CARITAS UGANDA (CU)| THE UGANDA FARMERS'

COMMON VOICE PLATFORM (UFCVP)

Consultancy services for a study to assess the pro-poor appropriate irrigation technologies in the different agro-ecological zones of Uganda

Final Report

Submitted to

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A report submitted to Uganda Catholic Society for conducting a desk study to assess the pro-poor appropriate irrigation Technologies in the different agro-ecological zones of Uganda

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EXECUTIVE SUMMARY

Introduction

despite the efforts by The Government of Uganda over the years aimed at improving access to water for production, farmers continue to face adverse effects of climate change and have remained in desperate need of irrigation in order to mitigate the impacts of climatic changes currently experienced in the country; having severe impact on farmers production and hence on household income potentials. The development progress from the poverty alleviation efforts of UGOPAP is further impeded by the low produce volumes, as the financial sustainability of the farmer associations and cooperatives depends upon large quantities of produce for collective marketing, generating incomes for these organizations. This report presents findings of a desk study to identify and assess the different pro-poor appropriate irrigation Technologies with the major aim of establishing which technologies can be adopted by the different farmers/farmer's groups/association and or cooperatives in the UGOPAP areas of operation in Uganda.

Advocacy Opportunities

The policy legal and institutional framework is well established for the management of water and land reosurces as well as the agricultural sector. However, in relation to pro-poor irrigation technologies the following are proposed potential advocacy opportunities.

1) In regards to NEMA approval: There is need to lobby NEMA in order for pro-poor appropriate irrigation technologies not to be categorised so as to require an EIA which is not specific in Third Schedule of the National Environment Act. In support of small-scale farmers using pro-poor appropriate irrigation technologies the requirement be reduced to a "notification of the Authority" before installation of the small scale irrigation system.
2) In regards to water abstraction: Thers in need to support small-scale farmers using pro-poor appropriate irrigation technologies to obtain permits or the requirement be reduced to a "notification of the Authority" before abstraction of water for small scale irrigation.
3) In regards to Government plans for Irrigation Development: Efforts are required to re-direct government emphasis to include pro-poor appropriate irrigation technologies in there focus.
4) In regards to Government Irrigation Acreage Development Targets: Efforts are required for advocacy to ensure government considers areas covered by pro-poor appropriate irrigation technologies as contributing to the target achievement.
5) In regards to the Irrigation Legislation under Development: Independent legislation for irrigation is currently under development. This would be directly guiding the establishment of pro-poor irrigation technologies and thus it important that the government is advised to ensure that legislation is clearly drafted for successful application of these technologies.
6) In regards to the Agricultural Extension: An opportunity for advocacy to encourage pro-poor appropriate irrigation technologies to be included in the District demonstration packages/kits.

Pro poor technology options

A pro-poor technology should be affordable, available, adaptable to existing setting, enhance farming profitability, effective and efficient, easy to operate, repair and maintain and environmentally and socially acceptable. Water source options are river diversion works, valley tanks and dams, shallow open wells, deep wells, springs, above ground water storage tanks and underground water harvesting tanks. Water abstraction technologies are treadle pumps, small motorized water pumps, solar powered pumps and water powered hydraulic ram pumps. The field water application technologies include: Drip irrigation systems (conventional drip irrigation systems, drum drip irrigation kits, greenhouse drip irrigation kits), sprinkler irrigation systems (overhead sprinkler and rain gun sprinkler systems), surface irrigation systems (Furrow and basin irrigation). The choice of irrigation system depends on the type of crop, the relative position of water source to the irrigation field, type and characteristics of water source, energy source, type of soil and investment costs.

Irrigation investment appraisal

Profitability of a business venture depends on the type of crop (variety) and the irrigation scenario. Gravity irrigation is the most feasible irrigation configuration due to no energy costs. It is most profitable to invest in irrigation of horticulture-vegetables followed by horticulture-fruits. The order of the other value chains is oilseeds (ground nuts), Pulses-beans (climbing variety), cereals-rice, coffee and lastly cereals-maize for flour. For horticulture-vegetables, it is most profitable to invest in irrigation of tomatoes, followed by cabbage and onions. There are other vegetables which are profitable but were not analyzed in this study. For horticulture fruits, it is most profitable to invest in irrigation of passion fruits followed by mangoes, apples and citrus. For coffee, it is most profitable to irrigate robusta (clonal) coffee than coffee arabica.

Conclusions

Irrigation has been shown to raise farm incomes by increasing the cultivable land area, enhancing crop choice, increasing cropping intensity, allowing the option to use high-yielding varieties, and provide the conditions for land groupings to boost labor productivity. Irrigation also brings many spill-over effects, such as increased and more evenly distributed farm labor opportunities, improved wage rates, reduced out-migration, improved security against impoverishment, low food prices, better nutrition throughout the year, growth in non-farm employment, greater urban-rural contact and new social networks, and more water for nonagricultural uses. Thus, with the majority of the poor living in rural areas and involved in agricultural activities, UGOPAP's planned intervention in development of irrigation have definite pro-poor directions. However for the irrigation intervention to be effective the following recommendations are proposed.

Recommendations

The recommendations provided are developed from the understanding of the requirements of the recommended pro-poor appropriate irrigation technologies, the potential users and lesson from reviewed information.

1) Strengthening the Legal, Policy and Institutional Environment. This is in relation to development, implementation and enforcement of appropriate laws and regulations. Of particular note is the agent requirement to ensure that the Draft National Irrigation Policy is finalized. It is important that the Irrigation policy is clear about the contribution of pro-poor appropriate irrigation technologies in the agricultural sector. The collaboration between MAAIF and MWE in relation to the promotion of pro-poor appropriate irrigation technologies should be streamlined and available opportunities that enhance dispersion and penetration of the technologies extensively publicized. There is need for a clear linkage between agencies and the technology users.
2) Adequate Irrigation Management. The technology users need to be strongly involved in the technology management process. However, the for successful farmers' involvement, they need to be very well conversant with the functional and operation requirements of the specific pro-poor appropriate irrigation technologies and the water requirements of the crops. The required knowledge may be attained from well-organized technology users' training sessions and regularly targeted information dissemination.
3) Financial Management. The technology users need to understand the financial requirement cycle for successful management of pro-poor appropriate irrigation technologies. Proper financial management will ensure availability of capital to operate, maintain, construct or repair irrigation infrastructure and agricultural input. A process to support the technology users to become competent in implementing/creating a sound financial cycle needs to be developed, based on local needs and conditions.

4) Adequate Monitoring and Extension Services. The majority of technology users would be transitioning to a new way of crop production. As such they will require dedicated and effective mentoring, monitoring and extension services. This will provide opportunities for implementation of early corrective measures of emerging issues before causing failure. The process should be robust enough to document and disseminate successful practices amongst the users of pro-poor appropriate irrigation technologies. Demonstrations need to be included in the extension programme and they are most effective if implemented over an extended period, spanning a full agricultural calendar.
5) Technical Support Services. Good results in the implementation of the pro-poor appropriate irrigation technologies can be directly attributed to good institutional system with effective support services. Technical support includes selection, design, implementation of the technology, introduction of appropriate agricultural practices and provision of spares maintenance of the system.
6) Market Access. Improved market access is important to ensure reduced marketing margins allowing higher farm gate prices. This requires improved communications for delivery of necessary quality information to the technology users, institutional development and higher traded volumes. Thus the pro-poor irrigation intervention will help the poor only if it is carried out as part of a broader set of pro-poor changes.

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ACRONYMS

AEATREC	Agricultural Engineering and Appropriate Technology Research Centre
ASSP	Agriculture Sector Strategic Plan
CAPCA	Central Archdiocesan Province Caritas Association
C-DK	Caritas Denmark
CICS	Competitiveness and Investment Climate Strategy
CIDI	Community Integrated Development Initiative
CU	Caritas Uganda
DWD	Directorate of Water Development
DWRM	Directorate of Water Resources Management
EADEN	Eastern Archdiocesan Development Network
EPRC	Economic Policy Research Centre
FAO	Food and Agriculture Organization
FSD	Financial Services Development
GWI	Global Water Initiative East Africa
MAAIF	Ministry of Agriculture Animal Industry and Fisheries
MWE	Ministry of Water and Environment
NBI	Nile Basin Initiative
NDP	National Development Plan
NELSAP	Nile Equatorial Lakes Subsidiary Action Program
O&M	Operation and Maintenance
OPM	Office of The Prime Minister
UFCVP	Uganda Farmers Common Voice Platform
UGOPAP	Uganda Governance and Poverty Alleviation Programme
VCD	Value Chain Development
WfAP	Water for Agricultural Production

GLOSSARY

Agro-ecological zone	An area characterized by specific environmental, land use and demographic factors whose interaction influences the productivity and sustainability of farming systems
Bimodal rainfall pattern	Annual rainfall has two distinct peak
Exchangeable nutrients	An indicator of nutrients available to plants
Unimodal rainfall pattern	Annual rainfall has one distinct peak

1 INTRODUCTION

1.1 BACKGROUND INFORMATION

The Uganda Governance and Poverty Alleviation Programme (UGOPAP) is funded by mainly Danida and implemented by Caritas Denmark (C-DK) in partnership with Caritas Uganda (CU), the Community Integrated Development Initiative (CIDI), the Central Archdiocesan Province Caritas Association (CAPCA), and the Eastern Archdiocesan Development Network (EADEN). The programme seeks to strengthen the civil society in Uganda and contribute towards poverty alleviation by building sustainable farmer associations and cooperatives and through support to the Uganda Farmers Common Voice Platform (UFCVP), a national advocacy platform working for the rights of the small-scale farmers in Uganda.

1.2 PROGRAMME CONTEXT

Despite Uganda being endowed with water resources which could be harvested for agricultural production, most farmers in the country rely on rain-fed agriculture due to limited access to irrigation based water sources. The limited use of irrigation practices limits potential crop and livestock output. Inability to exploit available water resources perpetuate food insecurity, rural poverty, unemployment and the perception that investing in agriculture is a risky business.

The report for the review of the DSIP I sighted climate change as one of the challenges hindering farmers increase in production and productivity. Indeed farmers have continued to grapple under the effects of climate change due to over reliance on rain- fed agricultural though there is great potential to harness the available water in order to increase agricultural production and productivity. Although the Agriculture Sector Strategic Plan 2015/16-2019/20 identifies irrigation as one of the strategies to increase water for agricultural production for farmers in Uganda, the results are not any different as farmers all over the country (apart from large scale farming like sugar cane, rice and others) continue to heavily depend on rain-fed agriculture.

The Government of Uganda over the years has invested funds in a number of interventions aimed at improving access to water for production for farmers; with the most recent being allocation of funds to purchase the earth moving equipment meant for digging valley dams and many others. However, despite the above efforts, farmers continue to face adverse effects of climate change and have remained in desperate need of irrigation in order to mitigate the impacts of climatic changes currently experienced in the country; having severe impact on farmers production and hence on household income potentials.

The development progress from the poverty alleviation efforts of UGOPAP is further impeded by the low produce volumes, as the financial sustainability of the farmer associations and cooperatives depends upon large quantities of produce for collective marketing, generating incomes for these organizations.

Upon the above background, and in an attempt to contribute to addressing the issue of water for agriculture/production in Uganda, Caritas Uganda; through the Uganda Farmers

Common Voice Platform (UFCVP); with support from Caritas Denmark engaged the Consultants to conduct a desk study to identify and assess the different pro-poor appropriate irrigation Technologies. This was done with the major aim of establishing which technologies can be adopted by the different farmers/farmer's groups/association and or cooperatives in the UGOPAP areas of operation in Uganda.

1.3 OBJECTIVES OF STUDY

UGOPAP is currently in the process of planning the 2018 intervention and wish to prioritize efforts towards improving access of small-scale farmers to affordable irrigation technologies. Many development actors are already involved in the field and much knowledge on best practices therefore already exists. However, there is a need to create an overview of existing knowledge of the available technologies most appropriate for the small-scale farmers. Such overview will inform the planning of UGOPAP's 2018 support to the members of the targeted farmer associations and cooperatives and to the UFCVP advocacy work towards the Government of Uganda, proposing the most appropriate technologies to prioritize in their service delivery.

Thus the objectives for this study included:

i) To identify the available irrigation technology (not necessarily within Uganda) and
ii) To assess the appropriateness of each technology, including considerations as to affordability, maintenance, prevalence of necessary water sources, as well as irrigation potential in relation to acreage and type of crops.
iii) To highlight the different laws and policies that govern water resources in Uganda; with a critical look at the gaps and opportunities for advocacy.

1.4 SCOPE OF STUDY

The tasks required to be accomplished in included the following;

a) Submit an inception report detailing the framework for the assignment and the work plan within a week from the start of the engagement.
b) Review secondary information/data/ reports of previous studies such as evaluations or other learning documents describing good practice in consideration of the study objective criteria, Progress reports from the Joint Annual Sector reviews of MAAIF and MWE.
c) Review and highlight the different laws and policies that govern the use of water resources in Uganda water resources and identify gaps and opportunities for advocacy.
d) Submit a draft report, receive and incorporate all appropriate comments by the UFCVP steering committee/CU and Caritas Denmark.
e) Presentation of the draft report during a validation meeting organized by Caritas Uganda/Uganda Farmers Common Voice Platform
g) Presentation of the final report to the different stakeholder during a national dissemination/dialogue meeting that shall be organized by Caritas Uganda/Uganda Farmers Common Voice Platform.

The assignment was scheduled for a maximum period of 3-4 weeks full time work.

1.5 ORGANIZATION OF THE REPORT

The rest of the sections in this report are arranged as follow; Chapter 2 presents the methods used to accomplish the assignment. Chapter 3 describes of the project area including a spatial representation of the extent, summarizes the relevant information about the technology users and the relevant agro-ecological zones in Uganda. Chapter 4: Analyses of the Policy, legal and Institution frameworks of irrigation in Uganda. The potential areas that provide opportunities for advocacy in relation to pro-poor appropriate irrigation technologies are suggested. Chapter 5 reviews and assesses the different available pro-poor appropriate irrigation technology options. Chapter 6, presents technology scenarios and provides an investment appraisal for each. Chapter 7, based on the outcomes of the study, presents conclusions and proposes recommendations for successful implementation of pro-poor appropriate irrigation technologies. The report includes a bibliography and sources of information.

2 METHODOLOGY

2.1 SELECTION OF PRIORITY VALUE CHAINS AND PILOT AREAS

In consultation with Uganda Catholic Secretariat, the Community Integrated Development Initiative (CIDI), the Central Archdiocesan Province Caritas Association (CAPCA), and the Eastern Archdiocesan Development Network (EADEN), the priority value chains and project areas were identified. The GIS map for the districts covered by the UGOPAP was developed.

The profiling of priority value chains focused on the production systems, scale of production/typical plot sizes, typical yields, existing irrigation practices and technologies used, Water requirements, target irrigation area, target markets, labour availability, production constraints and socio economic characteristics.

2.2 LITERATURE REVIEW

The study included review of available pro-poor irrigation technologies within Uganda and around the World, from Government and development partner documents as well as databases with the aim of developing an exhaustive inventory, understanding the requirements of each technology, ease of adoptability and provide synopsis of key issues that need to be addressed in order to be integrated within the existing national regulatory and policy framework.

2.3 GAP ANALYSIS OF RELEVANT LAWS AND POLICIES THAT GOVERN WATER RESOURCES

Through reviewing national laws and policies an inventory of different laws and policies that govern water resources in Uganda were developed. The selected national laws and policies relevant to water resources were analyzed to establish gaps and opportunities for advocacy to ensure ease of adoptability and operationalization of recommended pro-poor irrigation technologies.

2.4 PROFILING IRRIGATION TECHNOLOGY OPTIONS

All existing small scale irrigation technologies in Uganda and elsewhere were identified and profiled. During profiling, the technologies were grouped into four categories;

i) Water harvesting/storage,
ii) Abstraction and,
iii) Conveyance and distribution, and,
iv) Field application of water.

As much as information was available to the Consultants, technology profile included:

i. Description of the technology
    - *Design*
    - *Functionality;*

ii. Suitability of irrigation technology in terms of:
    - *Topography/landscape;*
    - *Soils;*
    - *Crops;*
    - *Climatic conditions,*
    - *Water requirements,*
    - *Energy requirements*.
iii. Estimated costs of the irrigation technologies
    - *Cost in $/ha;*
    - *Cost in $\$/m^3$*.
iv. Challenges and opportunities associated with the irrigation technology

The profiling information was fed into the crucial step of assessing the appropriateness of each irrigation technology.

2.5 IRRIGATION TECHNOLOGY APPRAISAL

Each technology was assessed against the criteria reflected in the study objectives as derived from the profiling information and based on this, most appropriate pro-poor irrigation technology for a particular UGOPAP operation area was recommended. The criteria included aspects on affordability, maintenance, prevalence of necessary water sources, as well as irrigation potential in relation to acreage and type of crops. This was be done with due consideration of each agro-ecological zone.

3 DESCRIPTION OF THE PROJECT AREA AND THE RELEVANT AGRO-ECOLOGICAL ZONES IN UGANDA

3.1 PROJECT LOCATION

The implementing partners (CAPCA, EADEN and CIDI) of UGOPAP are covering 16 districts (Figure 3-1). The majority districts are around the central and eastern regions of Uganda.

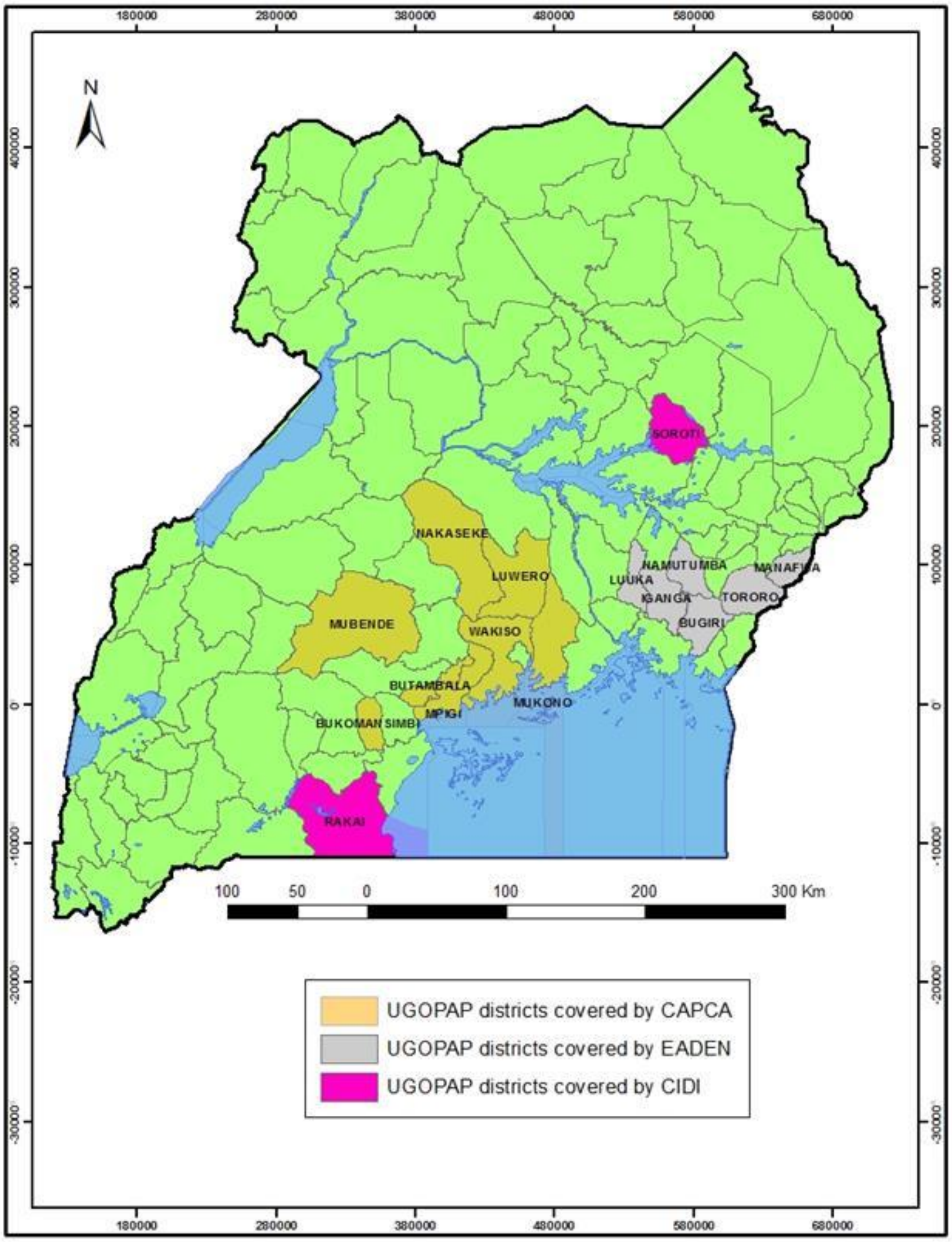

Figure 3-1: District where UGOPAP is implemented

3.2 TYPICAL PROJECT AREA HOUSEHOLD

The project area house has an average household size of seven (7) people which is above the national average of five (5) persons per household. At the national level the proportion of persons aged less than 15 years constitutes about 51 percent of the total population. The crops grown by these households include Coffee, Rice, Maize, Groundnuts, Beans, Sunflower, Soybean, Cassava, Sorghum, Banana and Vegetables. Six (6) of the crops grown in the project area (Coffee, Rice, Maize, Beans, Cassava, and Bananas) are among the 12 (Cotton, Coffee, Tea, Maize, Rice, Cassava, Beans, Fish, Beef, Milk, Citrus and Bananas) prioritized commodities in the NDP II.

Typical plot sizes are about three (3) acres of which 1-2 acres are to be targeted for irrigation. At the moment existing irrigation technologies in some areas include watering can, storage tanks, treadle pumps, small motorized pumps, manual pumps, bottle drips and distribution pipes. Water sources for the irrigation include rain water harvesting, wetlands, streams, rivers, shallow and deep wells. Other typical information characterizing a project area household in presented in Table 1.

