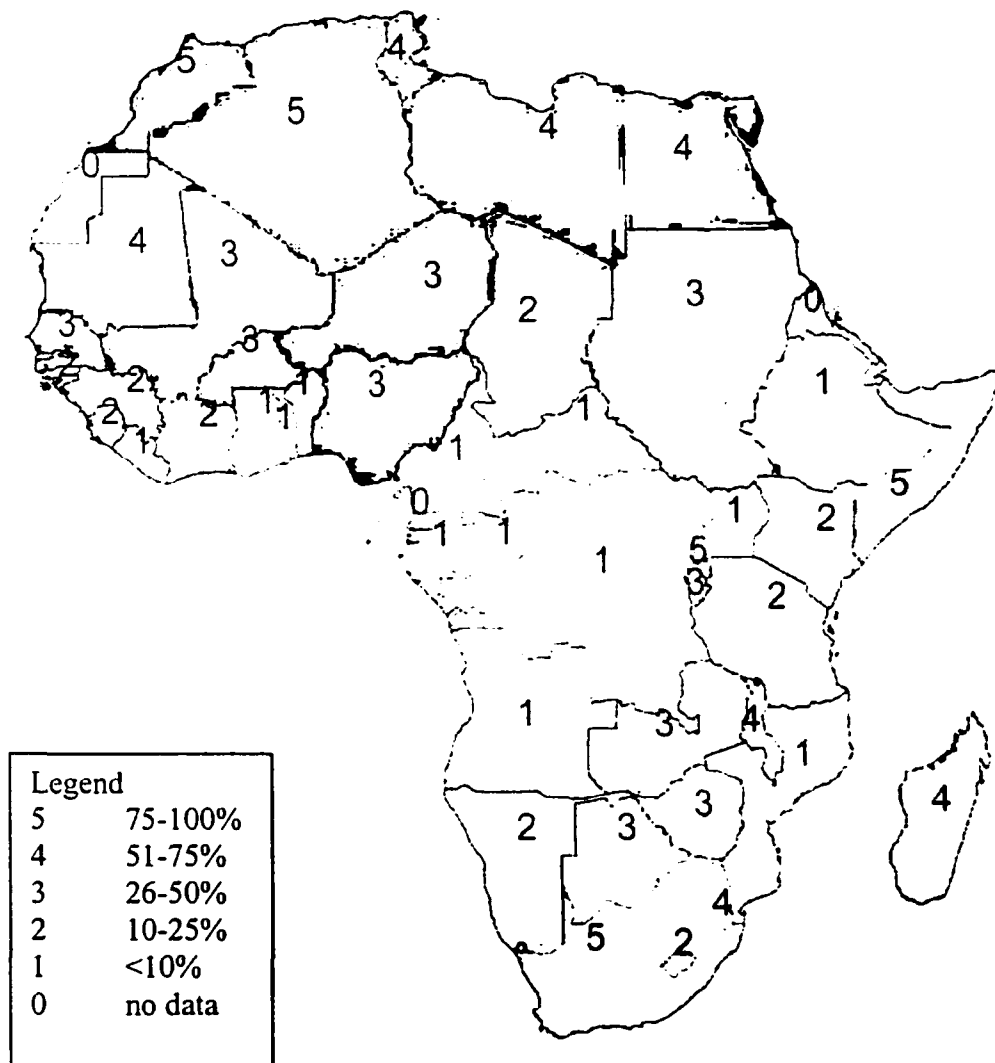


Figure 1.3: Water managed areas (% of irrigation potential)
Source: FAO (1995)

northern countries and in South Africa. Most of the Sub-Saharan countries still have less than 50 percent of potential developed.

This study focuses on irrigation development in one African country, namely Zimbabwe.

1.3 Zimbabwe: An overview

Zimbabwe is a Southern African country (Figure 1.4). It is located between latitudes 15° 30" and 22° 30" South of the Equator and longitudes 25° and 33° 10" East of the Greenwich Meridian. It has a land area of about 390,757 square kilometres. It enjoys a sub-tropical climate that varies in the country depending on altitude. The main rains are associated with the Inter-Tropical Convergence Zone where the northerly and easterly air masses converge. The rainy season stretches from September/October to March/April. The rest of the year is the cool and dry. The mean annual minimum temperature for 1996/97 averaged 13.9° C and the mean annual maximum averaged 27.2° C (Central Statistical Office (CSO), 1997 a). This shows that temperature is not limiting for crop growth but the limiting factors are moisture during the dry season and sometimes soil characteristics.

Zimbabwe is divided into five Natural Regions depending on soil type, rainfall and agricultural potential (Figure 1.5). Natural Region I comprises less than 2 percent of the country's total area and receives above 1000 mm annual rainfall. This region has the highest agricultural potential in Zimbabwe. Agriculture in this region is highly intensive and based on livestock and plantations. Natural Region II receives between 750 and

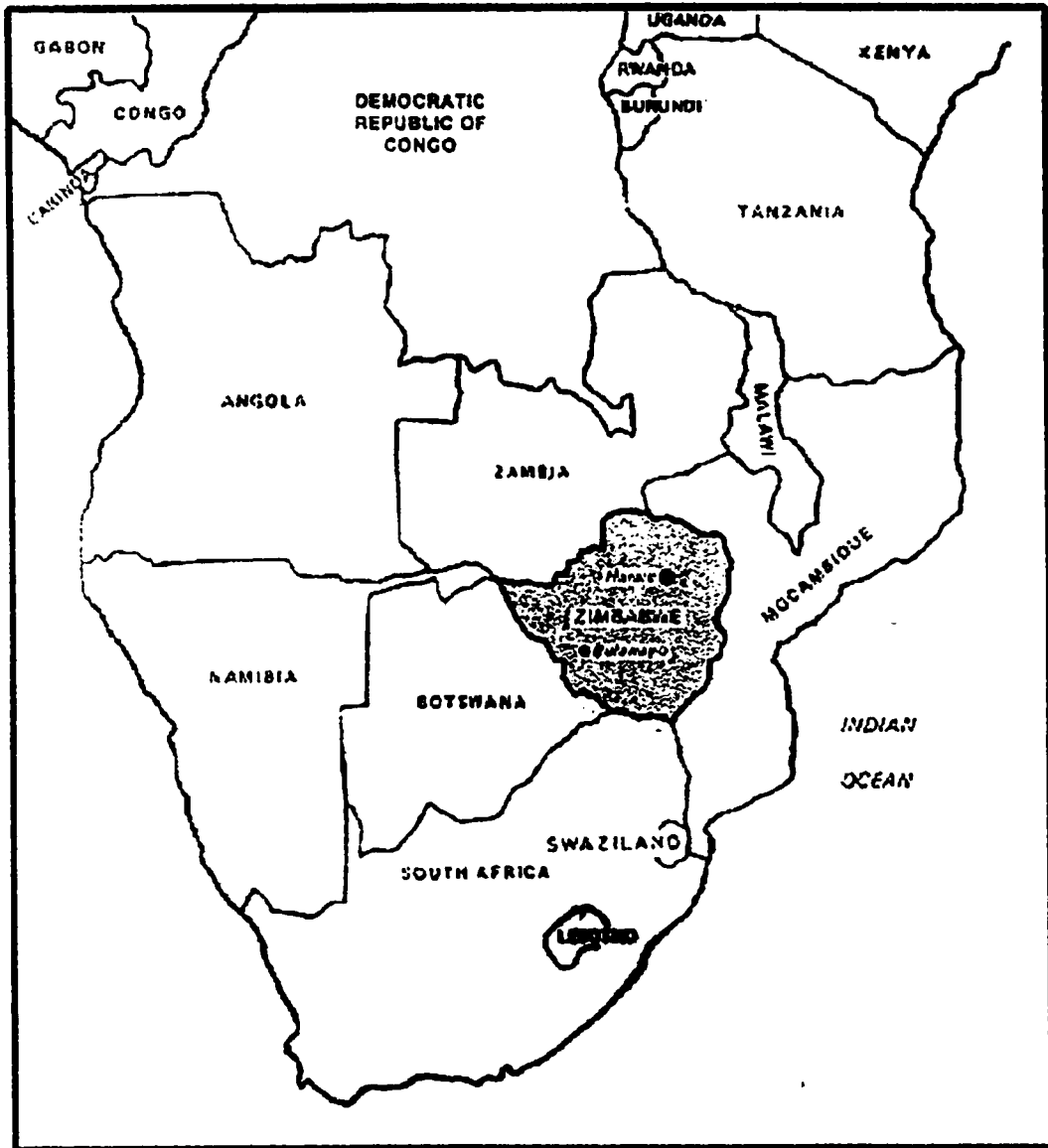


Figure 1.4: Location of Zimbabwe in Southern Africa
Source: CSO 1997a

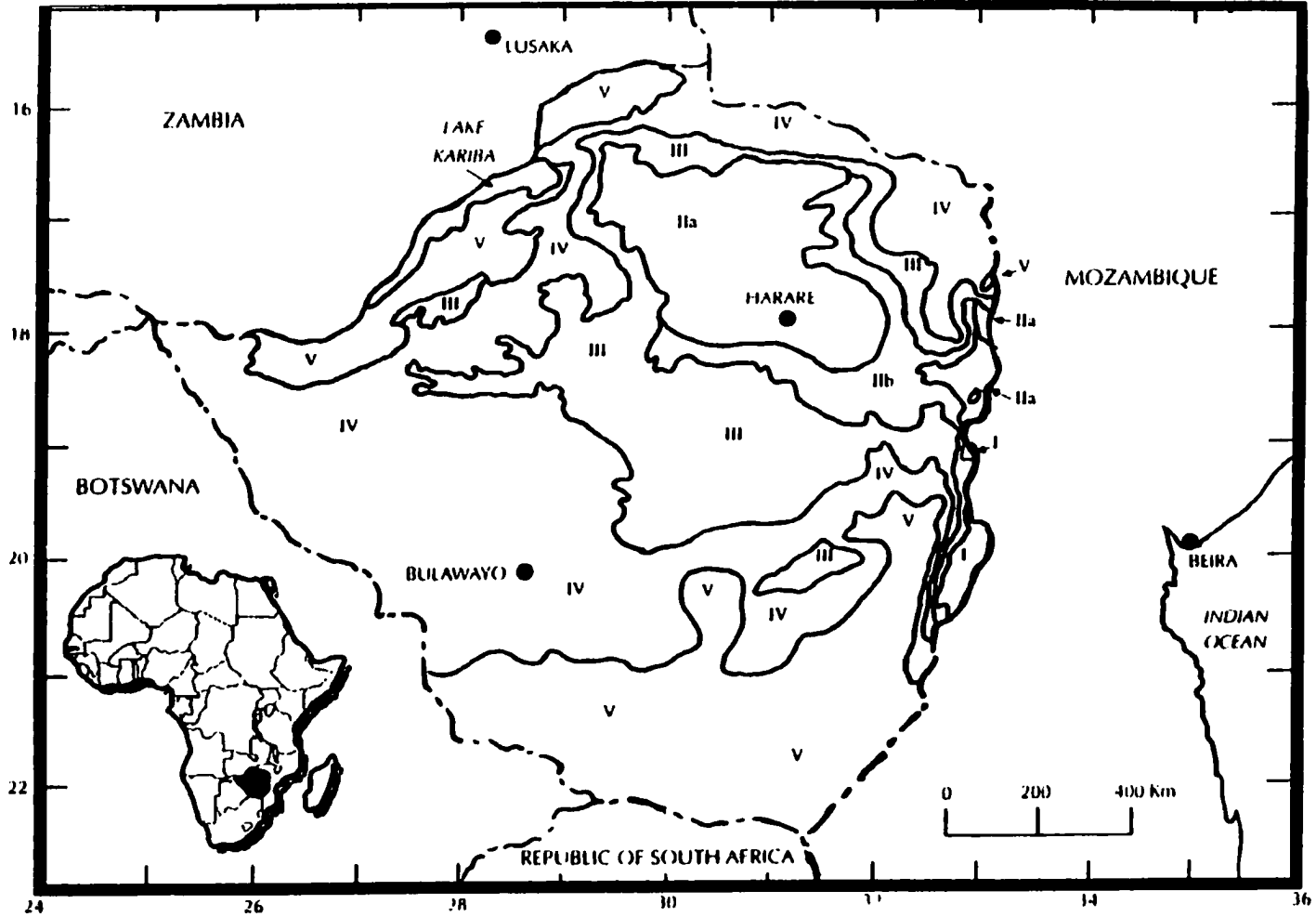


Figure 1.5: Zimbabwe: Natural Regions

1000 mm annual rainfall and agriculture is also intensive but based on crops and livestock production. It accounts for about 15 percent of the total area. Natural Region III receives between 650 and 800 mm of rainfall. Agriculture is semi-intensive and based on fodder crops, cash crops and livestock. It accounts for about 19 percent of the total area. Natural region IV receives about 450-650mm of rainfall annually. This region experiences severe dry spells during the rainy season and is drought prone. Drought tolerant crops are recommended for this region but farmers still grow food crops like maize that are not suitable for the region. Natural region IV comprises about 38 percent of the total area. Natural Region V receives less than 450 mm of annual rainfall. Because of the low rainfall, extensive cattle and game ranching are the major activities. This region comprises about 27 percent of Zimbabwe's area (CSO, 1997 a; Makombe, 1998; Makadho, 1994)

There are several land tenure and farming systems that exist in Zimbabwe. The Large-Scale Commercial farmers have land title deeds. Land in the Large-Scale Commercial Sector (LSC) is privately owned and farmers can sell and buy land. Average farm size in the LSC sector is 2223 ha (Table 1.2). Farmers grow a variety of crops and raise livestock almost completely for marketing. Market forces drive production decisions in this sector. There are a few farms held under lease arrangement in this sector. State owned farms, managed by the parastatal Agricultural and Rural Development Authority (ARDA) are also included in the LSC sector although these farms grow crops that are determined largely by the government and not by market forces.

Table 1.2. Major Features of Zimbabwe's Farming Sector.

Major Features of Farm Sub-sectors in Zimbabwe					
	Small-Scale			Large-Scale	
	Communal Area Farms	Resettlement Area farms	Small Scale Commercial Farms	Large Scale Commercial Farms (Private)	Parastatal Government Farms.
Number of farms	1,000,000	56,794	8,500	4,832	55
Total land area (million ha)	16.34	3.29	1.38	10.74	.42
Share of total agricultural land (%)	50.8	10.2	4.3	33.4	1.3
Average farm size (ha)	18	58	162	2,223	7,644
Of which Arable (ha)	3-5	3-5	10-40	Highly varied	Highly varied
% land in Natural Regions:					
1 and 2	9	19	19	35	4
3	17	38	35	22	32
4 and 5	74	43	46	43	64
Irrigated area (ha) ¹	7.2		3.6	126.0	13.5
Share of national woodland (%)	21			44	35
Estimated population ('000)	5,327	421	166	1,160	38
Population density (Persons/sq km)	32.6	12.8	12.0	10.8	9.0
Cropping intensity (Planted area/Total area) (%)	14.0	5.8	4.3	4.2	2.3
Livestock stocking rates (ha/LSU) ²	5.5	8.2	6.4	9.3	
Source: Government of Zimbabwe 3, 1994 Notes: 1. Derived from Government of Zimbabwe 2, 1994. 2. Cattle = 0.7 LSU; Sheep/Goats = 0.15 LSU.					

Small-scale commercial farms are often leased with the option to buy. When a farm has been bought, the farmer receives a deed to the land and is free to sell it. African customary law guides inheritance where the farm has not been bought. Market forces, in the main, drive production decisions in this sector but consumption decisions are also important. In this sector a variety of cash and food crops are grown. Average farm size is 162 ha (Table 1.2).

Resettlement areas resulted from the Government of Zimbabwe (GOZ) post independence attempts to correct the imbalances in land ownership that it inherited from the colonial government. In the resettlement system a farmer gets three permits; one that allows the farmer to graze livestock on a communal basis, one to reside on a given plot of land and one to cultivate an arable plot of land. The period over which the permits are valid is not specified and the settler has the right to use the land as long as the permit provisions are not violated. Farm size averages about 58 ha including the shared land, with each farmer having access to arable land averaging between 3 and 5 ha (Table 1.2).

