Experiences with Micro Agricultural Water Management Technologies:

Zambia

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Micro-Irrigation and Water Harvesting Technologies: Experiences and their Contribution to Poverty Alleviation Impacts in Zambia

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1.0 Introduction and purpose of the study

Zambia is a landlocked country with a population of 10.3 million as per 2000 census of which 60 percent lived in rural areas. The country is one of the heavily indebted poor countries (HIPC). External debt stood at US$ 7.3 billion in 2001. At about US$ 730 Zambia has one of the highest per capita debt. Gross Domestic Product (GDP) per capita in 2002 was US$ 330, and it is ranked 163 out of the 175 countries covered by the United Nations Development Programmed (UNDP) Human Development Index (HDI), 19 positions from the bottom. Out of 88 developing countries, Zambia ranks number 66 on the Human Poverty Index, 21 positions from the bottom. According to the Central Statistical Office (CSO) Surveys, poverty has increased from 69.7 percent in 1991, to 72.9 % in 1998. Some improvements in the country's GDP growth recorded at 4.5% in 2004 is noticeable due to increased exports and debt forgiveness by some countries after Zambia reached the HIPC completion point facility. This improvement is the major causal factor of a sudden rapid appreciation of the Kwacha currently experienced but is widely believed in economic cycles to be temporal.

This report highlights agricultural water technologies and practices that have helped or have shown potential to impact positively towards alleviating poverty especially among the rural poor. Some of these technologies transcend from indigenous knowledge to being modernized through modifications and have led to some of the state of the art modern water management technologies in use countrywide or in the Southern Africa Region.

A wide range of established and well-documented traditional technologies is available for use by smallholders. These clearly play a significant role in Zambian agriculture and will continue to do so. There is still considerable room to adapt traditional technologies to different circumstances, which because of their low cost and simplicity can be used and maintained by smallholders with little or no external support. They are particularly suited to subsistence farming and equally have an important role to play in the transition to cash cropping. For this reason they have attracted much interest from aid donors and governments wishing to support subsistence farming. Many lessons learned, about what needs to be done, have rather been concerned with the ways in which such technologies can be introduced into farming systems than the technologies themselves per se. However, there are still concerns about the technology and the ability of people to design and construct good engineering works that will provide lasting service. There is also a danger that `low-cost' solution, which may be attractive to aid donors, may become a euphemism for poor engineering.

There is a general consensus among technical development workers, policy-makers in the developing world and aid agencies that a lack of capacity is constraining the development and improvement of agricultural water management technologies and irrigated agriculture as a means of reducing poverty, increasing food security and improving livelihoods among both rural and urban populations. The need for capacity development in irrigation, drainage and water management became particularly obvious in early 90's twenty years after irrigation and water management transfer programmes were implemented by Government and when people realized that transferring responsibilities without transferring and/or raising the capacity of the people involved in implementation was a major threat to the success of this institutional reform. Many developing countries now say they need more capacity, and aid agencies are keen to supply it or at least help to create it. However, it remains a concept of enormous generality and vagueness wrapped up in a host of concepts such as ***participation, empowerment, technical assistance*** and ***organizational development (Morgan, 1998).*** Moore (1995) states that: "Capacity building includes everything that was covered by the different definitions of institution building and more besides financial resource capacity. Aid agencies would be wise to have no track with the new jargon of ***'capacity building'*** and to insist on using language and terms that have identifiable and precise meanings." Others (Browne, 2002) refer to the ***weary mantra*** of capacity building that is not leading anywhere. The calls for capacity building in irrigated agriculture suffer from these same vague generalities

This report has inventoried and described some technologies ranging from piloted but high potential for adoption by small-scale farmers and contribution to poverty alleviation to those currently in use but having had accelerated adoption at inception to slowed down adoption after external agencies withdraw assistance. Reasons for slowed adoption after withdraw of assistance are articulated and expounded from the point of view of capacity. The technologies include; (a) Clay pot sub-surface drip system, (b) Zilili river flood plain recession, (c) Micro-basin water harvesting (Conservation Farming), (d) Dambo cultivation (Inland valley swamp irrigation), (e) Hill-spring water gravity head sprinkler irrigation, (f) Low-cost bucket and drum kit drip irrigation system and (g) Treadle pump irrigation adapted to surface flood systems and (h) Roof Harvesting Rain water for domestic use.

In this report, capacity building has been defined after the United Nations Development Programme (UNDP, 1998) definition as ***"the sum of efforts needed to nurture, enhance and utilize the skills and capabilities of people and institutions at all levels - locally, nationally, regionally and internationally so that they can better progress towards sustainable development".***

It continues by saying: ***"at the basic conceptual level, building capacity involves empowering people and organizations to solve their problems, rather than attempting to solve their problems directly. When capacity building is successful, the result is more effective people and institutions better able to provide products and services on a sustainable basis."***

The report does not attempt to describe the process of implementation nor the detailed technical engineering aspects of the technologies. Where possible, some gross-margin budgets of crops grown under these technologies have been documented to reflect how impacting towards poverty alleviation through income generation these technologies are among the rural poor farmers. Hunger situation has been highlighted at country level. All the in-country water related projects under the USAID Initiative to End Hunger In Africa have been documented.

1.1 Methodology

The study gathered information by interviewing key-informants implementing some of the projects under the USAID- Initiative to End Hunger in Africa and those from NGOs, Community Based Organizations and Government Departments that are piloting some highly promising appropriate irrigation and water use technologies and collecting some reports where possible from them. Information was solicited from International Development Enterprises (IDE), Co-operative League of the United States of America (CLUSA) – implementing small-scale irrigation programme through Total Land CARE (TLC), World Vision International (WVI), CARE, AFRICARE and HODI. To some extent Irrigation Equipment suppliers including SARO and Aqua-Agro were visited and interviewed to ascertain their participation in local manufacturing of small-scale irrigation equipment as initiated by IDE.

1.1.1 Limitations

It was not easy to particularly collect end of project reports because of organizational policies on information sharing and data security. In some cases information had to be given at a cost. In almost all cases, poor economic data exists on profitability of technologies because users did not keep adequate financial records unless where the project monitored such information.

2.0 Overview of Food Security, Hunger, Agriculture and Water

This section of the report highlights the current food basket of Zambia, hunger situation and agriculture and water development trends.