Table 1: Typical information for a project area household

Information Name	Eastern Region (CIDI and EADEN)	Central Region (CAPCA + CIDI Rakai)
1. Enterprise priority	Coffee Rice Maize Groundnuts Beans Sunflower Soybean Cassava Sorghum	Coffee Banana Maize Beans Vegetables
2. Typical plot size	3 acres	3 acres
3. Typical yields	Coffee – 1 kg per tree per season Rice – 500 kg per acre Maize – 500 kg per acre Groundnuts – 250 kg per acre Beans – 800 kg per acres Sunflower – 350 kg per acre Soybean – 700 kg per acre cassava – 1800 kg per acre sorghum – 700 kg per acre	Coffee – 1 kg per tree per season Banana – 200 bunches per year of 12 kg per bunch on average Maize – 600 kg per acre Beans – 400 kg per acre

Information Name	Eastern Region (CIDI and EADEN)	Central Region (CAPCA + CIDI Rakai)
4. Existing irrigation practices and technologies	i) Tanks + manual power +Watering can ii) Tank + treadle pump + pipes	i) Tanks[1] + manual power +Watering can ii) Tank + treadle pump + pipes iii) Streams + small motorized pumps + pipes iv) Bottle drips
5. Target irrigation area	1–2 acres	1–2 acre
6. Soil type	Sandy loam	Black cotton soil
7. Rainfall variability	Two seasons	Two seasons (second season heaviest)
8. Target markets	Local markets	Local markets
9. Labor availability	Limited labor	Limited labor
10. Water sources	- Rain water harvesting - Streams / swamps - Rivers - shallow wells	- Rain water harvesting - Streams /swamps - Rivers - Deep wells
11. Socio – economic characteristics	- Mainly women - Organized in farmer group (groups, associations, cooperatives) - 40 – 65 years of age - Average income per household is approximately UGX 2 million year - Average household size is 7 persons	- Mainly women - Organized in farmer group (groups, associations, cooperatives) - 40 – 65 years of age - Average income per household is approximately UGX 2 million year - Average household size is 7 persons

3.3 AGRO-ECOLOGICAL ZONES

The 16 districts covered CAPCA, EADEN and CIDI are within 11 agro-ecological zones (AEZs) (Table 2). The following sections describe the AEZs as defined by Wortmann and Eledu (1999). The description of agro-ecological zones emphasized; variability in altitude, average rainfall and temperature, landscape, soil type and productivity and land use. These categories are largely determined by the amount of rainfall, which drives the agricultural potential and farming systems within each category. The farming systems and there environment are always changing and most have undergone profound changes in recent years. The information about the agro-ecological zone feeds into the suitability assessment of the various pro-poor appropriate irrigation technologies.

[1] Tanks include tarpaulin lined tanks, plastic tanks, concrete tanks and metallic tanks.

Table 2: Agro-ecological Zones covering the Project Area

UGOPAP implementing Partner	Districts in which Partner Operates	Agro-ecological Zone
CAPCA	Butambala	• Lake Victoria Crescent
	Mpigi	• Lake Victoria Crescent
	Mukono	• Lake Victoria Crescent
	Wakiso	• Lake Victoria Crescent
	Luwero	• Lake Victoria Crescent, • Central Buruli Farmlands, • Central Wooded Savanna
	Bukomansimbi	• Western Masaka Mityana Farmlands
	Mubende	• Western Mid-Altitude Farmlands, • Southwestern Grasslands
	Nakaseke	• Central Buruli Farmlands, • Central Wooded Savana
EADEN	Bugiri	• Lake Victoria Crescent
	Iganga	• Lake Victoria Crescent
	Luuka	• Lake Victoria Crescent, • Jinja and Mbale Farmlands
	Manafwa	• Mt. Elgon Farmlands
	Namutumba	• Lake Victoria Crescent
	Tororo	• Lake Victoria Crescent, • Mt. Elgon Farmlands
CIDI	Rakai	• Lake Victoria Crescent, • Sango Plains, • Southwestern Grasslands
	Soroti	• Northern Moist Farmlands, • North central Farm-Bush Lands with Sandy Soils

3.3.1 LAKE VICTORIA CRESCENT

This a large, extensive agricultural area that could be treated as three sub-zones: west of the Nile River, east of the Nile River and the eastern section that covers some districts in eastern Uganda. The average altitude is 1174 m above sea level (asl), with average temperature above 20 ^{o}C and average annual total rainfall greater than 1200 mm.

<u>Landscape</u>

West of the Nile River, the landscape is an old land surface marked by ridges or laterite-capped hills, long slopes and wide, often swampy valleys. East of the Nile, the landscape is rolling with wide valleys. The eastern part is relatively less rolling.

<u>Soils</u>

West of the Nile River, soils are variable often with high clay content, sandy clay loam soils are also common. Sub soil has a clay texture in some places which may interfere with rooting depth. Soils are often acidic and low in K but moderate levels of organic matter.
Crop production take place primarily on slopes where the soil is generally deep. Murram may limit rooting depth in places on the lower slopes; ridge tops and land fringing swamps are generally not suitable for crop production.

East of the Nile River, clay loam soils are typical on the hill slopes. In the east, soils are less fertile than in the west and are more typically sandy loam, and often acidic, especially in the southeast where K is often deficient.
The profitability of response to applied N and P in the AEZ varies with specific areas. Soil erodibility is low and rainfall erosivity is moderate.

<u>Land use</u>

The area has up to 80% of land farmed. Wetlands are important for plant products, environmental protection and rice cultivation in the east. Urbanization has resulted in many fast growing built up areas.

3.3.2 CENTRAL BURULI FARMLANDS

The average altitude is 1063 m above sea level (asl), with average temperature above 20 ^{o}C and average annual total rainfall range is 1000-1200 mm.

<u>Landscape</u>

The landscape is rolling with broad valleys in the southern part and undulating plains in the north.

<u>Soils</u>

The soils are variable; often sandy and acidic. Nutrient and water deficits often constrain crop productivity; many crops are likely to respond to application of moderate amounts of N and small amounts of P. Soil erodibility is low and rainfall erosivity is moderate.

Land use

This AEZ is mostly farmland with grassland on sandier soils. Relatively more of the land is grassland in the northern part, while the proportion of farmland is greater in the south. About 10% of the land is wetland.

Climate

Rainfall is lower in the first cropping season that in the second, with about 405 mm during March-May and about 470 mm during August-November.

3.3.3 CENTRAL WOODED SAVANNA

The average altitude is 1089 m above sea level (asl), with average temperature above 20 ^{o}C and average annual total rainfall range is 1000-1200 mm, bimodal rainfall.

Landscape

The landscape consists of undulating plains with wide valleys.

Soils

The soils are sandy and often acidic with low nutrient supply. Soil structure is weak and soil becomes hard upon drying; water infiltration with the early rains is poor and therefore crop productivity is generally low. Soil erodibility is low and rainfall erosivity is moderate.

Land use

The zone is primarily bush and grassland with about 10% used as farmland.

Climate

The second season is wetter than the first, with about 385 mm during March-May and about 500 mm during August-November.

3.3.4 WESTERN MASAKA MITYANA FARMLANDS

This zone is similar to the adjoining Lake Victoria Crescent, but with lower rainfall and the soils are less productive. The average altitude is 1235 m above sea level (asl), with average temperature above 20 ^{o}C and average annual total rainfall range is 1000-1200 mm, bimodal rainfall.

Landscape

The terrain consists of gently rolling hills with rounded summits separated narrow rounded valleys.

Soils

The soils are variable but are typically deep, acidic sandy load with generally adequate base supply and moderate organic matter levels. Crops are likely to respond to N and O applied at low to moderate levels. Water deficits frequently constrain productivity on the sandier soils. Soil erodibility is low and rainfall erosivity is low.

Land use

The zone is primarily farmland on the hill slopes.

Climate

Rainfall distribution is bimodal with pronounced dry periods in January and February and June-August. Monthly rainfall is higher in the first cropping season, but the second season is of longer duration.

3.3.5 WESTERN MID-ALTITUDE FARMLANDS

This a large, widely dispersed and variable AEZ. The average altitude is 1198 m above sea level (asl), with average temperature above 20 ^{o}C and average annual total rainfall range of 1000-1200 mm, bimodal rainfall.

Landscape

In the northwestern part, the landscape is rolling and rugged; slopes of 10^{o} are common. The terrain in the southwest is much more rugged. East of Lake Albert lies part of the rift Valley Escarpment with steep slopes. The landscape of the farmlands of Mubende, parts of Butambala and Central Rakai vary but typically are rolling with flat-topped hills, broad valleys and coarse soils on the slopes, in northern Mubende, the terrain is more rugged. Western Mubende's landscape is rolling to rugged.

Soils

In the west, soils are often shallow, coarse-textured and acidic; patches of deeper soil are cultivated. In northern Mubende, the soils are shallow except on the lower slopes where brown loam, typically a meter deep, occurs. Shallow soils at the base of rock outcrops are often intensively cultivated. In western Mubende, more productive loam and clay loam soils occur on the mid-slopes; productivity is low to medium. Crops are likely to be responsive to application of moderate amounts of N. Soil erodibility is low and rainfall erosivity is low to moderate.

Land use

About 50% of land is farm land with much fallow. Farmland is interspersed with wooded savanna in the western part of the zone, and with grassland in Mubende.

Climate

The first season is shorter with less rainfall (360 mm during March-May) than the second season (485 mm during August-November).

3.3.6 SOUTHWESTERN GRASSLANDS

The average altitude is 1220 m above sea level (asl), with average temperature above 20 ^{o}C and average annual total rainfall is less than 1000 mm, bimodal rainfall.

Landscape

In the wetter eastern part, the landscape is varied but is generally rolling with narrow, short valleys. High, narrow ridges dominate the landscape in the west, with steep slopes giving way to more gentle foot slopes and valleys. Parts of the south and north of this zone are gently rolling.

Soils

The soil in the east is generally clay loam, often moderately acidic, and usually with a good nutrient supply; soil is shallow on ridges. Soils in the west are sandy but generally enjoy good nutrient supply. Soil erodibility is generally low, and while rainfall erosivity is low, soil loss is often great at the onset of the rains due to extensive burning of grasslands. Water deficits constrain productivity, especially where soils are shallow.

Land use

The zone is a semi-arid grassland area. Most of the crop production takes place in the eastern part.

Climate

Rainfall distribution is bimodal with dry periods in from December-February and June-August. Precipitation exceeds 100 mm per month in April and November only. Daytime temperatures are hottest in January and February.

3.3.7 JINJA AND MBALE FARMLANDS

This zone is densely populated, intensively farmed with highly productive soils. The average altitude is 1213 m above sea level (asl), with average temperature above 20 ^{o}C and average annual total rainfall is more than 1200 mm, bimodal rainfall.

Landscape

The landscape of Jinja area consists of flat-toped ridges, gently sloping hillsides, and narrow valleys that drain into the Nile River. The Mbale area farmlands lie between Mt. Elgon and the plains to the west; the topography is varied but is generally sloping.

Soils

In the Jinja area, soils on the ridges are shallow, but soils on the gentle slopes are very deep and dark with high clay content. In the Mbale area, the soils are mainly red-brown loam and clay loam soils of good fertility. The soils are sandier and less fertile in the southern part where response to application of low rates of N and P is likely to be profitable. Soil erodibility is very low and rainfall erosivity is moderate.

Land use

Most of the land is used for crop production with little fallow.

Climate

The rain falls in two distinct but similar seasons with approximately 575 mm per season. July is relatively wetter near Mbale.

3.3.8 MT. ELGON FARMLANDS

This is a very productive area with fertile soils, high rainfall and moderately cool temperatures. The average altitude is 1466 m above sea level (asl), with average temperature below 20 ^{o}C and average annual total rainfall is more than 1200 mm, unimodal rainfall.

Landscape

The landscape is steeply sloped and divided by many valleys.

Soils

In the northern part, much of the soil is derived from volcanic parent material and the soils are typically red clay loam, well drained, highly leached, often acidic (as indicated by the presence of bracken ferns), but of good nutrient supply. In the south, the surface soils more often have high sand content and lower nutrient supply. Soil erodibility is very low and rainfall erosivity is moderately high.

Land use

Most of the land is intensively cropped while about 20% is woodland.

Climate

The AEZ is cool and wet. The southern part is warmer with less rain in July than in the north. Rainfall peaks in April and May but is generally more than 100 mm per month from March to November.

3.3.9 SANGO PLAINS

The average altitude is 1200 m above sea level (asl), with average temperature above 20 ^{o}C and average annual total rainfall is less than 1000 mm, bimodal rainfall.

Landscape

The landscape consists of a coastal plain with remnants of old lake terraces, such remnants can be seen near Lake Nabugabo.

Soils

The soils are typically sandy, acidic and generally of low nutrient supply. Soil erodibility is very low and rainfall erosivity moderate.

Land use

Land use is primarily grassland, with occasional patches of farm land found on the better soils, and areas of deciduous forest.

Climate

Rainfall is moderately high in this zone. March-May is the wettest period.

3.3.10 NORTHERN MOIST FARMLANDS

This is a large area of farmland that is very important for annual crop production. The average altitude is 1024 m above sea level (asl), with average temperature above 20 ^{o}C and average annual total rainfall is more than 1200 mm, unimodal rainfall.

Landscape

The Western Nile part of the zone contains the West Nile Escarpment, but otherwise is gently rolling with narrow valleys. In Soroti area, the landscape is rolling and undulating plains associated with the Pager and Agaga Rivers.

Soils

The soils are variable and often acidic and sandy, but they generally have moderately good nutrient supply. In the West Nile part of the zone, the soils are deep, sandy, acidic and often low in nutrient availability. In the Soroti area, red loam soils are associated with the higher slopes, brown sandy soils are common on the lower slopes, and dark clay soils predominate in the valleys. The soils near the Pager and Agaga Rivers are high in clay but are often acidic and have low nutrient supply. Throughout this AEZ, crops are likely to be very responsive to application of moderate amounts of N and P. Soil erodibility is low but rainfall erosivity ranges from moderate in the Soroti area to very high in the northwestern part.

Land use

Most of the land is arable farmland with some grassland and bush land interspersed.

Climate

The zone is sub humid and relatively warm with rainfall well distributed from April to October during which mean monthly rainfall exceeds 110 mm. The dry season is December-March.

3.3.11 NORTH CENTRAL FARM-BUSH LANDS WITH SANDY SOILS

This is AEZ is widely dispersed. The average altitude is 1023 m above sea level (asl), with average temperature above 20 ^{o}C and average annual total rainfall is more than 1200 mm, unimodal rainfall.

Landscape

The terrain consists of rolling or undulating plains.

Soils

The soils are sandy, often acidic, shallow, and low in nutrient supply. Soil erodibility is low and rainfall erosivity is moderate to very high.

Land use

Much of the land with less sandy soil is arable with a large proportion in fallow. Farmland is interspersed with bushland.

Climate

The zone is warm and sub-humid. Mean rainfall exceeds 110 mm per monthly for April to October with peak in August.

4 ANALYSIS OF THE POLICY, LEGAL AND INSTITUTION FRAMEWORKS OF IRRIGATION IN UGANDA

4.1 INTRODUCTION

This section provides the policy, legislative, and regulatory context in which pro-poor appropriate irrigation technologies operation should comply.

4.2 NATIONAL LEGISLATIVE FRAMEWORK

4.2.1 CONSTITUTION OF THE REPUBLIC OF UGANDA, 1995

The Constitution of the Republic of Uganda, 1995 is the overall national legal framework for Uganda. The constitution provides for, inter alia:

- Chapter XIII: The State shall protect important natural resources, including land, water, wetlands, oil, minerals, fauna and flora on behalf of the people of Uganda;
- Chapter XXI: The State shall take all practical measures to provide a good water management system at all levels;
- Chapter XXVII: The State shall promote sustainable development and public awareness of the need to manage land, air, water resources in a balanced and sustainable manner for the present and future generations;
- The right of every Ugandan to a clean and healthy environment (Article 39);
- The responsibility of government to enact laws that protect and preserve the environment from degradation and to hold in trust for the people of Uganda such natural assets as lakes, rivers, wetlands, game reserves and national parks [Article 237(2)];

Interpretation: *Establishment of the pro-poor irrigation technologies must be in compliance to the Constitution of the Republic of Uganda, 1995 as the overall national legal framework for Uganda.*

4.2.2 WATER ACT, CAP 152

Objective (c) of the Act states that "to allow for the orderly development and use of water resources for purposes other than domestic use, such as the watering of stock, irrigation and agriculture, industrial, commercial and mining uses, the generation of hydroelectric or geothennal energy, navigation, fishing, preservation of flora and fauna and recreation in ways which minimise harmful effects to the environment".

Abstraction of water that is required for irrigation of the crops will be regulated by this Act. According to Section 6 of the Act, no person acquires rights to use water, or to construct or operate any works unless authorized under Part II of the Act.

Section 7 of the Act, provides for the general rights to use water. Section 7 (1) Subject to section 8, a person may, (b) being the occupier of or a resident on any land, where there is a natural source of water, use that water for domestic use, fighting fire or irrigating a subsistence garden. (2) In addition to the right to water under subsection (1), the occupier of land or resident on land may, with the approval of the authority responsible for the area, use any water under the land occupied by him or her or on which he or she is resident on or any land adjacent to that land. (3) The rights under subsections (1) and (2) do not per se authorise a person to construct any works.

Section 8 of the Act, provides the limitations on use water. Section 8 (2) No person shall extract water unless authorised under this Part of the Act. (3) Water shall be deemed to have been extracted if there exists on the land in question any pipe, channel, tank or other means of extracting water.

Section 18 states that a person is not allowed to construct or operate any works unless he has a permit granted for that purpose by the Director, Directorate of Water Development (DWD). Construction is defined to include alteration, improvement, maintenance and repair.

Interpretation: *This Act is relevant because it empahasizes the orderly development and use of water resources for purposes other than domestic use.*

4.2.3 NATIONAL ENVIRONMENT ACT, CAP 153

This is the main law relating to protection of the environment in Uganda. NEMA was created under NEA and mandated with the responsibility to oversee, coordinate and supervise environmental management activities in Uganda. Third Schedule of the National Environment Act, Cap 153 (*Section 4 (a), (b), (c): "Dams, rivers and water resources including storage dams, barrages and weirs, river diversions and water transfers between catchments and flood control schemes.")* requires this project to undertake an EIA.

The Act provides for various strategies and tools for environment management, which also include EIA (Section 19) for projects likely to have significant impacts on the environment. NEMA sets multimedia environmental standards (Sections 24-32) to prevent contamination of air, water and soil resources. Section 36 entrusts NEMA, lead agencies and the district environment committee with powers to protect quality of watercourses, permanent or seasonal from human activities that could adversely affect them. Section 56 prohibits discharge of hazardous substances like chemicals, oil, etc into the environment except in accordance with guidelines prescribed by NEMA.

Interpretation: *This Act is relevant as it requires that implimentation of pro-poor appropriate irrigation technologies must be compliant with environmnetal protection. However there may be an opportunity for advocacy in order for pro-poor appropriate irrigation technologies not to be categorised so as to require an EIA which is not specific in Third Schedule of the act.*

4.2.4 LOCAL GOVERNMENTS ACT, CAP 243

This Act provides for decentralized governance and devolution of central government functions, powers and services to local governments that have own political and administrative structures. Districts have powers to oversee implementation of development activities under supervision of their relevant departments such as environment, lands and water resources. According to Section 9 of the Act, a local government is the highest political and administrative authority in its area of jurisdiction and shall exercise both legislative and executive powers in accordance with the Constitution.

Interpretation: *This Act is relevant since all potential scale irrigation farmers using the pro-poor appropriate irrigation technologies fall under the juridisction of specific District Local Governments whose requirements must be complied with. Accordingly, District Local Governments will have key responsibilities for monitoring compliance.*

4.2.5 THE PHYSICAL PLANNING ACT, 2011

The Physical Planning Act, 2011 establishes district and urban physical planning committees, provides for making and approval of physical development plans and applications for development. The committee includes the District Water Engineer who is in charge of water resources in the distrrict.

The Fifth Schedule of the Act emphasizes matters to be dealt with in district, urban and local physical development plans in which, classification of areas is specified, including for agricultural development, infrastructure, environmental protection, natural resource management, urbanisation, human settlements conservation, tourism and other purposes.

Interpretation: *This Act is relevant to ensure that the small scale irrigation farmers using the pro-poor appropriate irrigation technologies are located within the district physical planning guidelines.*

4.2.6 PUBLIC HEALTH ACT, CAP 281

This Act provides local authorities with administrative powers to take all lawful, necessary and reasonable measures to prevent the occurrence or deal with any outbreak or prevalence of any infectious communicable or preventable disease and to safeguard and promote the public health. The Act mandates local authorities (Section 103) to prevent pollution of watercourses in interest of public good.

Interpretation: *This Act is applicable in so far as pro-poor appropriate irrigation technologies increases the potential for contamination of the environment and water resources in particular by agricultural inputs. Increased humidity due to irrigation water application presents a the risk of water related disease outbreaks.*

4.2.7 OCCUPATIONAL SAFETY AND HEALTH ACT, 2006

The Act requires employers to provide and maintain safe working conditions, and to take measures to protect workers and the public from risks and dangers of their works, at his or her own cost (Section 13). Employers with more than 20 workers should prepare and often revise a written policy with respect to safety and health of workers (Section 14). Every workplace must be kept in a clean state, free from effluent arising from any drains and sanitary facilities (Section 46).

Interpretation: *This Act is relevant to the Project as it requires to ensure safety of the labour force that may be employed during the operation of the pro-poor appropriate irrigation technologies. The employer is obliged to provide employees with washing facilities, First Aid, facilities for meals and Personnel Protective Equipment (PPE).*

4.2.8 EMPLOYMENT ACT (2006)

The Employment Act is the governing legal statutory instrument for the recruitment, contracting, deployment, remuneration, management and compensation of workers. The Act is based on the provisions of Article 40 of The Constitution of Uganda. The Act mandates Labour Officers to regularly inspect working conditions of workers to ascertain that rights of workers and basic provisions are provided and workers' welfare attended to. The Act also provides for the freedom of association of workers permitting workers to join labour organizations. Section 32 addresses the issue of child labour and states that children under the age of twelve years shall not be employed in any business, undertaking or workplace (32(1)). Subsection 32(2) provides restrictions under which a child under the age of fourteen years may be employed; including for light work under the supervision of an adult aged over eighteen years and the work shall not interfere with the child's education.

