Experiences with Micro Agricultural Water Management Technologies:

Mozambique

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An input to the Study on Agricultural Water Management Technologies for Small Scale Farmers in Southern Africa: An Inventory and Assessment of Experiences, Good Practices and Costs

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1. Introduction

According to the TOR made available for the Inventory of Agricultural Water Technologies and Practices in Southern Africa and an Assessment of Poverty Impacts of Most Promising Technologies, water for agriculture is increasingly recognized as a major constraint to improving the lives of the rural poor and is an important component of rural livelihood programs to be established in Southern Africa. The overall objective of the study is to contribute to improving the lives of rural poor people through better and sustainable agricultural water technologies/practices leading to increased agricultural productivity and incomes for small farmers in Southern Africa.

Over much of the SADC region, the combination of population growth, rising food demands, and severe economic stress contributes to increase the pressure on the renewable natural resources basis. The scarcity of fresh water is presently one of most pressing concerns of the Region, Governments, and major International Organizations and Partners. In parts of the Region, these are aggravated by drought, resulting in less water available for human consumption, productive uses, and maintenance of ecosystems. Therefore, water is likely to become the most critical and scarce natural resource of the current century, and the most limiting input to food security, economic and social development.

Similarly Mozambique is facing the same situation as most countries in the Region, and as discussed by Gomes et al. (1999), the reality shows an increasing and apprehensive aggravation of the scarcity of water in certain regions of the country. Mozambique is in fact extremely dependent on fresh water flows coming from upstream countries. This is further illustrated by Vaz (1997), by the fact that from a total mean annual runoff of about 214 Km^3, only 88 Km^3 are generated within the country being the remaining 126 Km^3 the total inflow at the border. This makes the 'imported' flows more than 50% of the mean annual runoff. In terms of geographic distribution, the South of the country is the most critical one, with an annual runoff around 21 Km^3 from which only 4 Km^3 are generated within the country (Vaz, 1997).

This reports according to the TORs intends to summarise the state of knowledge of the country in terms of water resources for crop production, and to describe the on-going research on crop water management and identify further research needs based on good practices focusing on field experiences in the development and management of agricultural water technologies/approaches derived from farmers' local knowledge, external projects, agricultural research and from other actors.

2. Food Security, Hunger and Agriculture

Mozambique has a per capita income of US$ 230 per year in 2000 (PARPA 2001) that is amongst the ten lowest in the world. Some 65% of Mozambicans live on less than US$ 0.5 per day. Poverty remains essentially rural in character with over 80% of Mozambique's poor households living in rural areas. Rural poverty is primarily attributable to limited agricultural development, limited market development and poor productivity levels. Agricultural potential is poorly converted into tangible income generation and employment creation.

According to the last census (INE 1998), most of the population live in rural areas (77%) and most of the workforce is in the agriculture sector (95%), and poverty is greater in rural areas (71%) than in urban areas (62%). So, it can be said that poverty is mainly a rural phenomenon, although a high proportion of the urban population is also poor. The same study also shows that education levels are very low, with literacy rates at 52% for men and 16% for women in rural areas, and school enrolment rates at 49% for boys and 39% for girls.

According to a study[1] on household living conditions, coordinated by the MPF, there are almost no landless peasants in Mozambique (less than 2%). Productivity, however, is very low (less than half of neighbouring South Africa and Zimbabwe) and the use of modern inputs and mechanisation almost inexistent (less than 2% use fertilisers or pesticides, around 5% use animal traction and less than 10% use some equipment). In addition, most of the cropland is in the smallholder sector while less than 4% is in the private sector. Therefore, the study concludes that increasing the size of the land plots will not reduce poverty unless productivity is increased, particularly by investing in irrigation and fertilisers. The other important finding from this study is that development initiatives that focus on rural areas will provide a strong poverty focus.

According to recent figures (Agrifood Consulting International, 2005), agriculture contributes 25.9% of total GDP and is the source of livelihood for 75% of the population of Mozambique. Agriculture exhibited a rapid growth averaging 6.8% over the period 1996 to 2004 which was less than the growth of the GDP of 8.7% over the same period.

A main contributing factor was the high vulnerability of agriculture to natural disasters. If the year of the flood is excluded from the calculation of growth, agriculture shows an average growth of 9.7%, which is even higher than the growth of the GDP.

In Mozambique, the structure of the agriculture sector consists of three main groups of producers, i) the commercial business sector, ii) the traditional small-scale farming sector (subsistence cultivation – food crops), and iii) the smallholder cash cropping. Small holder and small-scale (both traditional subsistence food crop production and cash cropping farmers), cultivate about 95% of the total area, the majority practising rainfed agriculture, mainly for subsistence and with low level of inputs. The commercial and business sectors represents only 5% of the total area, although and particularly the sugar cane industry is facing currently a dynamic growth, on average nearly 50% during the period 2001/03. Other crops such as tobacco and soya, horticulture (flowers and

[1] Titled "Understanding poverty and well being in Mozambique: the first national assessment 1996-97" published in 1999.

vegetables), fruit trees and banana also attracted foreign investment during the last five years.

Table 1 shows estimates by MADER/DAP (2001) on the basis of the 1999/2000 agricultural survey which recorded about 3,054,106 smallholder farms, a number that rose to about 3.090.197 households by CAP/2000 records. Likewise, medium holdings were estimated to be about 10,180 (37,296 according to TIA/2002), and large holdings to be 429 units by both sources of information.

Table 1: **Summary of Key Characteristics of the Agricultural sector in Mozambique 1999-2000**

Indicators	Holdings Farm Types			Total
	Small	Medium	Large	
Number of Farming Households	3,054,106	10,180	429	3,064,715
Total Cultivated area (ha)	3,736,619	67,727	120,977	3,925,324
Land Area per Farming Household (ha)	1.22	6.65	282	1.28
% of cultivated area in basic food crops	84.4	74.2	7.6	81.8
% of cultivated area in cash crops	4.7	5.1	30.2	4.5

Source: Bias, C., and Cynthia Donavan, 2003). "*Gaps and Opportunities for the agricultural sector in Mozambique*," Research Report No 54E, MADER/DE Research Paper Series, April.

Taken as a whole, the smallholder agricultural producers comprise 99% of all rural households. These farmers are mostly subsistence, extremely dependent on rain fed production and on intercropped and rotational cropping systems. As TIA 1996 reports, most of the food crop produced by this segment of farmers is dedicated to home consumption. For instance, in 1996, 96% of sorghum, 94% of cassava, 88% of cowpeas, 80% of maize and 71% of groundnuts produced were retained for home consumption.

Stagnant yields[2] for most crops and constraints on production and marketing are the limiting factors to growth. According to Bias and Donavan (2003), the main crops are maize and cassava considered as the basic food crops and grown by about 79% and 63% smallholder households, respectively. However, crop diversification strategies include the production of groundnuts, beans, sorghum, millet, rice, cashew, and sweet potatoes.[3]

Cultivation of these crops is based mostly on manual cultivation, and very little use of modern/purchased inputs. Usually, there is a strong association between the type of agricultural activities undertaken by these smallholders, increases in their cultivated land area with the size of the household, use of animal traction, labour, modern inputs, cash crops and market access, and off-farm income.

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[2] For the past eight years, crop yields have been stagnant with an exception for cassava across provinces (SNAP). Across crops, these yields are considered to be below potential and those of other African countries in the region (Bias and Donavan, 2003; Howard et al., 1998).

[3] Many households are also involved in cash crop cultivation. These crops often include cotton, sugarcane, tobacco and more refined crops such as oilseeds (sunflower, sesame, soy), and spices (paprika and ginger)

As cultivated land area increases, so does the size of the household. The better off households have a higher likelihood (23%) to use animal traction than others, and this varies across regions. Higher proportion (54%) of animal traction use is in the south.

While women are active in rearing small livestock they are frequently excluded from large livestock programmes.[4] A gender approach recommends that any livestock programme needs to consider how it can target women and what are the most appropriate animal species for female farming, but this has to be based on an analysis of whether the livestock programme will create a conflict between women's added responsibilities and their capacity to earn an income.

The low usage of modern inputs forces them to use more labour, and this is correlated with increases in cultivated land area. As a consequence, there are more tendencies for expansion as opposed to intensification of agriculture. However, with the increasing impact of HIV/AIDs it is necessary to pay attention to appropriate strategies, some of which are explained in chapter seven.

Regarding the natural resource dependence of the rural poor, it is estimated that some 80% of Mozambicans depend on firewood and charcoal for domestic energy, and the annual consumption of this energy source is about 16 million m^3. The high dependence on this energy source makes its availability a key concern to poor rural households who often have no access to alternative sources. In addition to energy, especially non-timber products (foods, medicines, fibres) are important for subsistence use and income generation. Thirty percent of protein in the rural areas comes from bush meat, highlighting the importance of wildlife for rural families. The dependence on these products increases in times of crisis.

Within the agricultural sector, the crop production/commodity sector contributes to an average of 85.4% of agricultural GDP and has shown the strongest growth relatively to the livestock and forestry sector. Agriculture exports over the period 2002-2004 have increased by 41.7% from $187.5 million[5] to $265.8 million. Agricultural exports are dominated by five products (timber, cotton, cashews, sugar, and tobacco) which together comprise 87.7% of the total agricultural exports (FAO, 2005).

Whereas there seems to be more homogeneity among farming actors in the upper section of the agricultural sector structure (the medium to large holdings), this is not the case in the smallholder category.

Empirical evidence based on surveys about agriculture, food security, and nutrition have shown that, although poverty is widespread in rural areas, there can be distinguished three categories of rural households within the smallholder sector: (1) the poorest of all; (2) the medium poor, and (3) the less poor. The distinction is based on several perceptions about rural livelihoods (MISAU, 2001[6], and MADER, 2001[7]) and income

[4] Dohmen, C et al, *Report of a Mission on Gender and Livestock Development and Production in Mozambique*, (UE-ACP, 1997).
[5] In this paper, the symbol '$' refers to US dollar.
[6] MISAU e MPF. Perfis Distritais de Segurança Alimentar e Nutrição. Resumo das províncias, 1997-2000.

earning capacity and resource ownership (Carrilho et al., 2003; MADER/Visao, 2003; Mole 2000, and Marrule et al., 1998).[8]

Table 2 shows how some key indicators for the smallholder sector have evolved from 1996 to 1998 in central and northern Mozambique. Table 2 shows that there are remarkable differences within the smallholder sector.

Table 2: *Evolution of Mozambique's Smallholder Key Indicators in Central and Northern Mozambique from 1996-98*

Indicators	Net Income per capita terciles						Central and Northern Mozambique	
	Poorest		Middle poor		Less poor			
	1996	1998	1996	1998	1996	1998	1996	1998
On-Farm	-------- as a % age of Total of Income ----------							
Staple Food Retained	69	56.9	51	43.5	39	32.0	53	44.3
Fruits and Vegetables	7	5.5	20	5.9	21	6.9	16	6.2
Livestock Retained/Sold	5	22.4*	4	23.5	4	17.9	4	21.2
Staple Food Sales	5	2.6	6	5.5	4	6.4	5	4.5
Fruits and Vegetables Sales	1	2.1	2	2.8	2	3.1	2	2.7
Cash Crop Sale	6	5.0	9	8.6	10	9.3	8	7.7
Sub-Total On-Farm	**93**	**94.6**	**92**	**89.8**	**80**	**75.6**	**88**	**86.6**
Off-Farm								
Net labour Sales	3	2.3	0	5.0	1	14.8	2	7.4
Net Micro-enterprise Income	4	3.1	8	5.2	19	9.6	10	6.0
Sub-Off-Farm	**7**	**5.4**	**8**	**10.2**	**20**	**24.4**	**12**	**13.4**
Total Income Share	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
	----- **Mean in US Dollars** ----							
Total Household Net Income	67	65.1	161	162.3	176	458.5	201	228.1
Total Net Income per capita	12	12.4	30	33.3	91	108.4	44	51.4

Source: Taken and adapted from the 1996 MAP Smallholder Survey and 1996 MAP/MSU MSE Survey data from Carrilho et al., 2003, and Marrule et al., 1998.