2.1 Food Security and Hunger Situation in the Country

Zambia is currently facing food shortages and up to 1.7 million people which is 20% of the population are faced with hunger. Government has subsequently appealed to the international donor community for food aid. This is despite having had registered two successive bumper harvests in the 2002/03 and 2003/04 agricultural seasons which were followed by a drought season of 2004/05 characterized by poor crop harvests particularly by the small-scale farmers. Such droughts have been phenomenon indicating 1992, 1995, 2001 and 2004 as drought years in the last decade. The bumper crops were not well managed in terms of creating a strategic national food reserve but culminated in massive export of the staple maize to neighbouring countries like Malawi and Zimbabwe that registered food deficits. The current food deficit has resulted in Government allowing millers to import up to 150,000 metric tones of none genetically modified maize mostly from South Africa.

Zambia requires up to 141,889 metric tones of maize to feed the 10.3 million people but has a deficit of 85,000 metric tones to meet this requirement. Maize is a staple food for the country but is mainly produced by small-scale farmers who rarely access fertilizer and hybrid seed inputs due to inadequate financial capacity to purchase them. Despite this deficit, cassava which is a root tuber crop registered a surplus of 324,834 metric tones above the requirement of 731,546 metric tones whereas potatoes and sorghum/millet met their national requirements at 82,489 Mt and 50,742 Mt respectively. Rice which is produced in Dambos (inland valleys) did not meet its national requirement of 137,000 Mt by 25,440 Mt. Cereal wheat produced at 137,000 Mt almost met its requirement of 140,000 Mt due to a stimuli by Government's heavily taxing imported wheat and its products.

Historically, drought occurrences have shown to continue to depress food production and thus food insecurity threatens 80% of the population. Lusaka province, for example, registered a reduced maize production from 85 715 tones in 1993 to a meager 19 329 tones in 1995, whereas paddy rice showed systematic reduction from about 600 tones in 1991 to less than 5 tones in 1996 and cereal wheat from 20 251 to 11 504 tones in the same period. Similar trends of crop production were registered in other provinces and overall at national level. Reduced crop production has been attributed to the heavy dependency on rain fed agriculture, which is unreliable due to severe droughts, and thus food deficits, particularly maize, frequently occur.

2.1.1 Health and Nutrition

Major health related problems manifest particularly because of malnutrition due to inadequate food at household level. Malaria is prevalent throughout the country but serious problems arise in waterlogged areas such as swamps, rivers and lake areas where breeding sites are dominant. It is estimated that Zambia treats up to 3.5 million cases per annum. Malaria is a major public-health problem in Zambia accounting for nearly 40% of all outpatients and over 50% of these cases are among children under five years old. In Zambia malaria is one of the three major public health problems that include HIV/AIDS and tuberculosis (WHO: 2000; WHO: 2003). It is the leading cause of illness and death in the country accounting for 4,093,401 cases and 50,000 deaths each year (CBoH, 2003). The malaria incidence rate has tripled over the past three decades largely due to increasing treatment failure using the traditional chloroquine anti-malaria drug and difficulty in implementing preventive measures.

HIV-AIDS pandemic has been another serious health problem which is related to Zambia's socio-economic effects. Many deaths have occurred due to HIV-AIDS and it is believed that the infection rate is high among the youths who are sexually active. The continued spread of HIV/AIDS has affected the farming industry in Zambia in many ways. HIV/AIDS is estimated at about 20% of the adult population in the country. The prevalence rate for the 15-49 year age group is 20% according to the Demographic and

Household Survey 2001/2002 (UNDP, 2002). This has affected the quality and quantity of human labour available for efficient agricultural production. Increased medical expenses have diverted resources from agricultural investment. Trained staff in the industry continues to die or are rendered unproductive. Mitigation measures such as labour saving technologies are however being developed to ensure sustained agricultural productivity.

2.1.2 Agriculture and Water Resources Potential and Use

Zambia's irrigation potential is 2.75 million ha based on water availability and soil irrigability. From this potential, it is believed that 523 000 ha can be economically developed. However, the fact that different figures such as high as 28 million ha but not documented figures of the potential are quoted by other authors indicates the need for a systematic assessment to determine the correctness of the findings.

Zambia lies entirely within two large river basins, the Zambezi River basin and the Congo River basins. Following are three major river systems within the Zambezi River basin and two within the Congo River basin:

1. The upper main Zambezi River system is joined by the Luangwa and Kafue tributaries in Zambia. The upper Zambezi originates in Angola and flows to Mozambique after forming the border with Zimbabwe.
2. The Kafue River system covers an area of 152 000 km^2. The river has two important dams, the Itezhi-Tezhi dam and the Kafue Gorge dam, the latter of which is used for hydropower generation.
3. The Luangwa River has a catchment area of 165 000 km^2. It drains most of the central parts of the country and empties into the Zambezi.
4. The Chambeshi River and the Luapula River are associated with lakes Mweru and Mweru-Wantipa and drain their water into the Congo River system.
5. The small Tanganyika drainage system is also part of the large Congo River system.
6. Total renewable water resources of Zambia, amount to about **105 km^3/year**, of which about **80 km^3/year** are produced internally. An extensive area of 25 000 km^2 is covered with Limestone aquifer layers extending from Lusaka to the northwest.

There are about 1 700 dams. The total capacity is about **106 km^3**, but this includes 50% of Lake Kariba on the Zambezi River, which is shared between Zambia and Zimbabwe and which accounts for **94 km^3** of this capacity. Not taking into consideration this shared dam, the total capacity is thus about **12 km^3**. However, this figure probably also includes small dams with a height of less than 15 meters. Information related to dams at the Water Board is fragmented; although the Board in 1994 initiated a study to compile a dam inventory for the country, this is not available yet. In drought prone areas of the Eastern, Lusaka, Central and Southern provinces, water needs to be conserved for livestock, agriculture and domestic use. This has led to the construction of low-cost earth dams and water impoundment earth bunds, spearheaded by the farmers themselves or the government for drought relief since 1991. The number of such structures is estimated to be between 2 000 and 3 000. However, most of them are in a state of disrepair either by breaching, lack of or insufficient maintenance or poor design.

Wetlands, including Dambos, which cover about 3.6 million hectares or 4.8% of the total land area, are a source of livelihood for the majority of small-scale farmers in Zambia. Dambos are used for grazing animals in the dry season when upland vegetation is dry and with little nutritive value. They are also important for fishing, livestock-watering, hunting of small animals, collection of thatching grass and most importantly, for dry season vegetable growing. Seepage zones and shallow wells are used as sources of water. Sometimes water storage needs for irrigation may dictate the construction of a low-cost earth dam. This type of use at small-scale does not entail use of heavy machinery for cultivation or draining water.