Interpretation: *This Act is relevant to ensure that operators of pro-poor irrgation technologies are obligated to work within Uganda's labour laws, including restrictions on child labour especially where it can interfere with the child's education. Children under the age of twelve years shall not be employed in operation of pro-poor irrgation technologies.*

4.2.9 WORKERS' COMPENSATION ACT (2000)

Section 28 of The Workers' Compensation Act (2000) states that:

- Where a medical practitioner grants a certificate that a worker is suffering from a scheduled disease causing disablement or that the death of a workman was caused by any scheduled disease; and,
- The disease was due to the nature of the worker's employment and was contracted within 24 months immediately previous to the date of such disablement or death, the worker or, if he or she is deceased, his or her dependants shall be entitled to claim and to receive compensation under this Act as if such disablement or death had been caused by an accident arising out of and in the course of his or her employment.

Interpretation: *This Act is relevant in so far as in some instances labour will be employed for operation of the pro-poor irrigation technologies. The provision of personal protective equipment (PPE) to employees is required to minimise accidents and injuries.*

4.2.10 NATIONAL ENVIRONMENT (WETLANDS, RIVER BANKS AND LAKESHORES MANAGEMENT) REGULATIONS, 2000

These regulations provide principles for sustainable use and conservation of wetlands, riverbanks and lakeshores. The regulation requires that any person, community or organisation must granted wetland resource use permit undertake any regulated activities within wetlands. The regulations defines "drainage of wetlands" as the removal or exclusion of water from a wetland by pumping, excavation of channels, planting in a wetland fast growing non wetland trees or plants, abstraction of water from a river entering a wetland, channeling, reclamation and drainage itself.

Interpretation: *This Act is thus relevant since many potentail small scale irrigation farmers using pro-poor appropriate irrigation technologies consider wetlands as potential source of water.*

4.2.11 NATIONAL ENVIRONMENT (MINIMUM STANDARDS FOR MANAGEMENT OF SOIL QUALITY) REGULATIONS, 2001

Section 12 of this Act requires compliance with prescribed measures and guidelines for soil conservation for the particular topography, drainage and farming systems, contravention of which constitutes an offence.

***Interpretation**: The regulations will be relevant in regard to prevention of contamination of land covered by the installed systems. The regulations will apply to operation, repair and maintenance. These regulations are also relevant in areas where systems will be installed but are prone to soil erosion due to unstable slopes.*

4.2.12 NATIONAL ENVIRONMENT (WATER RESOURCES) REGULATIONS, 1998

These regulations provide guidance for the obtaining water permits. All developers of water supply for commercial irrigation, livestock development and fish for which the abstraction rates exceed 400 m^3/day from motorized water pump which whether temporarily or permanently, pumps water from a borehole or waterway boreholes shall apply for a permit for Water Abstraction. A permit is also required where there is a weir, dam, tank or other work capable of diverting or impounding an inflow of more than 400 cubic meters in any period of 24 hours

These regulations thus provides for the threshold and legal procedures for applications to construct any works for development of water resources for all uses (domestic, industrial, and agriculture water or discharge waste). the First Schedule of the regulation incudes requirements for irrigation that have to be included in the water permit application.

***Interpretation:** A water abstraction permit is required in order to abstract water from water sources. However it may also provide an opportunity for advocacy of either supporting small-scale farmers using pro-poor appropriate irrigation technologies to obtain permits or the requirement be reduced to a "notification of the Authority" before abstraction of water for small scale irrigation. A guideline for the abstraction volume threshhold to obtain a water permit is provided. The threshold may translates to anyone who at least irrigates one (1) acre with four (4) inches of water or two (2) acreas with at least two (2) inches of water per day during any 24 hours in the growing season.*

4.2.13 NATIONAL ENVIRONMENT (WASTE MANAGEMENT) REGULATIONS, 1999

These Regulations apply to among others all categories of hazardous and non-hazardous waste.

***Interpretation**: The regulations will relate to overall waste management of the project. The regulations require the generator of waste to take all practical steps to ensure that waste is managed in a manner which will protect human health and the environment against the adverse effects which may result from the waste. Thus, there will be need to minimise waste generation by:*

- *eliminating use of toxic raw materials;*
- *reducing toxic emissions and wastes;*

- *recovering and reuse of waste wherever possible.*

4.2.14 ENVIRONMENTAL IMPACT ASSESSMENT REGULATIONS, 1998

The regulations require a detailed study to determine possible environmental impacts and mitigation measures. The guidelines require that the EIA process should be participatory engaging the general public and stakeholders in consultations or to inform them and obtain their views about the proposed development during the EIA.

Interpretation: *These regulations are relevant to the Project as they detail the requirements for the EIA to be undertaken for the project. However there may be an opportunity for advocacy in order for pro-poor appropriate irrigation technologies not to be categorised so as to require an EIA which is not specific in Third Schedule of the act.*

4.3 POLICY AND PLANNING FRAMEWORK

4.3.1 COMPREHENSIVE AFRICA AGRICULTURE DEVELOPMENT PROGRAMME

The Comprehensive Africa Agriculture Development Programme (CAADP) developed under African Union auspices of the New Partnership for Africa's Development (NEPAD) is a collective policy framework for agricultural transformation in Africa – launched by AU Assembly in 2003 in Maputo with a goal to eliminate hunger and reduce poverty in Africa through agriculture. Pillar 1 of CAADP on extending the area under sustainable land management and reliable water control systems. The pillar focuses on building up soil fertility and the moisture holding capacity of agricultural soils and rapidly increasing the area equipped with irrigation, especially small-scale water control with the aim of not only providing farmers with opportunities to raise output on a sustainable basis but also contributing to the reliability of food supplies.

Interpretation: *Pro-poor appropriate irrigation technologies are in line with Pillar 1 of CAADP.*

4.3.2 UGANDA'S VISION 2040

The Uganda Vision 2040 was developed to operationalize the national vision statement,
"A Transformed Ugandan Society from a Peasant to a Modern and Prosperous Country within 30 years".

The relevant key interventions in agriculture are highlighted as in the paragraphs below:

103. As a way of increasing agricultural productivity, Government will do the following: invest in the development of all major irrigation schemes in the country; ensure continued investment in technology improvement through research for improved seeds, breeds and stocking materials; invest in the development of the phosphates industry in Tororo to reduce the cost of fertilizer.

173. To promote commercial agriculture, Government will sustainably use water resources for irrigation, livestock watering, fisheries and aqua-culture. Bulk water transfer systems will be built to cover long distances and large areas to provide water for multi-purpose use. Analysis shows that with even full exploitation of irrigation potential only 14.1 per cent of Internal Renewable Water Resources will be utilized. To mitigate local scale shortages large and medium water reservoirs will be developed.

177. Water use efficiency, water recycling and water re-use will be key strategies to optimally use this resource. Strategies will be put in place to ensure efficient use of water especially in water consumptive economic activities.

Interpretation: *The proposed pro-poor appropriate irrigation technologies are in line with aspirations of Vision 2040. However there may be an opportunity for advocacy of to re-direct government emphasis to include pro-poor appropriate irrigation technologies in there focus.*

4.3.3 NATIONAL DEVELOPMENT PLAN (NDP) II, 2015/16 to 2019/20

The theme of The NDP II is *"Strengthening Uganda's Competitiveness for Sustainable Wealth Creation, Employment and Inclusive Growth*".

As one of the priorities of the NDP II, Government is to invest in water for production infrastructure to boost commercial agriculture and industrial activities. Emphasis is on construction of large and small scale water schemes for irrigation, livestock and rural industries, while increase cumulative storage from 27.8 to 55 Million cubic metres.

The key relevant interventions are highlighted as in the paragraphs below:

420. To promote commercial agriculture, Government will sustainably use water resources for irrigation, livestock and aqua-culture. Bulk water transfer systems will be built to cover long distances and large areas to provide water for multi-purpose use. To mitigate shortages at local level large and medium water reservoirs will be developed. Government will construct large and small scale irrigation schemes to increase water for production.

421. Government plans to invest in the following projects and programmes in order to achieve the planned targets on water for production: (i) water for livestock in cattle corridor Areas; (ii) Livestock water (non-cattle corridor) Areas; (iii) Irrigation development Area A (Off-farm); Irrigation development Area B (Off-farm); Water for aquaculture; Water for Rural Industries; Human Capacity building and Operations and Maintenance support.

501. Over NDP II period the key areas of focus for the Agricultural Sector include: i) increasing production and productivity; ii) addressing challenges in the selected thematic technical areas including critical farm inputs, mechanization and water for agricultural production; iii) improving agricultural markets and value addition in the 12 prioritized commodities (Cotton, Coffee, Tea, Maize, Rice, Cassava, Beans, Fish, Beef, Milk, Citrus and Bananas), and iv) institutional strengthening for agricultural development.

532. Over the NDPII period, the Trade and Cooperative sub-sector's key focus areas include: increase market access for Uganda's products and services in regional and international markets; improve the stock and quality of trade infrastructure; promote the formation and growth of cooperatives; enhance the capacity of cooperatives to compete in domestic, regional and international markets; increase the share of manufactured goods and services in total exports; increase the diversity in type and range of enterprises undertaken by cooperatives; and improve the Private Sector competitiveness.

557. Over the NDP II period, focus will be put on: increasing the provision of water for production facilities; and increasing the functionality and utilization of water for production facilities.

The interventions will include:

i. Establish new bulk water systems for multipurpose use (dams, water abstraction, transmission and Distribution to industrial zones and other points of use) while factoring in the impacts of climate change.

ii. Protect and manage water catchment areas.

iii. Increase private sector involvement in the implementation of water for production facilities, including use of the Public-Private Partnership (PPP) arrangement.

iv. Prepare and implement the National Irrigation Master Plan that takes into account future impacts of climate change.

v. Gazette water reserve areas for large dams and involve private operators to strengthen management.

Interpretation: *The proposed pro-poor appropriate irrigation technologies are in line with NDP II as the prioritized crops for value addition can be irrigated. There an opportunity to support and facilitate cooperative society members to acquire irrigation equipment. However there may be an opportunity for advocacy of to ensure government considers areas covered by pro-poor appropriate irrigation technologies as contributing to the target achievement.*

4.3.4 NATIONAL AGRICULTURAL POLICY, 2013

This National Agriculture Policy (NAP) has been formulated in line with the Constitution of the Republic of Uganda. Objective XI (ii) of the Constitution provides that the state shall "stimulate agricultural, industrial, technological and scientific development by adopting appropriate policies and enactment of enabling legislation."Objective XXII (a) provides that the state shall "take appropriate steps to encourage people to grow and store adequate food."

The National Agriculture Policy is aimed at translating these high level national obligations into policies and strategies to enable their achievement. The policy shall guide all agriculture and agriculture related sub-sector plans, policy frameworks and strategies existing and those to be formulated in future.

The strategy for water for agricultural production laid out in this policy is based partly on the availability of bulk water supply, which is currently under-developed. Therefore, the ministries responsible for agriculture and water must continue planning jointly for provision of adequate water for agricultural production to cover irrigation for improved crop production, livestock production needs, and aquaculture. Accordingly, the Ministry responsible for water shall increase investment in off-farm bulk water development, including larger reservoir dam construction, bulk water transfer systems, water diversion systems.

Within NAP this information in these paragraphs is relevant

17(VI). Government will ensure that key agricultural resources including soils and water for agricultural production are sustainably used and managed to support current and future generations.

23 (X111). Objective 2 which has a strategy to Support development and sustainable use, management, and maintenance of water and land resources for agriculture to boost production, enhance value-addition, and reduce the effects of climactic shocks; and

26 (IV & VII). Objective 5 which has strategies to a) Promote and support the dissemination of appropriate technologies and practices for soil and water conservation and maintenance among all categories of farmers, including use of both organic and inorganic fertilizers. b) Develop capacity to harvest and utilize rain water for agricultural production.

Interpretation: *The proposed pro-poor appropriate irrigation technologies are in line with NAP especially the implementation of strategies of Objective 5.*

4.3.5 NATIONAL WATER POLICY, 1999

The National Water Policy aims at promoting integrated approach to manage the water resources in ways that are sustainable and most beneficial to the people of Uganda. The National Water policy (1999) Chapter Six gives a broad framework for planning financing, implementation and management of Water for Production interventions.

The policy objectives include to: "Promote development of water supply for agricultural production in order to modernize agriculture and mitigate effects of climatic variations on rainfed agriculture" through:

i. Promoting proper water resource assessment and planning for agricultural production,
ii. Increasing the capacity of the farmers to access and use of water for crop, fisheries and livestock production,
iii. Promoting appropriate water harvesting technologies for irrigation and livestock development,
iv. Promoting the participation of farmers and the private sector in the financing, planning, development and management of irrigation and livestock water supply systems,
v. Promoting and supporting, where appropriate, the development of adequate and reliable livestock water supply.

Allocation of water for commercial livestock, irrigation and aqua-culture will be done considering the economic, social and environmental value of the water.

The policy emphasis under the strategy for technology choice that Appropriate low cost technologies should be selected, offering good possibilities for community participation in decision making, implementation and management of the system, and measures to save water. Only well known tested, appropriate and cost effective technologies, preferably locally made/available should be used. Standardization of equipment e.g. pumps and sprinklers will be encouraged as means of safeguarding the community based maintenance system, through easy access to spare parts, repairs etc. on the open market. The Users should be involved in the choice of technology and emphasis should be placed on technology that responds to the farmers needs.

Interpretation: *This policy is relevant as it requires rational use of water during irrigation.The importance of community involvement in community in irrigation technology choice is ephasized. Consideration of economic, social and environmental value of the water is indicated.*

4.3.6 NATIONAL LAND POLICY, 2013

The Policy goal is "to ensure efficient, equitable and sustainable utilization and management of Uganda's land and land-based resources for poverty reduction, wealth creation and overall socio-economic development". The policy has several specific objectives including the need to enhance the contribution of the land sector to overall socio-economic development, wealth creation and poverty reduction in Uganda; to ensure sustainable utilization, protection and management of environmental, natural and cultural resources on land for national socioeconomic development; to harmonize all land-related policies and laws, and strengthen institutional capacity at all levels of Government and cultural institutions for sustainable management of land resources. Specifically in paragraph 148, Government shall regulate the use of land and water resources for agricultural production aligned with a National Agricultural Policy.

Interpretation: *This policy is relevant as it encourages sustainable utilization of land. Pro-poor irrigation technologies have a high potential to enhance the contribution of the land sector to overall socio-economic development, wealth creation and poverty reduction in Uganda.*

4.3.7 NATIONAL ENVIRONMENT MANAGEMENT POLICY, 1994

The overall goal of this policy is promotion of sustainable economic and social development mindful of the needs of future generations and EIA is one of the vital tools it considers necessary to ensure environmental quality and resource productivity on long-term basis. The policy calls for integration of environmental concerns into development policies, plans and projects at national, district and local levels. Hence, the policy requires that projects likely to have significant adverse ecological or social impacts undertake an EIA before their implementation. This is also reaffirmed in the National Environment Act (Cap 153) that makes EIA a legal requirement for "Third Schedule" projects. According to Uganda's National Environment Act Cap 153, Section 4 (a, b and c), i.e. *Dams, rivers and water resources including storage dams, barrages and weirs, river diversions and water transfers between catchments and flood control schemes,* respectively.

Interpretation: *This Policy is relevant as it requires that implimentation of pro-poor appropriate irrigation technologies must be compliant with environmnetal protection.*

4.3.8 NATIONAL WETLANDS POLICY, 1995

The national policy on conservation and management of wetlands aims at curtailing loss of these resources and ensuring that their benefits are equitably distributed to all people of Uganda. The wetlands policy requires:

- Sustainable use to ensure that benefits of wetlands are maintained for the foreseeable future;

- Environmentally sound management of wetlands to ensure that other aspects of the environment are not adversely affected;
- Equitable distribution of wetland benefits;
- Application of environmental impact assessment procedures on all activities to be carried out in a wetland to ensure that wetland development is well planned and managed.

In order to operationalize the policy and to provide a legal framework for its implementation, wetland related issues have been adequately incorporated into the National Environmental Act, Cap 153.

Interpretation: *This policy is relevant to ensure sustainable use of wetlands since many potentail small scale irrigation farmers using pro-poor appropriate irrigation technologies consider wetlands as potential source of water.*

4.3.9 NATIONAL AGRICULTURAL EXTENSION SERVICES POLICY, 2016

Under Strategy 3.1.7, MAAIF shall promote the integration of technical services and other software activities under irrigated agriculture, livestock watering, farm power and machinery, farm planning systems, soil and water management, postharvest handling and agro-food processing into field extension services. Activities include;

1. Develop guidelines for integration of water for production, farm power and machinery, farm planning systems, Soil and Water management, post-harvest handling, food processing into the field extension services.
2. Develop relevant extension content/materials.
3. Train selected trainers from Local Governmnets (LGs) and NSAs on the guidelines and extension content who would in turn train other LG staff and NSAs.
4. Conduct training for Local Government Production and Marketing staff in all districts.
5. Establish demonstrations in the Districts and provide demonstration packages/kits.
6. Technical backstopping by MAAIF Subject Matter Specialists

For effective implementation of National Agricultural Extension Services (NAES), it is essential that institutional mandates, roles, responsibilities, structures, linkages, coordination and legal framework and defined, operationalize and enforced.

The following decentralized functions will be undertaken by District Production and Marketing Departments of local governments:

1. Planning for the agricultural sector within the National Policy Framework;
2. Providing technical backup and support supervision to staff in Sub-counties on production, farm development and sustainable utilization of natural resources (soil fertility, water harvesting, pasture improvement, mechanization, fishing in the water bodies).

Interpretation*: This policy is relevant to support the farmers using pro-poor irrigation techonologies. However there may be an opportunity for advocacy to encourage pro-poor appropriate irrigation technologies to be included in the District demonstration packages/kits.*

4.3.10 NATIONAL AGRICULTURAL RESEARCH POLICY, 2003

This policy's vission is *"A market-responsive, client-oriented and demand-driven national agricultural research system comprising public and private institutions working in tandem for the sustainable economic growth of Uganda".* Following the vision, in formulating the national agricultural research plans and programmes, special focus will be on the following priorities: Land and water resources management, including soil fertility, land degradation, production systems (for crop, livestock, aquaculture, agro-forestry), water harvesting techniques and irrigation.

Interpretation*: This policy is relevant as it identifies irrigation as a special focus area for agricultural research.*

4.3.11 DRAFT NATIONAL IRRIGATION POLICY, 2017

A National Irrigation Policy has been drafted awaiting approval by Cabinet. The National Irrigation Policy (NIP) for Uganda is aimed at increasing agricultural production and productivity for social economic transformation through efficient irrigation activities in Uganda. The policy is born out of the realization that there is over reliance on rain fed agriculture and yet there are increasing incidences of droughts and floods due to climate change phenomenon responsible for low agricultural production and productivity including food insecurity. This policy shall apply to all aspects of irrigation and related activities in Uganda. It addresses expanded and intensified agricultural production, institutional strengthening, and creation of an enabling investment environment for irrigated agriculture.

Interpretation*: This policy is relevant as an independent legislation for irrigation. This would be directly guiding the establishment of pro-poor irrigation technologies.*

4.3.12 NATIONAL GENDER POLICY (1997)

The overall goal of this policy is to mainstream gender concerns in the national development process in order to improve the social, legal/civic, political, economic and cultural conditions of the people of Uganda, particularly women. Thus, in the context of the Agricultural sector, this policy aims to redress imbalances which arise from existing gender inequalities and promotes participation of both women and men in all stages of Irrigation project cycle, equal access to, and control over significant economic resources and benefits.

Interpretation: *This policy would especially apply to ensuring that women should have equal opportunity as men in establishment and use of pro-poor irrigation technologies. This policy also requires provision of a work environment that is conducive to women as well as for men in addition to gender-disaggregated impacts and vulnerabilities.*

4.3.13 NATIONAL HIV/AIDS POLICY 1992

In Uganda, current effort to combat HIV/AIDS is characterized by a policy of openness by Government and this has, to a large extent, been emulated by civil society, political and social institutions, and workplaces. HIV/AIDS is recognized by Ministry of Health as a considerable risk in construction projects and it (together with the ministry responsible for labour) encourages employers to develop in-house HIV/AIDS policies, provide awareness and prevention measures to workers and avoid discriminating against workers living with or affected by HIV/AIDS. To ensure HIV/AIDS is addressed in the workplace, the policy encourages employee awareness and education on HIV/AIDS. To protect the infected and affected persons from discrimination, employers are required to keep personal medical records confidential. Employees living with, or affected by, HIV and AIDS, and those who have any related concerns, are encouraged to contact any confidant within the organization to discuss their concerns and obtain information.

Interpretation*: This policy is relevant to protect any employees living with, or affected by, HIV and AIDS, and to reduce risk associated with HIV/AIDS.*

4.3.14 OCCUPATIONAL HEALTH AND SAFETY (OHS) POLICY

This policy seeks to:

- Provide and maintain a healthy working environment
- Institutionalize OHS in the Agricultural sector policies, programs and plans
- Contribute towards safeguarding the physical environment

The OHS Policy Statement is guided by the Constitution of the Republic of Uganda and other global, national and sectoral regulations and policies. The OHS Policy also takes into recognition of the Agricultural Policy and the Health Sector Strategic Plan, all of which aim to improve the quality of life for all Ugandans in their living and working environment.

Interpretation: *This policy will be especially relevant for OHS of small-scale farmers using pro-poor appropriate irrigation technologies. The policy will feed into mitigation measures that protect the public from health and safety impacts as a result of implememtation activities of pro-poor appropriate irrigation technologies.*

4.3.15 AGRICULTURE SECTOR STRATEGIC PLAN (ASSP) 2015/16-2019/2020

Water for Agricultural Production is among the priority investments in the Agriculture Sector Strategic Plan (ASSP) 2015/16-2019/2020 (MAAIF, 2016). The ASSP is an input to the National Development Plan II for the period 2015/16 - 2019/2020.