For instance, from 1996 to 1998, the share of on-farm sources of income has declined while the share of off-farm sources incresead for all farm categories except for the low income category of farmers. Overall, the total household net income declined for the poorer households whereas for the other two categories increased, and substantially for the higher income farm category. Net labour sales seems to have contributed to a large extend to this trend, particularily for the medium and large farm category.

There are certainly other factors such access to and the size of arable land area for cultivation, ownership of trees, particularily cashew trees, and engaging in small enterprises.

[7] MADER, 2001. Contribuição da Pecuária para o Alívio á Pobreza.

[8] Carrilho et al (2003) "*Que papel para a Agricultura Familiar Comercial no Desenvolvimento rural e na reducaop da pobreza em Mocambique?*" Relatório de Pesquisa No 53P, MADER/DE Série de Relatórios de Pesquisa, Julho; P. N (2000). "An Economic Analysis of Smallholder Cashew Development Opportunities and Linkages to Food Security in Mozambique's Northern Province of Nampula." Michigan State University; and Marrule, H., Rui Benfica, Paul Strasberg and Mike Weber (1998). "Algumas reflex? es sobre a Pobreza e as Perspectivas para o Crescimento Rural em Mocambique" in *flash*... No. 14P, PSA/MAP/DE, September 27.x

The data shows as well that despite the large differences across rural households, both total incomes per household and per capita is very low. In addition, off-farm sources contribute to less than 25% to total income, with higher proportion only for the less poor households in both years. Carrilho et al. (2003) reports that the households with higher incomes per capita a large proportion of their income come from cash crops sales such as cotton and cashew in the north. Furthermore, the poorest households have a large proportion of households led by women.

Other important factors to be taken into account are the fact that access to land and ownership of more long-term assets are correlated to income. Female farmers are especially prone to sell their labour when faced with crisis because their low economic status and high dependency ratio not only put them at greater risk but also reduce their ability to build up reserves against shocks such as drought, disease, HIV/AIDS, floods, etc.

That is, for instance, less poor households have larger cultivated areas, and in most cases these are twice as big as those cultivated by poorer households. Given that number of cashew trees is correlated to land, and land to income, the less poor households tend to have more perennial trees such cashew trees as well (Mole, 2000).

2.1 Gender and HIV Aspects in Agriculture

Considerable efforts have been made to raise the status of women in Mozambique, as shown by the increased number of women in the decision-making positions including high offices within government and public services. Nevertheless, gender inequality and gender differences (defined as the differences between women and men in relation to access to and control over recourses including farm inputs and labour, access to markets, cash income and decision making over income) are still a major issue, in particular in rural areas. Approximately 80% of the Mozambican population is active in the agricultural sector and 90% of all women are engaged in agriculture (UNDP 2001).

Poverty, HIV/Aid, food insecurity and environmental degradation have a disproportionately negative impact on rural women due to their inferior socio-economic, legal and political status as well as their critical roles as producers and household managers. The causes and effects of these problems are systemic and have far-reaching implications for agricultural and rural development as a whole and for all initiatives aimed at increasing household income, raising levels of nutrition, improving the production and distribution of food and agricultural products, and enhancing the living conditions of rural populations. Studies show that rural women in Mozambique are the most disadvantaged population group in terms of economic growth and development (Van den Bergh-Collier 2000 and USAID 2003). Studies on districts with food insecurity and nutrition vulnerability due to drought, market isolation, chronic nutritional problems and low production areas show that female headed households face a food security risk during 4.2 months per year compared to 3.5 months for male headed households (GIMAV 1997/98). Female-headed households (approx. a fifth of all households) typically have smaller fields and a high dependency ratio since they count fewer productive adults than other families. The impact thereof is exacerbated by HIV/AIDS.

Throughout the country, female farming is characterized by low productivity. Women are also predominating in the unpaid subsistence sector for household consumption. Gender bias and gender blindness persist, especially because farmers—in particular cash croppers—are still generally perceived as 'male' by policy-makers, development planners and agricultural service providers. Women thus remain primarily involved in household food production and small-scale cash cropping with low levels of technology, e.g., tending fruit and cashew trees. In the agricultural commercial sector, women's ability to generate surplus production is also hampered by *(i)* their relative lack of access to credit with which to finance the purchase of inputs and services to improve their productivity levels, *(ii)* their limited ability to transport produce to the markets in time, and *(iii)* their lack of decision-making power in farming associations. Measures to promote marketable surplus among female farmers will also require appropriate extension services that target women farmers and address their specific needs.

In the smallholder sector, women often make the decisions and provide most of the labour for a wide range of cultivation and post-harvest activities, including storage, handling and marketing. They also predominate in off-farm food processing activities either in micro-enterprises or as wage workers in agro-industries such as cashew processing, although they have little knowledge about the prices their crops fetch and the availability of services and products to improve their farming techniques. Moreover, where agro-factories have downsized or closed and jobs are scarce, women are gradually ousted from wage jobs they formerly occupied.

Recent studies show that women decide not to generate surplus production if they cannot transport it to the market in time or if husbands receive the proceeds of the sale.[9] Female-headed households typically have less labour so that they cultivate smaller areas and are reluctant to switch to more labour-consuming techniques. This is likely to be the same for HIV/AIDS affected households. Addressing this problem requires a detailed understanding of women's decisions to diversify and rationalize production based on an analysis of cost-labour-gains.

Rural women also play an important role as managers and users of natural resources such as fuel, biodiversity and domestic water supply. Based on their reproductive role they collect water, gather firewood and forage forest products, whereas men tend to be more involved in tasks related to their productive role, i.e., felling trees for construction and fencing, commercial logging, preparing fodder for livestock, clearing land for cultivation of cash crops. Women have extensive knowledge of biodiversity and various uses of plants and herbs.

Among the most important environmental concerns are soil degradation and erosion (to which poor female farmers are particularly vulnerable), deforestation and solid waste disposal. Measures combating these will have to consider women's roles, current practices, and preferences and empower them to make sustainable use of natural resources or alternatives.

Various gender concerns relate to HIV/AIDS. Women are disproportionately affected by the pandemic since they are biologically and economically more vulnerable to HIV

[9] Van den Bergh-Collier, *Gender Profile in Mozambique: Analysis and Action Plan for the New Strategy Period 2004-2010* (USAID Mozambique 2003), p 14.

infection and they can women transmit infection to their unborn babies in the womb, during childbirth, and through breastfeeding. The disease increases women's burden as caretaker and breadwinner and directly impairs their ability to ensure their family's food security. As such, women become the caretakers of sick household members, often take on responsibility for other people's orphaned children, engage in additional activities to ensure their family's food security, engage in risky behavior in exchange for cash, food or good, and are frequently ill while doing all of the former.

HIV/AIDS is unique and different from all the other problems that affect development initiatives. Though diseases such as malaria and tuberculosis kill millions each year and catastrophes (floods, droughts etc) have obvious implications for development, two factors make HIV/AIDS one of the biggest threats to development the world faces today, since it strikes the most economically productive members of society, HIV/AIDS is a problem of **critical importance** for agricultural, economic and social development.

As evidence suggests, the HIV/AIDS epidemic affects agriculture more than other sectors. The devastating effects of HIV/AIDS on agriculture, therefore, must be addressed since the epidemic undermines the progress made in the last 40 years toward agricultural and rural development. The impact of HIV/AIDS on the agriculture sector threatens sustainable agriculture and rural development primarily through:

?? **Loss of Labour** (less area cultivated, range of crops decreases, shift to less intensive crops, less time domestic tasks, etc).

?? **Loss of capital** (forced disposal of productive assets, sale for health care, funerals, asset stripping).

?? **Loss of indigenous farming methods, inter-generational knowledge, and specialised skills, practices and customs.**

?? **Disruption of traditional social security mechanisms** (increased number of orphans)

?? **Morbidity and mortality** among the staff of rural institutions and support services – weakening institutional capacity (FAO 2001).

By the end of 2001, 1.1 million Mozambican adults and children were living with HIV/AIDS, with adult prevalence over 13% (adults being 15-49 years old). Prevalence rates are higher and increasing more rapidly along the development corridors (e.g., Maputo-Nacala) and among the mobile populations (i.e., miners, migrant workers, traders, drivers and uniformed services) and their partners (FAO 2001).

The Mozambican HIV/AIDS scenario is extremely worrying because of the rapid increase in HIV/AIDS rates caused by dynamic rural-urban and cross-border movements together with persistent poverty and 50% illiteracy (of which 71% are women).

Projections indicate that the number of economically active persons in 2010 will not be 12.4 million, but 10.8 million with a high proportion of very young or very old workers. The forecasted impact on labour availability is of extreme concern since labour shortages are already constraining agricultural production.

Despite findings from other sub-Saharan African countries with similar or higher prevalence rates than Mozambique, there is as yet no empirical evidence, particularly from the agricultural sector (where more than 70% of the population resides) that there is a drastic reduction in production as a result of HIV/AIDS. Most of the survey work and data collection has been concentrated in urban and peri-urban areas. No comprehensive study of the impact of HIV/AIDS on the agricultural sector in Mozambique. The various impacts of the HIV/AIDS epidemic on the agriculture sector have been inferred from experiences and data from other sub-Saharan African countries (e.g., VETAID conference on Mitigating the Effects of HIV/AIDS on Agriculture in Southern & Eastern Africa in November 2003).

2.2 Land and water resources for irrigation

Recent estimates indicate that irrigated agriculture is the largest water consumer accounting itself for about 550 million of cubic meter per year (Mm^3), corresponding to about 87% of the country total water consumption. (FAO, 2005; Consultec, 1998), followed by the domestic sector using 70 million m^3 (11 percent) and industry consuming 15 million m^3 (2 percent). The main source of water for irrigated agriculture in Mozambique is surface water.

Although rainfed agriculture accounts for the majority of the cultivated land, irrigated agriculture, which currently occupies about 1% of the total cultivated area, constitutes a significant contribute to the national agricultural production.

Irrigated agriculture is also characterised by high water losses, low efficiencies, highly subsidised water rates, and low yields per unit of applied water. Any practice leading to increase water use efficiency, either by saving water or by increasing crop yields for the same amount of water, is just essential to make the best use of limited water resources. These savings would also inevitably mean more water available to expand irrigated areas or to allocate to other sectors within the same river basin.