2.1.3 Irrigation Water Use

Currently 155,912 ha of land are irrigated in Zambia, which is about 30% of the economical irrigation potential. It can be broken down as follows according to the technology used:

?? 32 189 ha is under surface irrigation; sugarcane covers more than 50% of this area
?? 17 570 ha is irrigated by sprinklers; wheat accounts for 68% of this area
?? Drip irrigation covers some 5 628 ha; coffee production accounts for 92% of this area
?? Small-scale farmers are growing vegetables in Dambos on an area of 100 000 ha, which are equipped with small drains, impoundment furrows and shallow wells for irrigating a wide range of vegetables in the dry season (May-October)
?? Some of the small-scale farmers use treadle pumps to irrigate areas of over one thousand two hundred hectares (1 200 ha); it is estimated that more than 5 000 treadle pumps are in use.

Total water withdrawal was 1.737 km^3 in 2000, with agricultural water use accounting for 1.320 km^3 (77%), or more than three-quarter of the total, domestic water use claiming 0.286 km^3 (17%) and dwindling industries taking 0.131 km^3 (6%). Future water use is estimated to reach 1.922 km^3/year by 2012, assuming that land under irrigation will continue to expand at the rate of 1 200-1 500 ha/yr, industrial use will increase by 10% and the population will increase at a moderate rate. About 88% of the area equipped for full or partial control irrigation draws its water from surface water and 12% from groundwater.

2.1.4 Summary Of Irrigation Systems

Table 1: Extent of Irrigation by Types and Systems.

Irrigation Type	Size (ha)	Irrigation System	Size (ha)
Small-scale	111,525	Surface	32,819
Medium scale	7,372	Sprinkler	17,570
Large scale	37,015	Localized (drip)	5,628
		Equipped wetlands & Inland valleys	100,525
Total	**155,912**	**Total**	**155,912**

Source: Fao-Aquastat-2003

Table 2: Irrigation area by crops.

Crop Type	Irrigated Area (ha)
Annual crops	1,344
Bananas	3,000
Citrus	2,210
Coffee	5,160
Cotton	35
Maize	1,500*
Rice	8,000
Sugarcane	18,418
Tea	520
Vegetables	125,525
Wheat	12,200
Total	**155,912**

Source: Fao-Aquastat-2003

*Dry season irrigated maize

3.0 Analysis of Good Practices in Micro Irrigation and Rain Water Harvesting

3.1 Micro-basin water harvesting (Conservation Farming)

This is an improved water management technique which is being practiced under rain fed agriculture and has been advocated to realize the best possible water supply for the crops. This has been achieved through advocacy programmes for adopting conservation farming using micro-basins of sizes of 35 cm x 15 cm x 15 cm prepared by hand hoes. When it rains, they act as water harvesting basins that store water for much longer time. This method has proved to yield 3 tons/ha of maize as compared to 1.5 tons/ha using conventional methods. This performance has led to accelerated adoption of this farming system. There are currently an estimated 200 000 ha under conservation and/or water harvesting farming by small-scale farmers. Although quite rare, supplementary irrigation is mainly practiced by commercial farmers on fields that are planted with rain fed soybean in rotation with irrigated wheat. A few commercial farmers supplement cotton with irrigation before the onset of the rains in November. Conservation farming is adopted by smallholders cultivating on average about 0.25ha land. The system is shown in Figures 1a and 1b.

Figure 1a: Land prepared to conservation farming using micro-basins.

Micro-basins dug this way are used as precision planting and fertilizer applications stations thereby ensuring maximum utilization of inputs. Crop residue is spread between planting rows to ensure mulching the soil against moisture loss due to evaporation and also to suppress weed infestation. Eventual decomposition of this residue enriches the soil fertility by adding organic matter.

Figure 1b: Soya beans planted using conservation farming technology.

3.2 Zilili River Flood Plain Recession Irrigation

Around 10 ha around Lake Kariba is used for flood recession cropping (Zilili). The technique involves planting crops following a receding flood in the flat flood areas along the river banks. The crops utilize the residual soil moisture in these alluvial soils. The crops often mature by the time the soil profile is depleted of moisture. It is rear that supplementary water is given but if this required, it does not exceed two to three irrigations accounting for 30mm of water. Supplementary water is supplied using buckets to draw water from the receding river flood or hand dug shallow wells.

Some farmers use this technique to grow crops in a drying river bed at the peak of the dry season between August and November but such crops risk being swept away by the early rain-storms at the onset of the rain season in November.

Figure 2: Non-fertilized crop grown after a flood recession that brought nutrients with it.

3.3 In- land Valley swamp Irrigation (Dambos)

About 100 000 ha of non-equipped lowland areas are cultivated particularly in the rainy season in the interfluves. These interfluves are known as Dambos in Zambia. Dambos cover about 3.6 million hectares countrywide and smallholder farmers have free access to them. Dambos possess seepage zones from which capillary rise moisture is exploited to grow crops without much water control. In the flood central zones of Dambos, rice cultivation is common but techniques like construction of raised beds and/or ridges makes it possible to grow other crops in this zone. Some areas in the Dambo fringes, commonly known as upper grasslands require that supplementary irrigation water is supplied to crops. The sources of such water would be hand-dug shallow wells or outlet streams from Dambos. Water can be drawn by using a bucket tied to a rope or a suction treadle pump. Shallow wells often do not exceed a depth of 1.5 m a reason for their drying even when the water table is resident at 3 m – 5 m in the dry season. Figures 3a and 3b show crop cultivation in a typical Dambo in Zambia.

Figure 3a: Leafy vegetable Rape grown in a seepage zone at Chipala Dambo.

Figure 3b: Raised beds prepared to drain excess water for restitution of a normal root zone a seepage zone of a Dambo in Zambia.

3.4 Clay pot Sub-surface Drip Irrigation

This is a low-cost indigenous sub-surface drip system achieved by use of unglazed fired clay pots that remain micro-porous and are molded by hand by women at rural level. There however exist molding machines that can mass produce clay pots with specifications of porosity and firing temperature to eliminate possibility of shrinking and swelling of clay which may lead to cracking. The clay pots are buried in the ground with their necks appearing above ground in a row at specific plant intervals. Plants are planted adjacent to the pot on either sides and the pots filled with water and covered with a clay lid on their mouth opening to avoid direct evaporation of water and rodents drinking the water.

Using the principle of moisture potential, water begins to ooze out of the pot from its high water potential to wet the surrounding soil outside the pot where the soil water potential is low. The water is instantaneously taken up by the crop from its root zone around the clay pot. It has been well established that irrigation intervals between 7 -14 days are achievable and that water saving between 50% and 70% are obtained resulting in yield increases between 30% and 45% over conventional flood furrow and basin irrigation systems (Daka,A.E. and Bosma, J., 1999 & 2001). This indicates a high potential for labour saving for irrigating. Crops meritorious under this system include tomatoes, rape leaf vegetable, cauliflower, maize and beans which yielded 42, 33, 22, 13 and 5 ton/ha respectively under clay pot system as compared to 40, 27, 16, 9.3 and 4.7 ton/ha under conventional irrigation systems.