Communal areas (formerly Tribal Trust Lands) were created by the colonial government to provide land for the indigenous African population that was displaced by the white settlers in what is now called the LSC areas. The land tenure system in the communal areas is intricate and is based on customary law. Each individual has a "right to avail" to resources. This right includes the right to cultivate land, graze livestock, fetch firewood, water, timber *etc* for domestic purposes. Each household is entitled to a residential stand. There are some communal resources, and no individual has the right to exclude another from using communal resources. (GOZ 1994a, and 1994b). Land in the communal sector

can be lent, inherited or sub-divided. It cannot be leased or sold. Farm sizes average 18 ha including the shared land with each family having access to 3-5 ha of arable land (Table 1.2)

Even though 66 percent of Zimbabwe's population makes a living from the communal areas (GOZ, 1994a) the majority of the communal sector, 74 percent, is located in the low agricultural potential regions IV and V. The land holdings in this sector are small, and population density is high. Cropping intensity is highest in the communal sector, because there is pressure to provide food and income for more people than in any other sector. These are partially some of the reasons why the government embarked on a land redistribution program post independence.

These land tenure systems resulted from formalized legislation and orders. For instance the Orders-in-Council of 1898 and the Land Apportionment Act of 1930 ensured that the European and African populations were settled in areas with contrasting land and water resources, with the Europeans occupying the better endowed areas (Cosgrove and Petts, 1990).

1.3.1 Zimbabwean Economy

The Gross Domestic Product (GDP) for Zimbabwe was estimated to be US\$8.028 bn in 1998 (World Bank, 1999b). Figures 1.6 (a) and (b) show the performance of the Zimbabwean economy. Figure 1.6 (a) shows that GDP has grown slowly over the period 1990 to 1998. The International Monetary Fund (IMF) World Outlook 2000 report

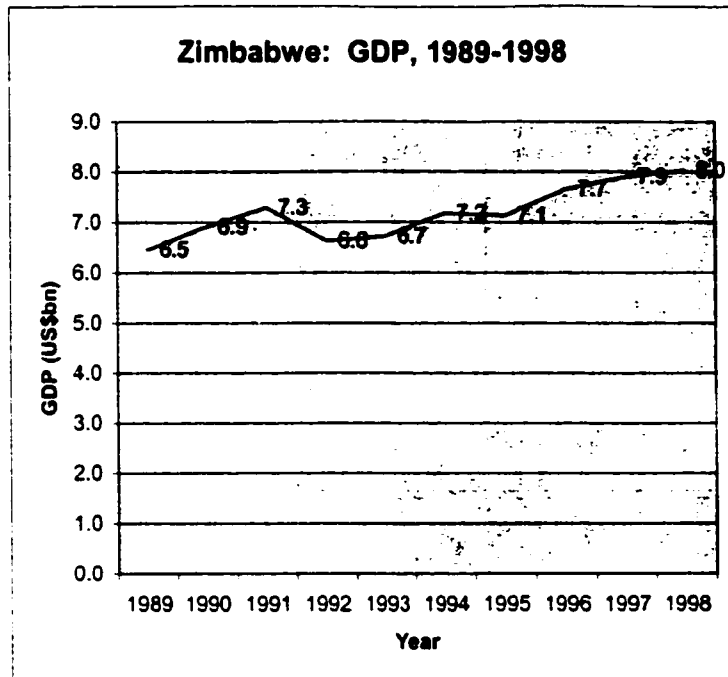


Figure 1.6a: Zimbabwe GDP Trend 1989-1998
 Source: World bank, World development indicators (1999)
<http://www.worldbank.org/data/>

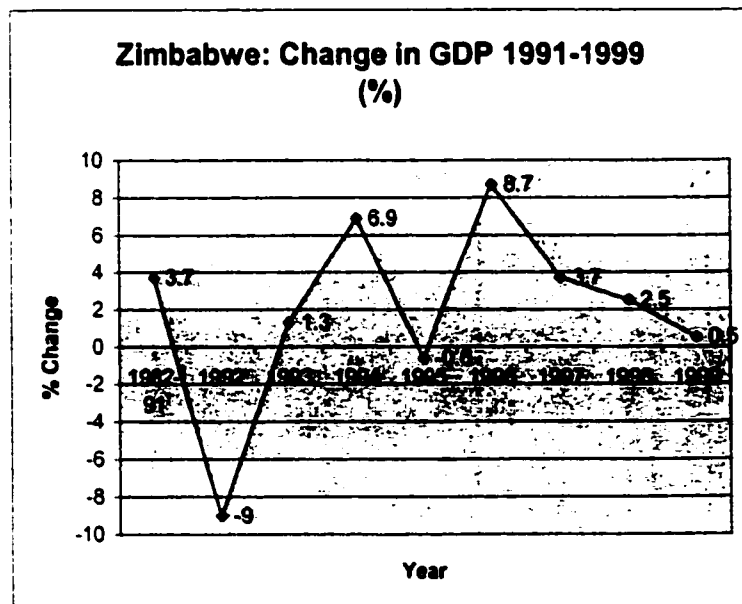


Figure 1.6b: Zimbabwe GDP growth
 Source: IMF (2000), World Economic Outlook 2000
<http://www.imf.org/external/pubs/ft/weo/2000/01/index.htm>

estimates that over the period 1982 to 1991 Zimbabwe's GDP grew by an average 3.7 percent. Over the period 1992 to 1996 GDP growth fluctuated wildly between a low of 9 percent to a high of 8.7 percent. From 1996 GDP growth shows a consistent decline since 1996. Between the years 1991 and 1999, GDP growth averaged 1.8 percent. Thus over the years economic growth has slowed down in Zimbabwe. This decline in GDP growth is a strong indicator for the need for policy reforms that can reverse it.

The IMF classifies Zimbabwe under the countries whose main source of export earnings are primary products (IMF 2000). In Zimbabwe, agriculture contributes significantly to the economy as a whole and to export earnings.

1.3.1.1 Agriculture in Zimbabwe

The importance of agriculture in the Zimbabwean economy cannot be over-emphasized. The minister of agriculture's 1994 policy statement bears testimony to the importance of agriculture to Zimbabwe's economy:

“The performance of the Zimbabwean economy is directly related to the performance of the agricultural sector with the economy doing well only when agriculture is buoyant.” (GOZ, 1994d, pp1).

Agriculture contributes on average 11 to 14 percent to GDP. In fact table 1.3 shows that in 1996 and 1997 agriculture contributed 22 and 19 percent to GDP respectively. An estimated 45 percent of the country's exports are agricultural. Agriculture employs about 70 percent of the population (formally and informally), contributes more than 60 percent of raw materials to industry and provides food for about 80 percent of the population (GOZ, 1994c and 1996).

Table 1.2 shows the major agricultural sectors in Zimbabwe namely: the communal,

Table 1.3. Sector Contribution to Gross Domestic Product at Factor Cost 1997-1998

Sector	Contribution (%)	
	GDP for 1996: Z\$75225 M	GDP for 1997: Z\$86761 M
Agriculture and Forestry	22	19
Mining and Quarrying	2	2
Manufacturing	18	18
Electricity and Water	3	3
Construction	2	3
Finance and Insurance	7	8
Real Estates	2	2
Distribution Hotels & Restaurants	20	20
Transport and Communications	6	6
Public Administration	5	5
Education	8	9
Health	2	2
Domestic Services	1	1
Other Services	4	4
Imputed banking services charges	-1	-1

Source: CSO Facts and Figures 1998

resettlement, small-scale commercial, large scale commercial and state farm sectors. Currently the land distribution pattern between these sectors is as follows; a million communal area farmers on about 16 million ha, 56,794 resettlement farmers on about 3.3 million ha, 8,500 small scale commercial farmers on 1.38 million ha, 4,832 large scale farmers on slightly more than 10 million ha and state farms on 0.42 million ha. (Table 1.2).

Given the importance of agriculture, the government of Zimbabwe's development strategy and policy emphasizes the agricultural sector. This sector can be effectively used as one of the strategies for reversing the downward spiral in GDP growth that Zimbabwe has experienced recently.

1.3.1.2 Zimbabwean Agricultural Policy

There are four basic fundamentals that guide the Zimbabwean agricultural policy:

- a. Transforming smallholder agriculture into a fully commercial farming system.
- b. Achieving an agricultural growth rate that is significantly larger than population growth.
- c. Developments of physical and social infrastructure in the rural areas through out the country.
- d. Developing a fully sustainable farming system through out the country, which controls the current environmental degradation and soil erosion.

(GOZ, 1996)

The current agricultural policy in Zimbabwe emphasizes the importance of developing the smallholder sector:

“The underlying thrust of government intervention.....will be directed towards the smallholder sector. Farmer training, extension and research will be intensified and targeted specifically at this objective” (GOZ, 1996, pp 2).

The government of Zimbabwe, among other development strategies uses irrigation development as one of the vehicles for achieving its policy objectives.

1.3.1.3 Irrigation Development and Potential in Zimbabwe

Figure 1.1 indicated water withdrawal as a percentage of internal renewable water resources ranges between 5 and 25 percent in Zimbabwe, suggesting considerable potential for water resources development. Currently an estimated 119,038 ha have been developed for irrigation of which about 82 percent is on 1,500 large scale commercial farms, 11 percent is on large scale state farms and about 7 percent on smallholder schemes (Table 1.2). The commercial irrigated farms grow a variety of crops ranging from apples in Natural Region I to maize, tobacco and flowers in other regions. ARDA estates grow crops that are seen as critical by the government. These include wheat, cotton and sugar cane. They also grow commercial crops like rice, paprika and pineapples.

There are four smallholder irrigation management systems in Zimbabwe, namely the Agritex managed system, community managed, ARDA smallholder outgrowers and the informal *bani (dambo)* system. The Agritex systems are completely managed by the government through the Agricultural Technical and Extension Services (Agritex), the national agricultural extension body. Agritex makes the decisions about what to plant, when farmers should plant and the timing and quantities of inputs. Farmers are required to follow the Agritex recommendations. Agritex is also responsible for maintenance. Average plot size on the Agritex systems ranges from 0.1 to 4 ha. Water sources are usually dams or river diversion weirs. Concrete lined canals deliver water. Agritex systems are developed by the government and farmers on Agritex systems pay maintenance fees which ranged between Z\$30 to Z\$145 per ha per year in 1994,

depending on the reliability of water supply. Farmers on Agritex systems grow maize as the major summer crop. Maize is usually sold green but it can also be left to mature to grain. Other summer crops include cotton, beans, groundnuts and okra. Winter crops include wheat, tomatoes, beans, onions and a variety of green vegetables (Makadho, 1994).

The community managed systems are similar to Agritex systems. The differences are that the community systems were largely developed by missionaries and then handed over to farmers. Farmers make their own production decisions and they are responsible for scheme maintenance, so they do not pay maintenance fees to government. However, farmers receive extension advice, which they follow at their own discretion. Plot size and cropping patterns are similar to those of Agritex systems.

Some ARDA state farms support smallholders called outgrowers. The smallholders on ARDA systems have land holding ranging from 0.8 to 10 ha (Makadho, 1994). They get support from the parastatal and enjoy economies of scale if they order their inputs at the same time as the estate. They can also hire equipment from the estate. Cropping patterns are strongly influenced by the parastatal estate.

For detailed descriptions of the management of the Agritex, community and ARDA systems see Rukuni, Svendsen, Meinzen-Dick and Makombe, 1994; Manzungu and van der Zaag, 1996).

The *bani* (*dambo*) system is controlled by local village leaders usually headmen. These leaders are responsible for identifying who gets a plot, referred to as a garden, its location and size. Plot sizes range from 0.1 to 0.5 ha (Andreini, 1993). The cropping pattern is similar to that of the Agritex and community managed systems. *Banis* are seasonally saturated pieces of land, which tend to have high water tables during the summer, the rainy season in Zimbabwe. They are usually open grass covered depressions at the headwaters of streams. The *bani* system is referred to as informal because the Agritex, community and ARDA systems are encouraged by the government as development alternatives whereas the *bani* system is not. A major reason for this has been the argument that the environmental impacts of *bani* cultivation are not known. However *bani* cultivation has been recorded as early as the 1800's and as Bell and Roberts (1991) point out, no significant evidence of environmental degradation in the *bani*'s has been attributed to cultivation. Unlike on the Agritex and community schemes the main water sources on *bani* systems are wells which are dug in the *bani* garden. Water is delivered to the plants using hoses, buckets and watering cans. During the times when the water table is high, farmers use open channels to drain excess water or to deliver water to plants. During these times a substantial portion of the crop water requirements is met by sub irrigation (Andreini, 1993).

For detailed descriptions of the organization of the *bani* system see Whitlow, 1984; Turner, 1986; Roberts, 1988; Bell and Hotchkiss, 1989; McFarlane and Whitlow, 1990; Bell and Roberts, 1991; Scoones and Cousins, 1991; Andreini, 1993; and Rukuni *et. al.*, 1994.

It is important to note that because the ARDA outgrowers have plot sizes much larger than many smallholder irrigators in Zimbabwe sometimes they are not included in the statistics for smallholders. Thus the figure of 7 percent land developed for smallholders does not include ARDA smallholders. If these are included then the figure increases slightly to about 9 percent.(Makadho, 1994) National irrigation statistics also do not include the informal *bani* systems.

There are about 5,700 dams on the commercial farms and in addition government developed dams are generally more accessible to these farms than smallholders. The state farms have irrigation infrastructure that is comparable to the commercial farms. Irrigation infrastructure and water development is still at a rudimentary stage in the communal and resettlement areas due to historical imbalances that were created by the colonial government. This is ironical given that one million farm families earn a living in the communal and resettlement areas (Table 1.2).

Estimates show that there are 600,000 ha which are potentially irrigable. However there is a lack of correlation between the location of water and the location of the irrigable land. The total water resources available amount to 11,200 million cubic meters(MCM) of which 8,500 can be exploited. Of this about 4,760 MCM are being exploited leaving a potential of 3,740 MCM. Assuming that 80 percent of this water potential is used for agriculture then 2,992 MCM would be available for irrigation development. This amount of water can irrigate 250,000 ha at current levels of water use efficiency. (GOZ, 1994c).

This means that only about 32 percent of possible total of 370,000 ha have been developed so far.

The Zimbabwean irrigation development policy aims to exploit this potential.

1.3.1.4 Irrigation Policy in Zimbabwe

The agricultural sector in Zimbabwe is largely dependent on rainfall. The country is prone to frequent droughts which, can be devastating as illustrated by the minister of agriculture's statements with reference to the drought that followed the 1991/92 production year:

“Of the one million families in the communal, resettlement and small scale areas, it is estimated over 80 percent have been seriously affected by drought. Most of the smallholder farmers relying on farm income and food retention from their own family farms are threatened by starvation unless food is provided free of charge” (GOZ, 1994d, pp 18).

And...

“In many parts of the country the drought has been nothing less than a catastrophe, and a complete recovery will require several years of sustained effort” (GOZ, 1994d, pp. 11).

Makarau uses rainfall data from 1903 to 1994 to estimate the frequency of occurrence of droughts defined as:

“...when the Zimbabwean summer rainfall is at least a standard deviation below the long term mean” (Manzungu *et al*, 1999, pp 4).

Using this definition he estimates that droughts occur with a frequency of 17 percent.

Using the converse definition of a drought, Zimbabwe receives above normal rainfall 12

percent of the time. This means that more than 70 percent of the years are at least normal, giving potential for the storage of water.

Given this potential, the Zimbabwean government, to mitigate the effects of droughts, uses irrigation development:

“There are valuable steps that can be taken to limit the effects of drought: dams are being built in order to increase irrigation capacity...” (GOZ,1994d, pp. 16).

In the irrigation policy, the Zimbabwean government promulgates that;

“The major objective of this (irrigation) policy is to achieve greater and more sustainable irrigation development in order to develop the remaining potential estimated at 250 000 ha. The policy recognizes that specific objectives for each farming sub-sector will be elaborated on at operational levels given the differences in priorities, design potential and constraints.” (GOZ 1994c, pp v.)

The key national irrigation policy guidelines are:

- a. To increase the rate of development of water resources with emphasis on greater efficiency and equity of water use. Greater effort to exploit ground water.
- b. Water allocation should take into account all uses, agriculture, urban (domestic) and industry.
- c. Irrigation technology to cover sprinkler, surface and micro irrigation shall be made available to all categories of irrigation farmers in spite of any current patterns of adoption and use. Priority should be placed on farmer-managed and operated systems. Where the government may assist in the development of irrigation facilities,

the farmers should retain responsibility for operation and maintenance of the irrigation system.

- d. The necessary institutional capacity for development shall be enhanced for the public and private sectors. Within the public sector, better coordination shall be achieved particularly between the extension organ AGRITEX, Department of Water Development and other implementing agencies involved in irrigation development from planning to implementation.
- e. There is need to invest in human resources development in irrigation in order to implement the strategy and to meet the objectives of the policy. Manpower planning shall encompass present and future needs both in terms of quantity and quality. Training should also be cognisant of the multidisciplinary nature of the river basin approach to planning and development.
- f. Effective water users associations shall be encouraged and facilitated in order to involve irrigation farmers and other water users and interest groups to participate fully in planning and development and evaluation of irrigation projects. The current River Boards and Irrigation Management Committees should be reformed and strengthened to allow broader participation and greater responsibility in irrigation development.
- g. Irrigation farming is a significant user of electricity accounting up to 9% of total national consumption. In future, irrigation planning, design and implementation has to be better coordinated with the power authorities at all stages of system development. In addition, small electricity generation units must be developed where

appropriate in order to supply rural irrigation communities with power for pumping and domestic use.