Previous reports, referring FAO estimates in 1983, indicate a potential of 3.3 million hectares of land suitable for irrigation throughout the country (UNESCO - DNA, 1984). This figures constituted a first approximation mainly based on reconnaissance studies, most of them carried out before 1975. When these estimates were updated with more recent and detailed information the country potential for irrigation was reduced to about 2.7 million of ha of irrigable lands[10] (Consultec, 1998). From this potential, more than 50% are located in the Zambezi river basin in the centre of Mozambique. The Umbeluzi, Incomati, Limpopo, Buzi and Pungoé river basins in the South of the country, where a

[10] Irrigable lands should be understood as areas that, with the present knowledge concerning land and water resources, are feasible to be irrigated in a near the future.

Master Plan for irrigation development was elaborated, cover about 15% of the total country irrigable area.

More detailed studies, including water resources and environmental impact assessment, can probably show more conservative figures. In the Zambezi river basin, for example, early studies identified an irrigation potential around 1,500,000 ha (HP, 1965). More recent studies (Burep, 1980), indicated that highly suitable soils for irrigation are around 1,000,000 ha, but from this only 200,000 ha do not require the elevation of water more than 10-20 m. These areas were suggested as the most recommended for a short-term irrigation development. Mention should be made to the existing conservation and protected areas in the right bank of the Zambezi river, which can further limit the implementation of these irrigation projects.

Estimates made by the National Irrigation Development Master Plan in 1993, indicate that in the Umbeluzi river basin, even with all the hydraulic structures in place, the availability of water will not be enough to cover all the soil potential for irrigation (only 8,100 ha out of 21,000 ha can effectively be irrigated). The Incomati and Limpopo river basin can easily reach their land potential for irrigation, but only if major hydraulic structures are put in place (Moamba and Mapai dams, Chuali dike).

From these examples, it can be drawn that Mozambique is endowed with soil potential for irrigation, which considerably exceeds the area that can currently be exploited, considering the availability of water resources, the implementation capacity of major hydraulic structures, and the actual land use. The scarcity of water resources for irrigation is more severe in the southern basins, where semi-arid climatic conditions and international river flows add to urban and industrial requirements, causing an enormous stress in the riverine ecosystem.

2.3 History of irrigated agriculture in Mozambique

In 1968, the irrigated area in Mozambique totalled 65,000 ha with Maputo and Gaza Province, in the South, concentrating about 72% of the irrigated areas. The expansion of the irrigation sector since 1968 occurred mainly with the implementation of major sugar cane schemes and the Chokwé scheme, which was actually initiated before 1968. Estimates from 1973 indicated a total irrigated area around 100,000 ha with Maputo and Gaza Provinces occupying the majority of the irrigated areas (Mello e Marques, 1973).

Inventories carried out in 1986 and 1987, indicated a total developed area for irrigation[11] around 120 000 ha, from which approximately 42,000 ha were fully operative at that time (Mihaljovich and Gomes, 1986; Sogreha, 1987). From these 42,000 ha, 67% were located in the Limpopo, Incomati, and Umbeluzi rivers, 25% in the Buzi, Pungoé and Zambeze river basins, and the remaining 8% were distributed among the other river basins.

The biggest irrigation schemes are the Chokwé (Limpopo river basin) and the sugar cane plantations (Incomati, Buzi, Pungoé, and Zambeze river basin). Chokwé is the most

[11] Total developed area for irrigation should be understood as areas with infrastructure and which can still be irrigated with reference to past practice.

important irrigated area in the country with 25,000 ha equipped for irrigation, representing 21% of the total developed area. Sugar cane schemes account for 29% (34,250 ha) of the country developed area for irrigation.

Recent estimates indicate that the actual irrigated area is around 35,000 ha (Consultec, 1998). However, a national irrigation survey carried out from 2001 to 2003 (Marques et al., 2003, 2002, 2001), concluded that currently, 118,120 ha are equipped for irrigation, of which only 40,063 ha are actually operational/irrigated.

The national survey on the irrigated agriculture on the basis of previous studies considered three different irrigation categories based upon size of the infrastructure and land areas, i.e. Class A for irrigated areas < 50 ha; Class B for schemes from 50 ha to 500 ha; and Class C for areas > 500 ha.

About 257 schemes have been recorded so far at country level, which corresponds to the total equipped land for irrigation, 118,120 ha, consisting mainly of large schemes Class C, over 500 ha schemes (about 70% of the total equipped irrigated area). Class B 50-500 ha size irrigated areas account for 17% (20.000 ha) from the total equipped land area, and 77 schemes were recorded. Class A irrigation areas registered account for 159, corresponding to 6.400 ha of equipped land.

Basin irrigation for rice and furrow irrigation for different types of vegetables are practiced. Sprinkler irrigation is widespread with agricultural companies, especially in sugarcane plantations, but also for citrus fruits and vegetables. Some producers employ drip irrigation to produce tomatoes (3,347 ha or 8 percent of the actually irrigated area); 50 percent of the actually irrigated area is under sprinkler irrigation, while the remaining 42 percent is surface irrigation. In most irrigation schemes, surface water from rivers is used. Groundwater is used to a very limited extent by the family smallholder sector.

In the north of the country there are only few large-scale irrigation schemes actually irrigated, and only irrigation of class A and B is operative. In the south part of the country, class C schemes account for approximately 80 percent of the equipped area. Class A schemes are mostly operated by farmers individually or organized in an association. Class B schemes are usually managed for industrial exploitation, mainly sugarcane and rice. Class C schemes are not promoted any more, as most of the recent projects are aimed at rehabilitation and development of class A and B schemes.

The following tables show results from the national irrigation survey (Marques et al. 2001, 2002, 2003).

Table 3 Irrigation and Drainage in Mozambique

	Year	Amount	
Irrigation potential		3,072,000	ha
Irrigation:			
1. Full or partial control irrigation: equipped area	2001	118,120	ha
- surface irrigation		-	ha
- sprinkler irrigation		-	ha
- localized irrigation		-	ha

- % of area irrigated from groundwater		-	%
- % of area irrigated from surface water		-	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)		-	ha
3. Spate irrigation		-	ha
Total area equipped for irrigation (1+2+3)	**2001**	118,120	**ha**
- as % of cultivated area	2001	3	%
- average increase per year over the last 8 years	1993-2001	1.3	%
- power irrigated area as % of total area equipped		-	%
- % of total area equipped actually irrigated	2001	34	%
4. Non-equipped cultivated wetlands and inland valley bottoms		-	ha
5. Non-equipped flood recession cropping area		-	ha
Total water-managed area (1+2+3+4+5)	**2001**	118,120	**ha**
- as % of cultivated area	2001	3	%
Full or partial control irrigation schemes: Criteria:			
Small-scale schemes (Class A) < 50 ha	2001	6,389	ha
Medium-scale schemes (Class B) 50 - 500 ha	2001	19,647	ha
large-scale schemes (Class C) > 500 ha	2001	92,084	ha
Total number of households in irrigation		-	
Irrigated crops in full or partial control irrigation schemes:			
Total irrigated grain production		-	metric tons
- as % of total grain production	1994	2	%
Harvested crops :			
Total harvested irrigated cropped area		-	ha
- Annual crops: total		-	ha
. Sugarcane	2001	23,858	ha
. Vegetables	2001	7,011	ha
. Rice	2001	4,130	ha
. Tobacco	2001	445	ha
. Other annual crops		-	ha
- Permanent crops: total		-	ha
. Citrus	2001	370	ha
. Other permanent crops		-	ha
Irrigated cropping intensity		-	%
Drainage - Environment:			
Total drained area		-	ha
- part of the area equipped for irrigation drained		-	ha
- other drained area (non-irrigated)		-	ha
- drained area as % of cultivated area		-	%
Flood-protected areas		-	ha
Area salinized by irrigation	1993	2,000	ha
Population affected by water-related diseases		-	inhabitants

Source: (FAO 2005)

Table 4 Irrigation in Mozambique

Item	North		Centre		South		Total	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Area equipped for irrigation:								
Class A (< 50 ha)	592	17	1,428	4	4,369	6	6,389	5
Class B (50-500 ha)	1,760	53	6,653	17	11,234	15	19,647	17
Class C (> 500 ha)	1,000	30	30,949	79	60,135	79	92,084	78
Total	3,352	100	39,030	100	75,738	100	118,120	100
Area actually irrigated:								
Class A (< 50 ha)	200	30	624	4	2,452	11	3,276	8
Class B (50-500 ha)	461	70	1,584	10	2,635	11	4,680	12
Class C (> 500 ha)	-	-	14,049	86	18,058	78	32,107	80
Total	661	100	16,257	100	23,145	100	40,063	100
Part of equipped area actually irrigated:								
Class A (< 50 ha)		34		44		56		51
Class B (50-500 ha)		26		24		23		24
Class C (> 500 ha)		-		45		30		35
Total		20		42		31		34
Irrigation technology in actually irrigated area:								
Surface irrigation	656	99	4,200	26	12,000	52	16,856	42
Sprinkler irrigation	-	-	11,530	71	8,330	36	19,860	50
Localized irrigation	5	1	527	3	2,815	12	3,347	8
Total	661	100	16,257	100	23,145	100	40,063	100
Main irrigated crops:								
Sugarcane	-	-	13,799	90	10,059	50	23,858	67
Vegetables	301	100	210	2	6,500	32	7,011	20
Rice	-	-	480	3	3,650	18	4,130	11
Tobacco	-	-	445	3	-	-	445	1
Citrus	-	-	370	2	-	-	370	1
Total	301	100	15,304	100	20,209	100	35,814	100

Source: (FAO 2005)

2.4 Irrigation Use in Mozambique

The main irrigated crops are sugarcane, rice, citrus, and vegetables (mostly tomato and lettuce), which are cultivated with low intensity of 1.1-1.2 crops/year; see previous Table 4.

The cost of irrigation system development varies according to type of irrigation technology. For surface irrigation it ranges from US$1,000 to 1,500/ha, and for sprinkler irrigation from US$1,500 to 2,000/ha. Maintenance cost is around US$500/ha per year. The rehabilitation cost, depending on the condition of the old system, can vary between US$500 and 1,500/ha (FAO 2005).

Irrigation efficiency is reduced to 25-50 percent, mainly in the surface irrigation areas of smallholder farmers. In agricultural companies, which use mainly sprinkler irrigation, efficiencies are up to 70 percent (FAO 2005).

3. Analysis of Good Practices in Micro Irrigation and RWH

3.1 Water management technology – swamp irrigation/inland valley swamps and dambos

As from the inventory form, this water technology or practiced is quite common in the central and northern parts of the country, where dominant landscape features in the slightly undulating plain are low hill interfluves alternating with valley floors and dambos. According to Chabwela (1991), such terrain units belong to the Palustrine System, and they may occur along rivers, lakes, or coastal area, or in a form of seepage or springs, being of enormous importance for small-scale agriculture.

The development of these areas in most of the region is limited to the rainy season, where surface and rain waters are the major limiting factors during the dry season once becoming seasonal and the rivers having low discharges.

During the rainy season with no limitations in terms of water and soil moisture, the swamps and dambos are used for paddy rice cultivation. Some of the valleys and dambos were developed with the help of other institutions, who provided the technologies to improve and to increase land use intensity year around. Where technology was introduced and developed locally, different structures were established in order to harvest water, i.e. small dams were built, or in the case of rainy season, earth canals were open following the centre of the valley to drain excess of water.