Interpretation*: This plan is relevant as it identifies irrigation among prioity investments.*

4.4 INSTITUTIONAL FRAMEWORK

4.4.1 MINISTRY OF AGRICULTURE, ANIMAL INDUSTRY AND FISHERIES, MAAIF

The Ministry's functions are derived from the Constitution of the Republic of Uganda; the Local Governments Act, (1997), and the Public Service Reform Programme (PSRP). As a result of the reforms, the role of Ministry of Agriculture, Animal Industry and Fisheries is to create an enabling environment in the Agricultural Sector by performing the following functions: *Enhancing crop production and productivity, in a sustainable and environmentally safe manner, for improved food and nutrition security, employment, widened export base and improved incomes of the farmers.* MAAIF is the lead agency for water use and management for agricultural development on-farm. "On-farm" water services for agricultural use involves extending the water from the off-farm sources to the final users and giving the farmers the necessary technical advice to ensure effective utilization of the water provided for increased productivity. "On-farm" refers to development of primary distribution and tertiary networks for irrigation systems and other on-farm irrigation infrastructure and works and water use management.

Key functions include:

- Formulate, review and implement national policies, plans, strategies, regulations and standards and enforce laws, regulations and standards along the value chain of crops, livestock and fisheries;
- Control and manage epidemics and disasters, and support the control of sporadic and endemic diseases, pests and vectors;
- Regulate the use of agricultural chemicals, veterinary drugs, biological, planting and stocking materials as well as other inputs;
- <u>Support the development of infrastructure and use of water for agricultural production along livestock, crop and fisheries value chains;</u>
- Establish sustainable systems to collect, process, maintain and disseminate agricultural statistics and information;
- <u>Support provision of planting and stocking materials and other inputs to increase production and commercialization of agriculture for food security and household income;</u>
- <u>Develop public infrastructure to support production, quality / safety assurance and value-addition along the livestock, crop and fisheries commodity chains;</u>
- Monitor, inspect, evaluate and harmonize activities in the agricultural sector including local governments;
- Strengthen human and institutional capacity and mobilize financial and technical resources for delivery of agricultural services;
- Develop and promote collaborative mechanisms nationally, regionally and internationally on issues pertaining to the sector;

Interpretation*: MAAIF is the main government agency that will be in charge of overseeing implememtation activities of pro-poor appropriate irrigation technologies.*

4.4.2 MINISTRY OF WATER AND ENVIRONMENT, MWE

The Ministry of Water and Environment (MWE) has the responsibility for setting national policies and standards, managing and regulating water resources and determining priorities for water development and management. It also monitors and evaluates sector development programmes to keep track of their performance, efficiency and effectiveness in service delivery. MWE has three directorates: Directorate of Water Resources Management (DWRM), Directorate of Water Development (DWD) and the Directorate of Environmental Affairs (DEA). With respect to water for production, MWE is the lead agency for water for production and development of off-farm requirements. "Off-farm" refers to development of water sources and transmission (bulk transfer) through closed conduits or canals to farmgates.

Interpretation: *In the development of pro-poor appropriate irrigation technologies, MWE and MAAIF are required to work in consultation to ensure that both off-farm and on-farm requirements are addressed.*

- **Directorate of Water Development (DWD)**

Under the DWD is the Water for Production Department. Water for Production (WfP) refers to development and utilisation of water resources for productive use in crop irrigation, livestock, aquaculture, rural industries and other commercial uses.

The current mandate in WfP facilities in Uganda is a shared responsibility between MWE and MAAIF. MWE is responsible for "off farm" activities while MAAIF is responsible for "On Farm".

Interpretation: *DWD is a key stakeholder in the successful implememtation of pro-poor appropriate irrigation technologies.*

- **Directorate of Water Resources Management (DWRM)**

The Directorate of Water Resources Management (DWRM) is responsible for developing and maintaining national water laws, policies and regulations; managing, monitoring and regulation of water resources through issuing water use, abstraction and wastewater discharge permits; Integrated Water Resources Management (IWRM) activities; coordinating Uganda's participation in joint management of transboundary waters resources and peaceful cooperation with Nile Basin riparian countries. The directorate comprises three departments namely Water Resources Monitoring and Assessments, Water Resources Regulation and Water Quality Management.

The roles and interests of DWRM include:

- Initiate national policies, set standards and priorities for water resources management in the country
- <u>Develop national plans for promotion of agricultural production through providing water for livestock, irrigation, aquaculture and rural industry</u>
- Make assessment for water for production
- Develop surface water reservoirs e.g. dams and valley tanks for livestock production in the cattle corridor
- Rehabilitation of existing dilapidated dams
- <u>Develop and disseminate small-scale irrigation technologies</u>
- Promote small-scale aquaculture in ponds and existing reservoirs
- Provide technical assistance to local governments and other stakeholders in design, construction and management of water for production infrastructure
- Promote sustainable management of water sheds

Interpretation: *The DWRM is an important stakeholder, specifically on issues relating to managing, monitoring and regulation of water resources through issuing water use, and abstraction permits.*

4.4.3 NATIONAL ENVIRONMENTAL MANAGEMENT AUTHORITY, NEMA

The National Environmental Act provides for establishment of NEMA as the principal agency responsible for coordination, monitoring and supervision of environmental conservation activities. NEMA is under the Ministry of Water and Environment (MWE) but has a cross-sectoral mandate to oversee the conduct of EIA through issuance of EIA guidelines, regulations and registration of practitioners. It reviews and approves environmental impact statements (EIS) in consultation with any relevant lead agencies.

NEMA's enforcement branch is the department of Monitoring and Compliance. They are responsible for ensuring that enterprises comply with the various environmental regulations and standards. NEMA has appointed environmental inspectors whose powers and duties are spelled out in Section 81 of the National Environmental Act and can include stopping any activity which pollutes the environment. The environmental inspector may also issue an improvement notice requiring an operator of any activity to cease any activities deleterious to the environment which are contrary to the Act. NEMA has power; to prosecute environmental offenders and offences committed under the National Environment Act may earn the offender fines and prison sentences. NEMA works with District Environment Offices and Local Environment Committees at local government level, which undertake inspection, monitoring and compliance enforcement on its behalf.

Interpretation*: NEMA together with input of stakeholders approves Environmental Impact Assessment and provides the conditions of approval.*

4.4.4 LOCAL GOVERNMENT ADMINISTRATION STRUCTURES

The Local Governments Act, Cap 243 provides for decentralised governance and devolution of central government functions, powers and services to local governments that have their own political and administrative structures. Districts have powers to oversee implementation of development activities under supervision of their relevant departments such as environment, lands and water resources.

District and Local Council administration within EADEN, CAPCA and CIDI would be vital in implementation of the project by mobilising political goodwill and sensitizing communities**.** Local administration leaders e.g. District Environmental Officers (DEO) will also play a role during environmental monitoring associated with implememtation activities of pro-poor appropriate irrigation technologies.

Interpretation*: District and Local Council administrations are stakeholders in the Project and will play a vital role in subsequent monitoring.*

4.4.5 THE MINISTRY OF GENDER, LABOUR & SOCIAL DEVELOPMENT, MGLSD

MGLSD is the leading and coordinating agency for the Social Development Sector. In collaboration with other stakeholders, MGLSD is responsible for occupational safety, labour relations, community empowerment, protection and promotion of the rights and obligations of the specified vulnerable groups for social protection and gender responsive development.

Interpretation*: MGLSD is a stakeholder that will have input in to the development and operation process pro-poor appropriate irrigation technologies.*

4.4.6 MINISTRY OF LAND AND HOUSING DEVELOPMENT

Ministry of Land and Housing Development is responsible for providing policy direction, national standards and coordination of all matters concerning lands, housing and urban development. The ministry is responsible for putting in place policies and initiating laws that ensure sustainable land management. Under the Ministry of Land and Housing development, the Directorate of Physical Planning and Urban development is vital because it is tasked with orderly, progressive and sustainable urban and rural development as a framework for industrialization, provision of social and physical infrastructure, agricultural modernization and poverty eradication. Additionaly under the directorate Department of Land Use Regulation and Compliance is responsible for formulation of land use related policies, plans and regulations. It also provides technical support and guidance to Local Governments in the field of land use regulation, monitoring and evaluation, and systematization of the land use compliance monitoring function and practice.

Interpretation: *The ministry is relevant since it is key in land use regulation specifically for agricultural modernization and poverty eradication. The involvement of Local governments within EADEN, CAPCA and CIDI working together with the ministry is necessary to enable communities understand the relevant land policies and regulations especially those dealing with land use under irrigation agriculture .*

4.5 SUSTAINABLE DEVELOPMENT GOALS

The Sustainable Development Goals (SDGs) aim to end poverty and hunger by 2030. Pro-poor appropriate irrigation technologies have the potential to directly contribute towards achieving the following SDGs.

SDG1: End poverty in all its forms everywhere

SDG2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture

SDG6: Ensure availability and sustainable Management of water and sanitation For all – It is noted that approximately 70% of all available water is used for irrigation.

SDG8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all – It is noted that small and medium sized enterprises account for significant proportion of employment arround the world, thus pro-poor appropriate irrigation technologies are relevant to this SDG.

SDG13: Take urgent action to combat climate change and its impacts. Pro-poor appropriate irrigation technologies enhance the adaptive capacity of the farmers involved to the impacts of climate change.

4.6 SUMMARY OF ADVOCACY OPPORTUNITIES

The policy legal and institutional framework is well establish for the management of water and land reosurces as well as the agricultural sector. However, in relation to pro-poor irrigation technologies the following are proposed potential advocacy opportunities.

1) In regards to NEMA approval: There is need to lobby NEMA in order for pro-poor appropriate irrigation technologies not to be categorised so as to require an EIA which is not specific in Third Schedule of the National Environment Act. In support of small-scale farmers using pro-poor appropriate irrigation technologies the requirement be reduced to a "notification of the Authority" before installation of the small scale irrigation system.
2) In regards to water abstraction: Theres in need to support small-scale farmers using pro-poor appropriate irrigation technologies to obtain permits or the requirement be reduced to a "notification of the Authority" before abstraction of water for small scale irrigation.
3) In regards to Government plans for Irrigation Development: Efforts are required to re-direct government emphasis to include pro-poor appropriate irrigation technologies in there focus.
4) In regards to Government Irrigation Acreage Development Targets: Efforts are required for advocacy to ensure government considers areas covered by pro-poor appropriate irrigation technologies as contributing to the target achievement.
5) In regards to the Irrigation Legislation under Development: Independent legislation for irrigation is currently under development. This would be directly guiding the establishment of pro-poor irrigation technologies and thus it important that the government is advised to ensure that legislation is clearly drafted for successful application of these technologies.
6) In regards to the Agricultural Extension: An opportunity for advocacy to encourage pro-poor appropriate irrigation technologies to be included in the District demonstration packages/kits.

5 DESCRIPTION OF THE DIFFERENT AVAILABLE PRO-POOR APPROPRIATE IRRIGATION TECHNOLOGY OPTIONS

A pro-poor appropriate irrigation technology should have the following attributes:

- Affordable
- Available
- Adaptable to existing setting
- Enhance farming profitability
- Effective and efficient
- Easy to operate , repair and maintain
- Environmentally and socially acceptable

This section evaluates irrigation technologies that smallholder farmers can use and maintain following the full cycle of the water supply system from the water source to the irrigated field.

5.1 WATER SOURCE OPTIONS

Water availability in the right quantity and quality is a prerequisite for irrigation. Irrigation water can come from various water sources such as rivers, lakes, runoff water harvesting in valleys, rainwater harvesting in tanks and groundwater. Indeed the existing irrigation practices within the project area use all these water sources. The various water source options are described below.

5.1.1 Small River Diversion Works

Description	• A diversion structure is a dam/weir constructed across a stream (Figure 5-1) to divert a regulated quantity of the river water towards a canal/pipe for gravity fed irrigation. The structure also helps to raise the water level at the head of the canal/pipe; to control the entry of silt into the canal/pipe and to control deposit of silt at the head of the canal/pipe. • Diversion structures are usually made of compacted earthen bunds, sand bags, concrete, bricks or gabions. The complexity of diversion works depends upon the cross-section of the river, the bed material in the river, the flow discharge and upon the consequences of failure.
Operation and maintenance	• Easy to operate for small structures • Low level of skills required for small structures • Good maintenance and timely repairs are key factors in the durability and lifespan of the diversion works. • Materials for repair and maintenance are easily accessible
Necessary	• Suitable for areas with natural river channels.

water sources and prevalence	• Rivers should have sufficient discharge of at least 2 L/s within reasonable distance (<2 km) to the irrigated area. • The elevation at the diversion works should be higher than the target irrigation area. • Diverted water can be channeled into a night storage reservoir during period of non-irrigation
Irrigation potential	• Suitable for gravity fed irrigation systems with canal or pipe distribution systems • A discharge of 1-1.5 L/s can command 1 ha per day. • Suitable for all crops as long as the field application method is appropriate • The soils and slope determine the distribution systems (canal or pipe)
Social considerations	• Suitable for all gender • A group of farmers can pool labour or cost share in the construction of the diversion structure • Conflicts could arise with downstream settlers mainly during low flow seasons when irrigators completely divert the stream flow to fields.
Environmental considerations	• River training works are required near the diversion works to ensure a smooth and an axial flow of water and thus to prevent the river from outflanking the works due to a change in its course. • Catchment management strategies should be considered to avoid flash floods, silt-laden soils and debris • Environmental flow must be considered to cater for downstream water users.

Cost	• Investment cost: The investment in gravity diversion schemes depend on the complexity of the weir, the materials used and on the length and complexity of the inlet canal.
	  ○ River diversion weir:
	    a. local materials, lower quality structures; 1,500 – 2,500 US$/ha
	    b. Standardized quality structures; 4,000 - 6,000 US$/ha
	• Operation and maintenance cost:
	• Life span: Depends on the type and material of construction

Interventions	• Acquisition of water permits if the abstracted amounts are above the threshold of 400 m^3/day (4 L/s) • Design and technical support in establishment of diversions works to irrigate more than 2 ha

	• Skills development in construction and maintenance • Partners: MWE (DWRM, DWD), MAAIF

Figure 5-1: Typical river diversion works (concrete weir)

5.1.2 Valley tanks

Description	• A valley tank (Figure 5-2) is an excavation in the valley that can store between 5,000 - 20,000 m^3 of water • Extraction of water from the reservoir can be done through: o A sump (well reservoir) in natural ground at the side of the reservoir, supplied by gravity from a screened inlet and pipe through the bed and side of the reservoir; o A bank-mounted motorized, solar or human-powered pump. • Suited for clayey soils. High dispersive soils render usage of valley tanks ineffective.
Operation and maintenance	• Ease of operation depends on the abstraction method • Local contractors can be used due to low level of technical capacity required • Easy to de-silt for small valley dams. For large valley tanks de-silting may

	require hire of equipment
Necessary water sources and prevalence	• Suited for a watershed area of at least a 2 km^2 catchment. • Suited for areas with an existing water course
Irrigation potential	• Suited for irrigating farm size of at least 0.5 ha. • At least 12,000 - 15,000 m^3 of water storage is need to irrigate 1 ha per season if storage is based on rainwater harvesting. • Valley tank of 10,000 m^3 can sustain about 1,000 livestock in 3-4 months drought period • The irrigated area is bigger if the valley tank is considered as night storage reservoirs fed by a stream/spring or underground water • Suitable for all crops along as the field application method is appropriate
Social considerations	• Suitable for all gender if the abstraction method is appropriate • Communities can pool their labour to construct and maintain shared valley tanks
Environmental considerations	• Year-round impoundment of water may lead to a significantly increased risk of malaria and schistosomiasis • Siltation of valley tanks shortens the lifetime unless proper soil conservation is implemented in the catchment areas.
Costs	• Investment cost: The cost valley tanks depends on the labour rates at the site and the construction method relating to whether the excavation is done: a) manually with shovels and wheelbarrows, or b) by hiring a crawler (bulldozer). o US$ 2 to 4 per m^3 water storage • Operation and maintenance cost: • Life span: Depends on maintenance and level of environmental degradation (siltation)
Interventions	• Access to equipment for construction and desilting at subsided costs • Technical support in siting and design of large valley tanks > 5,000 m^3 • Partners: MWE, MAAIF

Figure 5-2 Valley tank

5.1.3 Small earth dams (micro dams)

Description	• An earth dam (Figure 5-3) is a structure or barrier constructed across a valley, a river or stream to conserve, store or to control the flow of water basically using compacted earth.
	• A small earth dam has a crest height ranging from 2 to 5 m high, while the reservoir capacity is at least 5,000 m^3 but less than 1 million m^3 storage volume.
	• Extraction of water from the reservoir can be done through:
	  ○ A sump (well reservoir) in natural ground at the side of the reservoir, supplied by gravity from a screened inlet and pipe through the bed and side of the reservoir;
	  ○ A bank-mounted motorized, solar or human-powered pump.
	• An ideal dam site is where the valley narrows, to reduce the width of the dam. The site should have an impervious foundation, such as unfissured rock, or a clay subsoil. Soil type for embankment are loam, sandy loam, sandy clay loam or clay loam

Operation and maintenance	• Operation and maintenance is relatively low • Dams require regularly inspection for signs of deterioration, such as cracks, gullies, damage by rodents or insects, seepage, and damage to structures, especially the spillway
Necessary water sources and prevalence	• There should be sufficient watershed area to ensure the dam fills up • The site should be located where surface runoff from rains on the catchment area, or other runoff flows, can fill the dam reservoirs at least once a year. • The dam site should be selected on a natural valley which will provide a relatively high depth to surface area ratio (for a given design volume), to minimize evaporation losses.
Irrigation potential	• A small dam with a length of 20 m long by 2 m high will generally irrigate 0.5 ha, while a dam 100 m long and 5 m high will irrigate 20–25 ha. • At least 50 m^3 is required to irrigate 1 ha per day • Dams are sources of bulk water transfer by gravity to irrigate areas a distance from the water source. • Suitable for all crops as long as the field application method is appropriate
Social considerations	• Community can contribute towards the siting and construction (i.e. with the provision of land, their labour and possibly local materials) operation and maintenance of the dam. • Dams constructed as community based projects, thus are prone to the constraints associated with communally owned and operated infrastructures. • Valley dams are normally built across valleys and small seasonal water courses, which are often boundaries between two or more landowners. It is therefore important that the landowners are fully involved on sharing the ownership of the dam.
Environmental	• The dams regulate flow and thus also act as flood mitigation

considerations	structure • Valley dams may interfere with people's water supply downstream. Need to preserve low flows for vulnerable water dependent ecosystems. • Siltation of dam reservoirs will shorten the lifetime of dams unless proper soil conservation is implemented in the catchment areas. • Year-round impoundment of water may lead to a significantly increased risk of malaria and schistosomiasis • Since they are designed with open water surface within valleys, water storages suffer high evaporation losses especially in hot areas.
Costs	• Investment cost: ▪ Compared to a valley tank, the construction costs for a dam can be much lower per m^3 of water stored (half). The reason for this cost efficiency is that a dam can store water both behind the dam as well as in the excavated portion of the reservoir where earth fill is obtained for its construction. ▪ The cost of earth dams or valley tanks depends on the labour rates at the site and the construction method relating to whether the excavation is done: a) manually with shovels and wheelbarrows, or b) by hiring a crawler (bulldozer). ○ US$ 0.18 to 0.75 per m^3 water storage. ○ To irrigate 1 ha requires ~ 15,000 m^3 per season, the investment is US 2,700 to 11,250. • Operation and maintenance cost: • Life span:
Interventions	• Access to subsidized equipment which can be hired to farmers. The cost of dam construction and auxiliary works can be expensive, requiring earth moving machinery . • Need for technical support for professional designs. The designs of storages in valleys tend to carry a certain level of risk

	in case of collapse/failure. • Support in mapping suitable sites for dam construction ▪ Partners: MWE (DWD, DWRM), MAAIF

Figure 5-3 Small earth dam

5.1.4 Shallow open wells

Description	• Shallow wells (Figure 5-4) draw water from an unconfined aquifer or shallow groundwater table. • Depths of hand-dug wells range from shallow wells, about 5 metres deep, to deep wells over 20 metres deep. • It is impractical to excavate a well which is less than a metre in diameter; an excavation of about 1.5 metres in diameter provides adequate working space for the diggers and will allow a final internal diameter of about 1.2 metres after the well has been lined. • It is desirable for the well to have a concrete cover slab to reduce the possibility of contamination. The walls of an open well may be built of precast concrete rings or in brick or stone masonry, or simply unlined depending on well depth and soil type.