- h. Environmental sustainability of irrigation projects is a key policy objective and all future development shall incorporate adequate assessment and monitoring of this aspect. Environmental quality should be maintained in the broad areas of soil quality, water quality, pesticide use, use of wetlands for cropping and grazing, human health and settlement. Irrigation development shall observe all laws pertaining to the environment. In future all development shall be preceded by a full environmental impact assessment (EIA). Guidelines shall be developed for assessing smaller systems where full EIA may not be justifiable.
- i. Equity of water availability and use is a major policy requirement in order to achieve greater and wider farmer participation and increase production. In future water allocation should take into account and address the imbalances in water supply between large and small irrigators.
- j. The water act No 41 of 1976 is the major law and this act should undergo review as a matter of urgency, and periodic reviews to accommodate changing needs.
- k. Land reform and land tenure policies should allow greater access to land and water by irrigation farmers.
- l. Development of major irrigation infrastructure on state land is the responsibility of the government. At the same time, government should provide a policy environment, which would encourage private investment in irrigation.

- m. **Water pricing policy on future should reflect the scarcity of this valuable commodity. The price of water, therefore, should take its opportunity cost into consideration in order to arrest its wastage and inefficient use.**
- n. **It is policy that in future, costs of operation and maintenance of irrigation systems be met directly by beneficiaries. Any subsidies on O&M costs should be justified and targeted on a case by case basis.**
- o. **All irrigation development in future should be subjected to economic analysis. The Government and other interested parties shall also establish a system of monitoring evaluation and impact assessment of irrigation development.**
- p. **Annual returns stating area (ha), crop and season shall be made by every irrigator to the Central Statistical Office at the end of every irrigation year (April-March).**

The overall strategy for sustainable irrigation development is based on a sustained contribution by Government of Zimbabwe towards irrigation development, particularly for smallholder farmers in communal and resettlement areas. An integrated approach to planning and implementation, based on the principles of sustainable development will be used. Further, to be achievable, the following reforms shall be embarked upon as a matter of priority:

- a. **Implement legal reforms, especially the Water Act of 1976, so as to allow greater and more equitable irrigation development.**
- b. **Institutional restructuring and strengthening of Agritex and DWD in order to ensure capacity to execute and expand the program of action.**

- c. Adopt a river basin as a unit of irrigation planning and development.
- d. Invest in human capital at professional, managerial and technical levels in order to manage the strategy
- e. Involve all stakeholders in the planning and development process ; and
- f. Invest in irrigation research, technology development and testing.

These Irrigation policy guidelines are as listed in GOZ (1994c), with very minor rephrasing by the current author.

The specific objectives in irrigation development are listed as:

- a. Growth in area under irrigation with minimum negative environmental effects.
- b. Efficient use and equitable allocation of the scarce water resources
- c. The establishment of an irrigation water pricing structure which is commensurate with the cost and social efficiency
- d. The establishment of the institutional structure to represent irrigation stakeholders and to implement the proposed policies. (GOZ, 1994c).

1.3.1.5 Constraints to Irrigation Development

Although the government of Zimbabwe aspires to develop irrigation in order to increase rural incomes and food security and to increase the contribution of agriculture to economic development, it is constrained by a numerous factors which include:

- a. **Capital:** This is mostly limiting in the rural areas. Commercial farmers have enjoyed relatively good and sustainable access to capital for irrigation development.
- b. **Institutional capacity:** institutional constraints include small budgets and inadequate human capital. Institutional constraints are particularly binding for smallholder irrigation development, since irrigation development has previously been left to private initiative.
- c. **Water legislation:** The Water Act of 1976 has perpetuated pre-independence inequalities in water development between the Zimbabweans of European origin and the indigenous Africans. This act needs to be reviewed to suit current needs and realities.
- d. **Land tenure:** Farmers on state land, including the majority of the population (about 70 percent) living in communal lands, have no incentive to invest in land given the tenure that exists in these areas.
- e. **Land:** There sometimes is a mismatch between the location of irrigable land and readily exploitable water.
- f. **Markets and infrastructure:** the viability of smallholder irrigation systems is reduced by their long distances away from markets and the poor transport infrastructure that is characteristic of communal areas.
- g. **Water use efficiency:** Efficiency of water use is generally low, thus reducing the amount of land that can be developed. (GOZ, 1994c).

1.4 Plan of work

The findings of this study are presented in five independent chapters starting from chapter 2. Each chapter broadly comprises a subject introduction, the study objectives,

data requirements, methodology, results and discussion. Most of the data used in the analyses was collected from the UZ/IFPRI/Agritex Irrigation Performance in Zimbabwe Project. This was a large research project conducted by the University of Zimbabwe (UZ) and Agritex in collaboration with the International Food Policy Research Institute (IFPRI) and jointly funded by the Rockefeller Foundation and The International Development Research Centre (IDRC). Where applicable, this project is cited in the respective chapters. The data were collected from the 1990/91 summer and 1991 winter seasons. Since the data sources for this project were many each chapter indicates the sample used and the data pertinent to it. Sometimes the samples and data used in the different chapters overlap, but sometimes they do not.

Chapter 2 presents the findings from an analysis of the benefits of irrigation-induced technology using maize since it is a staple crop in Zimbabwe. A Marshallian partial equilibrium analysis is used to estimate benefits of irrigation development to consumers and producers to determine if the net benefits from irrigation are positive or negative. Chapter 3 looks at the water management performance of the smallholder irrigation systems in Zimbabwe. The Theil information theoretic measure is used to determine how accurately farmers match supply to crop water requirements. In Chapter 4 a simple benefit cost analysis is carried out for the smallholder irrigation systems using gross margins and input costs. Chapter 5 analyses the influence of socioeconomic variables on the performance of the smallholder systems using gross margins as the performance measure. Chapter 6 looks at the potential of the traditional (informal) *bani* smallholder irrigation system to determine whether it can be used as a smallholder irrigation

development strategy along with the formal Agritex and community systems. Chapter 7 provides an overall discussion of the results from the five chapters and offers some insights into policy recommendations for future irrigation development in Zimbabwe. This inquiry is guided by the hypotheses listed below.

1.5 Hypotheses

Irrigation as a development strategy has usually been taken for granted. Many times, the benefits of irrigation-induced technology have been assumed and not quantified or measured. This study will attempt to measure the benefits of irrigation induced technology in Zimbabwe by testing the hypothesis that the impact of irrigation induced technology is positive for both producers and consumers in Zimbabwe.

A major hypothesis guiding this inquiry is that smallholder irrigation systems are efficient and should be used as a development strategy to improve the living standards of the rural poor in Zimbabwe. The hypothesis that farmer managed systems are more efficient than government managed ones will also be tested. It is also hypothesized that the informal *bani* system achieves the objectives of irrigation and should be developed along similar lines as the other formal systems.

Chapter 2

An analysis of the impacts of irrigation-induced technological change in Zimbabwe

2.1 Introduction

Moris and Thom (1990) point out that most African countries do not have explicitly stated policies for developing irrigation. They argue that every country wishing to invest in irrigation should do so after clearly weighing the advantages and disadvantages. The evaluation of irrigation projects has been based mostly on the present value of future cash flows as recommended by the World Bank (Rydzewski, 1990). The evaluation of irrigation development can also be assessed from an aggregate perspective as offered in this chapter.

2.2 Objectives

The objectives of this study are to evaluate the benefits of irrigation induced technology in Zimbabwe by estimating benefits to consumers and producers and then evaluating whether the net benefit is positive or negative.

2.3 Evaluating the benefits of irrigation induced technology

In order to evaluate the benefits of irrigation induced technology, the model developed by Hayami and Herdt and further refined by Ahmed and Sampath (1992) is used. This

model incorporates the semisubsistence characteristics of crops like maize in Zimbabwe, for which part of the production is sold and part retained for own consumption by the producers. The model uses shifts in demand and supply to evaluate the benefits of irrigation induced technology. An evaluation of the gains and losses from producers and consumers is used as the evaluation criterion.

Maize is a staple crop and is grown on about 50 percent of agricultural land in Zimbabwe (Makadho, 1996a). The availability of maize determines food security for about 70 percent of Zimbabwe's population. On the large-scale commercial sector, about 9.1 percent of irrigated land is cropped to maize, compared to 68 percent on the smallholder sector. Given its importance, maize is used in the quantification of the benefits of irrigation induced technology. Figure 2.1 shows a graphical representation of the model.

This model utilizes the Marshallian partial equilibrium analysis. It is assumed that numerous growers grow the semi-subsistence crop maize such that perfect competition is approximated in the local maize market. The model is used to evaluate the gains and losses between consumers and producers as a result of irrigation development.

From figure 2.1, lines R^0R_0 and R^1R_1 represent maize retentions by producers for home consumption before and after irrigation development. After irrigation development, retentions will most likely increase given the fact that before irrigation development some of the households were deficit households and would retain more if their production were to increase as would result from irrigation development. This, coupled with an increase in both population and per capita income means that $R^0 R_0 < R^1 R_1$. The horizontal

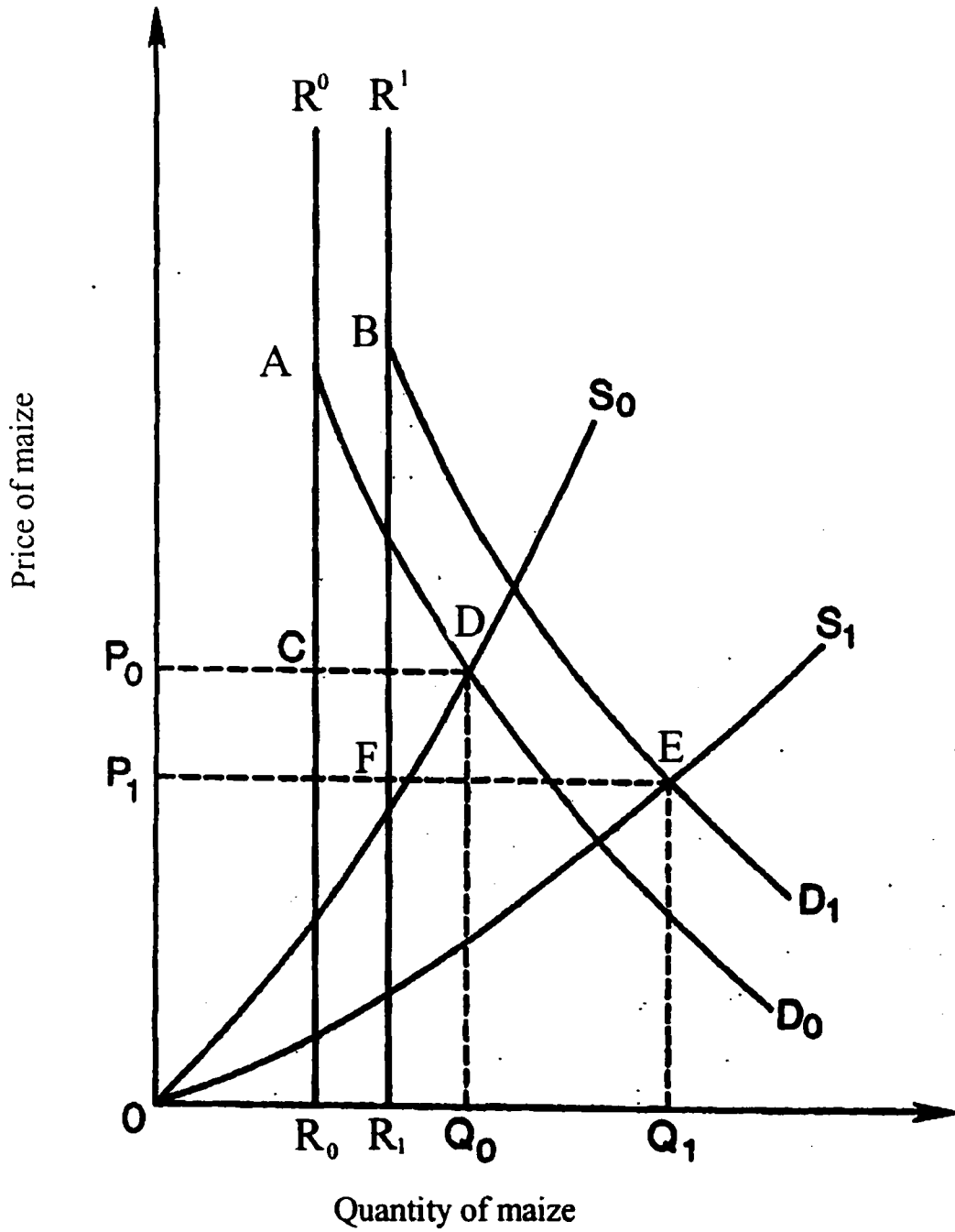


Figure 2.1: A model to estimate the benefits of irrigation induced technology

distance between $R^0 R_0$ and the market demand curve AD_0 represents what the deficit farmers and non-maize producers buy from the maize market. This is referred to as gross marketable surplus, which is provided by the surplus producers. The demand curve $R^1 BD_1$ represents the aggregate demand shift from $R^0 AD_0$ as a result of the development of irrigation. D and E represent the market equilibria before and after irrigation development respectively. The change in consumer surplus is therefore represented by $BEF - ADC$.

To measure the change in producer welfare, it is important to note that all the production is not sold. Some is retained. In this case it is not appropriate to use the traditional concept of producer surplus given by ODP_0 and OEP_1 prior to and after irrigation development respectively. Instead we will use the change in costs and the change in revenue. The change in revenue is given by $R_1 Q_1 EF - R_0 Q_0 DC$. The change in costs is given by $OQ_1 E - OQ_0 D$. Thus the change in producers cash income is given by the difference between the change in cash income and the change in costs given by $(R_1 Q_1 EF - R_0 Q_0 DC) - (OQ_1 E - OQ_0 D)$.

The mathematical model assumes that a constant price elasticity of demand market demand function can be specified as follows:

$$(2.1) \quad Q = \alpha p^{-\gamma}$$

Where p and Q are the price and quantity of maize demanded, respectively, γ is the price elasticity of demand and α is a constant.

A constant elasticity of supply function is expressed as follows:

$$(2.2) \quad Q = \beta p^{\delta}$$

Where Q and p are the quantity supplied and maize price respectively and δ is the price elasticity of supply.

The rate of increase of demand for maize will depend on the rate of population growth and the growth of per capita income. Let the shift in demand be represented by:

$$(2.3) \quad x = N + \eta Y$$

Where N is the rate of change in population, η the income elasticity of demand and Y is the change in per capita income.

If we assume an x shift in demand and a c shift in supply due to increase in irrigation, the new respective demand and supply are given by:

$$(2.4) \quad Q = \alpha(1+x)p^{-\gamma}$$

$$(2.5) \quad Q = \beta(1+c)p^{\delta}$$

Where c is given by the fraction of total maize production before over the total production after irrigation development.

From Figure 2.1 the change in consumer surplus described above can be mathematically represented as:

$$(2.6) \quad \Delta CS = P_0 Q_0 [1/v \{ u(1-(1-r_1)^v) - (1-(1-r_0)^v) \} - (ur_1 - r_0)]$$

Where:

$$u = (1+x)^{(1+\delta)/(\delta+\gamma)}(1+c)^{(\gamma-1)/(\delta+\gamma)},$$

$$v = 1-(1/\gamma) \text{ and}$$

r_0 and r_1 are the initial and final gross marketable surpluses expressed as fractions of total output for the initial and final conditions respectively.

From Figure 2.1 producer's revenue also as described above, changes by :

$$(2.7) \quad \Delta R = P_0 Q_0 (u r_1 - r_0)$$

And change in costs is represented by:

$$(2.8) \quad P_0 Q_0 w (u - 1)$$

$$\text{Where } w = \delta / (\delta + 1)$$

The change in producers cash income is given by change in revenue less change in costs given by:

$$(2.9) \quad \Delta CI = P_0 Q_0 \{u(r_1 - w) - (r_0 - w)\}.$$

The net result of the development of irrigation is given by the sum of the changes in consumer surplus and producers' cash income.

$$(2.10) \quad \text{Net benefit} = \Delta CS + \Delta CI.$$

For a more detailed exposition of the model, refer to Sampath and Ahmed (1992).