The clay pots have been made at village level and used for storage of seed, as flower pots and as water storage containers at household. Water stored in clay pots becomes cooler than room temperature thus simulating a refrigeration system because some water that oozes out is evaporated from the clay pot surface by heat.

3.5 Treadle Pumps

The treadle pump is only a means to draw and distribute water to the field where water is required to irrigate crops. It has a limitation of abstracting water from a depth of up to 8 m. For this reason, its application is common in Dambos where water tables are as shallow as 0.5m – 5m deep (see Figure 4) from the ground surface. Treadle pumps can also be used to lift water up to 6m – 10m into an elevated reservoir for later distribution by pressurized systems such as sprinklers or low-cost drip irrigation system. This technology is widespread and it is believed that over 5 000 treadle pumps are in use and up to 1 250 ha are irrigated using these pumps enabling a farmer to double crop on the same piece of land per year or season. Water delivered by treadle pumps can be reticulated to surface systems like furrow, basin and flood border strip irrigation system. The pressure treadle pump can also operate a few sprinklers for overhead systems depending on the energy of the operator.

Figure 4: Typical example of a shallow well in a wet Dambo.

The treadle pump technology has proven to be of high potential considering that farmers are able to expand their irrigated piece of land and that double cropping is also possible in a yearly production. For example Tables 3 and 4 shows that on a 0.25 ha piece of land, a farmer growing lemon grass would have 70.7% and 139.8% returns on investment for selling grass for lemon tea and extracting essential oil from it respectively. The scenario shown here is for one cutting but lemon grass can potentially be harvested 3-4 times per annum. Treadle pump costs for pump heads alone range from US$ 50 – US$ 71; US$83 – US$100 for the popular river and pressure pump designs (FAO/IPTRID, 2000). Manufacturers sell their pumps cheaper than retailers as the latter mark-up for commission.

Table 3: Gross Margin For Lemon Grass Essential Oil Extraction from 0.25 Ha land

1. OUTPUT:	Measure	Unit Price	Quantity	Amount (ZK)
Oil per tonne dry Leaves(40% moisture)	Ltrs	4,300	1,250	5,375,000
1.2 Other: Manure	Kg	200	400	80,000
Total Output:				5,455,000
2. INPUTS:				
2.1 Dry Leaves	Kg	3,500	500.00	1,750,000
2.2 Transportation cost	Lump sum			100,000
2.3 Distiller equipment hire	Days	50,000	7	350,000
2.4 Packaging	100 mls	500	150	75,000
Total Inputs:				2,275,000
GROSS MARGIN:				3,180,000
RETURN ON INVESTMENT:		%		139.8

NB: ZK3, 200 = US$ 1.0

Note from Angel 12/1/2006: **These gross-margins are for farmers already irrigating in the second and third years and thus do not include the capital costs for a treadle pump and pipes for water reticulation. Essentially an investment of a 50m pipe and a pressure pump would cost would cost US$200 COMBINED. Poly pipes cost ZK6000/m (US$2/m) and a pressure pump costs US$100 /PUMPHEAD.**

It would take sixteen irrigations per year to irrigate lemon grass. A labour cost for irrigating per person is about ZK5000/per irrigation.

Table 4: Gross Margin For Lemon Grass-Herbal Tea Production (0.25HA)

1. OUTPUT:	Measure	Unit Price (Zk)	Quantity	Amount (ZK)
1.1 Dry Leaves(10% moisture)	Kg	3,500	500	1,750,000
Total Output:				1,750,000
2.0 INPUTS:				
Planting materials(stools(slips)	Each	1,500	300	450,000
2.2 Labour: Land preparation	Mondays	5,000	15	75,000
2.3 Transplanting	Mondays	5,000	15	75,000
2.4 Weeding (2 times)	Mondays	10,000	10	100,000
2.5 Manure application	Mondays	5,000	10	50,000
2.6 Harvesting	Mondays	5,000	20	100,000
2.7 Grading	Mondays	5,000	5	25,000
2.8 Chopping	Mondays	5,000	10	50,000
2.9 Packaging	Materials	10,000	10	100,000
Total Inputs:				1,025,000
GROSS MARGIN:				725,000
RETURN ON INVESTMENT:		%		70.7

NB: ZK3, 200 = US$ 1.0

3.6 Low-cost Bucket/Drum kit Drip Irrigation

This is a simple system operating on the same principle as the clay pot drip system. The bucket which is a low volume (5 liters – 10 liters) reservoir as compared to the drum (200 liters) is installed at an elevation of 2m – 3m above ground to provide a low pressure head enough to operate micro-tube drippers installed on the laterals that are connected to the main line from the reservoir. Water is pumped from the source to the reservoir by using a treadle pump. The micro-tubes emit water drop by drop on the root zone surrounding the irrigated crops and thus wet the surrounding soil. Water is taken up by the plant and some water evaporates due to heat and wind. Fertilizer is supplied along with the irrigation water from the reservoir. This system has been known to optimize yields per unit volume of water and land. Yield increases up to threefold have been registered in piloted trials by IDE and the Ministry of Agriculture and co-operatives. To date, only about 10 ha of land are irrigated by this system countrywide. The major drawback to accelerated uptake is lack of manufacturing capacity in the country leading to sporadic supply of drip kits by IDE. World Vision once supplied some bucket kits as a one-off programme to its recipients. The system greatly reduces labour of irrigating and weeding the crops. This is meritorious to the disadvantaged vulnerable populations that are aged, disabled and weak from HIV-AIDS pandemic.

3.7 Hill-spring water Gravity head sprinkler Irrigation

This system has been implemented by individual farmers taking advantage of spring water oozing from a rock outcrop on top of a mountain or hill at an elevation of 10m – 20m. Water flowing at free-flow from a rock is directed into an open lined channel leading to a reservoir constructed on top of the mountain. The reservoir once filled up, is operated in such a way that water is discharged through a closed galvanized pipe by opening a gate-valve. The water under atmospheric pressure (1 atmosphere) flows such that it is able to operate more than 10 sprinklers for overhead system. In Katete a farmer irrigates Oranges, pineapples and bananas without additional costs of pumping to operate the system.