	• The volume of the water in the well below the standing water table acts as a reservoir, which can meet demands on it during the day and should replenish itself during periods when there is no abstraction. • The wells can be easily deepened, which may be necessary if the ground water level drops, by telescoping the lining further down into the aquifer. • The yield of an existing shallow well can be improved by deepening or introducing vertical tunnels or perforated pipes. • Extraction of water from the reservoir can be done through bank-mounted motorized, solar or human-powered pump. • Compared to surface water sources, ground water has the following advantages o Depending on locality, ground water can be cheaper than surface water sources o Ground water is easier to develop for individual irrigators o Where irrigators are scattered and not easy to develop canals, ground water may be a better alternative. Irrigators can have their own private wells and thus do not have to depend on centralized water delivery systems o The supply of water from a well can be started as soon as required and can be stopped at any moment, thus taking advantage of momentary rainfall. o The well water may be cleaner than from surface reservoirs and thus, the irrigation scheme may be combined with rural/urban water supply system. o There is usually no need for land acquisition or taking up space on the land, when using ground water sources.
Operation and maintenance	• Easy to operate using simple abstraction methods. Abstraction-depends on the well yield. Water is abstracted by means of either a bucket and windlass above an access hole, or a hand pump, depending upon the yield of water available and the ability of the benefiting community to pay for ongoing maintenance for the hand pump, spare parts, etc. • Ease of repair with limited prior training
Necessary water sources and prevalence	• Favorable hydro-geological conditions. Open well development is most common, particularly in the bottoms of valleys and wetlands where groundwater is at a shallow depth and farmers dig open pits; • Abstraction should at low discharges of the order of 0.5 m^3 up to 2 or more cubic metres per hour.
Irrigation potential	• Suited for irrigating small plots. Can be used to irrigate a maximum of 1 ha per day

	• Suited for all crops as long as the field application method is appropriate
Social considerations	• Suitable for all gender • Community involvement is typically high; May involve planning of site, contribution of cost, contribution of material, contribution of labour, direct participation Dug wells encourage entrepreneurial construction at a local level, owing to very low capital investment requirements. Because they are easily replicated, they place the project control back in the hands of village elders and civic minded individuals.
Environmental considerations	• Slightly greater chance of contamination if poorly constructed. There is danger from percolation of pesticides and herbicides • Widespread drawdown externalities, including the depletion of the all-important shallow aquifers if pumping is not regulated. The largely unseen nature of groundwater has resulted in development initiatives that are unaware of the hydrodynamic limits of the resource and unable to regulate the resulting patterns of abstraction. The consequences range from the drawdown of water levels beyond the limits of dug wells and manual pumping technologies to more subtle and deferred environmental health impacts resulting from the migration of poor-quality water.
Costs	• Investment costs: The costs for open wells can vary considerably depending on the well's depth and the equipment required for drilling; costs may vary between US$500 and 1 500 per open well fitted with concrete lining. • Operation and maintenance costs: • Life span: 10 to 15 years
Interventions	• Technical support for siting of wells, testing of well yield and water quality testing • Partners: MWE (DWRM, DWD), Licensed drilling companies

Figure 5-4 Shallow well

5.1.5 Shallow tube wells

Description	• A tube or pipe 100 or 150 mm diameter often in PVC vertically set into the ground at depth of 6 to 20 m for the purpose of suction lifting of water from shallow aquifers (Figure 5-5). • Tube wells are usually quicker and cheaper to sink, need no dewatering during sinking, require less lining material, are safer in construction and use, and involve less maintenance. • Seepage down the tube well bore is prevented by the sanitary seal. Seepage from the ground above the aquifer is excluded by the lengths of plain casing. • Extraction of water from the reservoir can be done through bank-mounted motorized, solar or human-powered pump.
Operation and maintenance	• Simple to operate and maintain

Necessary water sources and prevalence	• Potential shallow groundwater source are areas whose: ▪ ground water table depth is located 2 to 3 meters or less below ground surface at the onset of the dry season. ▪ top soil profile is 1 to 2 meters deep and the succeeding 3 to 7 meters thick are sand and gravel. ▪ Soil texture is light to medium.
Irrigation potential	• Suitable for irrigating all crops on small plots • An irrigation system consists of one or more fully developed shallow tube well equipped with appropriate pumping units that can serve a contiguous area owned by an individual or groups of farmers. can irrigate 1-3 ha per unit with safe yield of 4 L/s
Social considerations	• Suitable for all gender • Communities will usually supply unskilled labour.
Environmental considerations	• Encourage high water use efficiency • Potential for groundwater pollution from pesticides, fertilizers and other wastes
Costs	• Investment costs: $400 - $1,200 per unit • Operation and maintenance costs: • Life span: 10 to 15 years
Interventions	• Water quality testing • Groundwater mapping for potential sites • MWE, DWRM

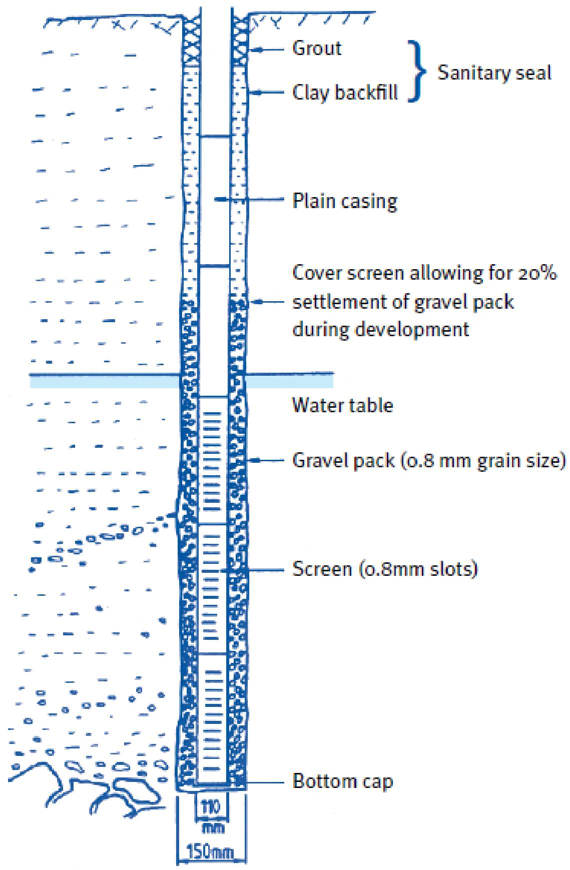

Figure 5-5 Shallow tube well (Source: WaterAid, 2009)

5.1.6 Deep wells/boreholes

Description	• A borehole is a well sunk through an impermeable stratum to draw water from a relatively deep, confined aquifer (Figure 5-6).
	• Boreholes are generally deep and narrow wells, measuring from less than 100 mm diameter to about 150 mm and can range from 15 m – 90 m.
	• Some salient features of a simple borehole include:
	  o The casing – often made of PVC to retain the hole in position.
	  o Submersible pump, which can be lifted out for maintenance or repair.
	  o Sanitary seal – which prevents seepage down the borehole
	  o Slotted casing – at the bottom of the borehole through which pumped water enters
	  o Capping - to support the external surfaces of the borehole against collapse, either temporarily or permanently.

Operation and maintenance	• Easy to operate • Require technical skills for repair and maintenance
Necessary water sources and prevalence	• Water quality should be guaranteed to ensure they are free of salts • Can be used in conjunction with a suction hand pump, solar pump or submersible electric pump • Best suited with temporary storage
Irrigation potential	• A well with yield of 15 m^3 per hr can command 3-4 ha per day • Due low output, its use is not often recommended for surface irrigation, specifically for paddy production.
Social considerations	• Suited for all gender • Can have substantial queuing if shared by big communities and located in or near town • Boreholes enable a farmer to maintain independent irrigation systems thus reducing conflicts over way leave and other land and property conflicts.
Environmental considerations	• Greater chance of salinity problems
Costs	• Investment cost: (~$5,000 USD to 20,000 depending on the depth of the well. Estimated cost per m^3 of water storage is 5 to 10 US $/$m^3$. 15% of the cost is usually for geological investigations • Operation and maintenance cost: • Life span:
Interventions	• High initial material costs and input of specialized expertise, i.e. construction, operation, and maintenance may require skills and expensive heavy equipment • well siting • groundwater mapping • water permits • Partners: MWE, licensed companies

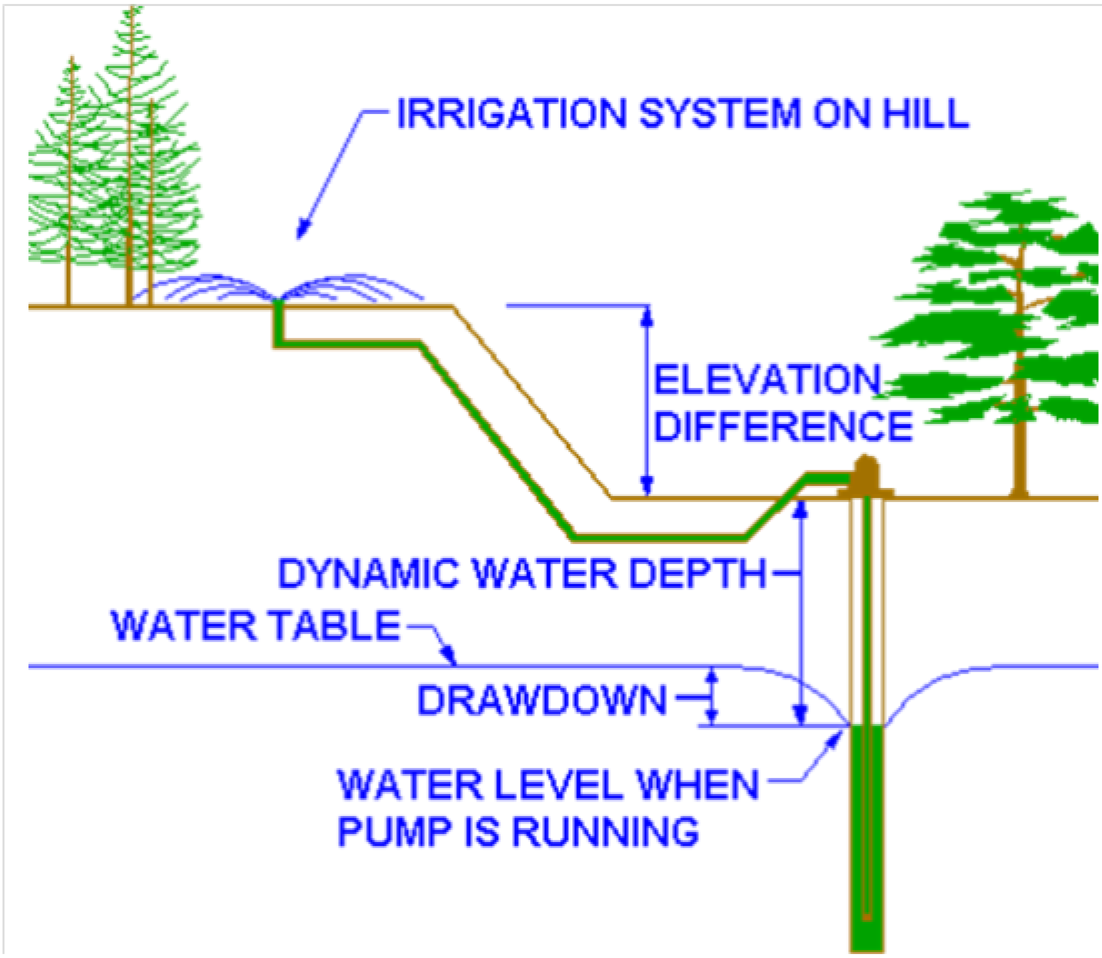

Figure 5-6 Borehole irrigation system

5.1.7 Springs

Description	• A spring (Figure 5-7) is a place on the earth's surface where groundwater emerges naturally. The water may appear as small water holes or wet spots on hillsides or along river banks. • The flow of water from springs may come from small openings in porous ground or from joints or fissures in solid rock. Surface springs occur where groundwater emerges at the surface because an impervious layer of ground prevents further seepage downwards. •
Operation and maintenance	• Only minor maintenance required • Proper management and maintenance of the area around the spring and its catchment area is necessary. There should be no cultivation upstream of the spring and natural vegetation should

	be maintained. Water depleting trees such as eucalyptus should not grow anywhere near the spring. The selection of trees and shrubs to cover the spring area is made with care to allow only plants that encourage water ponding e.g. reeds.
Necessary water sources and prevalence	• If a spring or stream is to be the source, it must be unpolluted and must be one which flows throughout the year; the flow must be measured in the dry season in order to know what yield can safely be relied upon. • The spring for protection should have at least a discharge of 5 L/sec. The farm land in the downstream area for irrigation should have a gentle slope with wide area. • If the flow from the spring is not sufficient to meet peak demands during the day, a storage tank can be incorporated into the structure of the spring protection. This enables the flow from the spring over the full 24 hours to be stored, then used throughout the day to meet intermittent demands by means of a tap in the structure.
Irrigation potential	• For irrigation development, most springs can only supply small quantities of water or irrigate relatively small area (< 3 ha) • Irrigation area is increased if the spring development is combined with a night storage reservoir • In most cases springs are found at foot of hills. In cases where command area is below the spring point, water is transported to irrigation fields by gravity flow and furrow or basin irrigation methods are used for irrigation development. • In other cases, water is pumped to storage structures constructed at high elevation areas. From storage structure water is transported to irrigation fields by gravity flow.
Social considerations	• Suitable for all gender • Water users are so many and sometimes water conflict arises/occurs among users. (Potable water, livestock, fishpond, farm land)
Environmental considerations	• An inspection of the ground upstream of the spring is essential to ascertain that there is no danger of pollution or, if there is, that measures can be taken to prevent it.
Costs	• Investment cost: Spring diversion: simple inlet structure; 500 -

	1,000 US$/ha ▪ Operation and maintenance cost ▪ Life span:
Interventions	• Skills development in spring protection • Water Quality Testing (Physical, Chemical Parameters) and Bacteriological analysis • Sensitization on the proper use and management of their developed spring water resource. • Partners: DWRM

Figure 5-7 Protected Spring

5.1.8 Aboveground tanks

Description	▪ An aboveground tank, is a water storage structure constructed above the ground. In most cases, aboveground tanks collect and store rainwater from roof catchments. Aboveground tanks

	are usually made of plastic and ferro-cement (Figure 5-8). 1) <u>Ferrocement tanks</u>: A Ferro cement structure is a reinforced concrete cement structure with a wall. It is made of mortar and reinforced with wire mesh. They have ability to resist shrinkage cracking during curing (due to the woven reinforcement chicken mesh), and its resistance to severe cracking under tensile load. 2) <u>Plastic tanks</u>: Ready-made tanks are factory produced and sold to users. Plastic tanks are portable and can thus be easily transported. They are also durable than and relatively reliable, as they do not corrode. Plastic tanks up to 10 m3 are common. These are 3 - 4 times costly as compared to masonry or ferrocement tanks of the same capacity. Plastic tanks are portable hence good for households that keep moving. Another advantage is that they are light and flexible, and can thus be easily transported. They are also durable than and relatively reliable, as they do not corrode. Plastic
Operation and maintenance	▪ Easy to maintain and service ▪ Low levels of skills required ▪ Spare parts are easily available ▪ periodic management and maintenance to ensure a reliable and high quality water supply. ▪
Necessary water sources and prevalence	▪ Roof catchment ▪ Water pumped from groundwater or river channel • The selection of an actual size depends on various factors such as the amount and distribution of rainfall over the year, available roof area, household demand, and the presence of other supply sources. ▪ The rainfall pattern of the area. (If the area experiences regular rainfall throughout the year, a small tank of 4,000–5,000 litres would suffice, whereas in particularly dry areas which experience dry spells for about 6 months of the year, it would be beneficial to store as much water as possible.)
Irrigation potential	▪ Best suited for Domestic, and backyard irrigation ▪ the irrigated area is limited if the period without recharge exceeds 10 days

	▪ A 10,000 L can irrigate 0.2 ha (0.5 acres) per day at a time ▪ Best suited as temporary storage (1 to 3 days water demand) with pumped irrigation systems like treadle pump, solar or motorized pumps where they are continually refilled
Social considerations	▪ Suited for all gender ▪ Suited for individual farmers ▪ Can serve as a communal system if the tanks are used as temporary storage as part of a community irrigation system
Environmental considerations	▪ Potential for water quality deterioration if not maintained over a long period of time
Costs	▪ Investment cost: ○ Ferro cement tanks. 12 to 15 \$ per m^3 of water storage ○ Plastic tanks. 75 to 300\$ per m^3 of water storage ▪ Operation and maintenance costs: ▪ Lifespan:
Interventions	▪ Cost still high for individual farmers

Figure 5-8 Aboveground tanks: plastic tanks (left); ferro cement tanks (right)

5.1.9 Underground water tanks

Description	▪ An underground tank (or sub-surface tank), is a water storage structure constructed below the ground (Figure 5-9). ▪ In most cases, underground tanks collect and store runoff from ground catchments such as open grasslands, hillsides, home compounds, roads, footpaths, paved and unpaved areas. However, in certain circumstances, roof catchments can also be channeled into underground tanks. ▪ Underground tanks have lower construction costs and therefore, are more suited for storing agricultural water than surface tanks. Get twice the capacity for the same cost. ▪ Underground tanks have volumes ranging from 20 to 150 m^3. ▪ There are many types of underground tanks, categorized according to shape, size, capacity, lining material, construction and utilization. The tank can be lined with geo-membrane plastics, concrete, bricks, and other water resistant material. Lined underground tanks have the advantage of applicability on almost any soil type. 1) <u>Tarpaulin lined underground tanks.</u> The largest tarpaulin can store up to 30 m^3. Tarpaulins can last for about five years in a termite free area and it is easy to replace. 2) <u>HDPE Dam lined underground tanks/geo-membranes.</u> Thick ultra violet resistant (UV) hard material polythene which lasts for over 10 years makes it feasible to easily make impervious a pond bottom and sides, thus eliminating percolation losses at an affordable cost. Usually fusion and extrusion welding is carried out to join the lining material to the required measurements. 3) <u>Concrete (reinforced) underground tanks.</u> The tanks can vary in size from a few cubic metres to about 5,000 m^3. The larger tanks are built with reinforced concrete.
Operation and maintenance	• Easy to manage • Low levels of skills required for tank maintenance • Availability of masons • Easy access to spare parts/accessories
Necessary water sources	▪ The rainfall pattern of the area. (If the area experiences regular

and prevalence	rainfall throughout the year, a small tank of 4,000–5,000 litres would suffice, whereas in particularly dry areas which experience dry spells for about 6 months of the year, it would be beneficial to store as much water as possible.) ▪ The tank should not be more than 1.75 m in depth in order to withstand the pressure of the water. The less deep the tank is constructed makes cleaning and use of the tank easier.
Irrigation potential	▪ The tank should be close to the area of cultivation to ensure ease of irrigation. ▪ Suited to smallholder irrigation as individual farm storages. Ground tanks are excavated near homesteads for growing fruit trees and irrigating small gardens.
Social considerations	Suited to all gender depending on the method of abstraction of water
Environmental considerations	▪ The tanks may be subjected to cracks due to the root zone activities (i.e. ramification), therefore, it is advisable not to construct the tank in close proximity to large trees. ▪ Potential for contamination if the tanks develop leakages
Costs	▪ Investment costs: o Tarpaulin lined tanks US $3 per m^3 of water storage given a cost of US $90 for a maximum storage capacity of per 30 m^3 o HDPE Dam lined underground tanks: 3 to 5 US $/$m^3$ of water storage. o Concrete (reinforced) underground tanks: 5 to 10 US $/$m^3$ of water storage. ▪ Operation and maintenance: ▪ Life span:
Interventions	▪ Welding machine for dam liners Availability of these machines are the main limiting factor ▪ Partners: Private sector dealers e.g. Balton, MWE, MAAIF, AEATREC

Figure 5-9 Underground tanks: Tarpaulin lined tanks (left); HDPE Dam lined tanks (right)

5.2 TECHNOLOGIES FOR WATER ABSTRACTION

One of the main constraints to irrigation in Uganda is the difficulty of water abstraction. In most areas pumping is required, to lift water uphill to the gardens.
The choice of an irrigation pumps is dependent on:

- Quantity and quality of water demanded;
- Elevation to which water is to be pumped;
- Available energy sources;
- Cost of pump (affordability);
- Sustainability (serviceability of pumps/ spares, longevity/lifespan, ease of use).

The pumps are categorized according to the source of power.

5.2.1 Suction hand pumps

Description	▪ Human powered positive displacement pump with reciprocating pistons or plungers. In a piston pump, the piston is fitted with a non-return valve (the piston valve) and slides vertically up and down within a cylinder which is also fitted with a non-return valve (the foot valve) (Figure 5-10). ▪ The maximum suction lift is about 7 m (i.e. atmospheric pressure less about 30% system losses due to the ineffectiveness of seals, friction). ▪ The capacity of a suction hand pump is 20 to 36 L/min ▪ Hand pumps can be adapted to different well depths ▪ Hand pumps require a cover slab which can be sealed to prevent

	ingress of polluted water
Operation and maintenance	▪ Efficient and easy to operate ▪ Hand pumps are prone to battering by intense use causing damage ▪ Spare parts are sometimes difficult to obtain in rural areas impeding maintenance. ▪ Require services of trained mechanics to fix ▪ Hand pumps deteriorate easily due to manual operation, wear and tear. They therefore require regular maintenance, repairs and replacement of various parts. The pump and the site around it should be kept clean. This is part of preventive maintenance which also involves a daily check.
Necessary water sources and prevalence	▪ The depth of water from which a hand pump will suck is limited by atmospheric pressure to an operating depth of less than 7 meters ▪ Water sources used in conjunction with suction hand pumps include: Spring wells of good discharge, sand and subsurface dams, infiltration galleries and shallow wells.
Irrigation potential	▪ Maximum acreage of 1/8 of an acre (0.05 ha). ▪ Suitable for most crops and soils ▪ Suited for livestock watering in conjunction with valley tanks or dams
Social considerations	▪ Labour intensive if the irrigation area requires pumping for more than 1 hour Community can share out maintenance costs
Environmental considerations	▪ Clean technology with carbon foot print of zero
Costs	▪ Investment cost: Each unit is estimated at approximately US$700 ▪ Operation costs ▪ Life span: With regular maintenance can have life span of over ten years
Interventions	▪ Access to spare parts ▪ Skills development in repair and maintenance

Figure 5-10 Suction hand pump (Source: Mati 2012)

5.2.2 Treadle pump

Description	• A human powered positive displacement pump whose principle of operation is based on suction lift using a cylinder and a piston to draw water from a source below ground level such as from a river or shallow well (Figure 5-11). • The pressure treadle pump can lift 5,000 to 7,000 litres of water an hour with a suction of 7 m and delivery head of 6 m. • Treadle pumps can be adapted for direct irrigation by connecting to low-cost water distribution systems such as a perforated end pipe or flexible hoses to distribute the water by sprinkling. Watering can also be pumped into an overhead tank and then either gravitated or use localized/micro irrigation.
Operation and maintenance	• The pump is portable and can therefore be carried from one well to another easily and form one part of the field to another. • Serviceable, spares can locally be made • Operation is relatively labour intensive; a minimum of 2 persons

	• It is portable, easy to operate and maintain
Necessary water sources and prevalence	• Water source should close to target irrigation area (< 10 m) not be deeper than 7 metres •
Irrigation potential	• Acreage: 0.25 ha can be irrigated with at least four hours' daily pumping. • Suitable for most of the crops and soil types
Socio considerations	• Easy to pedal even by women/children • Treadling for hours on a daily basis is very strenuous and laborious • Pump may not be suitable for pumping drinking water because of lubricants and the leather
Environmental considerations	• Environmentally friendly
Costs	• Investment cost: Pressure treadle pump, including a set of flexible hoses for intake and output, is around US$120 to 150 per treadle pump set irrigating 0.25 ha, which means around US$500/ha to 600/ha • Operation costs: labour costs to operate the treadle per season are estimated at US$150 per set or US$600/ha. • Life span: 4 to 5 years
Interventions	• Access to spare parts especially bushes • sills development in minor repair and maintenance • Training of local technicians and artisans in fabrication, operation and maintenance • Partners: AEATREC-NARO and Private dealers e.g. Davis and Shirtlif