2.4 Data

The most current national statistics for Zimbabwe go up to 1997 (CSO, 1998a), therefore 1997 is used as the base year. It is assumed that the 250,000 ha potential will be fully developed in a 10 year period up to 2007. GDP in 1997 was Z\$68885.47 (CSO, 1998a) and was assumed to grow at 2.1 % per year (World Bank, 1999a) to Z\$84797.92 in 2007. Smallholder irrigated maize yield is given as 3.72 t/ha and that of commercial farmers as 5.8t/ha (CSO, 1997b). The value added from maize production will be the cause of the change in per capita income, other things constant. Value added from commercial production is estimated as 49.3% of gross output whereas it is estimated as 80.9% of gross agricultural output for smallholder systems. The difference is largely due to the fact that the commercial system is capital intensive whereas the smallholder systems tend to be lower input systems even under irrigation (GOZ, 1999). The value added is computed for the additional maize production resulting from irrigation development and this is added to the 1997 GDP and then these figures are used to compute the change in per capita income with GDP being used as a measure of income.

Five scenarios of irrigation development are analyzed. The first assumes that all the 250,000 ha will be developed into commercial systems, the second assumes that the distribution will follow the current one which is 93% commercial and 7% smallholder, the third assumes an equal distribution of additional irrigated area between commercial and smallholder systems, the fourth assumes a reversal of the current distribution with 93% being developed into smallholder systems and only 7% into commercial while the fifth assumes all smallholder development.

The price elasticity of demand for maize is estimated as -0.6, income elasticity of demand is estimated as 0.86 while price elasticity of supply is estimated to vary between 1.87 and .055 (Sukume, 1988). The midpoint of 1.21 is used as the price elasticity of supply for the initial analysis and sensitivity analysis is conducted to see the impact of the price elasticity of supply. Since estimates of these three parameters are only found from one study, sensitivity analyses will be conducted for all three parameters. The Ministry of Lands and Agriculture estimates that gross marketable surplus averages 65.1% of gross output (GOZ, 1999). For simplicity, it is assumed that this does not change over the ten years in question.

2.5 The impacts of irrigation-induced technological change in Zimbabwe

The results of the estimation of the benefits of irrigation-induced technology are given in Table 2.1. Per capita income change is very small and negative. This is because population growth is greater than the rate of GDP growth. In order for the net benefits to be positive, the distribution of irrigation development needs to be skewed towards smallholder development. This is shown by the fact that the even distribution option has a negative net benefit. Policy choices however depend on whose needs are being addressed by a policy instrument. In this case, if net benefit is the desired result, then clearly the options emphasizing smallholder development are superior to the alternatives. However, in the case where the well-being of producers is the issue, then there can be circumstances under which the alternatives emphasizing commercial development might be desirable, but this will be at the expense of consumers. It is also apparent that the current distribution gives more benefits to producers in the commercial sector over the

bulk of the consumers who are located in the smallholder sector. This means that the current distribution of irrigation in Zimbabwe does not satisfy the governments aspired objectives of equitable distribution of the productive resources (GOZ, 1996). In the smallholder maize sector in Zimbabwe there is no clear separation between producers and consumers, and so it appears that the policy emphasizing the development of smallholder irrigation would better achieve the equity objective.

Table 2.1. Benefits of Irrigation Induced Maize Technology in Zimbabwe

Z\$ Change in	Distribution of irrigation development				
	100% Commercial	7% Smallholder	50% Smallholder	93% Smallholder	100% smallholder
Per capita income	-.0004	-.0004	-.0004	-.0003	-.0003
Consumer Surplus	-810.93	-653.64	-54.91	226.57	257.47
Producer cash income	281.56	226.93	19.07	-78.66	-89.34
Net Change	-529.42	-426.71	-35.85	147.91	168.08

Given that the parameters used in this study were obtained from one study, sensitivity analysis was conducted to see if the results are sensitive to parameter changes. The ranges used were -.1 to -1.1 for the price elasticity of demand, 0.36 to 1.36 for the income elasticity of demand and 0.55 to 1.87 for the price elasticity of supply. The results are not sensitive to changes in the first two parameters but they are sensitive to changes in the price elasticity of supply. When the price elasticity of supply is lower than 0.6, the development of smallholder irrigation results in lower net benefits than the development of commercial irrigation, largely due to the large negative changes in consumer surplus

under these circumstances. In order to be sure about which development option to pursue, it is essential to establish if the price elasticity of supply for maize is greater than 0.6 in Zimbabwe.

Zimbabwe is one of the countries that have been severely affected by the AIDS pandemic such that the population estimates used in this analysis may be on the high side. We do a sensitivity analysis using negative and zero population growth rates since we do not have estimates that incorporate the potential impacts of AIDS on the population. The results of this sensitivity analysis shows that the benefits from irrigation development become positive irrespective of which option is chosen, but are still higher for the options emphasizing smallholder development.

2.6 Discussion

This analysis shows that the impacts of irrigation induced technology are not always positive. In Zimbabwe in the irrigated maize sector, they become positive when more than 50 percent of the irrigation development is smallholder. If the intention of irrigation development is to maximize the benefits from irrigation induced technology, then the development skewed towards the smallholder sector is the desirable option. In the application of this type of analysis to policy options, it is essential to identify which group, producers or consumers is intended to benefit. Even though the option of no smallholder development has the lowest net benefit, it has the highest benefit to producers. So if the policy is intended to benefit producers, the option where there is no irrigation development in the smallholder sector becomes a superior option.

Issues of the equitable distribution of the benefits of irrigation are important to the government of Zimbabwe (GOZ, 1996). Given the fact that smallholder irrigation will be accessible to more farmers and farm families, it is likely that the development of the smallholder irrigation would lead to a more equitable distribution of these benefits. The majority of poor Zimbabweans live in the low agricultural potential and drought prone areas where they are at the risk of food insecurity. It therefore appears that emphasizing the development of smallholder irrigation is likely to have the greatest impact on poverty and food security.

Chapter 3

An analysis of the water management performance of small holder irrigation schemes in Zimbabwe.

3.1 Introduction

Very often, on an irrigation schemes one hears the complaint that irrigation water is wasted (Small and Currathers, 1991). In the process of developing irrigation projects a lot of attention was paid to trying to make resource use on the farms as efficient as possible. As mentioned earlier, projects were evaluated on the basis of discounted future cash flows. This completely left out some of the factors that have the potential to influence the success or otherwise of an irrigation project. A key component is the farmer's management skills through which the output of the engineering works, water, becomes an input into the production system (Rydzewski, 1990). Needless to say, water is one of the most important single inputs on an irrigation scheme, particularly in the areas where moisture is the most limiting factor to crop production as is typically the case with winter crop production in Zimbabwe. The water management skills of the farmers are therefore critical. Water management sometimes, but not always, boils down to matching crop water demand and supply. Simple though it might sound, this can be a daunting task for farmers, especially smallholders given their circumstances. This chapter gives insight into the water management performance of smallholder farmers in Zimbabwe.

3.2 Objectives

The water management performance of the small holder irrigation systems is evaluated in terms of meeting crop water requirements. Each scheme is analyzed individually and a comparative analysis between the Agritex and community systems is carried out. The objective is to identify which management system better achieves the objective of meeting the crop water requirements and based on this make recommendations about which management system should be adopted for future small holder irrigation development.

3.3 Data

The data used in this study were collected from 12 schemes comprising 9 Agritex and 3 community schemes, roughly representative of the distribution between Agritex and community systems in the country. Table 3.1 summarizes some of the characteristics of the sample schemes. Cropped areas and cropping intensities are generally lower during the winter because less water is available due to the absence of rainfall in the winter. During the summer, farmers produce crops both on the irrigated plots and on dry land plots. During the winter dryland plots cannot be used because of moisture limitations and crop production only occurs on the irrigated plots. Prices for crops grown during the winter are therefore generally higher than those grown during the summer and farmers who own irrigated plots try to take advantage of this price difference between winter and summer crops but often water availability limits the extent to which this can be done.

Table .3.1. Developed area, cropped area, plot size and cropping intensities for sample Agritex and community systems.

Scheme name	Developed area	CAS ¹ (ha)	CIS ² %	CAW ³ (ha)	CIW ⁴ %
Shagari ^a	25.9	20.2	78.0	13.8	53.0
Senkwazi ^a	29.3	23.3	78.9	19.1	66.0
Tawona ^a	162.8	151.8	93.0	109.7	68.0
Chibuwe ^a	304.1	298.8	98.0	166.2	55.0
Chakohwa ^a	86.5	86.5	100	78.4	91.0
Mabodza ^a	11.8	11.8	100	7.0	59.0
Sachipiri ^a	40.5	15.0	37.0	26.0	65.0
Nyamaropa ^a	417.4	396.5	95.0	159.0	38.0
Mwerahari ^a	3.1	3.1	100	2.3	74.0
Bangure ^c	14.0	13.2	94.0	13.2	94.0
Mkoba ^c	10.1	9.9	98.0	8.9	88.0
Mutambara ^c	144.2	132.7	92.0	62.4	43.0

1 = cropped area in summer 1990 2 = cropping intensity in summer 1990 3 = cropped area winter 1991

4 = cropping intensity winter 1991 a = Agritex c = community

Source: Makadho (1994)

For the small holder systems the challenges faced by the managers are first that of matching water demand and supply, and second making sure that farmers apply the water efficiently without waste. A third concern is that managers also want to supply the water in a timely manner (Rukuni *et. al.* 1994). The study addresses the issue of how successful the Agritex and community systems are at matching water supply and demand. The other issues raised above namely efficient and timely water application require detailed farm level data analysis which was not done in this study. Makadho (1996b) addresses issues of timeliness of water application on smallholder irrigation systems in

Zimbabwe. All the sample schemes use open lined canals. Cutthroat flumes were used to measure the water that was supplied to specific blocks in the schemes. Daily measurements were made from each of the flumes. The data from the daily measurements were aggregated over ten day periods. This divided the summer and winter into roughly 18 ten day periods each. Crop water requirements for the respective blocks and ten day periods were estimated using the modified Penman method (Doorenbos, 1984).

In evaluating the managerial ability of a system to supply the required water, the amount supplied over a ten day period was compared to the crop water requirements for that ten day period for each scheme for the summer and winter seasons. Because there is rainfall during the summer, there is the need for adjusting the demand based on rainfall. Rainfall at each scheme over each ten day period was measured using rain gauges. The crop water requirements for each ten day period was adjusted downward by the amount of rainfall. For instance when rainfall equaled or exceeded the estimated crop water requirements, the latter was considered to be zero since in that case no water was supposed to be supplied from irrigation, and in contrast when rainfall was less than estimated crop water requirements, the latter was adjusted downwards by the amount of rainfall for that ten day period since this is the amount that should have been supplied by irrigation. The demand or adjusted crop water requirements and the aggregate supply over the ten day period were compared to evaluate how much of the water that was expected to be supplied by irrigation was actually supplied. In making this adjustment, effective rainfall should have been used instead of the actual quantity of rainfall. In the

absence of estimates of effective rainfall, the actual quantity of rainfall was used for this adjustment. It should be noted that, though it is unlikely to change the results of this analysis, using the actual quantity of rainfall in this adjustment has the tendency to underestimate irrigation requirements.

The data for this study were collected under the UZ/IFPRI/Agritex Irrigation Performance in Zimbabwe Project .

3.4 Managerial performance analysis

In order to evaluate managerial performance, water supplied was compared to desired supply as measured by the adjusted crop water requirements for each ten day period. The deviation of actual supply from the desired supply gives a measure of how accurately the water management system is achieving the desired supply. The overall error committed due to deviations from the desired supply can be computed from the Theil (1966) measure of accuracy of forecasts. Marikar *et. al.* (1992) adapted the Theil measure of accuracy of forecasts to compute the error, e^2 , committed in trying to achieve the desired distribution as follows:

$$(3.1) \quad e^2 = 1/n \sum (W_i^* - W_i)^2 = (W^* - W)^2 + (S_{w^*} - S_w)^2 + 2(1-r)S_{w^*}S_w$$

where W_i^* is the desired and W_i is the actual or achieved distribution, W^* and W are the means of the desired and actual distributions respectively, S_{w^*} and S_w are the respective standard deviations of the desired and actual distributions; and r is the correlation coefficient of the distributions W_i^* and W_i defined as:

$$(3.2) \quad r = (1/n \sum_{i=1}^n (W_i^* - W^*) (W_i - W)) / ((S_{w^*})(S_w)).$$

In this case the desired distribution is represented by the crop water requirements over the ten day periods adjusted for rain and the actual is represented by the water flow measured daily and aggregated over the ten day periods.

The overall error, e^2 , can be decomposed into measures that indicate water delivery performance in terms of adequacy of water delivery, $(W^* - W)^2$, equity in the supply of water, $(S_w^* - S_w)^2$, and management capability error given by $(2(1-r)S_w^*S_w)^1$. The proportions of the overall error resulting from adequacy performance (e_{ap}), equity performance (e_{ep}) and managerial capability performance (e_{mp}) can be computed by dividing equation 1 through by e^2 to yield:

$$(3.3) \quad 1 = e_{ap} + e_{ep} + e_{mp}.$$

This method of estimating the error committed in trying to achieve the desired water distribution treats the errors resulting from over-supply and under-supply symmetrically, that is over-supply is as bad as under-supply. This approach is appropriate for this analysis because the water that is used up as a result of over-supply could be used to increase either the percentage of developed area irrigated in each season, or the cropping intensity, particularly during the winter season.

One of the variables used in determining the developed area is the available water. It is therefore appropriate for the schemes to aim to crop the whole developed area if water is

¹ This component of overall error measures the ability of management to meet demand exactly. When $W_i^* = W_i$ for all i , $r = 1$ making this term zero. The worst case occurs when $r = -1$ making this term $4S_w^*S_w$. The meanings of the other two terms are self explanatory.

available instead of over-applying it. If water is under-applied then this shows the failure of management to deliver the required amount or its failure to determine the area that should be irrigated during a particular season given the available water.

The overall error, e^2 , is compared to the maximum possible error E^2 . E^2 is computed in the same way as e^2 except that in computing E^2 , all the water supplied is assumed to have been supplied to one ten day period that least needed it. To compute E^2 , the ten day period with the least adjusted crop water requirement was identified, the water actually supplied in all the ten day periods was summed and assumed to have been all supplied to the ten day period with the least adjusted crop water requirement with nothing being supplied in the rest of the other periods. E^2 is then computed using equation 1 without the decomposition into e_{ap} , e_{cp} and e_{mp} .

3.5 The water management performance of small holder irrigation schemes in Zimbabwe.

Tables 3.2 and 3.3 show the results of the managerial analysis for the summer and the winter respectively. The analysis shows that during the summer on five of the nine Agritex schemes managerial capability error contributed more than fifty percent towards the error committed in trying to match water supply and demand. One of the Agritex schemes had a high adequacy error, one had a high equity error and the remaining two had the sources of error roughly evenly divided between the three sources of error

Table 3.2. Summer: Managerial performance errors for Agritex and community systems

System				e^2	E^2			
	e_{ap}/e^2	+	e_{cp}/e^2	+	e_{mp}/e^2	=	1.00	(e^2/E^2)
Shagari ^a							1338712	21383622
	.376		.476		.148		1.00	(.06)
Senkwazi ^a							484378	2680303
	.399		.349		.252		1.00	(.18)
Tawona ^a							23310557	353325558
	.141		.028		.830		1.00	(.07)
Chibuwe ^a							87826784	1674782540
	.111		.010		.879		1.00	(.05)
Chakohwa ^a							24812194	1120027629
	.613		.065		.322		1.00	(.02)
Mabodza ^a							266445	2177263
	.055		.341		.604		1.00	(.12)
Sachipiri ^a							997663	8398951
	.007		.205		.788		1.00	(.12)
Nyamaropa ^a							131655931	2200145867
	.230		.235		.535		1.00	(.06)
Mwerahari ^a							410160	1989305
	.129		.599		.272		1.00	(.21)
Bangure ^c							117130	372456
	.220		.041		.739		1.00	(.31)
Mkoba ^c							94758	1546610
	.000		.057		.943		1.00	(.06)
Mutambara ^c							526445776	1446153929
	.902		.002		.096		1.00	(.36)
Agritex							271102823	5363527418
	.219		.131		.651		1.00	(.05)
Community							526657664	1448072996
	.902		.002		.096		1.00	(.36)
Summer							799099199	6832984035
	.669		.047		.284		1.00	(.12)

a = Agritex

c = community

namely, adequacy, equity and managerial capability. In the summer, on average, managerial capability error contributed about sixty five percent towards the total error

Table 3.3. Winter: Managerial performance errors for Agritex and community systems.