In the case of the swamps and dambos where water regime is dependent on seepage water, water harvesting structures are also built along the lower slopes and parallel to the valley and later water diverted into the swaps and dambos. So improved systems contribute for year round crop production.

It may be concluded that such systems have been developed and adapted to match small scale irrigated rice production systems. In the absence of irrigation, smallholder rice growers in central and northern Mozambique have traditionally adapted their cultivation methods to suit the unpredictability of the natural system and offset the limited availability of resources. Thus over multiple generations, two key adaptations have been made within rice production systems to ensure adequate yield, combining productivity and water use efficiency:

1. Smallholders have limited the size of their holding to approximately 0.5ha or smaller, in line with the available manual inputs of hand tooling for ploughing and weeding (labor constraints at household level); production of rice in normal years under these circumstances is sufficient to satisfy household requirements, and enable seed regeneration for the following season. Any excess production is then sold to supplement income.

2. Smallholders have applied a range of risk minimization strategies within their rice production systems, including: the utilization of different planting methods on variable topography, such as direct dry sowing on higher, well-drained soils followed by transplantation onto inundated soils after rainfall; the staggering of planting dates; and the sowing of different varieties with varying tolerances for drought and flooding, thus ensuring baseline production irrespective of seasonal developments.

So for sustainable purposes, operational and maintenance of such systems are kept to a very low level of inputs, mostly assured by the farmers or with community participation, from the construction of the water diversion structures, open earth channels, and terrain levelling for water transportation and distribution from the source to the plot.

It is estimated that, for similar systems, the water supply of the primary channel to the field is 15L/sec, operating at a water supply efficiency of 50 percent in the wet season, due to seepage and evaporation. This delivery efficiency decreases to approximately 25 percent in the dry season, due to an increase in evaporation combined with decreased river flows.

These irrigation systems have been in operation for more than 25 years and the users situation is different from area to area, where it may be possible to have situations like there is only one private irrigator currently utilizing the system, or a farmer association running the system. Crops are grown with no pesticide, mechanical or fertilizer inputs, as well as they rely on local seed.

From interviews and from different government sources it was determined that 500kg of rice was produced off 0.5ha (yield 1 tonne/ha) in 2003/04. It appears that weeds have an adverse affect on final yield of the crop if not properly managed. The steep sloping topography of the field is not effectively bunded to maintain submergence of the field for optimal rice yields. The undulations in the surrounding areas limit the ability for future expansion of the irrigated area. So levelling due to labor limitation at household level further limit the efficiency of the system and productivity. The channels have a double function once they may be used for water distribution for irrigation purposes or in the case of excess of water, to act as drains.

1. Strengths of this irrigation system include:

    1. The irrigation water supply is gravity supplied (requiring no diesel input costs) and the quantity of water available is not a limiting factor for in-crop irrigation.

    2. Consistency - this small-scale irrigation system has been in operation for more than 25 years.

    3. A regular schedule of maintenance on the primary supply channel has been established. One person takes one week per year to maintain channels prior to the wet season.

    4. The smallholder farmers involved are aware that water delivery efficiencies to the field are sub-optimal, and they are eager to learn how to improve and seek for solutions to these issues, despite financial constraints.

    5. The potential of the available water resources are under-utilized during the wet season and expansion of the irrigated area off this river is feasible.

2. Weaknesses of this irrigation system include:

    1. There is an established farming practice of low-input/low-output irrigated rice production. Fertilizers are not used, rice varieties are mixed within the field to spread the risk of adverse seasonal conditions, and weed control is poor due to limitations of labor.

    2. The area sown to irrigated rice is limited by the shortage of manual labor for ploughing and weed control and in season weed control.

    3. The delivery efficiency of the primary supply channel is low (<50 percent) due to seepage and evaporation. While this low efficiency impacts the total water supply for dry season vegetable production rather than in the wet season rice, if future irrigated rice area expansion was to increase, the demand on water supplies would escalate and poor supply efficiency may become a hindrance to production.

3.2 Water harvesting technology – micro basin system

This technology or water harvesting practice is used again in the central and northern Mozambique, in the coastal zones, where mean annual rainfall ranges from 1000 to 1200 mm, in association with very flat terrain systems and heavy clay soils.

The system has been developed again by small holder farmers and is almost specialised for rice production. The area where such technique is widely spread is in the Mossuril District, Cabaceira Grande, in Nampula Province, and most of the lowlands of Quelimane, Nicoadala and Namacurra districts, in Zambezia Province. Two major terrain systems are used for rice cultivation, the coastal alluvial plain, almost flat topography, with no gradient, favouring ponding conditions, and the elongated depressions/fresh water swamps or baixas between the beach ridges. Both systems rely on the rainfall amounts and frequency of heavy storms, although in the alluvial plain surface drainage conditions are slightly better than in the depressions, almost inundated annually. The wider the depression the more the tendency too much wetter areas because of the lower gradient and slow run-off, so getting to a permanent flooded depression condition.

While adequate water quality is available during the rainy season, the water can be brackish before the start of the rains especially near the coast and river estuaries.

The system is labour intensive once all the construction and maintenance of the man made structures rely on the household members. Almost every year and before the beginning of the rainy season all the small earth bunds/dykes have to be repaired in order to be effective for rain water harvesting and flooding the micro basins, which are then used for paddy rice production.

The plots size ranges from 100 to 250 m² and the shape is conditional to the local topography. Soils are quite suitable for paddy rice cultivation, and such systems are just adequate for small holder rice production, although there is room for improvement of the current farming systems, particularly on the crop, soil and water management aspects.

Rice in the wettest places is the only crop to be grown and occupies practically all the available land in each depression from about mid-December to the end of June and July, depending on the rainfall pattern and household labour conditions. The deepest central parts of the depressions are not cultivated and are left, and fishing is an alternative use for the households. In the driest baixas, a second season crop is possible to be grown and farmers normally plant maize and sweet potato in the ridges they prepare to improve soil drainage. These large ridges are levelled while preparing the fields for the next rice growing season.

There is virtually no water control, except for the small earth bunds round each field. The flat area is different once soils are heavy textured clay soils of marine and alluvial origin, seasonally inundated to about 30 cm or more with rain water and in some cases with river water. The major difference in this terrain system is that groundwater quality year round is poor. Here also are established surface irrigation infrastructures, mainly used as supplementary irrigation for rice production during months or critical stages of crop development.

Major constraints in these systems is soil fertility decline after so many cultivation cycles without improving nutrient levels (especially phosphorous), and organic matter content. Also due to the use of brackish water, it may causes problems in the future and some areas may be lost due to degradation. However, drainage is not recommended because it may have a detrimental impact on the local environmental conditions. Most probably the fresh water layer is rather shallow and drainage can cause either water shortages in the upper areas of the ridges system, or creating another problem by draining the baixas, the under laying saline water ca rise and penetrate into the crop root system, affecting the yield and the soil.

Yields under the prevailing farming systems are low, ranging from nearly 700 kg up to 1.800 kg/ha and 2.000 kg/ha.

3.3 Water management technology – river floodplain irrigation

This system is common in the lowland coastal areas of the central and southern parts of the country, and again because of excessive moisture, in general is used for rice cultivation during the rainy and wet season, and very seldom used for another crop during the dry season. In some areas if terrain allows farmers do prepare ridges to improve drainage conditions and plant a second maize crop and sweet potatoes, in the dry season, but where there is some how an hydraulic infrastructure, and the system managed through a farmer association, the system is used just for a single rice crop. It is not allowed to grow any other crop because land preparation involves ridging, which results in changes in the terrain topography, thus being a constraint in water distribution due terrain irregularities.

The system operates through controlling the rise in floodwater using dykes, canals and sluice gates, taking advatage from terrain position in the topography, in order to prevent saline seawater intrusion into the irrigation system. Most common places where this technology is used are in coastal areas of Zambezia and Sofala Provinces, in the delta of the Zambeze River.

The irrigation systems lie in the flood plains of major Zambeze tributaries, in the low-lying flat areas. The method of irrigation are unique in the country because it is dependant on the tide. The system lay-out takes advatage of water flows in the river and the tides. So a quite substantial network of large earth channels are established for water distribution from the river, although with quite a number of culverts in the dike on the riverside, equipped with sliding gates to control the water flow from the river. On the inner side of the dike water enters into several parallel secondary canals, of which just part of the canals reach the far end of the system. This systems is then crossed by a network of tertiary canals. The network is used for irrigation and drainage, with a bottom slope of zero. At the end and limiting the system there is a dike which protects the area from floods, while marginal to the lay out the system is limited by beach ridges terrain systems.

The working of the irrigation system is fully dependant on the discharge of the river and the tide of the Indian Ocean. Flooding is possible at certain combinations of discharge and high tide. During the raiy season and for four to five months, December to April/May, the discharge of the river is high and the tidal fluctuation is superimposed on water heights. Once in two weeks and for sucessive days, the water heights are high enough to flood the fields and then the water is refreshed. During low tides the excess water is drained and leaves the system. Also during these combination of river flows and tides, the slicing gates are closed preventing from salt water intrusion. The advantage of the system is that also benefits from rain water, although during the dry season when river flows are reduced the use of the system is limited, in order to prevent salinization due to the use of poor quality water.

It seems that the system has some operational problems, which limit the fully use of the total irrigated area. Canals layout and levelling are major constraints, preventing water to be evenly distributed by all fields. This may be aggravated by the use of both irrigation and drainage channels, which seems wise to differentiate irrigation from drainage network and infrastructures. It has been reported the problem of salinization. The current layout may result in insufficient leaching and drainage of irrigation water, which may influence environmental local conditions.

3.4 Water management technology – swampy irrigation/fresh water swamps

According to Gomes et al. (1997), this practice is mainly limited to the southern part of Mozambique, occurring in the swampy peat lands, and it belongs to the Palustrine system (Chabwela, 1991). The South of Mozambique is characterised by arid and semi-arid climates together with light/coarse textured soil having low available water content (AWC). To face these adverse conditions, farmers usually cultivate the lowland areas where the residual soil water content can be used for crop growth.

Hydromorphic soils are found in areas of water seepage, at the footslopes (lower slopes) of the scarps which form the transition between the beach ridges, degraded beach ridges, coastal margins and the lower areas, such as flat marshy zones, swampy depressions, swales and tidal flats (Barradas, 1962). These soils are saturated with water either permanently or during most of the year. This causes a lack of oxygen, slowing the breakdown process of organic matter by bacterial activity. Although some mineralisation is caused by anaerobic bacteria, this is much less than under dryland conditions. A strong accumulation of organic matter gives rise to an organic peat horizon, which can vary from 0.4 to 1.0 m depth.

These organic (peat) soils are called *machongos* and they are generally very fertile and continuously wet. They receive fresh water all year round as seepage from the surrounding dune areas with high infiltration and high recharge rates. They also present a very good soil structure for plant growth with high water holding capacity, high soil aeration, and easy workability. These characteristics make these soils specially recommended and attractive for the small scale agriculture. When subjected to drainage, *machongos* are intensively used for crop production though excessive drainage can contribute to mineralisation of the peat, resulting in soil acidification.

The hydromorphic sandy soils are less rich in organic matter than the *machongos*, but they also have a watertable close to the soil surface. Due to the similarity of these soils, in terms of occurrence, wetness/drainage, land use, and vegetation, farmers also commonly call them as *machongos*.