3.8 Roof water Harvesting

The level of activity in rainwater harvesting in Zambia is very low and isolated. The commonest type of rainwater harvesting is the traditional one, where, families draw water falling from roof tops in drums of 200-210 litres capacity for short term use. This is usually done, without, them realising that they are even practising rainwater harvesting. The technology is quite novel in its formal state but it has existed for a long time. A similar type system involves the use of gutters on buildings like schools and hospitals. Though with limited application, the system referred to as institutional rainwater harvesting is quite effective and uses Ferro-cement tanks, sized between 10 to $20m^3$, which collect rainwater from roof tops via gutters. The collected water is used by the concerned communal institutions. Such interventions are currently pilot projects by the Zambia Rain Water Harvesting Association. Examples of such interventions are illustrated in Figures 5a and 5b.

While the collection of rainwater by a single household may not be significant, the impact of thousand or even millions of household rainwater storage tanks can be enormous. The main components in a simple roof water collection system are the cistern itself, the materials and the degree of sophistication of the whole system largely depends on the initial capital investment. Some cost effective systems involve cisterns made with Ferro cement, etc. In some cases, the harvested rain water may be filtered. In other cases, the rainwater may be disinfected. Storage structures for roof catchments include surface tanks like Ferro-cement tanks.

3.8.1 Construction of a water tank at Simbulo Primary School.

The Ferro cement tank is to cater for 400 pupils and a community of forty families. The community was encouraged to participate in the construction of the tank in order to instill ownership. The project to build a tank both at the teachers' compound and the school was

within the period of August 2003 to September 2004. **UNICEF** through its District Water and Sanitation programme funded the project (see Figures 5a and 5b).

Figure 5a: Construction of Ferro-cement Tank at Simbulo Basic School in Choma.

Figure 5b: Construction of Ferro-cement Tank at Simbulo Basic School Choma.

The incidence of droughts in recent years and the resultant problem of food insufficiency provide some potential and opportunity for investment in rainwater harvesting projects. This is because the water deficit areas can harvest some water from the unpredictable rains and be able to utilize the water for small scale irrigation as well as for non potable uses. Some existing water sources such as earth dams, though of higher capacity have open surfaces which are prone to high evaporative losses. So some closed rainwater harvesting systems can provide more water ***conservative*** alternatives.

Water scarcity, in general, can provide good ground for rainwater harvesting technology. See example in Figure 6 where communities fetch water from a remote hand pump fitted to a borehole.

Figure 6: Fetching water from a communal borehole fitted with a Hand pump

These women and children have to walk long distances to fetch water at this communal borehole equipped with a hand pump. This is another case of water insufficiency, which can provide a good opportunity for individually managed rainwater harvesting systems for the rural people.

The biggest challenge that the adoption of this technology would face is the acceptance of the seemingly new phenomenon of rainwater harvesting technology. However, the technology has been there among the farmers and individuals, except, it is in an adhoc, traditional form. It is done by placing buckets under eaves to catch rain during storms and storing water in 210 litre containers. The other challenge is that the materials like cement and other such like may be expensive. A comprehensive study would accurately bring out these factors more clearly. A project proposal and eventual research are proposed for rainwater harvesting systems applicability in the Zambian context. The challenge of building capacity among the rainwater harvesting technical staff and indeed the farmers and other individuals is to be handled with the seriousness it deserves if these projects are to be successful and sustainable.

3.9 Best Bet Technologies

From the review of existing agricultural water technologies, Inland valley (wetland Dambo) cultivation, Clay pot sub-surface drip irrigation and Treadle pump technologies stand out to be the best from the stand point of sustainability, cost-effectiveness and productivity increase by small-scale farmers.

3.9.1 In-land valley (Dambo) Cultivation

Firstly, Dambo cultivation and water control is indigenous and has been practiced for over forty-years in Eastern Zambia and ranging from twenty to thirty years in the rest of the country. Dambos are bound to impact over 300,000 vulnerable small-scale producers and transform them to productive groups with surplus production provided the following is adhered to;

?? Support farmer groups with credit to purchase irrigation equipment for supplementing water supply to crops in zones that require irrigation.
?? Build capacity for farmers to adopt sustainable production through water management, environmental protection and biodiversity conservation.
?? Support construction of lined shallow wells so as to enhance water recharge and availability all year round.
?? Enforce watershed management as they are inter-connected with the main Dambo cultivation area.
?? Market link the producer groups for them to produce for a market and generate steady incomes.

Dambos' wide coverage of 3.6 million hectares country-wide offers the greatest potential for irrigation expansion using small-scale farmers. Currently implemented Small-scale Irrigation Project (SIP) funded by the African Development Fund should follow this philosophical critical path of development. Great use for treadle pumps is found in Dambos.

3.9.2 Clay-pot Sub-surface Drip Irrigation

Secondly, clay pot sub-surface drip irrigation is one technology that would impact positively among the rural women who make them as they would generate income from this primary rural employment. Secondly the technology is less labour intensive and suits well the disadvantaged vulnerable populations i.e. handicapped and those weakened by HIV-AIDS as it entails less irrigations in a crop life-span and maximizes on water use as well as the applied fertilizers. The technology is thus low-cost in nature as the clay pots are made from local clay material. It has potential for backyard production and floriculture especially in urban areas where municipal erratic water supply is ever increasing and thus affecting enterprises in flower production or household flower landscapers.

The cost of each clay pot is ZK3, 500 which translates to about US$1.0 at the current exchange rate and the users can easily install them with simple instructions. The pots do not easily clog once in use continuously but care must be taken before and during installation as they would break if dropped from an appreciable height. The pots could also act as drainage media in saturated soil conditions wherein they are emptied of water, thus water moves from the surrounding saturated soil into the clay pot resulting into a well drained root zone for optimal plant growth. An entrepreneur in Lusaka is currently planning to mass produce and promote the clay pots for various applications but focusing on backyard crop production. Well maintained clay pots can be used for ten years without any problems of clogging.

3.9.3 Drum-kit Drip Irrigation with Treadle pumps as pumping devices

Thirdly, another high potential technology worth investing in is the low-cost drum-kit drip irrigation system. This system operates on the same principle of supplying water drop by drop to a plant as the clay pot but water is applied on the surface directly wetting the soil around the plant and infiltrates into the root zone. The system is popular in urban and peri-urban areas especially Lusaka. Advocates of this system claim to save on costs for pumping water, labour for irrigating their crops and also through fertigation savings on fertilizer are realized. The drip system of this nature comes in different sizes ranging from 10 m^2 to 5 ha sizes. Most popular sizes are 125 m^2 – 500 m^2 costing between US$ 40 - US$300. These systems (low-cost drip) would find their application for use appreciated by disadvantaged groups of people such as orphaned children, physically handicapped and those weakened from HIV-AIDS disease.