System	e_{ap}/e^2	+	e_{cp}/e^2	+	e_{mp}/e^2	=	e^2 1.00	E^2 (e^2/E^2)
Shagari ^a							243220	18121004
	.813		.021		.166		1.00	(.01)
Senkwazi ^a							1937409	28691024
	.127		.517		.356		1.00	(.07)
Tawona ^a							12891879	414926400
	.062		.391		.547		1.00	(.03)
Chibuwe ^a							80473078	2483347487
	.522		.098		.038		1.00	(.03)
Chakohwa ^a							3030174	86414660
	.930		.027		.043		1.00	(.04)
Mabodza ^a							129488	6172174
	.493		.245		.262		1.00	(.02)
Sachipiri ^a							8237868	95220054
	.124		.545		.331		1.00	(.09)
Nyamaropa ^a							125344619	1815273652
	.314		.419		.267		1.00	(.07)
Mwerahari ^a							130756	1117909
	.143		.712		.144		1.00	(.12)
Bangure ^c							154512	360329
	.636		.000		.364		1.00	(.43)
Mkoba ^c							84785	6601648
	.873		.113		.014		1.00	(.01)
Mutambara ^c							25678946	854029612
	.796		.042		.162		1.00	(.03)
Agritex							232418492	4949284363
	.372		.306		.322		1.00	(.05)
Community							25918242	860991588
	.795		.042		.163		1.00	(.03)
Winter							258579954	5828396956
	.415		.279		.306		1.00	(.04)

a = Agritex

c = community

committed with adequacy contributing twenty two percent and equity error 13 percent of the total error committed by the Agritex schemes. The total error committed by the

Agritex schemes during the summer ranged between 0.02 and 21 percent of the maximum possible error. On average the Agritex systems committed 5 percent of the maximum possible committable error for all the Agritex schemes during the summer (Table 3.2).

During the summer, on two of the three community systems managerial capability error contributed more than seventy percent of the total error committed by the schemes. On the remaining scheme adequacy error contributed more than ninety percent of the error. On average on the community schemes adequacy error contributed more than ninety percent of the error committed during the summer. Even though on average it appears as though the main source of error for the community schemes is adequacy error, the majority of the schemes have managerial capability error as the main source. This indicates that both Agritex and community schemes experience managerial problems in trying to match water supply to demand during the summer.

It should be noted that the errors committed by the schemes during the summer are not directly comparable. The schemes face different conditions during the summer. At some of the schemes the errors are due to the failure of management to adjust supply by the amount of effective rainfall. Some schemes are in areas that receive more rainfall than others. On these schemes the irrigated plot faces high competition from dryland plots in terms of management. For the schemes in drier areas the challenge is just to supply sufficient water to meet demand through irrigation. Due to these differences in circumstances, it is therefore difficult to draw the conclusion that the Agritex schemes

committed less error than the community schemes during the summer. In order to reach this conclusion it is important to establish the importance attached to the dryland and irrigated plots and how time is allocated between the two during the summer production period. This issue was not addressed in this study.

During the winter at four of the Agritex schemes adequacy error contributed more than 49 percent of the error in achieving the desired water supply. At four of the schemes equity error contributed more than 40 percent of the error while only one had managerial capability error contributing about 55 percent of the error. At the Agritex schemes, on average, the three sources contributed almost equal proportions, around thirty percent, towards the error committed by all the Agritex schemes during the winter. The total error committed by the Agritex schemes ranged from 1 percent to 12 percent as a proportion of total error and averaged 5 percent during the winter (Table 3.3)

During the winter, at all the community schemes, adequacy error contributed more than sixty percent of the error committed by the community schemes. On average, adequacy error contributed about 80 percent of the error committed by the community schemes with equity error and managerial capability error contributing 4 percent and 16 percent respectively. During the winter, the total error committed by the three schemes individually ranged from 1 percent to 43 percent of the total error but averaged only 3 percent. During the winter, the community schemes have adequacy error as their major source of error while Agritex has the error more evenly distributed between the three sources. During the winter, managerial capability error contributes more towards the

error committed by the Agritex schemes, 65 percent, than that of community schemes, 10 percent. Averaging across all the schemes during the summer the total error committed was 12 percent of the maximum possible compared to 4 percent during the winter. This suggests that water management is better during the winter, when rainfall is negligible, than during the summer as would be expected.

The conditions faced by the irrigation schemes during the winter are very similar. There is no rainfall in most of the country although there can be some sporadic thunderstorms. During the study there was no significant rainfall at any of the schemes. The challenge faced by management is to determine the area to be cropped as a function of available water and then to match supply with demand. This means that the errors committed by the schemes under these similar conditions are directly comparable since all farmers focus on managing the irrigated plot unlike during the summer when farmers make choices between allocating time to the dryland and irrigated plots. The analysis shows that the community schemes, on average, committed less error than the Agritex schemes. This suggests that when it is critical to match water supply to demand, the community systems do a better job than the Agritex system.

3.6 Discussion

During the summer, managers at the different schemes face different challenges in attempting to match water demand and supply. In the areas that receive some rainfall, management needs to adjust supply by the amount of effective rainfall received. In the drier areas management is faced with simply trying to match supply and demand. This

means that during summer the errors are committed under different circumstances and are, therefore, not directly comparable. During the winter the conditions faced by the schemes are similar. In the absence of rainfall, management's objective is to supply enough water to meet demand. The errors committed by the schemes are therefore directly comparable. Under these circumstances the community schemes committed less error, 0.03 percent than Agritex, 0.05 percent, expressed as a percentage of the total possible committable error. This shows that when it is critical to match supply and demand, community schemes achieve this objective better than Agritex systems. This is consistent with earlier findings by Makombe and Sampath (1998).

Chapter 4

A benefit cost analysis of smallholder irrigated farms in Zimbabwe.

4.1 Introduction

Economic viability and sustainability are important criteria for evaluating projects. Very often, in the African context projects have not lived up to expectations, particularly the large ones (Moris and Thom, 1990). This has led development agencies to look at smaller projects as an alternative (Adams, 1990). A starting point for evaluating the viability of smallholder irrigation systems is to assess their financial viability. This chapter offers a simple benefit cost analysis for smallholder irrigation systems in Zimbabwe.

The financial viability of smallholder irrigation systems in Zimbabwe has always been questioned. A study by Hunt in 1958 advised the government that smallholder irrigation systems were economically inefficient (Hunt, 1958). In a recent study Rukuni *et. al.* (1994) suggest that the smallholder systems may be economically viable. Given the conflicting evidence on the economic performance of smallholder irrigation systems, subsequent governments responded to both political and economic stimuli in determining whether to support the development of smallholder systems in the communal areas of Zimbabwe. The systems were developed initially to alleviate the land shortage that was

occurring in the communal areas. Later some irrigation systems, especially those funded by missionaries, were developed to alleviate famine in the drier parts of the country (Makadho, 1994). Another concern for the smallholder irrigation systems is what impact they have on the cash flow of the farmers who have access to them. This is a much broader question requiring cash flow information, which was not collected in this study. This study will be primarily concerned with the assessment of financial viability.

4.2 Objectives

The objectives of this study are to estimate the financial benefits and costs of the smallholder irrigation systems in order to determine whether they are financially viable and to carry out a comparative analysis of the the different management systems to determine the most financially viable system.

4.3 Data

Data were collected on a sample of 9 Agritex, 3 community, 4 *bani* and 2 ARDA schemes. The sample of farmers comprised 169 from Agritex, 92 from community, 72 from *bani* and 45 from ARDA systems. On the sample farms data were collected on cropping pattern, cropping intensity, quantities of inputs applied, sources of inputs, prices, transportation and application costs , crops sales, prices and quantities of produce consumed at home from the irrigated plot/s. Home consumption was valued at market rates.

The amount of labour used for each operation on the irrigated plot/s was estimated using a labour survey. The rates paid to labour when it was hired were collected for the peaks and troughs of labour demand.

A dryland sample of 40 farms was included in order to assess the gains from irrigation. Similar data were collected from the dryland sample farms.

These data were collected during the 1990/91 summer and winter seasons under the UZ/IFPRI/Agritex Irrigation Performance in Zimbabwe Project

4.4 A simple benefit cost analysis

In this analysis planted areas were divided into four ranges of sizes, ≤ 0.25 ha, $>0.25 \leq 0.5$, $>0.5 \leq 1.0$, and >1.0 ha. On these schemes a farm that can achieve a total planted area of 0.25 ha over the two seasons, summer and winter, is considered very small, between 0.25 and 1 is considered reasonable and over 1.0 ha is considered large. Using average cropping intensities for Agritex, community, *bani* and ARDA systems, the plot sizes that are needed to achieve these planted areas were computed and compared to the actual plot size distribution.

The gross margins achieved within the different planted area categories were computed as follows:

$$(4.1) \quad GM1 = \text{Gross revenue} - \text{cash costs} - \text{opportunity cost of labour}$$

$$(4.2) \quad GM2 = \text{Gross revenue} - \text{cash costs}$$

Then benefit cost ratios were computed as follows:

$$(4.3) \quad BCL = GM1 / (\text{cash costs} + \text{opportunity cost of labour})$$

$$(4.4) \quad BCNL = GM2 / \text{cash costs}$$

Cash costs consist of any direct cash costs associated with crop production on the irrigated plot including fertilizer and chemicals. Both BCL and BCNL did not take into account equipment depreciation and the costs (direct and indirect) of canal and scheme (for example fence) maintenance.

4.5 The benefit cost ratios for smallholder irrigated farms in Zimbabwe

Table 4.1 summarizes the results for the benefit cost analysis by size of planted area. On average the Agritex farmers achieved planted areas of 0.93 ha. This is about twice the planted area achieved by the community and *bani* system farmers of 0.47 ha. The size of planted area may reflect farmer's perception about the reliability of water supply. If farmers think that they will not get enough water, they usually adjust the area they plant downwards. Thus farmers on the Agritex systems may perceive that their water supply is more reliable than say the community system.

In terms of distribution of area planted within the management systems, the bulk of Agritex farmers, 67 percent, had planted areas greater than 0.5 ha. In contrast, on the community and *bani* systems 73 and 70 percent, respectively, had planted areas less than 0.5 ha. (Table 4.1) These distributions may indicate farmer perception about water supply

Table 4.1. Benefits and costs by system and planted area.

System Planted area Range	n (%)	Planted area Mean: (ha)	BCL (C.V.)	BCNL (C.V.)
Dryland	38	4.69	0.91 (1.70)	2.36 (1.30)
ARDA	45	11.52	1.95 (0.94)	2.78 (1.21)
Agritex	169	0.93	1.94 (2.59)	2.74 (3.11)
≤ 0.25	17 (10)	0.17	0.84 (1.93)	1.19 (1.58)
> 0.25 ≤ 0.5	39 (23)	0.39	1.58 (1.38)	2.29 (1.45)
> 0.5 ≤ 1.0	59 (35)	0.80	2.54 (3.19)	3.79 (3.69)
> 1.0	54 (32)	1.69	1.89 (0.96)	2.40 (0.89)
Community	92	0.47	2.15 (1.76)	3.69 (2.47)
≤ 0.25	41 (45)	0.17	2.04 (2.20)	3.10 (2.24)
> 0.25 ≤ 0.5	26 (28)	0.39	2.53 (1.48)	5.29 (2.70)
> 0.5 ≤ 1.0	14 (15)	0.70	2.25 (1.38)	3.39 (1.59)
> 1.0	11 (12)	1.51	1.51 (0.83)	2.48 (0.90)
Bani	72	0.47	6.42 (0.93)	21.06 (1.65)
≤ 0.25	38 (53)	0.09	6.83 (1.04)	21.8 (1.51)
> 0.25 ≤ 0.5	12 (17)	0.37	7.13 (0.80)	36.65 (1.62)
> 0.5 ≤ 1.0	11 (15)	0.78	4.89 (0.64)	13.87 (0.88)
> 1.0	11 (15)	1.58	5.73 (0.72)	8.61 (0.60)

reliability, as mentioned earlier. Farmers on the Agritex systems may have planted areas skewed towards the larger side due to perceiving their water supply as reliable unlike the community and *bani* farmers.

The benefit cost analysis indicates that when the opportunity cost of labour is taken into account, the Agritex systems achieve a benefit cost ratio (BCL) averaging 1.94, community 2.15 and *bani* 6.42. ARDA farmers achieve an average benefit cost ratio similar to that of Agritex farmers at 1.95. This shows that all the systems are able to cover their costs but the community system does this better than the Agritex system with the *bani* system achieving the highest benefit cost ratio. The benefit cost ratios on the irrigated systems are significant improvements on the benefit cost ratio of 0.91 from dryland farms.

If the larger planted areas on the Agritex systems are a reflection of the reliability of water supply, the farmers on these systems are using water less efficiently than those on the community and *bani* systems who achieve larger benefit cost ratios. It may well be that the unreliable supply on the *bani* and community systems prompts more efficient water use than on these systems.

Within the area categories the highest BCL was achieved by the category $> 0.5 \leq 1.0$ on the Agritex systems with a BCL of 2.54, the category $> 0.25 \leq 0.5$ on the community and *bani* systems with a BCL's of 2.53 and 7.13 respectively. The opportunity cost of labour was computed as the amount of labour multiplied by the average rate of hiring labour throughout the whole year. Based on the rates paid hired labour and the occurrence of

peaks and troughs during the year, the opportunity cost of labour was estimated to be Z\$1.00 per manday. The low opportunity cost is a reflection of the abundance of unskilled labour in the communal areas. Since labour is an opportunity cost and due to the abundance of labour, it is arguable that it may not be appropriate to include labour in the computation of the benefit cost ratios for the smallholder systems. The benefit cost ratio (BCNL) was computed without accounting for labour. The average BCNL for Agritex, community and *bani* systems 2.74, 3.69 and 21.06 respectively. The ARDA BCNL is also comparable to that of Agritex systems at 2.78.

Once again the highest is *bani*, followed by community. The inclusion or exclusion of the opportunity cost of labour does not distort the ranking. The large difference between the BCL and BCNL for the *bani* system reflects the fact that labour (time) is a larger proportion of investment on the *bani* schemes as compared to the other systems.

It is surprising that the *bani* systems achieve such high benefit cost ratios even given the fact that the farmers on the *bani* systems do not receive extension advice, financial and other technical support that are provided to community and Agritex systems. Since *banis* are natural geographic landforms, their development is limited to the areas where these landforms occur. These results suggest that the *bani* systems are financially viable and their cultivation meets the objectives of irrigation maybe more efficiently than the formal irrigation systems. This suggests that encouraging the cultivation of the *banis* should be based on an evaluation of the gains from irrigation relative to the costs associated with any environmental degradation that may be associated with the exploitation of the *bani*'s agricultural potential.

The community and Agritex systems only differ in terms of their levels of government intervention. The community systems, which have less government intervention, achieve higher benefit cost ratios. This suggests that the government should use the community system as the development model. This will result in savings due to reduced government intervention and an increase in the benefits created by irrigation development. Makombe and Sampath (1998) make similar observations.

Figure s 4.1 (a) and (b) pictorially shows the relationship between benefit cost ratios (BCL and BCNL) to area planted. This graph suggests that the most efficient planted area range is between 0.25 and 1 ha for all the systems. Using the different cropping intensities for the different systems the ranges of planted area can be translated to plot sizes in order to get a rough indication of the efficient plot size range for each system. Cropping intensities differ from year to year depending on the quality of the season and rainfall availability. Assuming that cropping intensity and area planted vary in the same direction the translation of the planted area to plot size may not be affected by the quality of the year. The cropping intensities for each system achieved during the year when this data was collected are shown in Table 4.2. Table 4.2 also shows the plot size range for each system that corresponds to the most efficient planted area range calculated on the basis of the cropping intensities for the 1990 summer and 1991 winter.