Water management is the key issue to the use and management of *machongos*. Shallow drains, combining the functions of drainage and irrigation, and maintenance of groundwater levels both in wet and dry season, are usually opened by hand. While for the hydromorphic sandy soils the impacts of drainage is not problematic, the same does not occur with the peat soils. Due to a strong accumulation of organic matter, and because they are nearly saturated with water for most of the year, peat soils usually have an acid reaction quite accentuated (pH values between 3.8 and 5.5). This is due to the release of hydrogen ions (H^+) during the decomposition of organic matter, which is strongly associated with increasing mean air temperatures and aeration of the soil when drained.

In the presence of better, relatively freely drained conditions, main cultivated crops are rice, maize, beans, and vegetables. Rice is considered the main crop to be grown on these soils due to its rooting system well adapted to waterlogged conditions and to its growing cycle during the hot and rainy season, when the peat soil is likely to be flooded. Yields of 1.9-2.8 t ha^{-1} for rice were recorded by some farmers in the *machongos* of Gaza province (Monteiro, 1957). Similar observations in farmer's fields, have shown yields around 20 t ha^{-1} for lettuce and sweet potato, and 10 to 15 t ha^{-1} for cabbage, onions, carrots and tomatoes during the dry season (INIA-DTA, in prep). These soils are though quite fragile due to the almost absence of the mineral component. Mismanagement of peat soils can lead to its degradation and loss for agriculture.

Salinity and/or sodicity are present particularly in the alluvial soils in the South of the country. This is due to the presence of saline and/or sodic lacustrian and estuarine deposits (primary salinization), which can be aggravated by an inadequate management of the irrigation and drainage system (secondary salinization). Some other cases are also influenced by the sea water intrusion, due to reduced fresh water flows.

Based on this results some basic principles for a sustainable management of these soils (Monteiro, 1957; Dikshoorn *et al.*, 1988) were confirmed by the Manguenhane case-study (Mafalacusser *et al.*, 1997):

?? Shallow drainage must be encouraged in order to avoid the watertable to low more than 0.2-0.40 m depth; drain spacing and depth should be determined for each case, according to the physical conditions of each site. Soil subsidence results from the mineralization but also from the shrinkage of the organic material. These factors should also be considered when reclaiming these soils for agricultural use. Drains should be opened by hand and artisanal gates can be used to control the water table at farm level.

?? Irrigation should be as frequent as possible in order to maintain high water content in the upper layers and decrease soil temperature specially during the hot season. The water should flow from the top to the bottom in order to leach the salts downwards and avoid salinisation.

?? Mechanisation is limited in these soils due to its low carrying capacity. A technology based on intensive use of manual tools should be recommended.

- Land clearing should avoid burning of the vegetation and crop residues as it also destroys the peat topsoil; burning should occur outside the *machongo* area or in selected places with high water table levels to avoid its spread. Ashes can then be spread on the soil surface to improve the soil nutrient status.
- Crop selection and rotation should consider the conditions of these soils: shallow water table and soil acidity. Most suitable crops are rice during the rainy season, and vegetables (with shallow rooting system and with tolerance to acidity) during the dry season. Depending on the depth of the water table, other crops such as maize and beans can also be considered.
- Flooded rice cultivation will contribute for peat layers reestablishment and maintenance. Cultivation in mounds or hills permits the farming of some crops (e.g. sweet potato) while the soil is still poorly drained.
- Mulching with crop or vegetation residues will reduce the effect of solar radiation in the oxidation and decomposition of peat layers.
- There are always risks of flood during the wet season. If not taken into account, all investment will be lost. Intensive maintenance of the drainage system is crucial for the development of these wetlands.
- Peat soils are also important to keep a certain ecological habitat. Impact assessment of reclamation for agricultural use should always be studied and weighed.
- Non agricultural uses of these soils are also possible. Reeds, natural vegetation of unreclaimed *machongos,* are important materials of construction. Fishing, grazing, hunting, and soil compost are other rural activities possible in these wetlands.

3.5 Water management technology – river floodplain irrigation/dry season crop production

It is the commonest water management practice in the country and dominates major river floodplains and alluvial plains in the country, and it is part of the Riverine system (Chabwela, 1991). This is the largest inland wetland in Mozambique and it includes the floodplains and swamps, following the main drainage system. Floodplains and swamps are important environments for livestock production, fisheries, wildlife and agriculture.

They comprise the following main systems: a) Rivers of Maputoland, b) Limpopo system, c) Inharrime river and the interior of Inhambane Province, d) Save, Gorongosa, Buzi, and Pungoé rivers, e) Lower Zambezi river, f) Rivers of Zambezia Province, and g) Rivers of the NE Coast (Hughes and Hughes, 1992).

In terms of human impact and utilisation of these riverine swamps and floodplains systems, the most affected are the Zambezi River and those south of it. The northern rivers have been subjected to less pressure (Hughes and Hughes, 1992). In the Zambezi River, the dams of Kariba and Cahora Bassa reduced downstream peak season flows, but increased the dry season flows (Hughes and Hughes, 1992). As a result of these regulations the flood regime on the lower Zambezi is now greatly reduced, erratic, and mainly out of season. This has affected the prawns capture rates in the Sofala Bank (Gammelsrod, 1992). There are also evidences suggesting that the wetlands of the

Zambezi Delta have come through severe changes (DNFFB, 1997), due to the regularisation of the river flows by these two major hydraulic structures. The Zambezi delta is one of the areas where the reduction of mangroves forest have been quite severe in the last years (Saket, 1994).

Agriculture development, sometimes involving irrigation, takes place in the lower section of the Zambezi River. Overgrazing and burning has been a problem in many areas. Among protected areas it has been very serious in the Zambezi Wildlife Utilisation Area where the new controlled flood regimes favour the spread of wildfire and the reduction of the pastures (Hughes and Hughes, 1992).

Upstream impoundment also affected the annual flows of the Revué/Buzi, Save, Limpopo, Incomati, Umbeluzi, and Maputo rivers, decreasing the availability of water during the dry season. These are international rivers covering the most of the semi-arid zone of the country. It is also in these rivers that most of the irrigated areas are located [67% in the Limpopo, Incomati, and Umbeluzi rivers, 25% in the Buzi, Pungoé, and Zambezi rivers, and 8% among the other river basins (Marques et al. 2001, 2002, 2003; Mihaljovich and Gomes, 1986)].

Most of these irrigation areas in Zambezia and Sofala Provinces are predominantly occupied by small landholders (0.5-1.0ha) who are often members of water user associations that occupy and farm areas of medium sized rehabilitated or disused colonial irrigation schemes (>100ha).

Irrigation delivery methods include gravity diversions during seasonal river flooding, low cost controlled flood irrigation, and a diverse range of diesel pumping systems from rivers. Some systems have the capacity for both diversion and pumping irrigation; the primary transfer systems are predominantly open earth channels with some closed piping in operation.

Most of the systems were established during the colonial time, in the early fifthies, for rice production. In the 80s after independance the systems were runned by state farms and due to civil war, were abandoned. In the middle 1990s several of the systems were rehabilitated with support of non governmental organizations and govermnent agencies, and management hand over to farmer associations.

Current operational irrigated areas are limited because of several problems with floods, contributing for the destruction of irrigation infrastructures, and associated equipment, i.e. diesel pumps, and also due to the increasingly high diesel pumping costs. The primary, secondary and tertiary irrigation supply infrastructure is in need of physical earthworks to repair, and also requires cleaning to remove overgrown vegetation which potentially restricts water flows.

Some of the systems operate as follows: during periods of seasonal flooding the water in the Rivers, which is of relatively distance from the irrigation schemes (aproximatelly 1 to several kms far from the water source), backs up through hydraulic infrastructures such as weir and small dams, filling the reservoirs, and also using natural water bodies (small lakes and lagoons for the same purposes).

As river levels peak, the weir and small dams are closed off holding water in the reservoir, to be diverted via gravity through one or more sluice gates into the primary canal situated at the principal pump station (operation termed 'controlled flood irrigation'). Once the water level in the reservoir recedes below the gravity diversion level of the primary supply channel, diesel pumping is required. Normally the Rivers have a considerable permanent flow and pumping is used to complement the controlled flooding system. The pumps currently in operation at the different systems pump stations varies from a 200L/sec (ranges from 150 L/sec to 300 L/sec) mixed flow pump, powered by a 6 cylinder diesel motor to significantly larger engines. Other irrigation schemes, are entirely dependent on the direct changes in river height. There is no potential to hold surplus capacity in a reservoir. Also to mention that is common to find several of these systems protected by a large network of dykes to protect them from floods. The year 2000 floods have had severe impact in the dykes system, and quite a number of schemes are still left with no protection at all.

Because of the terrain conditions and local topography, water is transported by a open earth channel and water is distributed at farm plot by gravity. There are significant undulations in ground level with the rice fields which make seed establishment, weed management and effective in-crop irrigating difficult to achieve, which accordingly impacts negatively on rice yields.

In some systems, irrigation costs each season, regarding the cost in diesel to irrigate 1.0ha is approximately 1,500,000 Mts or USD$62 and even more, once diesel costs have been rised almost every three months (1 L of diesel in Maputo is USD1,00).

The rice yields range from 2.5 tonnes/ha to 5.0 tonnes/ha. As is with nearly all development projects, there is a strong focus on the costs of irrigation infrastructure. Tendered quotes for irrigation system construction range from US$2000/ha to US$13,000/ha, with the average in the vicinity of US$3000/ha for the Small Scale Irrigation Project (Government Based BAD Funded Project) . The costs of constructing the irrigation systems are likely to increase significantly over the life of the project.

Maintenance costs are really high. The farmers spend in some cases in average 10 million Mts (USD = 30.000,00 Mts) per annum on running costs such as weeding of the supply channels, repairs and maintenance and diesel for pumping operations.

The irrigation scheme is drained into the Rivers, utilizing the natural drainage of the floodplains and other natural drainage lines. In the South of Mozambique, the irrigation systems in the Gaza Province rely primarily upon a rehabilitated, large scale, open channel gravity diversion scheme on the Limpopo river. Rice production in the Chokwe region takes place across a range of farm sizes. Small landowners (0.5ha) conduct all farming operations manually, including threshing, with no external inputs. Landowners irrigating areas from 1.0-2.0ha rent tractors for ploughing operations, with minimal inputs of nitrogen fertilizer.

Sowing is dependent on rain from October to December, with transplanting occurring 60 days after sowing. In-season irrigation is frequent, supplementing the limited rainfall in the region. The larger commercial operations (>50ha) in the Chokwe system focus on high input agriculture, using mechanical ploughing and dry seed sowing. In this case, sowing is not dependent on rainfall as irrigation is used for rice establishment. There is also extensive use of fertilizer and herbicides for weeding, along with combine harvesting.

The Massigir Dam Smallholder Agriculture Scheme near Xai Xai consists mainly of smallholder farmers with no external inputs.

In the Maputo province, small landholders (0.5-1.0ha) are organized as members of water user associations that occupy small to medium sized (50ha) rehabilitated irrigation systems. Irrigation water is supplied via diesel pumps from seasonal flowing rivers into open earth channels. Fertilizer inputs are high, however mechanical harvesting and threshing is absent. Dry seed sowing is rainfall dependent, commencing in November with transplanting in December.