4.0 Review of Agricultural Water Programs under the Initiative to End Hunger in Africa (IEHA)

4.1 ASNAPP- Zambia: Partnership for Food Industry Development (Fruits and Vegetables/Germplasm Development)

Agribusiness in Sustainable Natural African Plant Products (ASNAPP) is implementing a USAID funded project under the Initiative to End Hunger in Africa addressing the needs of over 3,000 small-scale farmers in Southern, Central, Lusaka and Copper belt provinces. ASNAPP has partnered with IDE to facilitate production of fresh fruits and vegetables using irrigation and selling them to Sun-International Hotel and lodges in Livingstone. This is enhancing rural incomes generated by small-scale farmers. The project at Sun-Hotel involves hydroponics and greenhouse production operated by the vulnerable communities who are physically blind (see greenhouse in Figure 7). About sixty households are also involved with open vegetable production using treadle pumps and drip irrigation. IDE is building capacity with respect to Irrigation technology transfer whereas CLUSA is mobilizing the farmer groups and training them in business-skills, financial management and marketing strategies.

Figure 7: Hydroponics green house and filtration tanks for the vulnerable groups' project in Livingstone.

The project also works with small-scale farmers who grow irrigated lemon grass, multiplies germplasm for geranium-an essential oil crop (see Figure 8) and also produce both rain fed and irrigated paprika. The smallholder groups generated an income of US$450,000 in the last season of 2004; a total of 300 small farmers received these profits in proportion to deliveries. This income is expected to more than double with the green house now producing.

Figure 8: Lemon grass inter-cropped with Geranium (left) and sole geranium crop (right).

4.2 IDE- Smallholder Market Creation (SMC) Project

Under the USAID – funded projects promoting the Initiative to End Hunger in Africa, IDE is leading a US$1,537,444 market led water management technology project called Smallholder Market Creation (SMC) (IDE, 2005). The project interfaces well with USAID Strategic Objective 15 and has been cost-shared with other donor sources equivalent to US$439,774. The project uses the IDE PRISM (Poverty Reduction through Irrigation and Smallholder Markets) approach. The project was for two years and has just ended but is continuing its approaches under a new funding in the Chinyanja Trade Triangle of the Eastern province of Zambia where the project is promoting use of treadle pumps and drip kits for crop production by small-scale farmers. About 300 households have been reached out in one year and 1,100 males and 717 females have been trained in crop agronomy, water management and operation and maintenance of the treadle pump. Leveraging resources to scale-up activities, IDE formed twenty (20) public private partnerships in Eastern province. Under the SMC project, a total of 9,839 farmers of which 38% were women, were reached out in terms of capacity building. Most of these farmers were linked to financial lending institutions and out-grower operators for input credit. Some of these included Micro-Bankers Trust and Cheetah Zambia- a paprika commodity focus out-grower operator. Through use of irrigation technologies, IDE increased the rural incomes of 2000 smallholder under SMC to an average high of US$328 per annum above the targeted increase of US$300 per annum giving a farmer a gross annual income of about US$800.

4.3 TLC- CLUSA

Total Land Care (TLC) in collaboration with CLUSA are implementing a US$ 650,000 treadle pump irrigation project among 350 small-scale farmers in Southern and Copper belt provinces. With an elaborate training programme of field layout, irrigation agronomy and treadle pump operation and maintenance, TLC and CLUSA managed to transform the lives of the programme beneficiaries who are now making on average US$800 per annum as compared to less than US$100 per annum before the project growing a mix of vegetables and marketing them within the project areas. The groups[1] have now begun to treat irrigated farming on business lines and have opened bank accounts for their groups. From treadle pump irrigation farmers are now investing in motorized irrigation pumped systems as seen in Figure 9. Dambos are indeed an economic common good and have contributed to rural livelihoods and food security (Daka, A.E. 1998; Daka, A.E. and Kokwe, M. 1996). The elaborate training TLC approach in field layout has made farmers realize the potential benefits of using the technology. Hayes et al (2002) has outlined irrigation systems layout and use of treadle pumps in crop production.

Figure 9: Irrigating Egg-plants using a motorized pump purchased from initial sales of a treadle pump irrigated crop.

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[1] The 350 small-scale farmers referred to in this section were split into seventeen discrete groups each with about twenty (20) individual farmers. Each group selected its leadership comprising the chairman, vice chairman, Secretary and his/her vice, Treasurer and committee members. In this way training programmes are made easy within groups. Each group has two Lead Contact farmers who received various technical training for production and use of pumps and they replicate such training to fellow farmers. The Lead contact farmers are remunerated by the group for their time in training them. The groups bulk their produce at harvest at a central place called a depot where market linkages to buyers are made. Buyers collect the produce from one place and pay the groups respectively according to what was delivered. (*footnote added 12/1/2006)*

5.0 Summary of key Actors in Micro Irrigation and Rain Water Harvesting Technologies

The quality, depth and breadth of institutional support to agriculture that is provided by public institutions is inadequate on its own to address the dynamic needs of the different categories of farmers and stakeholders. In recent years, the sector has benefited from more structured institutional support frameworks that have inbuilt consultative mechanisms between public and private sector players in policy development and project design. These include the Agricultural Consultative Forum (ACF), District Agricultural Committees, and Trusts (GART in research, CDT in cotton, Livestock Development Trust in livestock, In-service Training Trust in training and Zambia Export Growers Association (ZEGA) in exports of flowers and vegetables.

The Technical Services Branch (TSB) in the Department of Field Services of the Ministry of Agriculture and Cooperatives (MACO) is the main institution mandated to plan and develop all aspects related to irrigation and water management technologies in the country. The TSB consists of three sections, namely: i) Irrigation Engineering Section; ii) Land Husbandry Section; iii) Farm Power and Machinery Section. The TSB through the Irrigation Engineering Section provides services to farming enterprises in irrigation agronomy, catchments hydrology and related hydraulic and civil engineering aspects. It also helps the Government to formulate policies for irrigation development, to carry out water resources assessments and to implement irrigation projects.

While many other government agencies and some NGOs with interest in the irrigation sector exist, the Ministry of Energy and Water Development (MEWD) is a key one. It houses the Department of Water Affairs and the Water Development Board of Zambia, both of which are mandated to deal with water resources development and management. The Water Development Board of Zambia allocates water rights although no water charges have been levied on any irrigation abstractions. All land allocations for any development purposes, including irrigation, are the responsibility of the Ministry of Lands (MOL), which is also responsible for issuing title deeds. Its current policy is to set aside at least 30% of the demarcated land for women and other vulnerable groups.