Table 4.2 suggests that the most efficient (optimal) plot sizes for the three systems are very similar ranging between 0.13 and 0.61. This suggests that plots smaller than, 0.13

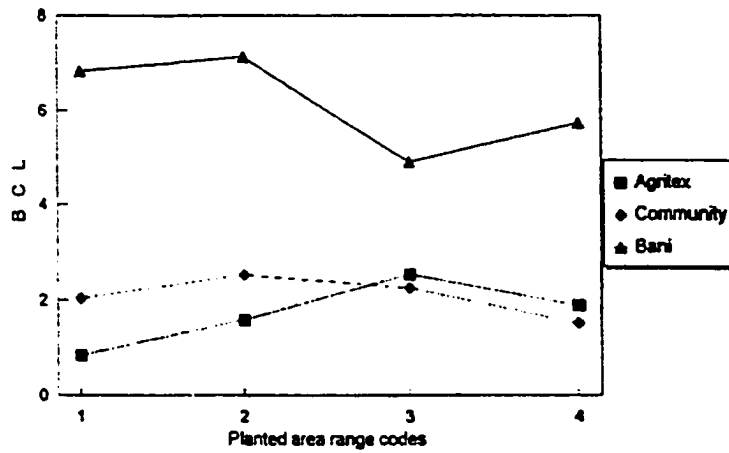


Figure 4.1 (a): BCL relationship to planted area

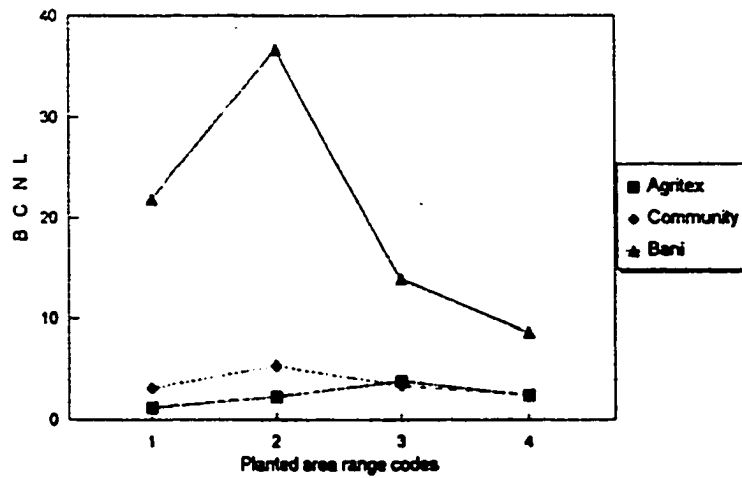


Figure 4.1 (b): BCNL relationship to planted area

Planted area range codes

1=less than 0.25 ha

2=greater than 0.25, less than or equal to 0.5 ha

3=greater than 0.5, less than or equal to 1 ha

4=greater than 1 ha

may be too small whereas those larger than 0.61 may be too large for these smallholder farmers. This is only an indication of the optimal plot sizes, which is why it is given as a range. More sophisticated methods can be used to determine the optimal plot size within the systems.

Table 4.2. Cropping intensities by system and season and optimal plot size range

System	Cropping intensity %			Optimal Plot size range (ha)
	Summer 1990	Winter 1991	Total	
Agritex	98.6	90.7	187.1	0.13 - 0.53
Community	91.3	71.9	163.2	0.15 – 0.61
Bani	118	74.6	192.6	0.13 – 0.52
ARDA	100	71.9	171.9	N/A

Table 4.3 shows the distribution of farm sizes in relation to the optimal range. Since the calculation of the optimal plot size range is based on total cropped area, plot size in this context refers to all the irrigated land owned by the farmer. Thus if the farmer owned more than one plot, these were summed to get the plot size that is referred to in this context.

Table 4.3 shows that on the Agritex, community and *bani* systems, 23, 5 and 33 percent respectively, of the farmers had more than one plot. Table 4.3 also shows that on the Agritex systems 78 percent of the farmers had plot sizes outside the optimal range with most of these farmers, 50 percent having plots larger than the upper limit. On the

community systems fewer farmers, 53 percent , had plot sizes outside the optimal range with most of them, 45 percent having plots less than the lower limit. On the *bani* system 49 percent of the farmers have plots outside the optimal range with 35 percent having

Table 4.3. Distribution of plot sizes in relation to optimal range

System Plot size Range (ha)	% of Sample	Outside range	Multiple plots(%)
Agritex			
<0.13	28		
≥ 0.13 ≤ 0.53	22	78	23
> 0.53	50		
Community			
<0.15	45		
≥ 0.15 ≤ 0.61	47	53	5
> 0.61	8		
Bani			
<0.13	35		
≥ 0.13 ≤ .52	51	49	33
> .52	14		

plots smaller than the lower limit. These results suggest that the distribution of land is better on the community and *bani* systems than on the Agritex systems. B/C ratios peak in the range .5 to 1 ha for the Agritex systems and at half that for the community and *bani* systems. This may be a result of the differences in water management and input use intensity in the systems. The smaller *bani* and community farms may be better managed than the larger Agritex farms. The smaller *bani* and community farms achieve the same

B/C ratio as the larger Agritex farms when labour is accounted for and higher B/C ratios when labour is not accounted for (Figure 4.1).

4.6 Discussion

The results of this study suggest that the financial performance of irrigated systems is significantly better than that of dryland farms. The community system performs better than the Agritex system. The *bani* system do achieve the objectives of irrigation and appear to be financially more viable than both the community and Agritex systems. The optimal plot size for all the systems appears to range between 0.13 and 0.61, as it was this range that achieved the highest benefit cost ratios. The distribution of land seems to be better on community than Agritex systems. It is recommended that the government should use the community system as the development model since this will result in a more efficient smallholder irrigation sector while at the same time the government saves money through less involvement in the running of the schemes. The government should also seriously consider the *bani* irrigation systems as a development alternative.

It should be noted that the conclusions reached in this paper are based on micro-financial analysis. A more robust conclusion can be reached by combining this analysis with other socio-economic factors like the financial surplus that farmers achieve in relation to their expenses. This study does not answer the question: Do those farmers with large B/C ratios receive enough income to achieve subsistence? This involves carrying out a more holistic economic benefit-cost analysis including depreciation and capital costs, data for which were not available for this study. The results may not change very dramatically given the fact that the systems are capital deficient. These results are, however,

indicative of the systems that are likely to better achieve both farmer and government objectives for developing smallholder irrigation.

Although there have been conflicting results in terms of the financial viability of smallholder irrigation systems, recent studies indicate that smallholder irrigation systems can be financially viable (Rukuni *et. al.* 1994, Manzungu and van der Zaag, 1996). These results and those of this study indicate that the government should definitely consider smallholder irrigation as a development option.

Chapter 5

A comparative analysis of the influence of socioeconomic variables on the financial performance of smallholder irrigation systems in Zimbabwe

5.1 Introduction

The activities that are of direct benefit to farmers have received increased attention in many development projects. Many agricultural projects, whether they are targeted at improving efficiency or equity, seek to implement changes at farm level. It is therefore critical to understand farmers and their circumstances in order to implement effective institutional change that achieves the desired farm level objectives (Skold and Lybecker, 1985). Both the technical and socioeconomic factors affect the success or failure of development efforts. This chapter sheds some light on the effects of socioeconomic variables on the financial performance of smallholder irrigation schemes in Zimbabwe

5.2 Objectives

The objectives of this study are to evaluate whether socioeconomic variables influence the financial performance of smallholder irrigation systems. A comparative analysis of the influence of the socioeconomic variables is carried out for the Agritex, community and *bani* systems.

5.3 Data

Data were collected from 166 Agritex, 75 community and 76 *bani* irrigation system farmers, from 8 Agritex, 3 community and 4 *bani* schemes during the 1990/91 summer and winter seasons. Data were collected from the farmers about their participation in marketing cooperatives, labour groups, and savings clubs. Farmers were asked whether they had received the master farmer training, used credit, could read (literacy) and whether they kept records of the plot. The gender of the decision-maker on the plot was also recorded. These were all yes/no questions.

Plot level information was collected on the quantities and prices of inputs used on the summer and winter crop. Where farmers did not remember prices and quantities they usually could give a good estimate of total input costs. The total value of the crops grown in these two seasons was estimated, including that which went to home consumption. These data enabled the use of gross margins as a proxy for financial performance. These data were collected under the UZ/IFPRI/Agritex Irrigation Performance in Zimbabwe Project.

5.4 Chi-Square (χ^2) for association analysis

Since the socioeconomic variables of interest were collected as categorical variables, the χ^2 for association was used as the test statistic. Gross margins were defined in two ways as in chapter 4. The gross margins were each classified into three categories, low, medium and high. For each system the mean gross margin was computed. The lower bound of the medium category was defined as the mean less one third of the mean and

the upper bound was defined as the mean plus one third of the mean. Anything less than the lower bound of the medium category was classified as low and similarly all the margins higher than the upper bound were classified as high.

5.5 The influence of socioeconomic variables on the financial performance of smallholder irrigation systems in Zimbabwe

Total cropped area (the sum of the cropped area in summer and winter for each farmer) for the three systems averaged 0.93 ha, 0.47 ha and 0.47 ha for Agritex, community and *bani* systems respectively. Table 5.1 shows the mean gross margins for the three systems. Even though both the *bani* and community total cropped area is close to 50 percent of that of the Agritex system, if the gross margins of the community and *bani* systems are doubled, the result in both cases is higher than the gross margin for the Agritex system. Agritex also has the highest gross margin range.

Table 5.1. Mean Gross margins (Z\$) by System.

System	N		Mean Gross Margin	Range
Agritex	166	GMNL	837	-446 to 4126
		GML	772	-500 to 4098
Community	75	GMNL	688	-281 to 3894
		GML	635	-300 to 3387
<i>Bani</i>	76	GMNL	821	-21 to 4023
		GML	778	-26 to 3956

Table 5.2 shows the results of the gross margin classifications by system. It is important to note that a large proportion of the farmers fall into the low category. If we only

Table 5.2 Gross margin (Z\$) classifications and means per category.

System		Gross margin category		Mean	N
Agritex	GMNL	Low	<558	121	87
		Medium	558 to 1116	867	28
		High	>1116	2041	51
	GML	Low	<515	65	86
		Medium	515 to 1029	783	27
		High	>1029	1914	53
Community	GMNL	Low	<459	196	44
		Medium	459 to 917	684	16
		High	>917	2135	15
	GML	Low	<423	154	44
		Medium	423 to 847	600	13
		High	>847	1835	18
<i>Bani</i>	GMNL	Low	<547	236	47
		Medium	547 to 1095	797	13
		High	>1095	2304	16
	GML	Low	<519	200	46
		Medium	519 to 1037	703	13
		High	>1037	2162	17

consider GMNL we find that 52 , 59 and 62 percent of Agritex, community and *bani* farms, respectively fall in the low category.

5.6 Farmer socioeconomic characteristics

Table 5.3 shows the percentage distribution of the socioeconomic variables under study across the three systems. The participation of the *bani* system in marketing cooperatives is high because one of the *bani* sites had a very active marketing cooperative that was initiated through the Agricultural and Rural Development Authority. Credit use is similar on the Agritex and community systems but is lowest, only 11 percent, on the *bani* system. Labour groups are more prominent on the community schemes, which have 35 percent of

the farmers participating in labour groups. Farmers participate in labour groups to manage labour bottlenecks during peak labour demand periods like weeding and harvesting.

Table 5.3 Distribution (%) of socioeconomic characteristics by system

Characteristic	System		
	Agritex	Community	<i>Bani</i>
Marketing coops	16	20	25
Credit	31	32	11
Labour group	13	5	20
Master farmer	55	52	42
Literacy	68	91	80
Records	43	52	12
Savings club	8	9	7
Gender (Female)	48	65	46

Agritex conducts a master farmer-training program. Master farmers are taught the recommended ways of producing crops, how to plan for production, the value of keeping farm records and some gross margin analysis as a performance evaluation tool. After going through the program farmers get a (prestigious) certificate which they display in their homes. Agritex conducts these for the dryland and formal irrigation systems. It is therefore surprising that 42 percent of *bani* farmers are master farmers. Given that the *bani* schemes were not near any formal irrigation schemes, it is most likely that these master farmers were trained on dryland farming.

The literacy rate is generally high in Zimbabwe such that the literacy rate of 68 percent on Agritex systems is surprising. Community scheme farmers have the highest

proportion, 52 percent, of farmers keeping records. Farmer participation in savings clubs is generally low, less than 10 percent in each system. The idea behind savings clubs is to form organizations to which farmers contribute annually and can then borrow from at reasonable rates, in times of need so as to alleviate the credit access constraint.

Community schemes also had the highest proportion of female plot holders, 65 percent.

It has sometimes been argued that female farmers have less access to productive resources. These data will be used to give some insight into this argument.

Table 5. 4 summarises the results of the χ^2 analysis. On the Agritex system, the only significant variable is labour group participation. This is not a surprising result given the fact that all the production decisions on Agritex schemes are made by extension agents.

This leaves the management of resources like, labour, to the farmer. Table 5.5 shows that the mean for GMNL of 783 achieved by farmers who do not participate in labour groups is statistically significantly lower than the mean of 1023 achieved by labour group participants. Thus, alleviating the labour constraint through labour groups appears to have a positive impact on the financial performance of Agritex schemes.

In retrospect, another variable that we should have collected for the Agritex schemes is a measure of how closely the farmers try to follow the extension workers' recommendations given the requirement that they have to follow these recommendations. This may not be an easy variable to collect given that following the recommendations is a requirement and those farmers not following, or unable to follow the recommendations may not be too willing to share this information. However, assuming that the Agritex recommendations

Table 5. 4 Chi-Square analysis results by system

System	Variable	χ^2 Values		df	Sig ¹	
		GMNL	MGL		GNL	GML
Agritex	Marketing coops	1.855	1.669	2	NS	NS
	Credit	2.398	1.744	2	NS	NS
	Labour group	5.435	4.792	2	*	*
	Master farmer	0.464	0.686	2	NS	NS
	Literacy	0.231	0.114	2	NS	NS
	Records	2.357	2.125	2	NS	NS
	Savings club	0.399	0.282	2	NS	NS
	Sex	0.049	0.025	2	NS	NS
Community	Marketing coops	0.836	1.552	2	NS	NS
	Credit	1.479	1.663	2	NS	NS
	Labour group	0.994	3.315	2	NS	NS
	Master farmer	2.188	2.304	2	NS	NS
	Literacy	5.959	8.554	2	*	**
	Records	2.002	2.240	2	NS	NS
	Savings club	2.822	2.692	2	NS	NS
	Sex	0.770	0.812	2	NS	NS
<i>Bani</i>	Marketing coops	6.955	5.858	2	**	*
	Credit	9.369	8.413	2	**	**
	Labour group	2.510	3.893	2	NS	NS
	Master farmer	1.823	2.566	2	NS	NS
	Literacy	7.492	8.030	2	**	**
	Records	11.593	10.717	2	**	**
	Savings club	1.185	1.237	2	NS	NS
	Sex	6.629	7.617	2	**	**

1. NS = Non significant. * = significant at 10 percent ** = significant at 5 percent

are appropriate, identifying the constraints farmers face in trying to follow the recommendations may shed light on potential areas of improvement.

On the community schemes the significant variable is literacy. This result can be explained by the fact that farmers on the community schemes receive extension advice

Table 5.5. Analysis of variance for the variables with significant χ^2 s by system.

System	Variable	Gross Margin	F value	df	Sig	Gross Margin Means by Participation	
						No	Yes
Agritex	Labour group	GMNL	3.567	1	*	783	1023
		GML	3.557	1	*	720	1131
Community	Literacy	GMNL	0.067	1	NS	608	695
		GML	0.042	1	NS	574	641
<i>Bani</i>	Marketing	GMNL	5.871	1	**	666	1297
		GML	5.495	1	**	631	1230
	Credit	GMNL	11.985	1	**	696	1933
		GML	11.924	1	**	656	1863
	Literacy	GMNL	5.098	1	**	298	954
		GML	5.119	1	**	266	909
	Records	GMNL	20.774	1	**	640	2026
		GML	20.800	1	**	601	1956
	Gender	GMNL	4.351	1	**	567 ¹	1042 ²
		GML	4.293	1	**	531 ¹	992 ²

* = significant at 10 percent. ** = significant at 5 percent.

1 = Female

2 = Male

but they have to use their discretion as to what they should follow. The ability to process and operationalise the information they receive from extension agents is better if one is literate. Table 5.5, however, shows that the means for both GMNL and GML achieved by the two groups of literate and illiterate farmers are not statistically significantly different. This may be so because the impact of literacy may depend on extension contact. Thus, a better variable that we should have tried to collect is the amount of extension advice farmers on community schemes get for which extension contact can be reasonably used as a proxy.

Marketing cooperatives, credit, literacy, record keeping and the plot holder's gender are all significant on the *bani* system (Table 5. 4). Table 5. 5 shows that farmers participating in marketing cooperatives, those using credit and those keeping records achieve statistically significant gross margins than those who do not. It also shows that male farmers achieve statistically significantly higher gross margins than female farmers do.

The marketing coop effect has already been mentioned earlier. The farmers on the *bani* scheme in Mushimbo, Mutoko were achieving significantly higher gross margins by improved access to (largely urban) markets. This shows the potential of this type of organization. Infact it is surprising that the coops are not significant on the other schemes because on the schemes marketing certainly appears as a constraint especially during the winter when perishable crops are produced. Farmers on the *banis* do not have access to credit. The few who did use credit achieved significantly higher gross margins. When asked what they would buy if they had access to credit the major uses included 54 percent of the farmers who responded that the highest priority would be to buy a fence. *Banis* are also used for grazing cattle and therefore improving crop protection from animal damage becomes a priority. Sixteen percent of the farmers responded that they would buy some irrigation equipment, which included buying hoses, buckets, watering cans and improving the well. Fifteen percent said they would buy inputs like fertilizer and 4 percent reported that they would use credit to hire labour.