Figure 5-11 Treadle pump: Money maker model (left); NARO-AEATREC Model (right)

5.2.3 Small Motorized Water Pumps

Description	• Small motorized pumps (Figure 5-12) are applicable for an individual farmer or a group of small-scale farmers. Equipment has proved reliable provided that adequate maintenance is undertaken and spare parts are available. • The small motorized pumps driven by small petrol or diesel engines have a capacity of 2 to 5 horsepower (hp) and a typical discharge of 2–15 L/s for a head of up to 70 m. • Electric pumps can be surface pumps or submersible pumps. A submersible pump is a turbine pump close-coupled to a submersible electric motor. Both pump and motor are suspended in the water, thereby eliminating the long drive shaft and bearing retainers required for a deep well turbine pump. Because the pump is located above the motor, water enters the pump through a screen located between the pump and motor.
Operation and maintenance	• Requires financing of fuel costs at 1 -2 L of fuel per hour • Portable making it easy to be moved from once place to another • Diesel engines tend to be heavier and more robust than petrol engines and are more expensive to buy. However, they are also more efficient to run and if operated and maintained properly they have a longer working life and are more reliable than petrol • Electric motors are very efficient in energy use (75 - 85%) and can be used to drive all sizes and types of pumps. The main drawback is the reliance on a power supply which is beyond the control of the farmer,

	and which in many places is unreliable.
Necessary water sources and prevalence	• Available adequate surface (rivers) and groundwater sources (shallow wells)
Irrigation potential	• Acreage: 1 to 5 ha for irrigation of up to 6 hours a day. • Suitable for most crops and soil types as long as the application system is suitable.
Social considerations	• Individual farmers may extend their garden plots to irrigate a larger area as a result of the motorized pump, while groups of farmers can irrigate a common or collective area.
Environmental considerations	• The pump capacity should match the amount of water available to avoid drying the wells and impacting on downstream water users
Costs	• Investment cost: US$200 and US$500 for 2 to 5 horsepower (hp) centrifugal • Operational costs: These are mainly fuel (energy) costs, which are estimated at US$500 to 700/ha per season. • Life span: Petrol-driven pumps usually need replacing after 3 years. Diesel pumps operating in similar conditions could be expected to last at least 6 years. However, useful life depends on how well the pumps are operated and serviced.
Interventions	• Skills development in operation, repair and maintenance • Access to spare parts • Irrigation scheduling

Figure 5-12 Small motorized pumps

5.2.4 Solar powered pumps

Description	• In Africa, the sun is the most abundant source of energy, although not often tapped. Few smallholder farmers have access to electricity while the purchase of petrol or diesel is too expensive. Solar power is freely available and could be used. The use of solar energy in irrigation is still very limited but may play a bigger role in near future as solar panels are getting cheaper and more powerful. • Generally, a typical solar powered pumping system consists of a solar panel array that powers an electric motor, which in turn powers a bore or surface pump (Figure 5-13). • Can be adapted for surface water and groundwater -shallow wells and bore holes. • Suitable for irrigation systems with temporary storage then gravity • Solar powered water pumping systems are similar to any other pumping system, only the power source is solar energy. PV pumping systems have, as a minimum, a PV array, a motor, and a bore pump. Solar water pumping arrays are fixed mounted or sometimes placed on passive trackers (which use no motors) to increase pumping time and volume. AC and DC motors with centrifugal or displacement pumps are used
Operation and maintenance	• The electric pumps linked to the solar energy units have proved reliable and have low maintenance costs. • Maintenance and safety of a solar pumping system is also a major issue, with a high concern for vandalism or theft of the valuable solar panels and components. Therefore, a system would have to be installed in a protected manner, likely on an elevated platform. • There are many advantages of solar pumps. For instance, they are reliable, easy to install, can be long lasting (20+ years), low maintenance, simple repair if related to solar array, clean and no fuel is needed. In addition, photovoltaic (PV) systems are used to pump water for irrigation, livestock, or domestic use. Solar powered pumps enable better pasture management as livestock can access water at multiple distribution points. Photovoltaic (PV) powered pumping systems are a cost-effective alternative to agricultural wind turbines for remote area water supply. • Other benefits include the fact that PV technology can be put to

	multiple purposes, e.g. to charge batteries which supply electrical power for other uses. The modular system can be closely matched to individual needs and power is easily adaptable to changing demands. Pumping water using PV technology is simple and requires almost no maintenance. In irrigated agriculture, water is most needed during the hot sunny days, when solar energy is at its optimum, making it an obvious choice for this application.
Necessary water sources and prevalence	• Water source not too deep. Solar pumps are best operated on water source (river, wells) with limited depth (<10 m) and in areas with adequate sunshine (8 to 12 KWh/m^2/day) • As the sun's incident energy on a photovoltaic cell changes during the day, positioning of the solar array is critical for full performance of the system. The location selected for the installation of the solar array should have unrestricted sun exposure throughout the day and through the year. The solar array can be placed several hundred metres or more from the well head. There is no loss of performance if the electrical wire is sized properly, but naturally, the cost of wire increases significantly with increase in distance.
Irrigation potential	• Energy outputs of solar panels are limited, however, and in most cases a solar-driven electric pump may irrigate only a small garden area of 0.3 to 1 ha. • One 150 Watt solar module can irrigate over 1,000 m^2 (0.1 ha). • To irrigate effectively, water needs to be stored in an intermediate water reservoir or tank and gravitated to a low pressure pipe system or drip system.
Social considerations	• Appropriate for all gender
Environmental considerations	• Clean energy with carbon foot print of zero
Costs	• Initial investment. Estimates for the cost of batteries and electric regulators, electric motor pumps and a water reservoir are between US$10,000 and 15,000/ha inclusive of installation costs. • Operational and maintenance costs: These are mainly labour costs estimated at 50–100 US$/ha. • Life span: 8 to 12 years

Interventions	• Quality control of panels • Sizing of solar powered systems-panel • Technical support for design and installation • Partners: Ministry of energy, MWE, MAAIF, Private dealers

Figure 5-13 A solar powered abstraction adapted on a borehole

5.2.5 Hydraulic ram pumps

Description	• A hydraulic ram pump (Figure 5-14) is a water pump powered by hydropower. It is an automatic device which uses the energy contained in free flowing water to pump the same water without using any electricity or fuel. • Once installed, the pump can be operated, pumps 24 hours per day automatically • The hydraulic ram pumps comprise an automatic pumping device which utilizes a small fall of water to lift a fraction of the supply flow to a much greater height. The device uses the water hammer effect to develop pressure that allows a portion of the input water that powers the pump to be lifted to a point higher than where the water originally started. The main advantage of the hydram is that it has no substantial moving parts, and is therefore mechanically simple, which results in high reliability, minimal maintenance requirements and a long operational life. • A low drive-head hydraulic ram pump has been developed at Agricultural Engineering and Appropriate Technology Research Centre (AEATREC) in Namalere. Water can be raised to a delivery head of 45-50 m at a fall of 2-5 m. Pumps 0.5-1 L/s

Operation and maintenance	• Easy to maintain and service. All serviceable parts can be fabricated locally using simple tools.
Necessary water sources and prevalence	• Selective terrain • Requires a flowing stream in which the 'loss' is released downstream for other users • Not suitable for water harvesting systems due to low efficiency • Requires a sizeable intermediate storage • During the installation of a typical hydram, a supply head is created either by digging a small contoured diversion canal bypassing a river, or in some cases, particularly with small streams, it is normal simply to create a weir and to install the hydram directly below it. Where greater capacity is needed, it is common practice to install several hydrams in parallel. This allows a choice of how many to operate at any one time so it can cater for variable supply flows or variable demand. • The size and length of the drive-pipe must be in proportion to the working head from which the ram operates. Also, the drive-pipe carries severe internal shock loads due to water hammer, and therefore normally should be constructed from good quality steel water pipe. Normally the length of the drive-pipe should be around three to seven times the supply head. Also, ideally the drive-pipe should have a length of at least 100 times its own diameter. The drive pipe must generally be straight; any bends will not only cause losses of efficiency, but will result in strong fluctuating sideways forces on the pipe which can cause it to break loose.
Irrigation potential	• Can irrigate up to 0.1 - 0.4 ha per day
Social considerations	• Suitable for all gender • Communities irrigating in a common area can contribute to purchase the pump
Environmental considerations	• Green-technology with an operational carbon-footprint of zero and is thus environmentally friendly.
Costs	• Investment costs: The estimated cost of a solar pump is 400 US $. • Operation and maintenance costs
Interventions	• Access to spare parts • Mapping potential sites where hydraulic ram pumps can be used • Capacity building in operation and maintenance • Partners: AEATREC-NARO, MAAIF

Figure 5-14 AEATREC-NARO low drive-head hydraulic ram pump model

5.2.6 Small wind powered pumps

Description	▪ Wind power is a renewable and clean source of energy which can be relatively predictable, and is commonly used for water pumping applications. ▪ Wind pumps offer a competitive source of energy for small or medium-scale irrigation schemes and individual use. However, the wind speed should be at least 3.5 m/s for a month. ▪ A dense (multi-bladed) rotor extracts torque from the wind at low wind speeds and shaft rotations per minute. ▪ To pump water, wind pumps can be used to convert wind energy into mechanical energy in which case, the wind mill directly pumps water. Alternatively, wind energy can be converted into electrical energy whereby the wind generates electricity which then pumps water. ▪ Windmills are well adapted for use with submersible water pumps (Figure 5-15). ▪ Diaphragm pump can deliver 60,000 to 75,000 L/day for medium wind speeds (3-4 m/s)
Operation and maintenance	▪ Easy to operate ▪ The main limitation with wind powered pumps is the availability of winds with sufficient speed to turn/rotate the turbine.
Necessary water sources and prevalence	▪ Valley tanks and dams and ground water of sufficient volumes ▪ Requires intermediate storage
Irrigation potential	▪ Acreage: up to 1 ha ▪ Suited for livestock watering especially in the cattle corridors where vast winds exist

Social considerations	▪ Reduction in human drudgery and time to manually irrigate ▪ Reduce silting and pollution of the water source ▪ Reduce erosion of the surrounding catchments ▪ Community empowerment in the management of the water resource
Environmental considerations	▪ Green energy technology with carbon foot print of zero
Costs	▪ Investment costs: The estimated cost of a wind pump is US$5,000 to 10,000 ▪ Operational costs ▪ Life span:
Interventions	▪ Establishment of communal wind mills ▪ Wind roses and potential ▪ Decision support tool to guide in siting and sizing windmills

Figure 5-15 Wind mill for groundwater abstraction

5.3 TECHNOLOGIES FOR WATER CONVEYANCE AND DISTRIBUTION

Water conveyance from intake to crops is an essential element of the irrigation system. Water distribution can be done using canals or pipe systems.

5.3.1 Canal Distribution System

Description	▪ Water is taken in through a diversion structure or from pumps and distributed in open canals. ▪ For larger areas, a network of secondary and tertiary canals is required (Figure 5-16). ▪ Regulating structures are required to control water flow and levels in the canals and the distribution of the appropriate quantity of water to each canal segment, field channel and field outlet. Canal regulating structures include flow and water level regulators, drop structures, inlets and outlets, as well as bridges and siphons for road and drain crossings. ▪ Unlined channels: Designed so that the velocity is low and the bed and sides are not eroded by the water. ▪ Lined channels : Designed to handle high velocities
Operation and maintenance	▪ Given these technical requirements, adequate technical support is required to ensure the proper design and installation of an irrigation canal system. ▪ Farmers need to receive O&M training of the system, as well as advice regarding when and how much water needs to be applied to the various crops. ▪ Maintenance of small scale irrigation is routine work, which must be done to keep an irrigation scheme working properly. ▪ Beneficiaries participate in the construction of scheme through contribution of labour and locally available materials such as stone, sand and gravels.
Necessary water sources and prevalence	▪ Permanent stream diversion works ▪ Small reservoirs like valley tanks and dams. ▪ Lift irrigation (pump supply) from open water and groundwater.
Irrigation potential	▪ The areas are limited in size, 200 ha or less, and the extensions or the new construction schemes are for areas of less than 50 ha.
Social considerations	▪ Users organized in water user association should take initiatives to generate some resource to carry out some maintenance works of this sort.
Environmental considerations	▪ Main canals highly charged with sediment. ▪ The silt load is observed to come either along with the river water (suspended and bed load) or as a runoff from upstream nearby

	catchment. ▪ The seeping water is seen to ooze through the underneath of the soil and hence significant quantity of irrigation water is lost prior to arriving to the distributing watercourses. Besides the loss of valuable diverted water, the seepage moisture in the vicinity houses is also a serious problem in the area. ▪
Costs	▪ With basic assumptions of excavation costs of US$4 per m^3, concrete work at US$150 per m3 for lining and cost of regulating structures, canal construction costs may amount to US$600–800/ha including partial lining (10 percent) and small regulation structures. To reduce the costs, local contractors should do as much of the work as possible. When large national or international contractors undertake the design and construction, costs are likely to be substantially higher and investment costs can range from US$3,000 to 8,000/ha. ▪ Operation and maintenance costs: These are mainly maintenance costs estimated at US$120 to 160 /ha ▪ Life span: 10 to 15 years
Interventions	▪ Technical support in canal construction and canal maintenance for irrigation schemes > 2 ha.

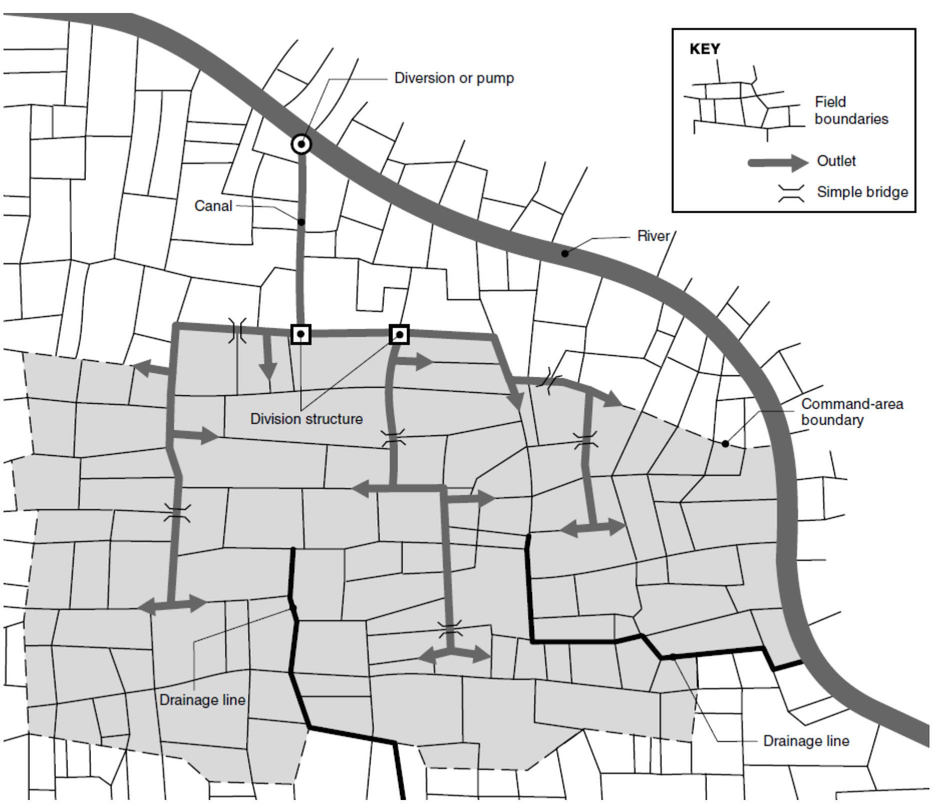

Figure 5-16 Typical small-scale irrigation system

5.3.2 Pipe Distribution System

Description	▪ The low-pressure pipe distribution system has proved to be an effective and efficient irrigation technology for small-scale farmers and small farmers' groups for conveying water efficiently to fields and crops. In general, most materials (PVC or Polyethylene (PEP) pipes, flexible hoses) are locally available and farmers can install the system with minimal technical assistance, or with help from locally trained private irrigation technicians. ▪ To reduce operating pressures, it is sometime necessary to introduce break-pressure tanks, which are usually made of concrete or ferrocement. If such tanks are used, the hydraulic gradient starts again at tank water level. If suitably sized, these tanks can be used within the system as storage tanks to meet peak demand.
Operation and maintenance	▪ Easy to operate ▪ Easy to maintain
Necessary water sources and prevalence	gravity from an elevated small reservoir or river diversion works for gravity fed system or direct pumping with a small motorized pump, a pressure treadle pump from other water sources
Irrigation potential	▪ The total irrigable area depends on the pipe size. ▪ system efficiently is able to convey and distribute water directly to the irrigated areas (> 0.5 ha) and fields, rotating irrigation between the different pipe outlets. Pipe outlets or hydrants are placed at a regular distance (±20 m) on a fixed underground PVC system. ▪ The outlets can be opened directly to the field or connected to a flexible hose that can be dragged around to irrigate individual fields and crops
Social considerations	▪ Suitable for all gender
Environmental considerations	▪ Environmentally friendly
Costs	▪ Investment cost: The investment required for low-pressure pipe systems is still high at around US$1,000 to 1,500/ha, but can easily be recovered as water allocation and easy operation ensure more accurate and efficient water application, resulting in higher yields, water savings and larger irrigated areas. ▪ Operation and maintenance cost: These are mainly maintenance

	costs estimated at US$20 to 40/ha ▪ Life span: 8 to 12 years
Interventions	▪ Access to affordable pipes ▪ Technical support in designing and sizing of pipes ▪ Partners: Privates sector dealers

5.4 TECHNOLOGIES FOR FIELD WATER APPLICATION

5.4.1 Watering cans

Description	• The watering can (Figure 5-17) is a container usually made of plastic with a capacity of about 10 litres, usually with a handle and a spout, used to water plants by hand. At the end of the spout, a device, like a cap, with small holes can be placed to break up the stream of water into droplets, to avoid excessive water pressure on the soil or on delicate plants. • The watering can provides a simple and accessible irrigation technique.
Operation and maintenance	• Suitable in areas where labour is abundant • No specialized skills required • Spare parts are readily available • Portable
Necessary water sources and prevalence	• In general, the water source should be in walking distance (< 50 m away from the area to be irrigated); not be too deep; and allow easy access for filling the watering can. • Normally, irrigated gardens are found along rivers and streams or where surface and groundwater can easily be reached. • Not sensitive to water quality
Irrigation potential	• Acreage: suitable for small gardens (50 to 100 m^2). • Widely practiced for small-scale vegetable production but is suitable for all crops. • Use of watering can is applicable to most types of soils.
Social considerations	• Suitable for all gender • Group of farmers can share out the watering can
Environmental considerations	• No negative environmental impacts
Costs	• Investment cost: UGX 10,000 to 15,000 for a watering can that irrigates around 100 m^2, i.e. 1,750,000 per hectare (ha). • Sometimes additional costs are incurred when a water source has to be

	made accessible, for instance via a pump, reservoir or open well. • Operation and Maintenance cost: Labour costs depending on the distance of the water source to the field, can vary between US$1,200 and 1,500/ha per season (assuming US$1/workday and a crop with a water requirement of 3,000 to 5,000 m^3/ha). • Life span: 2 years
Intervention	• Popularization among resource poor commercially oriented farmers • Training in irrigation scheduling

Figure 5-17 Irrigation of vegetables with watering can

5.4.2 Bottle/jerrycan drip irrigation

Description	▪ In this type of irrigation, a bottle/jerrycan is filled with water and sealed with a top (Figure 5-18). Then a small hole is punched onto the bottle top and bottom. The water enters the soil as small droplets, lasting several days, after which the bottle is refilled.
Operation and maintenance	▪ The technique is laborious for areas > 0.25 acres.
Necessary water sources and	▪ Water source should be close to the field ▪ Suitable for areas with limited water sources

prevalence	
Irrigation potential	▪ Can be used on to irrigate areas up to 0.25 acres. ▪ Suitable for tree establishment for vegetable irrigation in small gardens.
Social considerations	• Suitable for all gender
Environmental considerations	▪ No negative environmental impacts
Costs	▪ Investment cost: o The estimated cost of 2-3 US $ for purchasing a jerrycan and no cost for the bottles
Interventions	• Popularization among resource poor commercially oriented farmers as first aid to avoiding total crop failure ▪ Training in irrigation scheduling


Figure 5-18 Manual irrigation: Bottles used for drip irrigation of coffee seedlings (top right); Jerrycan used for drip irrigation of water melon (bottom left).

5.4.3 Conventional drip irrigation system

Description	• An irrigation system in which water is slowly applied directly to the root zone of plants by means of emitters at very low flow rates (0.5–10 litre/hr), located at selected points along the delivery line (on flexible polyethylene tubes). • System components include (Figure 5-19): o Pump unit: Takes water from the source and provides the right pressure for delivery into the pipe system. o Control head: Consists of valves to control the discharge and pressure in the entire system. It may also have filters to clear the

	water. Some control head units contain a fertilizer or nutrient tank. These slowly add a measured dose of fertilizer into the water during irrigation. o Main, submain lines and laterals: Supply water from the control head into the fields. Usually made from µPVC, PVC, HDPE or PE o Pressure regulators o Emitters or drippers: Devices used to control the discharge of water from the lateral to the plants. • Adaptable to small pumps and water sources such as rivers and wells. • Drip-irrigation application may be simply managed and programmed with an AC- or battery-powered controller, thereby reducing labor cost. • Adaptable to oddly shaped fields or those with uneven topography or soil texture, thereby maximizing the use of available land.
Operation and maintenance	• Low labor requirement • Simple to operate • Polyvinyl chloride (PVC) and polyethylene parts are widely available in several diameters and are easy to assemble. • Many customized, easy-to-install connectors, end caps, and couplers are available in different diameters. • Cutting and gluing allows for timely repairs
Necessary water sources and prevalence	• Water source must be able to supply maximal daily requirement. For example: 1 m^2 of vegetables grown in dry, hot regions will require 5-10 liter/day at peak growth under highest temperatures. • *Water quality: I*t is essential to use clean water free of sediments. Generally, water used in drip irrigation is usually filtered. Blockage may occur if the water contains sediments, algae, fertilizer deposits and dissolved chemicals which precipitate such as calcium and iron.
Irrigation potential	• Acreage: Recommended for farmers irrigating at least 1 acre of land. Acreage depends the water availability and energy source. • Crop types: Row crops especially vegetables and fruits. For tree crops one or more emitters (button drippers) can be provided for each plant. Generally only high value crops are considered because of the high capital costs of installing a drip system. • Suitable slopes: Normally the crop should be planted along contour lines and the water supply pipes (laterals) would be laid along the contour also. This is done to minimize changes in emitter discharge as a result of land elevation changes.