At present, major interventions in terms of the development of irrigation in Mozambique include:

1. The rehabilitation of Massingir Dam, which will allow for the irrigation of around 9,000ha of land in the Limpopo River lower basin and will also regulate water in most of the Limpopo Valley, including Chokwe. This will reopen agricultural opportunities for smallholder and commercial farmers who have traditionally operated in the area, with the possibility of resuming rice production.
2. The rehabilitation of Corumana Dam to improve irrigation conditions on the Incomati River Valley. This scheme already serves two sugar producers (Xainavane and Maragra) and has the potential to serve other smallholder and commercial sector producers. The approximate total area cropped in 2001/2002 season (estimates from FDHA, 2002a; 2002b) considering only irrigated agriculture in the Incomáti River Basin (figures for Maputo Province and part of the Southern Gaza) is 11.261,9 ha or 43% of total arable land already equipped (Incomáti). Current arable land equipped for irrigated agriculture accounts for approximate 26.177,9 ha (Incomáti). The Incomáti Valley is differentiated in three major sections, the Upper Incomáti, the Middle Incomáti and the Lower Incomáti respectively. The Upper Incomáti considers the Moamba and Sábiè regions, the Middle Incomáti being associated to the Magude region and the Lower Incomáti represented by the Manhiça and Marracuene regions. Table 5 presents data on current equipped irrigated land and used within the Incomáti Basin. Most of the irrigated land in the Upper Incomáti region is allocated to commercial farmers. These farmers

currently have the capacity to farm small areas under irrigation conditions generally less than 50 ha. Farming in the Upper Incomáti is also undertaken on old state farms or irrigation projects that developed in the 80s and early 90s irrigation facilities in Moamba and Sábiè; such farms as the Blocos I and II, Blocos 5 and 48 are still managed by the State through the Agriculture Hidraulic Development Fund within the Ministry of Agriculture and Rural Development although on-going negotiations indicate the possibilities for its utilization and development by commercial farmers and smallscale farmers associations, i.e. Blocos I and II are currently managed by two farmers associations who are responsible for operational and maintenance costs of the facilities. Most of the irrigation facilities existing in Magude region corresponding to Middle Incomáti are partly abandoned, i.e. former irrigation areas of Magude State Farm and the Citrus Timanguene Project. Only commercial farmers using areas less than 50 ha are active. In the past, some non-alluvial areas on mostly red sandy soils (basalt-derived soils and Post-Mananga deposits), which are situated above the alluvial plain, were used.

Table 5: Distribution of existing irrigation facilities and correspondent areas within the river basin

River Basin	River	District/Location	Company/farm	Area (ha)	
				Equipped	Irrigated
Incomáti	Incomáti	Moamba	Undifferentiated <50 ha commercial irrigated crop production	1248.5	434.5
			Bloco I - Moamba	350	0
			Bloco II - Moamba	208	96
	Sábiè		Bloco 48	426	106
			Bloco 5	596	0
			Commercial Farmer	70	15
	Incomáti	Magude	Undifferentiated <50 ha commercial irrigated crop production	142	140
			Smallscale Farmers Association	330	103
			Ex. Magude State Farm (Blocos I e II)	245	28
			Timanguene Citrus Project	1.000	0
		Manhiça	Undifferentiated <50 ha commercial irrigated crop production (farms)	5	2
			Commercial Famers	130	25
			Smallscale Farmers Association	900	0
			Palmeiras Sugar Enterprise Maragra SARL (Sugar Plantation)	60 6.089,4	60 6.089,4
			Inácio de Sousa	600	30
			SAI-Xinavane (Sugar Plantation)	5.254	3.770
		Marracuene	Undifferentiated <50 ha commercial irrigated crop production (farms)	187	39
			Commercial Farmers	110	55
			Smallscale Farmers Association	63	0
			Emp. Agrícola Marracuene	200	0
		Macia/Bilene	Emp. Agrícola Macia	8.000	300
		TOTAL		**26.213,9**	**11.292,9**

Large extensions of land in Moamba, Sábiè and Magude have been used for extensive livestock production; including cattle breeding in the calcareous clay soils (Mananga soils). In Lower Incomáti downstream of the Plantations of Santiago, the SAI sugar-cane plantation is established. Maragra is another sugar-cane plantation with irrigation infrastructures. Both SAI and Maragra sugar-cane plantations are protected from floods by dikes. These sugar production areas together with the Macia farm account for more than 70% of the irrigated land in the Incomáti valley. Since SAI and Maragra farms have been rehabilitated some new developments are reported. There is the possibility at short to medium terms that some currently abandoned irrigation facilities will be rehabilitated for sugar cane production supported by both SAI and Maragra states. Table 6 presents a summary of results considering the equipped areas and actual irrigated land in the Incomáti valley at different locations, as well as the potential for irrigated agriculture at different periods of time.

Table 6: Summary of equipped and irrigated areas comparing with the potential for irrigation agriculture at Basin level

River Basin	River Section	Location	Area (ha)			
			Equipped	Irrigated	Potential (short to medium term)	Potential (long term)
Incomáti	Lower Incomáti	Marracuene	554,0	78,0	4.850,0	245.403,0
		Macaneta/Maragra/Manhiça/Maragra/Palmeira/Macia/Xinavane/Ilha Josina Machel	21.038,4	10.276,4	48.600,0	
	Middle Incomáti	Magude/Timanguene	1.687,0	256,0	3.400,0	
	Upper Incomáti		2.898,5	651,5	14.300,0	
		TOTAL	**26.177,9**	**11.261,9**	**71.150,0**	**245.403,0**

3. Construction and operation of small-scale irrigation systems throughout the country as part of the 'Small Scale Irrigation Program' (SSIP), targeting primarily the smallholder sector. Under this Government initiative funded through the African Development Bank, the rehabilitation and construction of irrigation schemes are concentrated in three provinces of the country, Maputo, Sofala and Zambezia. The SSIP has construcuted (is constructing) several types of irrigation schemes, but the majority is lift irrigation of which 15 have diesel pumps, 2 electrical pumps and there are two gravity schemes, coming to a total of 460 ha of irrigated crop land, with sugar cane, rice and vegetables so far as the main crops grown in the schemes.

3.6 Hill Irrigation

This method is quite common in central and northern parts of the country taking advantage from the mountainous terrain and several water springs as well as abundance of water resources. Again it is a method which is quite spread among small holder farmers and small private commercial farmers.

It normally consists of small and simple infrastrucutures to harvest water which are built up by using local material or in the case of support, small concrete dams are also available.

From these dams and other water harvesting structures upstream the water is diverted into concrete or earth opened channels down slope and to farm plots where water is than distributed throughout the terrain by terciary irrigation network, in most of the cases by surface gravity systems. In same cases however and learning mostly from commercial farmers in Zimbabwe, the small holder and small commercial farmers in the Manica and Tete province are able to take advantage from the springs, using different size pipes to increase pressure at the filed level, with a systematic reduxtion of sections, which than makes it possible to fit sprinklers and use it for irrigation of the fields.

If there is a need to install a pump, than small engines and diesel pumps system are used, normally 1 cylinder stroke engines, which may irrigate as much as 10 ha. In these cases farmers are organized into associations and the pumps are the association asset.

Im most cases farmers grow vegetables once the systems are mainly used in the dry season. Garlic, onions, paprika, irish potato, cabbage, tomato, are some of the cash crops with a good market. However, for most of the areas, transportation and access to the areas are the major constraints. During the rainy season food crops such as beans, maize, are grown, although beans may also be used as cash crop.

These systems are quite environmental friendly but deforastation and clearing of vegetation at the upper catchment may contribute in short term to severe ersion problems and thus limiting water resource availability and sisltation of the dams, reservoirs and water streams.

It needs quite an amount of organization and discipline among the water users in order to avoid land use conflits. So strong leadership is normally required in these cases.

In some places also the system is sophisticated and it may consists of several km of earth canals following the contour lines before it reaches the fields, so again farmers are aware of erosion hazard and are willing to build barriers to reduce water speed, although these conservation barriers are quite demanding in terms of labor at the household level.

3.7 Low Cost Micro Irrigation Systems

Different stakeholders have been involved in developing and promoting these technologies. The stakeholders include government, NGOs, and private companies. Two technologies are identified to be the best practices and have been recommended for up scaling in other places with similar conditions, and where not practiced. The technologies are:

(i) The treadle pumps
(ii) Drip irrigation (Family size kit)

It is however important to note that in the context of a free market agricultural economy, funding for agriculture is more dependent on resources mobilised by the producers themselves than on public or government money. So any technologies introduced have to be carefully assessed otherwise its sustainability won't last, i.e. soon the interventions come to an end, from any partner at local level, it is the condition to stop running or using introduced rechnology.

3.7.1 The Treadle Pumps

This kit has been introduced not long ago, late 90s/early 2000, by government departmens at district level, involving also the extension workers, as well as by NGOs and private companies. Currently there are quite a number of small business either at central level as at provincial level not only manufacturing the kits (two and one piston pumps), but also quite active on the design of the pumps based on lessons learned from the field level.

Most of the work at the farm level is done by women and young men and women, and from several baseline surveys, labour at household level is very often a constraint. Households are busy caring for rainfed crop production farms, and also the irrigated plots, normally different from the dry land areas, where farmers are involved with vegetable production. They usually cultivate small plots, ranging from 0.25 to 0.4 ha, largely dependent on use of water resources, labour availability, and farm inputs.

It is foressen that such kits are supposed to improve productivity of growing systems but it seems where the technology has been introduced with no follow up, farmers are resistant to use the pumps, due to among several reasons, the lack of spares (rubber, very weak one), system needs plenty of energy to pump water, needs to be moved to and back very often to prevent from theft, requires most of the times extra labour to handle the hose in order to prevent veges from been damaged, and the costs.

So farmers and partners are quite busy looking for improvement of the kit, and on the use of it, either making available the water from a wel near the plot or any container to harvest water from where to apply. Regarding the costs of the pumps farmers query why they are offered such technology for the same amount of small petrol engines which they prefer instead.

Support delivered by NGOs and government agencies, the promotors of the techologies, is important once enable producers to learn about the innovations in growing techniques, as well as of training and familiarization with the irrigation technique. There is an urgent and real need for capacity buiding in those areas where producers are not happy with technologies in order to keep up with technical innovations, and to improve on the management practices.

3.7.2 Drip-fed Irrigation Techniques

Still quite limited used in the country and mainly by commercial farmers, it has been introduced in the beginning of 2000. Most of the producers are using such irrigation technique to grow high valuable crops, i.e. vegetables. Major advantages addressed by producers are higher water use efficiency, minimal labour required, although a major concern is the costs of the systems and maintenance. These systems are promoted by national agri-tech companies as well as from the SADC region, i.e. Zimbabwe and South Africa. Some of the farmers are replacing conventional irrigations systems with drip irrigation, mainly in regions where farming is a lot more competitive and good market access, like in Maputo and Gaza in the southern part of Mozambique, and in central Mozambique, in Manica Province. Unfortunatelly there is no data on any cost-benefit analysis on such technology.