Farmers on the *bani* system do not receive extension advice that is directly pertinent to *bani* circumstances due to government policy on *bani* cultivation. Therefore, just like the

farmers on the community systems, the ability to process the information which they get, and to adjust it to the *bani* circumstances, can be a critical determinant of performance. Those farmers who keep records also achieved higher margins. The explanation for this is similar to that for literacy. Those farmers keeping records improve their ability to process the production recommendations, which they receive and they improve their ability to adjust them to their *bani* circumstances.

On the *bani* schemes, the gender of the plowholder is significant. Male farmers achieve higher yields than female ones. This is not the case on the Agritex and community managed systems. There may be circumstances specific to the *bani*s that constrain female farmers from performing as well as their male counterparts. This issue requires further investigation.

5.7 Discussion

Labour groups appear to be an effective mechanism for alleviating labour constraints on Agritex systems. To this extent they should be encouraged. The variables studied do not seem to have any impact on the financial performance of the community schemes. Given this result, it may be better to look at extension worker/farmer interaction since this may have impact on the performance of the community schemes. On the *bani*s, the results suggest that marketing cooperatives should be encouraged. The results also point at the need for establishing some mechanisms for extending credit to the *bani* farmers since *bani* credit appears to have good returns. Literacy and record keeping both have a significant impact on *bani* farmer performance. This suggests that if the government

invested resources in developing recommendations specific to farmer circumstances and training farmers, this may improve the performance of *bani* farmers. The significance of these variables suggest that those farmers who have the ability to process and adjust the recommendations mostly from dryland and also maybe from the irrigated systems perform better than those who do not. The government can help in bridging the gap between these farmers. The specific circumstances faced by female *bani* farmers that constrain them from performing as well as their male counterparts require further investigation.

These results suggest that the government should not continue to sideline the *bani* system as an irrigation development alternative. Makombe and Sampath (1998) show that the *bani* system achieves the most equitable distribution of income from irrigation when compared to the Agritex and community systems. Therefore the government policy of not investing research effort to improve *bani* production is in direct contradiction with the concepts of equity and efficiency.

Chapter 6

An evaluation of *bani* (*dambo*) systems as a smallholder irrigation development strategy in Zimbabwe.

6.1 Introduction

This chapter looks at the potential of the informal *bani* system as a smallholder irrigation development strategy in Zimbabwe. Figure 6.1 shows the structure of one form of *bani* which exists in the water seepage zone and beyond. It should be emphasized here that this is the structure of only one example of the *bani* landform. *Banis* are not a homogeneous resource. They vary in structure, size shape and soil type. Some characteristics are common though. For instance in most *banis* the water table is usually within two meters from the ground so it can be extracted easily by buckets, hosepipes and simple hand pumps with no need for complex systems for lifting and or storage (Cosgrove and Petts, 1990). *Bani* irrigation practices can be defined as indigenous or traditional to Zimbabwe since *bani* cultivation has been practiced for a long time. Bell and Roberts point out that in Zimbabwe, explorers in the early 1900's reported :

“...valleys converted into the most fruitful gardens full of ripe maize, other indigenous grains, cotton and tobacco.” (Cosgrove and Petts, 1990; pp131).

Moris and Thom (1990) complement this with the observation that even though indigenous irrigation systems feed more people than the introduced systems, they have

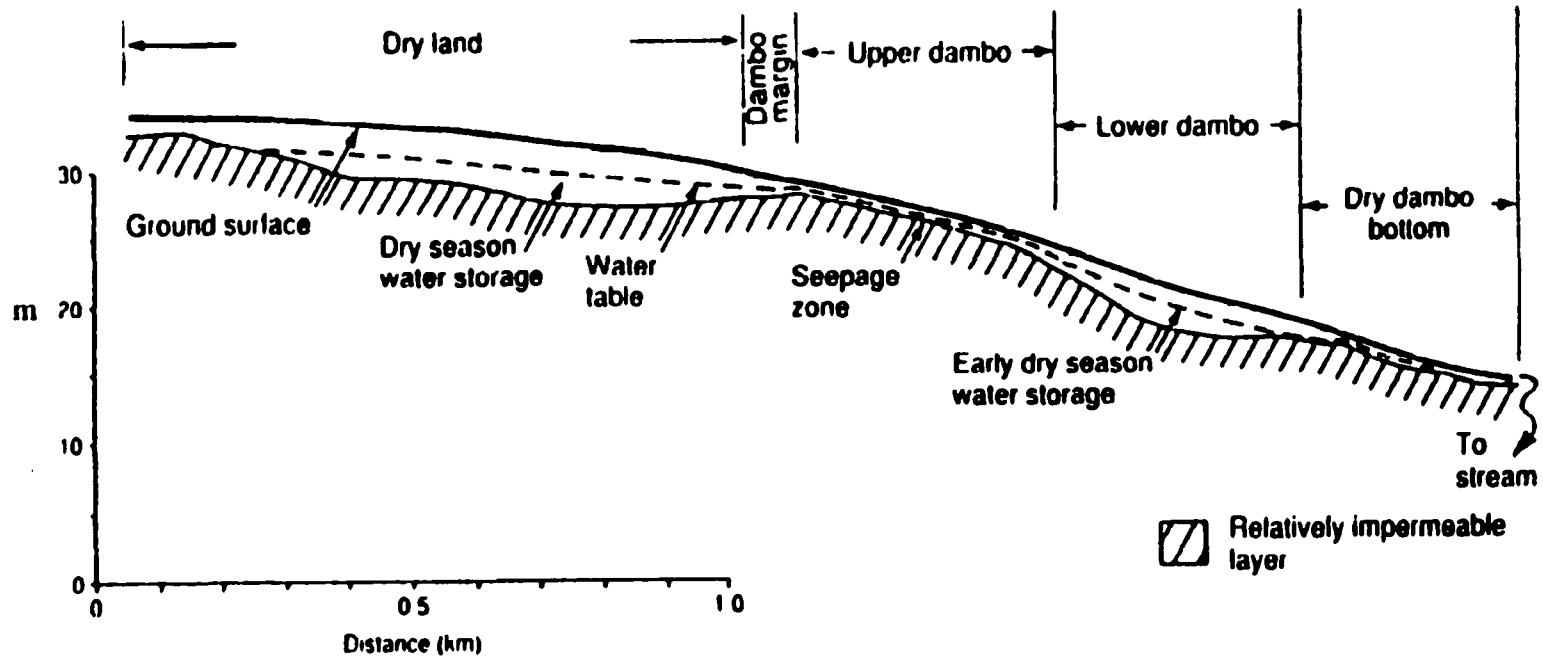


Figure 6.1: Example of a *bani* structure Source: Cosgrove and Petts (1990)

been ignored by engineers and most post colonial governments. This may well be a result of the fact that:

“All too often, irrigation schemes rely too heavily on outside consultants and contractors for direction.” (Singleton, 1991; pp 9).

It is not only the irrigation schemes (at operational level, as implied by Singleton) that have relied heavily on external consultants and contractors for direction, but many governments have had substantial input from outside consultants injected into their irrigation development policies. It is therefore not surprising that these external technocrats did not give much attention to the indigenous irrigation practices and indigenous irrigation technical knowledge. Bell and Roberts contend that many western engineers misread the African water management styles and thought that they were not efficient so they ignored them completely. They argue that :

“...The search for smaller scale alternatives (in irrigation development) reveals that before European colonial rule there already existed a significant African tradition of water management.....It was small in scale, often informal in organization, and lacked the impressive engineering structures of ancient or modern hydraulic civilizations. Precisely for these reasons, it was overlooked by Europeans, for whom manifestations of traditional African water use in the landscape were largely invisible. Indigenous African achievements were by no means unimpressive, however, and they continue to be important today despite decades of neglect or even discouragement by the governments and other agencies.” (Cosgrove and Petts , 1990; pp 129).

The *bani* irrigation system falls under the water management systems that are described above. Infact the *bani* system is not encouraged by the Zimbabwean government as a development strategy. There has been very little research and/or development on the *bani* system. On the formal systems, water is delivered through lined canals whereas on

the *bani* system farmers use unlined ditches, pipes, buckets and watering cans to move water from source to plants. Whereas most formal systems get water from dams and river diversion weirs most *bani* systems have wells dug in the plot itself as water sources. Irrigation infrastructure is more developed on the formal systems. Bell and Roberts argue that perhaps the traditional systems were ignored because they did not need centralized planning and coordination, nor the collection of hydrologic and agricultural statistics, so their contribution to the economy has always been understated. In Zimbabwe *bani* irrigation has succeeded despite rather than because of government intervention (Cosgrove and Petts, 1990).

Restrictions of the cultivation of *banis* by the government were because there was uncertainty about the impacts of cultivation on soil erosion and downstream flow. As a result government passed several pieces of legislation that meant to severely restricted *bani* cultivation. The Water Acts of 1927 and 1976 sought to protect downstream water flows by restricting the extraction of water from the sources of streams and *banis*. The Streambank Protection of 1952 aimed to protect against erosion by preventing cultivation within 30m of a stream and or *bani*. However Bell and and Roberts observe that the legislation was initiated by soil degradation that occurred to *banis* on commercial farmland not on the smallholder areas. Some authors refer to the :

“...careless degradation of *dambos (banis)* by settler farmers.” (Cosgrove and Petts, 1990; pp 134).

The degradation of the *bani* in the commercial lands was not surprising given the fact that they (the commercial farmers) ignored the environmentally friendly African ways that had been used for long periods on the same landforms in favour of more western type practices. They viewed the African water management practices as inefficient. This view was held by both the farmers and colonial government officials:

“...White colonial government officials were largely blind to the ability of African farmers to cope with seasonal variations in water supply through technologically simple but environmentally effective water management. In the absence of large engineering structures or neatly contoured slopes, the African agricultural landscape appeared to, be haphazard, disorganized and inefficient.” (Cosgrove and Petts, 1990; pp 136).

That the *bani* cultivated landscape appears haphazard and disorganized takes only one visit to single *bani* to confirm. However several studies have shown that *bani* cultivation is economically viable (Rukuni *et. al.* 1994, Makombe and Sampath, 1998). Haphazard though they may look, the *bani* resources were and still are locally carefully managed in response to priorities and resource endowments of the individual communities and households exploiting this resource (Cosgrove and Petts, 1990). The cultivated *bani*s have also demonstrated that the traditional *bani* cultivation practices are environmentally friendly because whereas the *bani*s in the commercial farming sector are in pretty bad shape, those in the smallholder areas where most of the traditional practices have been maintained have been better maintained over time.

Even given the legislation that attempted to limit *bani* cultivation, there have been different levels of *bani* cultivation in different areas. *Bani* cultivation is more intense in the higher rainfall areas that are more densely populated. In these areas there are more

bani lands that are not associated with the streambanks. In the drier areas, *bani*s tend to be linear and along stream banks. The government tended to enforce the streambank cultivation more strongly than other legislation so there is less *bani* exploitation in the drier areas as Table 6.1 shows. Gutu is a drier area than Chihota and less households have access to a garden (which is usually in the *bani*) and less get income from a garden. Both

Table 6.1 A comparison of the use of *bani*s between two smallholder (communal) areas

Communal area	Western Gutu	Chihota
Mean annual rainfall (mm)	700	850
<i>Bani</i> area (km ²)	125	195
<i>Bani</i> area % of total area	12.2	29.6
Total <i>bani</i> garden area (km ²)	1.7	24.5
Mean <i>bani</i> garden size (ha)	0.06	0.50
Households with <i>bani</i> garden access (%)	56	96
Households with income from <i>bani</i> garden	46	95

Source: Cosgrove and Petts (1990).

the *bani* size and average garden size are smaller in the drier area than in the wetter area. This is ironical given the fact that the families in the drier areas are more food insecure than those in the wetter areas. Some of these inconsistencies have led some people to believe that:

“...legislation of this type (restricting *bani* cultivation) was also enacted as a means of controlling the African farmers and reducing competition for agricultural markets. Many peasant households were forced to seek alternative ways of meeting their nutritional needs.” (Cosgrove and Petts, 1990; pp 136).

Some of the alternative ways involved going to work on commercial farms and then buying in food. This worked very well for the colonial commercial farmers since they would produce the food for sale in the dry areas.

In Zimbabwe, the development of the *bani* systems is cheaper than that of the formal systems. Currently, the development cost for the *bani* system is estimated to be about US\$50 per ha. compared to US\$200 to US\$1000 per ha. for the formal smallholder systems (Rukuni *et. al.*, 1994). Furthermore, the development of the formal systems is financed by the government whereas on the *bani* system farmers pay for their own development

Zimbabwe has 1.28 million ha of *bani* landform, about 3.6 percent of the total land area (Whitlow, 1984). Approximately 15,000 - 20,000 ha. of this area is currently under cultivation in comparison to 118,000 ha. of formal irrigation development. An estimated 80,000 ha. of *bani* land could potentially be brought under cultivation. This means that only 20 percent of potentially exploitable *bani* land is currently cultivated (Bell , Faulkner, Hotchkiss, Lambert, Roberts and Windram, 1987). Much of this land is located in the communal sector.

Banis and the implications of *bani* cultivation are not limited to Zimbabwe. There are related landforms in other countries (Figure 6.2). *Banis* are also found in Malawi,

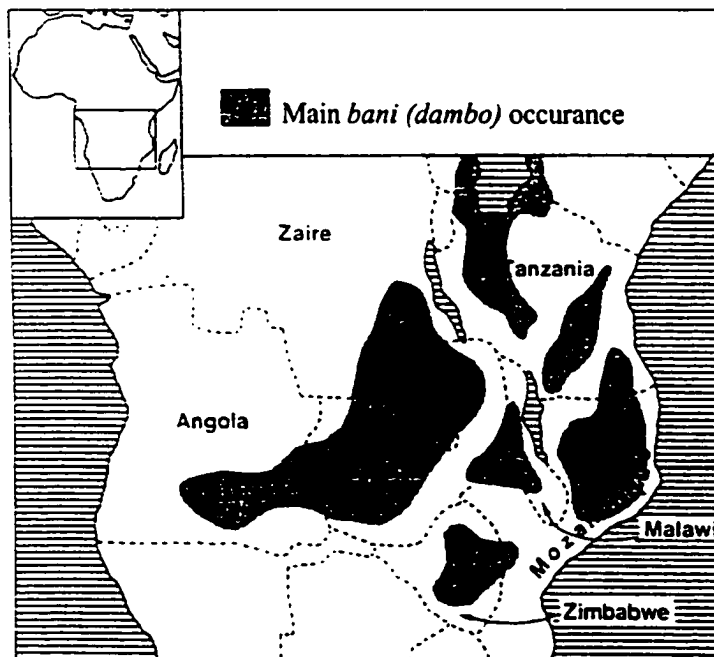


Figure 6.2: *Bani (dambo)* distribution in central Africa
 Source: Roberts (1988)

South Africa, Rwanda, Sierra Leone, Tanzania and Nigeria where they are called *dambos*, *vleis*, *marai*, *boli*, *mbuga* and *fadama* respectively (Roberts, 1988). Given this widespread existence of the *bani* landform, they may exist in other countries that we have not mentioned.

While restriction on the cultivation of *banis* is often circumvented, either through loose interpretation of the legislation or lack of enforcement, it has broader implications for *bani* cultivation. Little research or extension is available to inform farmers how to make *bani* irrigation realize its productive potential. Although there is considerable farmer-to-farmer learning, this is limited by the dispersed nature of *banis*. *Bani* farmers are not eligible for credit from the National Farm Irrigation Fund or other formal agricultural sources. This is unfortunate given the productivity of the *bani* system as demonstrated by recent research. Makombe and Sampath (1998) also show that the *bani* system distributes the benefits of irrigation more equitably than the formal systems.

A further constraint to *bani* production is the limited infrastructure for transport and marketing. Many farmers are not able to get crops to market, and either suffer losses or decide not to grow perishable crops. The most profitable of the *bani* sites in our study had a marketing cooperative assisted by the Agricultural and Rural Development Authority (ARDA), that took vegetables to Harare. Even though recent research has shown that indigenous *bani* cultivation is economically viable and that the irrigation practices can be environmentally sustainable, further technical and agronomic research is needed to determine what types of cultivation practices can maximize returns with least

damage to the environment. It appears that a key factor to the sustainability of the systems is the fact that communities regulate the amount of land allocated on the *bani*, especially as water becomes scarce. This is done to prevent overexploitation and to reserve part of the area for livestock, domestic water, and other alternative uses of the *banis*.