	• Soils: Suitable for most soils. On clay soils water must be applied slowly to avoid surface water ponding and runoff. On sandy soils higher emitter discharge rates will be needed to ensure adequate lateral wetting of the soil.
Social considerations	▪ *Suitable for all gender*
Environmental considerations	▪ In drip irrigation there is minimum control of the microclimate ▪ Salinity is one problem need to be controlled in drip irrigation, where the salts accumulate during the irrigation. To control the salinity in drip irrigation, the bed surface should be raised above that normally used for planting. The drip system in then operated moving the salts into the raised portion of the bed
Costs	▪ Investment costs: US$ 5,000 to 10,000 /ha without considering water delivery system from the water source to the field. ▪ Operation and maintenance costs: Mainly energy costs estimated at US$500–700/ha and labour costs estimated at US$500 to 600 /ha. ▪ Life span: 4 to 6 years
Interventions	▪ Investment cost still high for most individual famers for irrigated areas > 1 ha ▪ Capacity building for system operation and minor maintenance

Figure 5-19 Conventional drip irrigation system

5.4.4 Drum Drip Irrigation Kits

Description	• The suited technology drum irrigation kits for small-scale irrigation is the 1/8th acre (0.05 ha)

	• System components include (Figure 5-20);
	  ○ A Drip irrigation kit is a low-pressure (<10 m head) package comprising the core components required to install a drip irrigation system.
	  ○ Comprises a water tank drum made of any material capable of holding at least 1,000 L placed 2-5 m above ground to ease refilling. The water tank should have 1” outlet installed at minimal height of 15 cm above tank’s bottom. Also to be installed is a drainage outlet at the bottom of the tank to allow sediments to be washed out.
	  ○ Main valve 1” installed at tank’s outlet.
	  ○ Filter: 1” Screen filter
	  ○ a 3/4" (25 m) of HDPE manifold/distribution line connecting between tank and dripper lines
	    ○ Drip lines: 600-m roll of 16 mm drip line enough to set 20 drip lines of 30 m each. drip lines are connected to distribution line by start connectors
	• Adaptable to small manual and motorized pumps
	• Can be adapted to rainwater harvesting structures.

Operation and maintenance	• Low labor requirement. • Simple to operate. Does not require prior acquaintance with modern irrigation. • Polyvinyl chloride (PVC) and polyethylene parts are widely available in several diameters and are easy to assemble. • Many customized, easy-to-install connectors, end caps, and couplers are available in different diameters. • Cutting and gluing allows for timely repairs
Necessary water sources and prevalence	• Water source must be available near by the plot and able to supply maximal daily requirement. For example: 1 m^2 of vegetables grown in dry, hot regions will require 5-10 liter/day at peak growth under highest temperatures. • *Water quality:* Clean water free of sediments. • *Water quantity.* Limited water resources available.
Irrigation potential	• *Acreage: 100-500 m^2* • *Crop types:* Row crops especially vegetables and fruits. For tree crops one or more emitters (button drippers) can be provided for each plant. • The drum kit system can be used to grow 2,000 plants if the plant spacing is 30 cm. Crops such as tomatoes and eggplant require a

	spacing of 60 cm and are better adapted to the drip lines with outlets spaced at 30 cm yielding a plant population of ~1,000 plants. • *Suitable slopes:* Flat land or slight slopes. • *Soils:* Suitable for most soils. On clay soils water must be applied slowly to avoid surface water ponding and runoff. On sandy soils higher emitter discharge rates will be needed to ensure adequate lateral wetting of the soil.
Social considerations	▪ Suitable for all gender
Environmental considerations	▪ Salinity is one problem need to be controlled in drip irrigation, where the salts accumulate during the irrigation. To control the salinity in drip irrigation, the bed surface should be raised above that normally used for planting. The drip system in then operated moving the salts into the raised portion of the bed
Costs	• Selling systems in kit form helps to keep the cost down and the idea is that farmers can add to the kits as they receive cash from the increased profits on their crops. Low-cost can mean low initial capital outlay rather than low-cost per hectare. • Investment costs: US$ 200-400, per unit for 500 m^2 resulting into investment costs per hectare of US$10,000–12,000/ha. • Operation and maintenance costs: • Life span:
Interventions	▪ Investment cost still high for most individual famers ▪ Capacity building for system operation and minor maintenance ▪ Partners: Private dealers, MWE, MAAIF

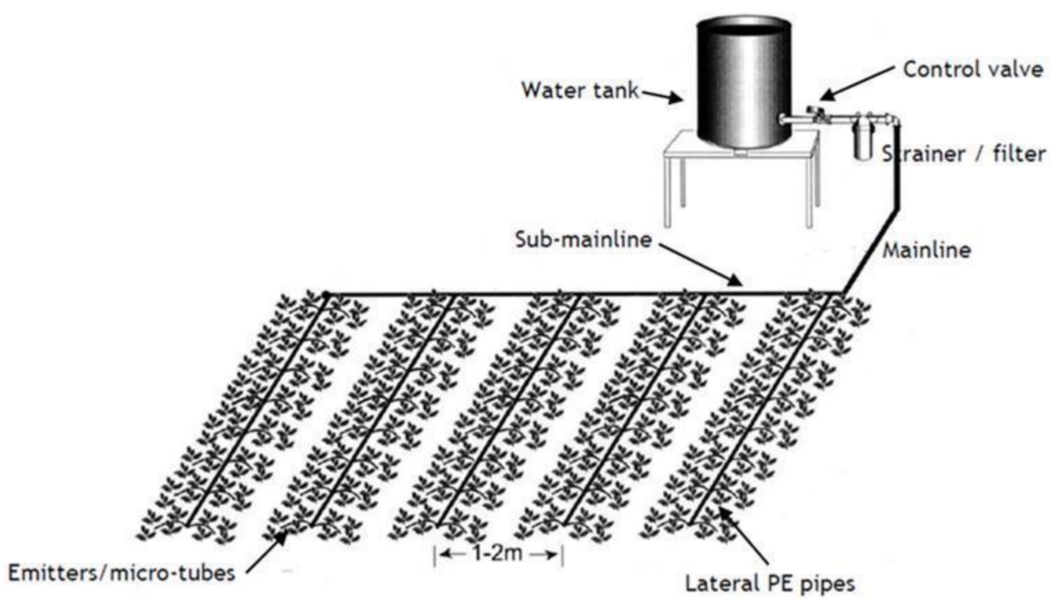

Figure 5-20 Drum irrigation kit

5.4.5 Greenhouse drip irrigation kits

Description	System components (Figure 5-21) • Comprises of; drip kit (200 m^2), green house (~200 to 300 m^2) , water tank (at least 500 litres) raised 2-5 m above the ground. • Suppliers usually provide a knapsack sprayer, safety gear and inputs for the first season (i.e. seeds, fertilizers and agro – chemicals). • The system is gravity–fed and enables the farmers to apply fertilizers and agrochemicals with the irrigation water to the crops • Adaptable to small manual and motorized pumps. • Can be adapted to rainwater harvesting structures.
Operation and maintenance	• Polyvinyl chloride (PVC) and polyethylene parts are widely available in several diameters and are easy to assemble. • Many customized, easy-to-install connectors, end caps, and couplers are available in different diameters. • Cutting and gluing allows for timely repairs
Necessary water sources and prevalence	• Water source must be able to supply maximal daily requirement. For example: 1 m^2 of vegetables grown in dry, hot regions will require 5-10 liter/ day at peak growth under highest temperatures. • *Water quality:* Clean water free of sediments. • *Water quantity.* Limited water resources available. Drip kits are usually promoted along with development of rainwater harvesting structures.
Irrigation potential	• *Acreage: 100-500 m^2* • *Crop types:* High value vegetables. • The greenhouse kit system can be used to grow 900 to 1,400 plants if the plant spacing is 30 cm. Crops such as tomatoes and eggplant require a spacing of 60 cm and are better adapted to the drip lines with outlets spaced at 30 cm yielding a plant population of ~1,000 plants. • *Suitable slopes:* Flat land • *Soils:* Suitable for most soils.
Social considerations	▪ Suitable for all gender
Environmental considerations	▪ Salinity is one problem need to be controlled in drip irrigation, where the salts accumulate during the irrigation. To control the salinity in drip irrigation, the bed surface should be raised above that normally used for planting. The drip system in then operated moving the salts into the raised portion of the bed
Costs	• Investment costs: US$3,500 to 4,500 per kit for 200 m^2 resulting into US$ 175,000 to 225,000 per ha. • Operation and maintenance cost: • Lifespan of major components of the kit:

	○ Prefabricated galvanized metal greenhouse structure= more than 15 years ○ Drip irrigation system = not less than 6 years if well maintained ○ Cover for the greenhouse= 5-6 years

Figure 5-21 Greenhouse drip irrigation kit (inset: tomatoes)

5.4.6 Drag-hose sprinkler irrigation system

Description	• It involves using a flexible pipe to manually irrigate with water under pressure directly onto the plants (Figure 5-22). The spray is created by attaching a slotted head or by simply squeezing the pipe outlet. Hosing should be only be used as an emergency measure while more reliable methods of sprinkler irrigation is being organized.
Operation and maintenance	• Easy to operate • Potentially time consuming • low levels of skills required
Necessary water sources and prevalence	• Gravity fed from an overhead reservoir or pumping from nearby water source (surface or groundwater)
Irrigation potential	• Adaptable to any farmable slope, whether uniform or undulating. • Best suited to sandy soils with high infiltration rates although they are adaptable to most soils. • Suited for most row, field and tree crops and water can be sprayed over or under the crop canopy.
Social considerations	▪ *Suited for all gender*
Environmental	▪ *Potential for causing erosion*

considerations	
Costs	▪ Investment costs: Estimated investment costs of a movable drag and hose systems are around US$1,000–2,000/ha. ▪ Operation and maintenance costs: Due to the amount of fuel required for this high-pressure system, operational costs are high, amounting to US$800–1,000/ha per season. ▪ Life span: 5 to 8 years

Figure 5-22 Drag and hose sprinkler irrigation system

5.4.7 Overhead (rotating head) sprinkler irrigation system

Description	• An irrigation system in which water is applied using perforated pipes or nozzles operated under pressure so as to form a spray pattern. ▪ The rotating head sprinkler system (Figure 5-23) has small sized nozzles are placed on riser pipes fixed at uniform intervals along the length of the lateral pipe. The lateral pipes are usually laid on the ground surface. The nozzle of the sprinkler rotates due to a small mechanical arrangement which utilizes the thrust of the issuing water.
Operation and maintenance	▪ Easy to operate ▪ Medium level skills required

Necessary water sources and prevalence	• Gravity fed from an overhead reservoir or pumping from nearby water source (surface or groundwater)
Irrigation potential	• Adaptable to any farmable slope, whether uniform or undulating. • Best suited to sandy soils with high infiltration rates although they are adaptable to most soils. • Suited for most row, field and tree crops and water can be sprayed over or under the crop canopy.
Social considerations	▪ *Suited for all gender*
Environmental considerations	▪ *Potential for causing erosion*
Costs	▪ Investment costs: Estimated investment costs of the sprinkler systems are around US$3,000–5,000/ha. ▪ Operation and maintenance costs: Due to the amount of fuel required for this high-pressure system, operational costs are high, amounting to US$800–1,000/ha per season. ▪ Life span: 5 to 8 years
Interventions	▪ Access to sprinkler technology ▪ Cost still prohibitive to many resource poor commercially oriented farmers ▪ Capacity building for operation and maintenance ▪ Partners: MAAIF, MWE, AEATREC-NARO and Private dealers

Figure 5-23 Overhead sprinkler irrigation system (Source: Mati, 2012)

5.4.8 Micro sprinkler system

Description	▪ The micro-sprinkler irrigation system (Figure 5-24) is a variation of conventional sprinkler system, whereby water is applied to localized areas using mini sprinklers or spray jets. Thus, smaller quantities of water are applied and the diameter of wetting is smaller Micro-sprinklers utilize lower operating pressures and are capable of higher uniformity coefficient. These systems are suited to irrigation of widely spaced tree crops as they can irrigate just the tree root zone and avoid wetting unnecessary spaces between the trees. ▪ They are also suited to irrigation of closely spaced horticultural crops and widely spaced row crops.
Operation and maintenance	▪ Easy to operate ▪ Medium level skills required
Necessary water sources and prevalence	• Gravity fed from an overhead reservoir or pumping from nearby water source (surface or groundwater)
Irrigation potential	• Adaptable to any farmable slope, whether uniform or undulating. • Adaptable to most soils. ▪ Suited for tree crops and vegetables
Social considerations	▪ *Suited for all gender*
Environmental considerations	▪ Environmental friendly. ▪ Care should be taken to avoid soil erosion
Considerations as to affordability	▪ *Investment costs: Estimated investment costs of the sprinkler systems are around US$3,000–5,000/ha.* ▪ *Operation and maintenance costs: Due to the amount of fuel required for this high-pressure system, operational costs are high, amounting to US$800–1,000/ha per season.* ▪ *Life span: 5 to 8 years*

Figure 5-24 Micro sprinkler irrigation system

5.4.9 Rain gun sprinkler system

▪ *Description*	▪ An irrigation system in which water is applied using perforated pipes or nozzles operated under pressure so as to form a spray pattern. ▪ A movable sprinkler system consists of the following components (Figure 5-25): ▪ A pump unit and suction pipe. The suction pipe has a foot valve that is dipped into the water. ▪ Mainline (Fire hose 2") and its connectors. This is the delivery pipe that is connected from the pump to the sprinkler. ▪ Sprinkler unit: This will consist of sprinkler head, tripod stand and other connectors
Operation and maintenance	▪ Easy to operate ▪ Portable ▪ Easy to maintenance ▪ Low level skill required
Necessary water sources and	• Gravity fed from an overhead reservoir or pumping from nearby water source (surface or groundwater)

prevalence	• The source should sustain an extraction rate of at least 5 m^3/hr
Irrigation potential	• Adaptable to any farmable slope, whether uniform or undulating. • Best suited to sandy soils with high infiltration rates although they are adaptable to most soils. • Suited for most row, field and tree crops and water can be sprayed over or under the crop canopy.
Social considerations	▪ *Suited for all gender*
Environmental considerations	▪ *Potential for causing erosion*
Costs	○ Investment costs: Estimated investment costs of the sprinkler systems are around US$3,000–5,000/ha. ○ Operation and maintenance costs: Due to the amount of fuel required for this high-pressure system, operational costs are high, amounting to US$800–1,000/ha per season. ○ Life span: 5 to 8 years

Figure 5-25 Rain gun movable sprinkler irrigation system

5.4.10 Basin irrigation

Description	▪ Basins are flat areas of land, surrounded by low bunds (Figure 5-26). The bunds prevent the water from flowing to the adjacent fields.
Operation and maintenance	▪ Basin irrigation requires less labour and skills compared to furrow irrigation ▪ Requires regular maintenance
Necessary water sources and prevalence	▪ Requires large quantity of water
Irrigation potential	• Basin irrigation method is suitable for crops that can withstand temporary water-logging (e.g. 12-24 hours) e.g., lowland rice. • Suitable for relatively flat land.
Social considerations	▪ *Suited to all gender* • Gravity irrigation implies a certain level of organization among water users to ensure • satisfactory levels of operations and maintenance. The model of water user associations • promoted in most cases has often shown to be much more difficult to implement than • initially planned (see next section). Individual irrigation in many cases reduces the need for ▪ joint management and maintenance of irrigation infrastructures. *Communities can pool for operation and maintenance of canals and bunds*
Environmental considerations	▪ *Care should be taken to avoid erosion* ▪ *Ponding could lead to malaria proliferation*
Costs	▪ Investment costs: US$ 3,000 to 8,000 /ha ▪ Operation and maintenance costs: ▪ Life pan

Figure 5-26 Basin irrigation of lowland rice

5.4.11 Furrow irrigation

Description	▪ **Furrow irrigation:** Furrows are small channels (Figure 5-27), which carry water down the graded land slope between crop rows. Water infiltrates into the soil as it moves along the slope. The crop is usually grown on the ridges between the furrows. Suitable for row crops and for crops that cannot withstand water-logging for long periods.
Operation and maintenance	▪ Levelling of farm plots for a more regular and efficient water distribution in the field, ▪ Requires regular maintenance
Necessary water sources and prevalence	▪ Requires large quantity of water
Irrigation	▪ Furrow irrigation is suited to (i) row crops such as maize, sunflower, sugarcane, soybean, (ii) crops that would be damaged by inundation,

potential	such as tomatoes, vegetables, potatoes, beans, (iii) fruit trees such as citrus, grape and (iv) broadcast crops (corrugation method) such as wheat. ▪ Furrow irrigation is suited to most soil types. However, as with all surface irrigation methods, it works best with heavy clay soils. Coarse sands are not recommended as percolation losses can be high. ▪ Furrow irrigation is suited to very gently sloping with slopes less than 2%
Social considerations	▪ Gravity irrigation implies a certain level of organization among water users to ensure satisfactory levels of operations and maintenance. The model of water user associations promoted in most cases has often shown to be much more difficult to implement than initially planned (see next section). Individual irrigation in many cases reduces the need for joint management and maintenance of irrigation infrastructures.
Environmental considerations	▪ Potential for erosion if the field slopes and discharge are not controlled
Costs	▪ Investment costs: US$ 3,000 to 8,000 /ha ▪ Operation and maintenance costs: ▪ Life span:

Figure 5-27 Furrow irrigation of onions

6 IRRIGATION INVESTMENT APPRAISAL

6.1 IRRIGATION SCENARIOS

The following irrigation assumption guided costing of the irrigation project:

i. Average reference evapotranspiration is ~5 mm/day
ii. Water source exists with substantial volumes of water to support irrigation
iii. Complete irrigation targeting offseason
iv. Maximum head difference between water source and the irrigation field is 20 m i.e. a pump with head of 50 m is sufficient
v. Water source is close to the irrigation field (<100 m)

The choice of irrigation system depends on the type of crop, the relative position of water source to the irrigation field, type and characteristics of water source, energy source, type of soil and investment costs. Based on the above, seven most suitable irrigation system combinations (appropriate options) for small farmers are considered for investment appraisal for different value chains:

1. Gravity => pipeline => temporary storage => drip irrigation system;
2. Motorized pump => pipeline => temporary storage => drip irrigation system;
3. Solar PV pump => pipeline => temporary storage => drip irrigation system;
4. Gravity => pipeline => overhead sprinkler irrigation system;
5. Motorized pump=> pipeline => overhead sprinkler irrigation system;
6. Motorized pump => pipeline => rain gun sprinkler irrigation system;
7. Gravity => pipeline/lined canal => surface (furrow/basin) irrigation system.

The investment and operation and maintenance costs of the irrigation system combinations (options) are shown in Table 3.

Table 3 Estimated investment and operation and maintenance costs of the most feasible irrigation system combinations and suitable enterprises

Options	Irrigation system	Water pump costs ($)	Temporary water storage tank ($)	Field irrigation system costs ($/ha)	Seasonal energy costs ($)	Seasonal labour costs ($)	Annual maintenance costs ($)	Total investment cost costs ($/ha)	Annual Total O&M Costs ($/ha)	Total investment cost costs (Ugx/ha)	Annual Total O&M Costs (Ugx/ha)	Suitable enterprises*
1	Gravity => pipeline => temporary storage => drip irrigation system	-	1,000	7,500	-	500	750	8,500	1,750	30,600,000	6,300,000	Groundnuts, Vegetables (cabbage, onions, tomatoes,) Fruits (apples, passion fruits, mangoes, citrus)
2	Motorized pump => pipeline => temporary storage => drip irrigation system	1,000	1,000	7,500	600	550	950	9,500	3,250	34,200,000	11,700,000	Vegetables (cabbage, onions, tomatoes,) Fruits (apples, passion fruits, mangoes, citrus)
3	Solar PV pump => pipeline => temporary storage => drip irrigation system	5,000	2,000	7,500	-		800	14,500	800	52,200,000	2,880,000	Groundnuts, Vegetables (cabbage, onions, tomatoes), Fruits (apples, passion fruits, mangoes, citrus)
4	Gravity => pipeline => overhead sprinkler irrigation system	-	-	5,000	-	600	500	5,000	1,700	18,000,000	6,120,000	Maize for flour, Upland rice, Groundnuts, climbing beans, Coffee-robusta (Clonal), Vegetables (cabbage, onions, tomatoes), Fruits (apples, passion fruits, mangoes, citrus)
5	Motorized pump=> pipeline => overhead sprinkler irrigation system	1,000	-	5,000	700	700	600	6,000	3,400	21,600,000	12,240,000	Groundnuts, Vegetables (cabbage, onions, tomatoes), Fruits (apples, passion fruits, mangoes, citrus)
6	Motorized pump => pipeline => rain gun sprinkler irrigation system	1,000	-	2,000	1,000	800	400	3,000	4,000	10,800,000	14,400,000	Groundnuts, Vegetables (cabbage, onions, tomatoes), Fruits (apples, passion fruits, mangoes, citrus)
7	Gravity => pipeline/lined canal => furrow/basin irrigation system	-	-	5,000	-	1,000	500	5,000	2,500	18,000,000	9,000,000	Maize for flour, upland rice, Groundnuts, Vegetables (cabbage, onions, tomatoes), Fruits (apples, passion fruits, mangoes, citrus), lowland rice,

*for interest rate of 20% p.a

6.2 IRRIGATION INVESTMENT APPRAISAL

Investment appraisal involved assessing different types of irrigation systems and their feasibility for the target value chains.