4. Review of Agricultural Water Programs under the Initiative to end Hunger in Africa (IEHA)

Identified as one of six priority areas in the GOM's poverty reduction strategy, agriculture and rural development are of critical importance to the government and people of Mozambique and is fundamental to the country's long-term economic growth and sustainable development. Poverty is deeply rooted in Mozambique's rural regions, where more than 70 percent of the population lives (GOM 2001). Rural incomes are considerably lower than Mozambique's average per capita annual income which is already among the lowest in the world. One third of the rural population experiences chronic difficulty meeting their basic food needs. Women are extremely vulnerable because of their inadequate access to essential resources and services. Rural areas are highly vulnerable to alternating floods and droughts, which regularly threaten livelihoods.
Challenges to growth in agricultural production and productivity include the predominant use of manual labor, a water control and irrigation system that covers only 2.3% of cultivated areas, the impact of a growing AIDS epidemic, lack of credit, lack of information about agricultural markets and trade, and weak transport infrastructure that provides poor access to markets.

The poverty reduction strategy of the GOM is embodied in the Action Plan for the Reduction of Absolute Poverty (PARPA) 2001-2005. The document is based on prior Government plans, including the Lines of Action for the Eradication of Absolute Poverty (1999), the PARPA 2000-2004 (Interim PRSP), and the Government Programme 2000-2004, as well as the sectoral and inter-sectoral plans, policies and strategies developed by organs of the State. Unlike many countries whose Poverty Reduction Strategy Papers (PRSPs) are initiated and led by international organizations, Mozambique initiated and developed its own strategy, making it one of the first countries to do so. The PRSP elaborated by GOM also closely reflects the Millennium Development Goals (MDGs). In this context the GOM relies on strong partnerships with several interational aid agencies and organizations and govermnents, to implement PARPA.

Besides suffering from acute material poverty, the poor in Mozambique also suffer from a high degree of vulnerability to natural disasters and economic shocks. The PARPA recognizes the crucial importance of medium and long-term measures to fight poverty through policies to sustain rapid and broad-based economic growth. The poverty reduction is based on six priorities aimed at promoting human development and creating a favorable environment for rapid, inclusive, and broad-based growth. The "fundamental areas of action" are: (i) education, (ii) health, (iii) agriculture and rural development; (iv) basic infrastructure, (v) good governance, and (vi) macro-economic and financial management.

Priority iii) is addressed by the Ministry of Agriculture through the National Agricultural Development Program (PROAGRI), which aims to "*Contribute to improved food security and poverty reduction by supporting the efforts of smallholders, the private sector, of governmental and non-governmental agencies to increase agricultural productivity, agro-industry and marketing within the principles of sustainable exploitation of natural resources*". To achieve this general objective, ProAgri II will focus on three broad intervention areas:

- ??smallholders;
- ??the commercial agriculture sector; and
- ??natural resources management.

It is within the above framework and targeting smallholders and natural resources management, that agricultural development and food security issues are dealt with, particularly assuming that such challenge will be difficult to achieve if irrigation is not considered, to mitigate the potential impacts of severe droughts which limit most of the crop farming systems. So much effort from all partners involved in agricultural and rural development in the country is focused on water management techniques, by promoting, training, supporting and making possible most of farmer communities to have access to such techniques.

USAID and partners currently are involved in such initiatives in several regions of the country, not only supporting crop production, but introducing technologies which enhance food security at family, community, and regional levels. Micro irrigation systems developed at family level, or 5 ha irrigated plots managed by farmer associations, using different technologies, are promoted as part of a sustainable water management program for irrigated crop production, under the coordination of the Agricultural Department, and priority areas being the most drought prone and vulnerable agricultural regions, and also in those regions with potential for development of micro irrigation systems, i.e. hilly areas, following some of the basic principles recommended by the sector policies, i.e. promote and stimulate small-scale irrigation by smallholder farmers by mobilizing financial and technical resources, in order to gradually transform subsistence-oriented agriculture into a market-integrated model; adopt the use of low-cost alternatives to conventional irrigation, and; support capacity building for management, operation and maintenance of low-cost irrigation schemes.

5. Summary of Key Actors in Micro Irrigation and RWH

Key institutional stakeholders within the irrigation policy context include:

1. National Directorate for Agricultural Hydraulics (DNHA) within the Ministry of Agriculture (MINAG) is the coordinating authority for activities relating to irrigation and drainage, MINAG undertakes studies, executes agricultural hydraulics projects and supports smallholder irrigation development (FAO 2005).

2. The Programa Nacional de Irrigação de Pequena Escala (PRONIPE – National Small Scale Irrigation Program), located within the DNHA, was specifically created to support small-scale irrigation (FAO 2005).

3. Also within the DNHA, the Fund for Agricultural Hydraulics Development (FDHA) is charged with promoting, stimulating and funding hydro-agricultural works or other activities related to irrigated agricultural development (FAO 2005).

4. The National Water Directorate (DNA) at the Ministry of Public Works and Housing (MOPH) oversees policy making and implementation, overall planning and management of water resources, as well as the supply of water and sanitation services at the national level. Its main mandate is to ensure that ground and surface water resources are used appropriately. While on a regional level Mozambique is divided into five Regional Water Administrations (ARAs) (only one of which is operational at present) to oversee basin water development, management and the collection of water fees (FAO 2005).

5. The National Water Council (CNA) was created in 1991 as consultative body to the Council of Ministers. In general, however, the CAN has not been very effective and coordination between agencies involved in water resources management has been a constant source of concern (FAO 2005).

On the national level, water management is the responsibility of the National Water Directorate (DNA), while on regional level the five Regional Water Administrations (ARAs) are responsible. They control the irrigation systems and collect water fees. The only ARA fully operational is ARA-Sul (South), while a second one, ARA-Centro, is under formation. ARA-Sul is in charge of the southern part of the country up to the Save River, where most problems of water management exist. In areas not yet covered by an ARA, the Provincial Directorates of Public Works and Housing are the authority responsible for water resources management in the province (FAO 2005).

The territorial responsibility of the five ARAs is as follows; see Table 77:

1. ARA South, which includes all the basins south of the Save, and the Save River basin itself
2. ARA Center, which covers all the basins between the Save and Zambezi basins
3. ARA Zambezi, which corresponds to the Zambezi basin

4. ARA Center-North, which covers the Zambezi basin as far as Lúrio River, including the Lurio basin
5. ARA North, which covers all the basins north of the Lurio basin

Table 7 Characteristics of Areas of Responsibility of Regional Water Administrations (ARAs)

ARA	Mean annual runoff		
	At border	Generated in Mozambique	Total
South	17	3.8	20.8
Center	1.2	18.4	19.6
Zambezi	88	18	106
Center-North	0	35.2	35.2
North	10	24.9	34.9
Total	116.2	100.3	216.5

(km^3)

Source: (FAO 2005)

5.1 Irrigation Policy

Key policy initiatives within the irrigation context include:

1. In 1991, the creation of a National Water Council (CNA), a consultative body to the Council of Ministers. Since its creation, however, CAN have not been particularly effective and coordination between agencies involving water resource management has been a source of concern.

2. In 2002, the adoption of a National Irrigation Policy and its Implementation Strategy (NIPIS).

This latter initiative recognized the great strategic importance vested in irrigation, and established a set of guiding policy principles as follows (FAO 2005):

1. Ensure integrated water management for multiple purposes in agriculture and rural development;

2. Promote irrigated agriculture and research, as well as adaptation and adequacy of appropriate technologies. Empower the development of irrigation systems for the smallholder sector, and thus transform primarily subsistence agricultural production towards a market-integrated sector;

3. Promote and foster entrepreneurialism in irrigated agriculture, at the small, medium and large enterprise level;

4. Activate the development of irrigation potential in Mozambique through the promotion of new irrigation systems of medium and large scale;

5. Establish the technical and financial mechanisms to prevent and mitigate the occurrence and impact of cyclic droughts;

6. Promote decentralization and foster a greater participation of beneficiaries, communities and local authorities in integrated water resources management, as well as in the management and operation of infrastructure;

7. Acknowledge the role of women in agriculture, creating stimulus for their economic and social affirmation through participation as beneficiaries of irrigated agriculture.

In terms of practical strategies for implementing the abovementioned guiding principles, NIPIS proposed the following:

1. Maximize water use through the improvement of water use efficiency.

2. Transfer responsibility to the end user for systems maintenance to minimize water losses.

3. Ensure cost equity for the price of water, recognizing the fiscal constraints of smallholder irrigators and irrigation associations versus commercial agricultural enterprises.

4. Promote and stimulate small-scale irrigation by smallholder farmers by mobilizing financial and technical resources, in order to gradually transform subsistence-oriented agriculture into a market-integrated model.

5. Adopt the use of low-cost alternatives to conventional irrigation.

6. Support capacity building for management, operation and maintenance of irrigation schemes.

7. Undertake research relevant to the adoption of appropriate technologies.

8. Implement development centers and disseminate successful water retention systems.

9. Ensure participation of local beneficiaries and other stakeholders in the full irrigation cycle, from planning and water resource management to rehabilitation, maintenance and management of existing irrigation schemes.

10. Establishment of a legislative framework pertaining to the authorization of water use for irrigation, irrigable land and public irrigation infrastructures, taking into account the abovementioned guiding principles.

Despite the policy initiatives of both CNA and NIPIS to promote small-scale irrigation throughout the country, to increase water use efficiency and to integrate irrigation into the socio-economy of Mozambique, the development of irrigation remains hindered by an inflexible legal and political framework, and concerns of landholders regarding the access to, and use of, land and water. A major challenge relates to the deteriorated status of irrigation infrastructure, which requires rehabilitation, maintenance and future investment.

6. Recommendations and Conclusions

The preliminary conclusions of the survey on the agricultural water technologies and practices in Mozambique and the assessment of poverty impacts of most promising technologies could be summarized as follows:

?? Without a determined effort to develop the agricultural water technologies and practices, the country will increase its vulnerability on food crop production and miss the opportunities deriving from its rich natural resources. More fundamentally, Mozambique will miss the opportunity to reduce poverty in the most populous rural areas in the country and retard the development of a more balanced commercial agricultural sector.

?? The effort to develop agricultural water technologies and practices and the irrigation sector is consistent with the country overall strategy for poverty reduction and agricultural development included in the PARPA and PROAGRI. The water management strategy discussed in this study is inspired by a vision of a competitive and commercialized food and cash crops production system based on increasingly productive smallholder farmers integrated with an increasingly high water use effciency and productivity and the marketing system for agricultural inputs and outputs.

?? The water technologies and practices aim at improving productivity of food and cash crop farming systems, integrating smallholders with commercial value chains, and increasing competitiveness of markets

?? The expected impact of the adoption of different sustainable technologies will be to improve food security and reduce dependence on food imports, increase income of smallholder farmers and the stakeholders (millers, wholesalers, and traders), reduce poverty (particularly in the rural areas of the center and north), and contribute to the development of a commercialized agricultural system.

?? Promote awareness and strenthgen the adoption of the 2002 National Irrigation Policy and its Implementation Strategy (NIPIS).

?? One policy achieving medium level adoption related to irrigation systems maintenance. While it appeared that responsibility of maintaining irrigation structures had been successfully passed on to the end user, the desired outcome of minimizing water losses as a result of this management shift had not been achieved.