6.2 Objectives

The objectives of this study are to: compare the technical inefficiency of the *bani* system to the formal systems, make recommendations on whether the *bani* system should be considered as an irrigation development option based on these analyses.

6.3 Data

Data were collected from 16 smallholder irrigation systems during the 1990/91 summer and winter seasons. The sample comprised 9 Agritex, 3 community and 4 *bani* systems from which the sample sizes were 149, 69 and 42 farmers respectively. Plot level data were collected on the area planted, number of irrigations, fertilizer and labour used by farmers during the growing season. The value of output, both marketed and consumed at home, was estimated for the summer and winter crops in all the systems. Since all the systems plant summer and winter crops, value of output was summed for the two seasons for every farm. In the absence of rainfall data, the dummy variable REGION was used as a rainfall proxy. Most of the sample irrigation systems are in regions IV and V although one was in region III. These data were collected under the UZ/IFPRI/Agritex Irrigation Performance in Zimbabwe Project .

6.4 Evaluating the *bani (dambo)* systems as a smallholder irrigation development strategy in Zimbabwe.

The frontier production function as proposed by Aigner, Lovell and Schmidt (1977) was used to estimate technical inefficiency. Aigner *et. al.* propose the following model:

$$(6.1) \quad Y_i = f(X_i; \beta) + \varepsilon_i \quad i = 1, \dots, N$$

Where;

Y_i is the output of the i^{th} farm,

X_i is a vector of inputs,

β is a vector of production function parameters and

ε_i is the error term which is made up of two components where;

$$(6.2) \quad \varepsilon_i = v_i - u_i$$

In equation 6.2, the error term v_i is a symmetric disturbance which is iid distributed as $N(0; \sigma^2_v)$. This error term is a result of favourable and unfavourable external variables that the farmer is not in control of, such as luck and errors of measurement. u_i is assumed to be independent of v_i . It is also assumed to be iid distributed as $|N(0; \sigma^2_u)|$. This error term meets the condition $u_i > 0$. This means that it is truncated above zero. Equation 1 is supposed to give the maximum output that can be produced by a combination of inputs. A farm cannot, therefore, produce above this maximum. The negative error term makes sure that this condition is met. Since the frontier can vary randomly across observations and over time for an observation, it is stochastic (Aigner *et. al.*, 1977). The frontier production function can be estimated for both cross sectional and panel data. In this

study the frontier production function is estimated using farm level cross sectional data. Coelli, Rao and Battese (1998) provide a recent theoretical review of the frontier production function methodology. Taylor and Shonkwiler (1986), Bravo-Ureta and Pinheiro (1993), Bhattacharyya, Harris, Narayanan, and Raffiee (1995), Coelli and Battese (1996), Yao and Liu (1998), Olowofeso (1999), Koo and Sangho (1999) and Bera and Sharma (1999) are some examples of the applications of the frontier production function.

After testing several functional forms, the translog specification was selected as the best fit for the formal systems and the Cobb Douglas for the *bani* system. Limdep, which uses the maximum likelihood method, was used to estimate the frontier production function.

6.5 An evaluation of *bani* (*dambo*) systems as a smallholder irrigation development strategy in Zimbabwe.

Table 6.2 shows levels of input use of *bani* farmers in relation to those on the formal schemes. *Bani* farmers use less inputs, except for labour, but they achieve the highest output per ha. compared to those on the formal systems.

Zimbabwe has a long history of *bani* cultivation (Roberts, 1988, Scoones and Cousins, 1991). The crops grown on the *banis* have changed as new crop varieties have been introduced, largely for dryland farming. The farmers must, therefore, be using their experience in cultivating *banis* and some modifications of the dryland recommendations to produce crops on the *banis*.

Table 6.2: Input use and farmer characteristics by system

	<i>Bani</i>	Formal Agritex	Community
<u>Input Use</u>			
Value of output(Z\$/ha)	2,130	1,353	1676
Planted area (ha.)	.36	.86	.43
Fertilizer (kg/ha.)	28	108	112
Labour (Mandays/ha)	117	73	100
Irrigations (Number)	4.7	6.6	5.5

Source: Sampath and Makombe, 1999

Tables 6.3 and 6.4 summarize the results of the frontier production function analysis.

For the estimation of the equation in Table 6.3 three outliers were omitted because their residuals were outside two standard deviations and they made the skewness go the wrong way. Similarly, for the estimation of the equation in Table 6.4, two outliers were omitted for the same reason.

The stochastic frontier production functions were evaluated at the means of the variables in the regression equations. The results of this evaluation, showed that the formal systems require 0.57 ha of land, 65 kg fertilizer, 35 mandays of labour and 5 irrigations to produce a value of output of Z\$1450, whereas the *bani* requires 0.17 ha, 4 kg fertilizer, 28 mandays and 3 irrigations to produce a value of output of Z\$895 (Table 5).

The average productivities of land, fertilizer, labour and irrigation are 2565, 22, 42 and 327 Zimbabwe dollars respectively for the formal systems in contrast to 5151, 221, 28

Table 6.3. Combined Agritex and Community Stochastic Frontier Production

Function

Dependent variable = LN value of output.

Variable	Coefficient	t Ratio
Constant	4.3386	1.565
ln_A	-0.8988	-0.917
ln_F	-0.1453	-0.146
ln_L	0.8695	1.943
ln_I	-0.7389	-1.434
REGION	0.0004	0.308
Ln_A-SQ	-0.2592	-2.399
Ln_F-SQ	0.1776	1.686
Ln_L-SQ	0.0110	2.605
Ln_I-SQ	0.1399	2.542
Ln(AxF)	0.2634	-0.181
Ln(AxL)	-0.0161	-1.543
Ln(AxI)	-0.1594	-1.593
Ln(FxL)	-0.1803	0.851
Ln(FxI)	0.1030	0.083
Ln(LxI)	0.4757	-4.014
σ^2_v	0.1942	
σ^2_u	0.9281	
σ^2_u/σ^2_v	4.7791	
Log Likelihood	-216.22	

Table 6.4. Bani Stochastic Frontier Production

Function

Dependent variable = LN value of output.

Variable	Coefficient	t Ratio
Constant	7.4244	5.741
ln_A	0.5764	3.900
ln_F	0.1517	1.362
ln_L	-0.0797	-0.248
ln_I	0.4277	3.281
σ^2_v	0.2015	
σ^2_u	1.1101	
σ^2_u/σ^2_v	5.5092	
Log Likelihood	-52.43	

and 339 respectively for the *bani* systems. All the inputs, except labour, have higher average productivity on the *bani* than on the formal systems. Marginal productivities for all the inputs, with the exception of labour, are also higher for the *bani* system compared to the formal systems. Labour is an abundant resource and the *bani* system uses more labour than the formal systems (Table 6.1). This may explain the low and negative average and marginal productivities respectively.

Table 6.5: The productivity of inputs for the *bani* and formal systems

Attribute	System			
	Formal		<i>Bani</i>	
	Level ¹	Productivity ² Per Unit	Level	Productivity ² Per Unit
Value of output (Z\$)	1450		895	
Area (ha)	.57	2565 (513)	.17	5151 (3035)
Fertilizer (kg)	65	22 (16)		221 (33)
Labour (mandays)	35	42 (9)	32	28 (-2)
Irrigations (number)	5	327 (49)	3	339 (128)

1. Rounded off to the nearest whole number (except in the case of area)
2. Average and marginal in brackets (in Z\$, all evaluated at mean of regression variables)

The results of the inefficiency estimations show that the estimated inefficiency for the formal system is sensitive to the assumptions made about the distribution of the error term. Three assumptions were made about the distribution of the error term, namely

the half normal, truncated normal and exponential. The truncated normal model did not converge. The results of the other two assumptions are summarized in Table 6.6.

Table 6.6. Results of inefficiency estimation (%)

System	Assumed error distribution	
	Half Normal	Exponential
Formal	11	8
<i>Bani</i>	13	13
Significance at .05	NS	S

With the half normal assumption, the inefficiency of the formal systems is estimated to be 11 percent, which is not statistically significantly different from the 13 percent estimated for the *bani* system. However, using the exponential distribution of the error term, the inefficiency of the formal systems is estimated to be substantially lower and is statistically significantly different from that of the *bani*. Bearing in mind that not all the inputs are accounted for in the frontier production function, the production function may not be so much a measure of technical inefficiency as it is a measure of the marginal product of the unobserved inputs. Given this caveat, the estimated inefficiencies, suggest that there is more to be gained by improving *bani* production. The half normal distribution results suggests that the *bani* system is as at least as efficient as the *bani*, even given all the government support given to the formal systems. The exponential distribution assumption suggests that *bani* efficiency can be improved to approach that of

the formal system, with significant gains since the productivities of the *bani* are higher than those of the formal systems except for the abundant labour.

6.6 Discussion

These results indicate that the *bani* system has the potential to achieve the objectives of irrigation at least as well as, if not better than the formal systems.

Given that the practices of cultivating the *banis* can be environmentally sustainable, the *bani* should be seriously considered as a smallholder irrigation development strategy. Research should be carried out on the *banis* to generate production recommendations that are suitable to the *bani* circumstances. *Banis* currently do not compete for any resources with the government. This is a desirable situation since it alleviates of the responsibilities that the government has to shoulder for the formal systems. It is therefore recommended that the initial involvement of the government should only be at the research extension level.

Chapter 7

Conclusions and policy recommendations

7.1 Introduction

There is no doubt that the development of water resources will take precedence in the new millennium. Water resources are developed for multiple uses including mainly industry, domestic and agriculture (FAO, 1995). In many parts of the developing world, Africa included, deaths, hunger and malnourishment are sometimes directly associated with the failure to produce sufficient food to feed the population. Agricultural development can play a critical role in alleviating the problems of hunger and malnourishment.

Central to the role of agriculture in alleviating these problems is the ability to develop water resources for agriculture through irrigation. Irrigation can produce two and a half times more than non irrigated production (Hren and Felts, 1998). However irrigation projects need to be assessed for viability before they are developed.

African irrigation development efforts have been characterized by large engineering projects that have not performed according to expectation (Moris and Thom, 1990).

Adams, Potkanski and Sutton (1994) point out that:

“The lessons of failure are clear, for example in the large scale government irrigation

schemes promoted in Nigeria and Kenya in the 1970's and early 1980's." (Adams *et. al.*, 1994; pp 17).

The frustration with the performance of large-scale irrigation has led to the search for alternatives. One alternative that quickly came to mind is smallholder irrigation (Adams, 1990; Undehill,1990; Singleton,1991; Adams *et. al.*, 1994;)

Some of the factors that compromise the potential of irrigation development on the African continent include high costs and poor management. The United States Agency for International Development found that investment costs of US\$10,000 or more per hectare are very common in Africa (Quiroga, 1990).

Given this background, issues of project evaluation and management should take precedence in the development of irrigation projects in Africa. This study explored some of the concepts related to these issues and ensuing are the conclusions and policy recommendations emanating from the study with specific reference to Zimbabwe.

7.2 The impacts of irrigation induced technology in Zimbabwe

This study used a Marshallian partial equilibrium analysis to assess the impacts of irrigation induced technology in Zimbabwe. The conclusion from the study is that the impacts of irrigation induced technology are not always positive. The choice of the type of irrigation to develop in Zimbabwe is a critical factor in determining the extent to which irrigation has positive impacts. In Zimbabwe, the choice is between the large scale commercial irrigation projects and the smallholder irrigation systems. Using maize as the

crop to assess the impacts of irrigation induced technology in Zimbabwe, this study concludes that the smallholder irrigation development option maybe the most viable option.

However, the interest groups that are being served by the development of irrigation need to be considered. The option that develops the smallholder sector the least has the highest net benefit to producers. So, this option is the best if producer's interests are a priority. If the government is interested in overall effects, then the smallholder option is the desirable one. This option is rendered even more attractive by the desire of the government to achieve equitable development between the largely European owned high agricultural potential large scale commercial farms and the low potential smallholder farms owned by the indigenous African population. This is so not only because the benefits of smallholder irrigation development have higher net benefits but also because smallholder irrigation will be accessible to more farmers, a critical factor in Zimbabwe given that the majority of the population still lives off the land.

After this aggregate analysis the study then focused on smallholder irrigation development in Zimbabwe in relation to water management, financial performance, the impacts of socio-economic variables and the potential of the informal *bani* irrigation system as a smallholder irrigation development alternative in Zimbabwe. Ensuing are the conclusions and policy recommendations from these studies.

7.3 Water management performance

This study evaluated the water management performance of the formal smallholder irrigation systems namely the government managed Agritex and the farmer managed community system. The study was motivated by the questions which are frequently asked about which one of these systems is a better development alternative for the government to pursue. Farmers on both schemes grow crops during the rainy summer and the dry winter. The challenges that they face in terms of irrigation during these two times are different. During the summer, irrigation aims to satisfy the difference between effective rainfall and crop water requirements when the former falls short of the latter. During the winter, all the crop water requirements need to be satisfied through irrigation. This study concluded that, when it was required, the farmer-managed systems were better able to match crop water requirements to supply. This means that the government ought to seriously consider developing the farmer-managed systems as opposed to the government managed ones. This option reduces government staff requirements since it does not get involved with management of the schemes. With this option, the involvement of the government would cease after the scheme is fully developed a point at which it would be handed to the farmers.

7.4 The financial performance of smallholder irrigation systems.

This study sought to use simple benefit cost analysis to evaluate the financial performance of the smallholder irrigation systems including the informal *bani* systems. Benefit cost ratios for the three different systems were computed and compared. The study concludes that the *bani* system performs better than the community system which

performs better than the Agritex system. This points to the fact that the informal *bani* system has the potential to achieve the objectives of irrigation in the same manner as the formal systems. Consistent with the water management performance results, the farmer managed community system performs better than the government managed Agritex systems.

A caveat in this analysis is that the estimation of benefit cost ratios did not include depreciation and capital costs. This would be necessary to answer the question: What level of benefit cost ratio is necessary for farmers to achieve subsistence. To this extent these results are only indicative.

7.5 The impact of socio-economic factors on smallholder irrigation performance

Skold and Lybecker (1985) point out that smallholder production is often characterized by a high degree of both complexity and interdependence, yet many smallholder systems lack the social organizations to support and coordinate this complexity and interdependence. A starting point to build these institutions is through farmer organization like labour groups and small scale credit unions. This study looked at the impact on smallholder irrigation financial performance of some variables namely: marketing coops, access to credit, labour group participation, master farmer training, literacy, record keeping, savings clubs and gender.

These farmer organizations like labour groups and savings clubs were, not surprisingly, found to be more developed on the formal irrigation systems than the informal *bani*

system. This further points to the extent to which the informal *bani* system has been ignored as a development strategy. Of the variables studied, labour groups appear to have impact on the Agritex systems. None of the variables appear to influence the community schemes and marketing cooperatives had impact on the *bani* systems. This points to the fact that each system might have different needs in terms of support institutions.

7.6 The potential of the *bani* system as a smallholder irrigation development strategy

Zimbabwe has a long history of *bani* cultivation (Roberts, 1988; Scoones and Cousins, 1991). However in the recent years *bani* cultivation has been discouraged by government through a series of legislation including the The Streambank Protection of 1952 and The Water Acts of 1927 and 1976. These legislations were partly based on the fear that cultivating the *banis* would be environmentally damaging and partly to protect the interests of the European settler farmers. There is mounting evidence to the effect that the traditional methods of *bani* cultivation are not environmentally damaging. There is also mounting evidence to the effect that the *bani* system can achieve the objectives of irrigation in much the same way, if not better than the formal systems. The results of the frontier production function presented in this study support this. The government should therefore seriously consider the *bani* system as a smallholder irrigation development strategy.

7.7 Policy Recommendations

Four clear policy recommendations stand out in this study:

1. The government of Zimbabwe should develop the smallholder irrigation systems more aggressively than the large scale commercial systems given its drive for the equitable distribution of the resources in agricultural production.
2. Given the choice between the farmer-managed community systems and the government managed Agritex smallholder systems, the government should develop the farmer-managed systems. Not only do these farmer-managed systems perform better than the Agritex systems in many respects, but they also result in a large net saving in government expenditure that could be spent elsewhere where it can be more productive.
3. The government has ignored the traditional *bani* cultivation system as a smallholder development strategy. However this system is capable of achieving the objectives of irrigation at least equally, if not better than the formal systems. To this extent, the government should revise the Water Act and Streambank Protection to be in line with contemporary knowledge. This may lead to the sustainable exploitation of this valuable resource in Zimbabwe.
4. Finally, the government should pursue an aggressive smallholder irrigation development strategy, because since irrigated agriculture is more productive, this may reduce the need to reallocate land, a need for which the government is currently under extreme pressure.

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