The investment appraisal was guided by the following assumption:

i) Analysis period of 10 years;

ii) The discount/interest rate used is the prime lending rate of commercial banks which varies from 18% to 25% as at 1st October, 2017, an interest rate of 20% was considered in the analysis.

iii) The scale of irrigation considered is 1 ha.

The costs considered included capital costs and operation and maintenance costs that cover energy costs, maintenance costs and labour costs. For each investment irrigation scenario, the Net present value, Internal rate of return (IRR) and Return on Investment.

Sensitivity analysis was done to determine the risks associated with the investment by considering the following:

- Projected costs increased by 20 percent;
- Projected benefits decreased by 20 percent;
- Interest rates increase and decrease by 25%

The results show that profitability of a business venture depends on the type of crop (variety) and the irrigation scenario. Gravity irrigation is the most feasible irrigation configuration for all value chains due to the high energy costs in pumped irrigation systems.

The finds also show that it is most profitable to invest in irrigation of horticulture-vegetables followed by horticulture-fruits. The order of the other value chains is oilseeds (ground nuts), Pulses-beans(climbing variety), cereals-rice, coffee and lastly cereals-maize for flour.

For horticulture fruits, it is most profitable to invest in irrigation of passion fruits followed by mangoes, apples and citrus.

For horticulture-vegetables, it is most profitable to invest in irrigation of tomatoes, followed by cabbage and onions. There are other vegetables which are profitable but were not analyzed in this study.

For coffee, it is most profitable to irrigate robusta (clonal) coffee than coffee arabica.

The findings of an investment appraisal of the various irrigation system combinations as subjected to different value chain is at interest rates of 15%, 20% and 25% p.a for 1 ha farm size are show below.

With 20% reduction in project costs, various irrigation system combinations may become feasible to different value chains. This could be through a subsidy programme like that of the Dutch embassy which offers 25% subsidy on solar energy equipment. A rise in project costs by 20%, various irrigation system combinations may be rendered un-feasible to different value chains.

Table 4 Investment appraisal of the various irrigation system combinations as subjected to different

Suitable enterprise	Rank of enterprise per irrigation scenario	NPV**			Benefit/cost ratio			IRR***	ROI****		
		15%	20%	25%	15%	20%	25%		15%	20%	25%
Option 1	Gravity => pipeline => temporary storage => drip irrigation system										
Tomatoes-Comando-F1	1	339,287,071	278,154,416	232,120,883	5.15	4.78	4.44	210%	1109%	909%	759%
Passion fruits-purple	2	96,491,710	74,585,276	58,017,658	2.18	2.01	1.86	70%	315.33%	244%	190%
Cabbage-Fabiola	3	81,322,363	62,661,351	48,597,015	2	1.9	1.7	68%	266%	205%	159%
Mangoes-tommy	4	76,947,248	51,354,069	23,117,289	1.94	1.76	1.34	33%	251.46%	148%	76%
Onions-red Creole	5	71,716,440	54,636,959	41,763,072	1.9	1.7	1.6	62%	234%	179%	136%
Apples	6	67,354,430	39,461,514	19,963,048	1.82	1.54	1.3	32.80%	487.26%	369%	286%
Citrus-oranges	7	50,665,949	24,556,878	6,607,825	1.62	1.33	1.1	27%	165.57%	80%	22%
Ground nuts-Serenut 14R	8	50,626,821	38,073,961	28,610,914	1.8	1.6	1.5	57%	207%	156%	117%
Pulses-beans (NABE-8C - Climbing variety)	9	13,107,260	5,677,270	66,735	1.2	1.1	1	24%	43%	19%	0%
Option 2	Motorized pump => pipeline => temporary storage => drip irrigation system										
Tomatoes-Comando-F1	1	301,629,341	245,309,434	202,896,447	3.53	3.31	3.1	157%	882%	717%	593%
Passion fruits-purple	2	58,833,980	41,740,294	28,793,222	1.4927255	1.39228	1.2979425	44%	172%	122%	84%
Cabbage-Fabiola	3	43,664,633	29,816,369	19,372,579	1.4	1.3	1.2	39%	128%	87%	57%
Mangoes-tommy	4	39,289,518	22,129,633	-6,107,147	1.33	1.23	0.94	#DIV/0!	114.88%	36%	-18%
Onions-red Creole	5	34,058,710	21,791,977	12,538,636	1.3	1.2	1.1	34%	100%	64%	37%
Apples	6	29,696,700	6,616,532	-9,261,388	1.25	1.06	0.9	21.90%	87%	19%	-27%
Ground nuts-Serenut 14R	7	20,500,637	11,797,975	5,231,366	1.2	1.1	1.1	30%	75%	43%	19%
Citrus-oranges	8	13,008,219	-8,288,104	-22,616,611	1.11	0.92	0.77	18%	38.04%	-24.23%	-66%
Option 3	Solar PV pump => pipeline => temporary storage => drip irrigation system										
Tomatoes-Comando-F1	1	328,932,983	267,078,874	220,489,694	4.57	4.16	3.79	146%	630%	512%	422%

Passion fruits-purple	2	86,137,623	63,509,735	46,386,469	1.94	1.75	1.59	51%	165%	122%	89%
Cabbage-Fabiola	3	70,968,276	51,585,809	36,965,826	1.8	1.6	1.5	48%	136%	99%	71%
Mangoes-tommy	4	66,593,161	39,722,880	11,486,100	1.72	1.5	1.15	28%	127.57%	65%	22%
Onions-red Creole	5	61,362,353	43,561,417	43,561,417	1.7	1.7	1.5	44%	118%	83%	58%
Apples	6	57,000,342	28,385,972	8,331,858	1.62	1.34	1.11	27.70%	286%	217%	167%
Ground nuts-Serenut 14R	7	42,343,551	29,213,528	19,305,963	1.6	1.4	1.3	40%	101%	70%	46%
Citrus-oranges	8	40,311,862	13,481,336	-5,023,364	1.4376893	1.15929	0.9364509	23%	77.23%	26%	-10%
Pulses-beans (NABE-8C - Climbing variety)	9	2,753,173	-5,398,272	-11,564,454	1	0.9	0.9	14%	5%	-10%	-22%
Option 4	Gravity => pipeline => overhead sprinkler irrigation system										
Tomatoes-Comando-F1	1	358,417,777	295,908,775	248,846,588	6.72	6.3	5.91	322%	1991%	1644%	1382%
Passion fruits-purple	2	115,622,416	92,339,636	74,743,363	2.85	2.65	2.47	104%	642%	513%	415%
Cabbage-Fabiola	3	100,453,069	80,415,710	65,322,720	2.6	2.4	2.3	108%	558%	447%	363%
Mangoes-tommy	4	96,077,954	68,079,774	39,842,994	2.5343808	2.34306	1.7860118	42%	533.77%	350%	221%
Onions-red Creole	5	90,847,146	72,391,319	58,488,777	2.5	2.3	2.2	100%	505%	402%	325%
Apples	6	86,485,136	62,331,894	36,688,753	2.38	2.23	1.72	42.60%	480%	318%	204%
Citrus-oranges	7	69,796,655	42,311,238	23,333,530	2.1146641	1.75818	1.4603176	35%	387.76%	235%	130%
Ground nuts-Serenut 14R	8	65,931,386	52,277,449	41,991,478	2.3	2.2	2	93%	458%	363%	292%
Pulses-beans (NABE-8C - Climbing variety)	9	32,237,966	23,431,630	16,792,440	1.5	1.4	1.3	49%	179%	130%	93%
Upland rice	10	24,248,087	16,757,214	11,108,199	1.39	1.3	1.22	40%	135%	93%	62%

Coffee (Robusta-clonal)	11	15,948,991	5,073,872	-2,641,906	1.3	1.1	0.9	21%	89%	28%	-15%
Coffee (Arabica)	12	15,948,991	5,073,872	-2,641,906	1.3	1.1	0.9	21%	89%	28%	-15%
Maize for flour	13	15,174,153	9,177,225	4,652,729	1.24	1.16	1.09	32%	84%	51%	26%
Option 5	Motorized pump=> pipeline => overhead sprinkler irrigation system										
Tomatoes-Comando-F1	1	316,426,534	259,325,214	216,331,390	4.02	3.81	3.6	212%	1465%	1201%	1002%
Passion fruits-purple	2	73,631,173	55,756,074	42,228,165	1.703877	1.60349	1.5075179	60%	341%	258%	196%
Cabbage-Fabiola	3	58,461,826	43,832,148	32,807,522	1.6	1.5	1.4	56%	271%	203%	152%
Mangoes-tommy	4	54,086,711	35,564,575	7,327,796	1.52	1.43	1.09	28%	250.40%	122%	34%
Onions-red Creole	5	48,855,903	35,807,757	25,973,579	1.5	1.4	1.3	50%	226%	166%	120%
Apples	6	44,493,892	29,816,695	4,173,554	1.43	1.36	1.05	26.60%	206%	96%	19%
Citrus-oranges	7	27,805,412	5,727,676	-9,181,668	1.2658058	1.06	0.89	22%	128.73%	27%	-43%
Ground nuts-Serenut 14R	8	21,110,784	13,567,258	7,880,456	1.2	1.2	1.1	34%	122%	79%	46%
Option 6	Motorized pump => pipeline => rain gun sprinkler irrigation system										
Tomatoes-Comando-F1	1	336,229,185	277,480,692	233,253,307	4.96	4.74	4.52	324%	3113%	2569%	2160%
Passion fruits-purple	2	93,433,824	73,911,552	59,150,082	2.1017444	1.99565	1.8923822	91%	865%	684%	548%
Mangoes-tommy	3	73,889,362	52,486,493	24,249,714	1.8712818	1.79185	1.3658492	35%	684.16%	412%	225%

Apples	4	64,296,544	38,787,789	21,095,472	1.76	1.52	1.32	34.80%	595%	359%	195%
Cabbage-Fabiola	5	58,461,826	43,832,148	32,807,522	1.6	1.5	1.4	56%	541%	406%	304%
Onions-red Creole	6	48,855,903	35,807,757	25,973,579	1.5	1.4	1.3	50%	452%	332%	240%
Ground nuts-Serenut 14R	7	48,180,513	37,534,982	29,516,854	1.7	1.6	1.6	76%	558%	434%	342%
Citrus-oranges	8	47,608,063	23,883,154	7,740,250	1.56	1.32	1.12	28.27%	441%	221%	72%
Pulses-beans (NABE-8C - Climbing variety)	9	10,049,374	5,003,546	1,199,159	1.1	1.1	1	26%	93%	46%	11%
Option 7a	Gravity => pipeline/lined canal => furrow irrigation system										
Tomatoes-Comando-F1	1	351,396,482	290,565,721	244,770,976	6.05	5.75	5.47	378%	3254%	2690%	2266%
Passion fruits-purple	2	108,601,121	86,996,582	70,667,751	2.56	2.42	2.29	112%	1006%	806%	654%
Cabbage-Fabiola	3	93,431,775	75,072,656	61,247,108	2.3	2.2	2.1	118%	865%	695%	567%
Mangoes-tommy	4	89,056,659	64,004,161	35,767,382	2.28	2.17	1.65	41%	824.60%	534%	331%
Onions-red Creole	5	83,825,851	67,048,265	54,413,164	2.2	2.1	2	108%	776%	621%	1715%
Apples	6	79,463,841	58,256,281	32,613,140	2.14	2.06	1.6	41.40%	735.78%	480.30%	301.97%
Citrus-oranges	7	62,775,360	36,968,184	19,257,918	1.9	1.6	1.35	34%	581.25%	342%	178%
Ground nuts-Serenut 14R	8	60,314,350	48,003,005	38,730,988	2.1	2	1.9	99%	698%	556%	448%

Pulses-beans (NABE-8C - Climbing variety)	9	25,216,671	18,088,575	12,716,827	1.4	1.3	1.2	46%	233%	167%	118%
Upland rice	10	17,226,792	11,414,160	7,032,586	1.25	1.19	1.13	36%	160%	106%	65%
Coffee (Robusta-clonal)	11	8,927,696	-269,182	-6,717,519	1.1	1	0.9	18%	83%	-2%	-62%
Coffee (Arabica)	12	8,927,696	-269,182	-6,717,519	1.1	1	0.9	18%	83%	-2%	-62%
Maize for flour	13	8,152,858	3,834,170	577,116	1.12	1.06	1.01	26%	75%	36%	5%
Option 7b	Gravity => pipeline/lined canal => basin irrigation system										
Lowland rice	1	22,000,452	14,405,466	8,678,082	1.28	1.20	1.14	35%	122%	80%	48%

*Feasibility at 100% of the estimated costs

**NPV-Net Present Value, ***IRR-Internal Rate of Return, ****ROI-Return on Investment

7 CONCLUSIONS AND RECOMMENDED OPTIONS FOR PRO-POOR APPROPRIATE IRRIGATION TECHNOLOGIES

7.1 CONCLUSIONS

Irrigation has been shown to raise farm incomes by increasing the cultivable land area, enhancing crop choice, increasing cropping intensity, allowing the option to use high-yielding varieties, and provide the conditions for land groupings to boost labor productivity. Irrigation also brings many spill-over effects, such as increased and more evenly distributed farm labor opportunities, improved wage rates, reduced out-migration, improved security against impoverishment, low food prices, better nutrition throughout the year, growth in non-farm employment, greater urban-rural contact and new social networks, and more water for nonagricultural uses. Thus, with the majority of the poor living in rural areas and involved in agricultural activities, UGOPAP's planned intervention in development of irrigation have definite pro-poor directions. However for the irrigation intervention to be effective the following recommendations are proposed.

7.2 RECOMMENDATIONS

The recommendations provided are developed from the understanding of the requirements of the recommended pro-poor appropriate irrigation technologies, the potential users and lessons from reviewed information.

7.2.1 Strengthening the Legal, Policy and Institutional Environment

This is in relation to development, implementation and enforcement of appropriate laws and regulations. Of particular note is the agent requirement to ensure that the Draft National Irrigation Policy is finalized. It is important that the Irrigation policy is clear about the contribution of pro-poor appropriate irrigation technologies in the agricultural sector.

The collaboration between MAAIF and MWE in relation to the promotion of pro-poor appropriate irrigation technologies should be streamlined and available opportunities that enhance dispersion and penetration of the technologies extensively publicized. There is need for a clear linkage between agencies and the technology users.

7.2.2 Adequate Irrigation Management

The technology users need to be strongly involved in the technology management process. However, the for successful farmers' involvement, they need to be very well conversant with the functional and operation requirements of the specific pro-poor appropriate irrigation technologies and the water requirements of the crops. The required knowledge may be attained from well-organized technology users' training sessions and regularly targeted information dissemination.

7.2.3 Financial Management

The technology users need to understand the financial requirement cycle for successful management of pro-poor appropriate irrigation technologies. Proper financial management will ensure availability of capital to operate, maintain, construct or repair irrigation infrastructure and agricultural input. A process to support the technology users to become competent in implementing/creating a sound financial cycle needs to be developed, based on local needs and conditions.

7.2.4 Adequate Monitoring and Extension Services

The majority of technology users would be transitioning to a new way of crop production. As such they will require dedicated and effective mentoring, monitoring and extension services. This will provide opportunities for implementation of early corrective measures of emerging issues before causing failure. The process should be robust enough to document and disseminate successful practices amongst the users of pro-poor appropriate irrigation technologies. Demonstrations need to be included in the extension programme and they are most effective if implemented over an extended period, spanning a full agricultural calendar.

7.2.5 Technical Support Services

Good results in the implementation of the pro-poor appropriate irrigation technologies can be directly attributed to good institutional system with effective support services. Technical support includes selection, design, implementation of the technology, introduction of appropriate agricultural practices and provision of spares maintenance of the system.

7.2.6 Market Access

Improved market access is important to ensure reduced marketing margins allowing higher farm gate prices. This requires improved communications for delivery of necessary quality information to the technology users, institutional development and higher traded volumes. Thus the pro-poor irrigation intervention will help the poor only if it is carried out as part of a broader set of pro-poor changes.

Bibliography

1) Agriculture Sector Strategic Plan (ASSP) 2015/16 to 2019/2020.
2) Analysis of relative profitability of key Ugandan agricultural enterprises by agricultural production zone. Uganda Strategy Support Program (USSP) Background Paper no. USSP 04 (IFPRI, 2009).
3) Assessment of the Irrigation Potential in Burundi, Eastern DRC, Kenya, Rwanda, Southern Sudan, Tanzania and Uganda (Nile Basin Initiative report, 2012)
4) Best Practices and Guidelines for Water Harvesting and Community Based (Small Scale) Irrigation in the Nile Basin (Nile Basin Initiative report, Anderson and Burton 2009).
5) Best practices for rainwater harvesting from open surfaces with storage in structures (Nile Basin Initiative report, Mati 2012).
6) Best practices for water harvesting and storage within valleys (Nile Basin Initiative report, Mati 2012).
7) Biltonen, E.; Hussain, I., Tuan, D. D. (Eds.) 2003. Pro-poor Intervention Strategies in Irrigated Agriculture in Asia. Vietnam Country Paper. Colombo, Sri Lanka: International Water Management Institute.
8) Comprehensive Africa Agriculture Development Programme (CAADP) compact 2003.
9) Cost Benefit Analysis (CBA) of Climate Change Adaptation and Prioritization in Agriculture, Environment and Water Sectors in Uganda: Final Vulnerability Assessment Report (FAO report, Baastel 2016).
10) Developing groundwater and pumped irrigation systems (Nile Basin Initiative report, Mati 2012).
11) Drip Irrigation in Smallholder Markets: A cross-partnership study (USAID & FINTRAC 2016).
12) Enhancing agricultural production and productivity in Uganda through irrigation. Issue No. 25. (Economic Policy Research Centre, 2014).
13) Estimating Yield of Food Crops Grown by Smallholder Farmers. A Review in the Uganda Context (International Food Policy Research Institute, 2011).
14) FAO Irrigation and Drainage Paper 66: Crop yield response to water (FAO, 2012).
15) FAOSTAT 2017.
16) Farming Systems Report. Synthesis of the Country Reports at the level of the Nile Basin. Information Products for Nile Basin Water Resources Management (FAO, 2011).
17) Hussain, I. (2005). Pro-poor intervention strategies in irrigated agriculture in Asia. International Water Management Institute, Colombo, Sri Lanka.
18) In-field water management in irrigated agriculture: adaptable best practices (Nile Basin Initiative report, Mati 2012).
19) Irrigation best practices for smallholder agriculture (Nile Basin report, Mati 2012).
20) Irrigation Development in Uganda: Constraints, Lessons Learned, and Future Perspectives (Wanyama et al 2017).
21) Irrigation subsector review: Republic of Uganda (FAO, 1998)
22) Livelihood mapping and zoning exercise: Uganda (The Famine Early Warning System Network, 2010).
23) Low Cost Micro Irrigation Technologies For The Poor (DFID, 2003).
24) MAAIF Agricultural Sector Development Plan 2015/16 to 2019/2020-Revised Water for Agricultural Production Framework Implementation Plan
25) MAAIF Operationalization of The Non-ATAAS Component of The Development Strategy and

Investment Plan 2010/11 to 2014/2015- Water for Agricultural Production Framework Implementation Plan
26) MWE Draft National Irrigation Master Plan 2010-2035
27) MWE Water Sector Strategy and Investment Plan (2010-2035)
28) National Agricultural Extension Policy 2016
29) National Environment Management Policy (1994);
30) National Water Resources Assessment Report - Uganda. Ministry of Water and Environment. Directorate of Water Resources Management 2013
31) Opportunities for private sector participation in agricultural Water Development and Management (IWMI, Working Paper 100, de Vries et al 2005).
32) Smith, M., Muñoz, G., & Sanz Alvarez, J. (2014). Irrigation techniques for small-scale farmers: key practices for DRR implementers. FAO
33) State of the River Nile Basin 2012
34) Statistical Abstracts for at least the past 5 years (Uganda Bureau of Statistics).
35) The 2010–2011 Integrated Rainfall Variability Impacts, Needs Assessment and Drought Risk Management Strategy (Office of the Prime Minister, 2012).
36) The Draft National Irrigation Policy 2017
37) The Land Act 1998
38) The National Agricultural Policy 2013
39) The National Development Plan II 2015/16 to 2019/2020
40) The National Land Policy 2013
41) The National Water Act, 1999 – Cap 152
42) The National Water Policy 1999
43) Uganda's Vision 2040
44) WaterAid (2011) technology Notes.
45) Water for Food: Innovative Water Management Technologies for Food Security and Poverty Alleviation (UNTCTAD, UN 2011).
46) Water Resources Management-Water Productivity in Uganda (FAO National Report, Kiggundu 2014)
47) Wortmann, C. S., & Eledu, C. A. (1999). Uganda’s agro ecological zones: A guide to planners and policy makers. Centro Internationale de Agricultural Tropical CIAT. Kawanda, Uganda.

Sources of Relevant Information

The main sources of literature/key stakeholders included:

i. Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) and her agencies:
   - *National Agricultural Advisory Services (NAADS),*
   - *National Research Organization (NARO),*

ii. Ministry of Water and Environment (MWE) and her agencies,

iii. Ministry of Finance, Planning and economic Development (MoFPED) and her agencies,
   - *National Planning Authority (NPA),*
   - *Uganda Bureau of Statistics (UBOS),*
   - *Bank of Uganda.*

iv. Ministry of Trade, Industry and Cooperatives,

v. Office of the Prime Minister (OPM),

vi. Nile basin Initiative,

vii. East African Community,

viii. Civil Society Organizations (CSOs) engaged in food security and poverty alleviation:
   - *Hunger Project;*
   - *aBi Trust;*
   - *Uganda National Farmers Federation (UNFF).*

ix. International Food Policy Research Institute,

x. UN Agencies:
   - *Food and Agriculture Organization (FAO),*
   - *World Food Programme (WFP),*

xi. World Bank,

xii. African Development Bank.