?? For all irrigation systems, regardless of size, the most appropriate and effective way of promoting the efficient use of water is to introduce a charging structure directly linking the cost of water to the quantity supplied in the field. In most irrigation systems, water charges are instead linked to the size of the landholding. While this charging method is convenient to administer, due to ease of calculation and management, it does not actually promote the efficient use of water. By linking end users to the direct input costs of the irrigation system, preferably through small, peer-influenced water user associations, a sufficient incentive should be created and thus establish an environment where water efficiency is encouraged.

?? Evidence of the implementation of another NIPIS strategy, namely that associated with information dissemination and development centers, is not sistematycally recorded at local level. While this is one of the key elements addressed by the SSIP, it appears not to have been implemented in many of the rehabilitated systems.

?? Another strategy that requires attention pertains to the participation of local beneficiaries and other stakeholders in the irrigation cycle. It is not enough to rely on the flow-on effects of irrigation to stimulate this sector in a timely manner. Efforts should be made to address the capacity of the industries servicing the maintenance aspects of the irrigated sector. Repairs and maintenance is the "Achilles heel" of most irrigation systems - in variable climates, a system's profitability is often primarily determined by the landholder's capacity to keep the system functioning.

?? Therefore, it is strongly suggested that the development of a new repair and maintenance strategy be considered – namely, 'mobile irrigation maintenance units' (MIMU). The latter would be locally-operated, stand alone, mobile units with the capacity to perform on-site repairs in a timely manner. To complement this maintenance strategy, it is recommended that a new element be introduced within the irrigation design model, namely 'repeatability criteria assessments'. Such assessments would identify irrigation systems already in place in the relevant area of proposed activity. Where practicable, the assessment process would encourage the replicatio n of infrastructure within new designs, to enable ease of service by MIMUs. This strategy has been suggested for the rice sector which in fact accounts for most of the irrigation potential for development in short term which can also be introduced for other sectors.

?? So far from the survey and existing information on the agricultural water management technologies and practices adopted at country level, those associated with the use of swamp irrigation and inland valleys (3.1), micro basin systems

(3.2), and hilly irrigation (3.6), for the time being show the highest potential for improvement, development and sustainable use, both in terms of water use effciency and productivity of the systems.

?? Strengths of this irrigation system consider mainly water transport and distribution, i.e. the irrigation water supply is gravity supplied (requiring no diesel input costs) and the quantity of water available is not a limiting factor for in-crop irrigation. It is an indigenous or it has been introduced for decades or centuries, which results in consistency - this small-scale irrigation system has been in operation for more than 25 years.

?? A regular schedule of maintenance on the primary and secondary supply channels have been established. One person or group of members or water users take one week per year to maintain channels prior to the wet season.

?? The smallholder farmers involved are aware that water delivery efficiencies to the field are sub-optimal, and they are eager to learn how to improve and seek for solutions to these issues, despite financial constraints.

?? The potential of the available water resources are under-utilized during the wet season and expansion of the irrigated area is feasible.

?? It needs to be kept simple, small, in order to achieve sustainability, in socio-economic terms as well as environmentally friendly.

?? In the case of the fresh water swamps or the wetland systems, shallow drainage must be encouraged in order to avoid the watertable to low more than 0.2-0.40 m depth. Soil subsidence results from the mineralization but also from the shrinkage of the organic material. These factors should also be considered when reclaiming these soils for agricultural use. Drains should be opened by hand and artisanal gates can be used to control the water table at farm level. Irrigation should be as frequent as possible in order to maintain high water content in the upper layers and decrease soil temperature specially during the hot season. The water should flow from the top to the bottom in order to leach the salts downwards and avoid salinisation. Mechanisation is limited in these soils due to its low carrying capacity. A technology based on intensive use of manual tools should be recommended. Burning of vegetation and crop residues shoul be avoided as it also destroys the peat topsoil; burning should occur outside the *machongo* area or in selected places with high water table levels to avoid its spread. Ashes can then be spread on the soil surface to improve the soil nutrient status. Crop selection and rotation should consider the conditions of these soils: shallow water table and soil acidity. Flooded rice cultivation will contribute for peat layers reestablishment and maintenance. Cultivation in mounds or hills permits the farming of some crops (e.g. sweet potato) while the soil is still poorly drained. Mulching with crop or vegetation residues will reduce the effect of solar radiation in the oxidation and decomposition of peat layers. There are always risks of flood during the wet season. If not taken into account, all investment will be lost. Intensive maintenance of the drainage system is crucial for the development of these wetlands.

?? Peat soils are also important to keep a certain ecological habitat. Impact assessment of reclamation for agricultural use should always be studied and weighed. Non agricultural uses of these soils are also possible. Reeds, natural vegetation of unreclaimed *machongos,* are important materials of construction. Fishing, grazing, hunting, and soil compost are other rural activities possible in these wetlands.

?? In the high rainfall areas of the north, centre and some localised sites in the south, research and development priorities should focus on water harvesting and storage techniques and use of water for livestock and dry season irrigation, as follows:

?? Identification of the potential for the development and establishment of small dams and reservoirs, taking into account the rainfall regime, the topography and soil conditions of each region,

?? Identification of the potential for run-off farming according to each local conditions, taking into account the climate, the topography and soil conditions as well as the risk of soil erosion,

?? Conservation farming, taking into account the joint aspect of soil and water conservation and covering many different farming techniques and practices, such as: terracing, strip cropping, rotations, fallows, mixed cropping and interplanting, etc.

?? Studies on sowing strategies, in order to match the crop cycle with the length of the growing season avoiding the occurrence of periods of water deficit in critical stages of development.

?? As a final remark, water is considered as a natural resource whose exploitation can promote the socio-economic development of a country or a region. One of the biggest issues in water resources management is, and will continue to be if nothing is done, the resolution of conflicts between different users competing for the limited available quantities of the resource. A water demand management strategy is therefore a necessary step but which has not yet received enough attention. Reasons for this are: lack of research and familiarisation with this modern concept of water management, shortage of measuring and regulating devices in order to control the amounts of supply and use of water, and the general lack of funds, trained staff, and properly oriented institutions to carry out that kind of activities.

?? Despite the fact that irrigation is the largest water consumer, most of the irrigation withdrawals are not measured. The irrigation investment program (MAP, 1998) foresees the establishment of regulatory norms for hydro-agricultural activities. These regulations aim to provide a mechanism that can be used to enforce a more efficient, equitable and sustainable use of water resources. They would be related to the use, conservation and inspection of infrastructure, elaboration of statues for water users associations, establishment of water fees, and establishment of regulations for construction of infrastructure for hydro-agricultural activities.

?? Impacts expected to arise from appropriate regulations are a) increasing water use efficiencies, b) prevention of land and water degradation, c) improved operation and maintenance of irrigation infrastructure, d) reduction of water related conflicts within irrigated areas, and e) increased agriculture production. This might ultimately contribute for the establishment of the principles for water demand management, though the constraints arising from the fragmented and unquantified nature of the irrigation sector must be recognised.

?? Soil and water conservation techniques can also be used in order to make a better use of water resources, especially in those areas of the country where rainfall is scarce and erratic. Most of the national agriculture production in Mozambique is carried out under rainfed conditions. Any practice that increases crop yields without increasing the water supply contributes to rise the crop water use efficiency and to make best use of rainfall. Some research is presently under way in order to identify and quantify soil water conservation measures that contribute to increase food production in marginal areas.

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Annex 1: An inventory and characterization of agricultural water technologies and practices adopted in Mozambique (attached inventory file)

Annexes 2: List of contacts

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ABBREVIATIONS

ADB	African Development Bank
ARA	*Administraçao Regional de Aguas* (Regional Water Administration)
BAD	*Banco Africano de Desenvolvimento*
CAP	*Censo Agro-pecuario*
CFMU	Crop Forecasting and Monitoring Unit
CNA	*Conselho Nacional da Água* (National Water Council)
DINA	*Direcção Nacional da Agricultura* (National Directorate of Agriculture)
DNA	*Direcção Nacional de Aguas* (National Water Directorate)
DNAP	*Direcção Nacional de Agro-Pecuária* (National Directorate of Livestock)
DNER/SG	*Direcção Nacional de Extensão Rural/*Sasakawa-Global 2000
DNHA	*Direcção Nacional da Hidraulica Agricola* (National Directorate for Agricultural Hydraulics)
DPA	*Direcção Provincial da Agricultura* (Provincial Directorate of Agriculture)
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	FAO Statistical Database Online
FDHA	Fund for Agricultural Hydraulics Development
FSNS	Food Security and Nutrition Strategy
FSU-EC	Food Security Unit - European Commission
GAPI	Gabinete de Consultoria e apoio a Pequena Industria
GAPVU	Office for the Support to Vulnerable Population Groups
GCA	*Grupo Consultivo de Arroz* (Rice Consultative Group)
GDP	Gross Domestic Product
GoM	Government of Mozambique
GPSCA	*Gabinete de Promoção do Sector Comercial Agrario* (Office for the Promotion of Commercial Agriculture)
ha	hectare
IAF	*Inquérito Nacional aos Agregados Familiares sobre Condições de Vida* (National Household Survey on Living Conditions)
IIAM	*Instituto Nacional de Investigação de Moçambique* (Institute of Agrarian Research in Mozambique)
INE	*Instituto Nacional de Estatística* (National Institute of Statistics)
INIA	*Instituto Nacional de Investigação Agrícola* (National Agricultural Research Institute)
kg	Kilogram
km	Kilometer
L	Liter
M&E	Monitoring and Evaluation
MADER	*Ministério da Agricultura e Desenvolvimento Rural* (Ministry of Agriculture and Rural Development, now MINAG)

MAP	*Ministério da Agricultura e Pescas* (Ministry of Agriculture and Fisheries, now MINAG)
MDG	Millenium Development Goals
MINAG	*Ministério da Agricultura (*Ministry of Agriculture)
MOPH	(Ministry of Public Works)
MPF	*Ministério do Plano e Finança* (Ministry of Planning and Finance)
MSU	Michigan State University
mt	Metric Ton
MZM	Meticais (Mozambican currency)
NIPIS	National Irrigation Policy and its Implementation Strategy
NERICA	New Rice for Africa
NGO	Non-Governmental Organisation
ORAM	*Organizaçao Rural de Ajuda Mutua*
PARPA	*Plano de Acção para a Redução de Pobreza Absoluta* (Action Plan for the Reduction of Absolute Poverty)
PROAGRI	*Programa Nacional de Desenvolvimento Agrario* (National Programme for Agricultural Development)
PRONIPE	*Programa Nacional de Irrigaçao de Pequena Escala* (National Program for Small Scale Irrigation)
PRSP	Poverty Reduction Strategy Papers
SADC	Southern African Development Community
SEMOC	*Sementes de Moçambique* (Seed Company of Mozambique)
SIMA	*Sistema de Informação sobre os Mercados Agrícolas* (Information System on Agricultural Markets)
SMI	Small and Medium Industries
SMS	Subject Matter Specialists
SNAP	*Sistema Nacional de Aviso Previo* (National Early Warning System)
SNS	Serviço Nacional de Sementes (National Seed Service)
SSIP	Small Scale Irrigation Program
TIA	*Trabalho de Inquérito Agrícola* (Agricultural survey of the family sector)
UEM	*Universidade Eduardo Mondlane* (Eduardo Mondlane University)
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
$	United State Dollar
WUA	Water Use Association