The private sector and NGOs play an important role in community mobilization for irrigation, with respect to traditional farmers or emerging farmers adopting irrigation. The one NGO taking a lead in this regard is the International Development Enterprises **(IDE)**, whose main focus in operation was initially the sale and promotion of Treadle Pumps as a water lifting device. They have for some time now been involved in the promotion of this technology and training and collaborating with some manufacturing houses such as Amiran, Aqua-agro and Duram to start mass producing the treadle pumps and drip kits.

Some of these manufacturers import treadle pumps and land them at a much lower cost than the locally manufactured ones. IDE has also been involved in the promotion of low cost drip irrigation kits or packages. The component of agribusiness has also lately been given some prominence for the success of the technological transfer programmes. The sales and marketing component ensures that the farmers' incomes are enhanced and they can afford the treadle pumps and expand their farming enterprises.

The other organizations like Food and Agriculture Organization (FAO) of the United Nations, USAID-CLUSA, World Vision, ZATAC, CARE and other such like organizations do not have independent irrigation programmes per se but have helped promote irrigation technologies through credit to purchase equipment, capacity building and/or market creation for irrigation output. They just engage in collaborative programmes, especially with the Irrigation Engineering Sections of the Ministry of Agriculture and Co-operatives through out the country. The irrigation firms like Aquagro Limited, Amiran Limited, Lamasat International Limited, Saro Agri Limited, just come in to fill the gap of irrigation component supplies as well as installations capacity.

The Zambia Rainwater Harvesting Association (ZARHA) is a national network of individuals, institutions and organizations that promote and advocate for the sustainable utilization of rainwater for the ultimate goal of improving livelihoods. The association is also an advocate of general water management and draws a large representation in terms of membership from the water sector.

The Association is non-profit oriented and focused towards community development. Membership is open to all individuals and institutions as may be represented by different professions. Currently, the association is engaged in a vigorous capacity building programme by ensuring that they have a sizeable number of Zambians attending training in rainwater harvesting. This is to ensure that there is enough capacity to implement rainwater harvesting projects in the country, since the potential exits.

Over the past three years, the Government of the Republic of China, under the auspices of her Ministry of Commerce has been offering an International Course in Rainwater Harvesting and Utilization at the Gangsu Research Institute of Water Conservancy in Lanzhou. The ZAHRA has benefited, as well as the country as a whole, in drawing membership from professionals in industry, NGOs and Government, who have attended this course.

The association was registered in 2002 and is the first national network in Zambia. It is a branch of the Southern and Eastern Africa Rainwater Network **(Sear Net**), registered in Kenya. In addition to Zambia, Sear Net has branches in Zimbabwe, Malawi, Tanzania, Botswana, Rwanda, Kenya and Ethiopia.

Zambia currently does not have a policy on rainwater harvesting. ZARHA is working closely with the Ministry of Agriculture and Cooperatives to influence the Government to include Rain Water Harvesting in the Water and Irrigation Policies. The country is currently reviewing its water policy thus creating an opportunity for ZARHA to actively contribute to the recognition of rainwater as a water source.

5.1 Effectiveness of Actors in Micro-Irrigation and Water Harvesting Technologies

Whilst the Technical Services Branch of the Department of Agriculture is mandated to deal with matters concerning irrigation development in the country, they can best be described as facilitators whose services have been far from being appreciated by farmers. The Ministry of Agriculture and Co-operatives under which the TSB falls, has a huge network of extension staff countrywide but they are largely under-utilized because of poor funding and they lack capacity to deliver services that are non-traditional activities of the ministry. For this reason some government departments in the agricultural sector have resorted to using NGOs to implement some projects such as the Smallholder Enterprise and Marketing Programme implemented by CLUSA, AFRICARE and HODI on behalf of the Ministry of Agriculture and Co-operatives; Smallholder Irrigation and

Water Use project under TSB was partially implemented by Keepa Zambia and CLUSA in the final year after IFAD noticed some implementation failure by Government.

5.1.1 Treadle pump and Drip Irrigation Technologies

With respect to Irrigation and Water management, IDE is the best NGO with competence core to implement and promote irrigation and water management projects. They have a sufficient spread and leveraging public private partners in all the provinces of Zambia. They have also created a supply chain of treadle pumps and drip kit irrigation systems using local manufacturers. Besides the creation of a supply chain, IDE possesses a capacity building section which deals with training of producers and partner organizations to replicate at grass-root level the technical aspects of irrigation. The market linkage approach that IDE has adopted through PRISM (Poverty Reduction through Irrigation and Small Markets) has worked well and is well appreciated by the farmers. IDE also works with a network of the Ministry of Agriculture and Co-operatives extension staff. IDE is to handover the marketing of Irrigation equipment and spares to private entrepreneurs and concentrate on building their capacity in manufacturing, quality control and mass-marketing.

Table 5: Distribution of treadle pumps in Zambia

Organization	Areas	Number
IDE	Mainly Eastern, Western and Southern Provinces	3,500
CLUSA	Southern, Central, Eastern, Copper belt	800
GTDP	Southern Province	150
Red Cross	Livingstone	500

5.1.2 Conservation Farming

Conservation Farming has been widely promoted by the Conservation Farming Unit (CFU) of the Zambia National Farmers Union (ZNFU) and CLUSA who used it as a farming system for all the 15,000 small-scale farmers it supported in the out-grower scheme of Soya-beans, maize, paprika and groundnut production.

Currently, CFU is the main NGO promoting conservation farming in Zambia and its main function is in this field. It trains quite a number of NGOs and Community based organizations in the technical aspects of the farming system and its many challenges. CFU has created a network of representative offices country-wide and promotes the conservation farming technology from those locations. Zambia has officially adopted conservation farming as a farming system for smallholder farmers and is promoting the technology under its subsidized Fertilizer Support Programme to small-scale farmers.

Government Food Security Projects implemented by NGOs have leveraged the subsidized inputs given to small-scale farmer co-operative groups to apply/adopt conservation farming as a farming system. This accelerated the adoption rate and increased the area under this system from a paltry 50,000 ha to 200,000 ha by the end of 2004. Subsequent agricultural season which did not have massive subsidy with food for work programmes witnessed slowed down adoption.

6.0 Recommendations and Conclusions

From the foregoing, the study has established that a number of irrigation and water harvesting technologies exist in the country and some have been tried and assumed static adoption rate after promoter withdrawal. Various reasons have been established but all do not point to technological or engineering design faults. Given the above interpretation, the following conclusions and recommendations abound;

Irrigation Technologies

1. Although there is now in place an Irrigation Policy in Zambia, its long absence has depressed irrigation development in the country especially among small-scale farmers who have always perceived irrigation to represent state of the art super structures like centre pivot and sprinklers. There is urgent need for donor support in irrigation investment to demand country policy guidelines on how development will take place before they render such support.

2. Some high potential technologies which could make an impact and real difference to the lives of vulnerable groups have not taken off after the pilot phase because farmers expected handouts as occurs with some implementing NGOs of social programmes. There is need to ensure sustainability of programmes by incarcating responsibility through incorporation of cost-sharing activities with the community and avoid freebies. Farmers should also be linked to micro-credit if they have to afford purchasing the technology or indeed apply the knowledge gained in such technological transfer efforts.

3. There is need to build capacity among the extension workers and the producer groups in terms of technology transfer, operation, maintenance and related technical aspects so that when there is donor withdrawal, the project activities and linkages continue on sustained basis.
4. Government initiated irrigation schemes should be planned and designed together with recipients whose capacity to manage the scheme should be built before complete handover takes place.
5. Government ministries involved in irrigation such as agriculture, environment, and water resources are often criticized for a lack of cooperation in what is essentially an interdisciplinary activity. Although they usually have common objectives, they tend to work independently. A typical division of responsibility is between the planning, design and operation of irrigation systems, usually the responsibility of TSB of in the Ministry Agriculture and Co-operatives and department of field services in the same ministry. The former is staffed by engineers, who have little knowledge of crops and farming, and the latter by agriculturalists, who have little knowledge of engineering and hydraulics. The sad fact is that most of those involved do not see the need for such knowledge

nor for closer linkages with each other. As one senior irrigation consulting engineer put it: **"My engineers do not know the difference between wheat and rice - but the really sad thing is they do not want to know."** This emphasizes not just serious laws in organizational attitude but in the education system that continues to produce young engineers who still think that a career in irrigation is only about building dams and pumping stations. This same argument might also be made about engineers and social science. There is need to integrate socio-economic aspects in an engineering curriculum and vice-versa for a social curriculum at colleges and universities so that graduates meet industrial needs.

Support services

1. There are many examples of poor organizational performance in the irrigation sector. Some stem from a mismatch between what the organization was set up to do and what it actually does. The reasons for this are varied and complex. A government research institute may be carrying out research that interests its staff and encourages their career development through publication, but critics may point to drainage practices being promoted that do not fit well with local physical and socio-economic conditions and do not address the priorities of local people. Typically, there may be poor links between researchers and farmers. Extension services are weakened by a lack of well-trained local professionals and resources to do the job properly. The local professionals have little to offer farmers beyond formalized messages about water management and do not have the skills to cope with today's farmers seeking a livelihood from a range of natural resources.
2. Farmers need organizations to provide advice and support. Traditionally, government has provided these in the form of extension services that link research with practical farming. However, there are some places were the private sector is beginning to play a role. This is particularly the case in private farming, where large farms require specialist services and smallholders need to acquire new skills to keep up with the dictates of the market.

On the whole, supporting organizations do not serve irrigators well. Government agencies are still the principal source of knowledge and skills. However, they tend to concentrate on crops, fertilizers and pesticides rather than on water, even in irrigated areas. They tend to be under funded and staffed by inexperienced people who do not have the logistical support to reach the farmers. Where there have been successes, they have usually been underpinned by external aid, and thus there are question marks about their sustainability once the support ends.

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Annex1: List of Contacts

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Brian Likando	Farmer at Kabangwe wetland	
Frank Likando	Farmer at Kabangwe wetland	

Annex 2: List of Major Documents Consulted

1. Final Programme Evaluation for USAID funded Smallholder Market Creation (SMC) project. Lusaka, Zambia. PP774.

2. Project Documents for the Country Cooperation Framework 2002-2006

3. Irrigation Policy and Strategy; A strategy for the Development of Zambia's Irrigation Sector.

4. Agricultural and Livestock Use of Groundwater Resources in Zambia.

5. GroundUp- Agricultural Innovations.

6. An introduction to low-cost drip irrigation for small-scale farmers.

7. Field Manual For Treadle Pump Irrigation in Malawi; TLC- Irrigation Training Manual.

8. Treadle Pumps for Irrigation in Africa; International Programme for Technology and Research in Irrigation and Drainage.

9. Development of a Strategy for Smallholder Market Integration in Africa Volume 1: Main proposal document submitted to International Development Centre.

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Annex 3: Case study: Developing farmer and institutional capacity - Zambia

This case study is about improving knowledge and skills and changing the attitudes of both local professionals and farmers (FAO, 2003).

Zambia has more than 100 000 ha of private smallholder irrigation. The Zambian government advisory and support services are poorly developed and so smallholders rely on their own resources. However, the government wanted to improve their productivity and to help more farmers to take up irrigation in order to solve the country's growing food security problem. To help meet this objective, the government's strategy was to strengthen its advisory and support services to farmers.

An externally-funded project with technical assistance was launched to introduce low-cost irrigation technologies as an entry point for training both local professionals and farmers. This was an unusual move at a time when many governments were running down services and transferring responsibility for irrigation to farmers' organizations. However, Zambia does not have strong private organizations that can take on a support role and so it was decided to strengthen the existing government organization rather than to build something new.

Government staff had little contact with farmers and were more familiar with top-down approaches to training and providing advice. Therefore, participatory approaches and facilitation methods formed an important part of their training in addition to the more technical subjects. Training was done in a very structured way and implemented through a pyramid process of training trainers who then trained technicians who in turn trained the farmers. The methods used were based on the experience of using similar methods, but for differing circumstances, in Nepal, Cambodia, Bangladesh and Indonesia. They have led to the production by FAO of guidelines on participatory training and extension in farm water management and a farmers' training manual (FAO, 2003).

In four years, the government services have trained more than 10 000 "private" farmers. A significant number of women joined the programme and, indeed, in later training campaigns women outnumbered men in some districts.

The impact of the programme was measured by establishing what farmers had learned and by measuring the uptake of technologies. However, both methods produced inconclusive results, consumed a great deal of resources in data collection, and proved far more complex to analyse than first envisaged. For example, the lack of a baseline survey of farmers' knowledge made it difficult to determine what they had learned from the training or what the true level of technology uptake was. This did not mean the attempt was without worth, but it did highlight the complexity of evaluation.

This case is a good example of how the provision of resources, technical assistance and training can strengthen a moribund government department, which in turn can have a significant impact on the private farming community. It also demonstrates that irrigation technology can provide a useful entry point for engaging farmers in a participatory way. Where private institutions are weak, the government still has a major responsibility for capacity development. The question of cost recovery from those who benefit has yet to be resolved and so the process may not continue once the external support has stopped.