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IRRIGATION-FED AGRICULTURE

The Medium-Cost Business Case for Irrigation-fed Vegetable Production in Northern Uganda.

Promoting Rural Development – Water for Agricultural Production

IMPRINT

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Registered offices
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'Promoting Rural Development in Northern Uganda'
Plot 19, Nakasero road
GIZ office or address line 1
Address line 2
Phone +256 (0)417 888 500
giz_prudev@giz.de
www.giz.de/en/worldwide/59817.html

As at
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Design
AFC Agriculture and Finance Consultants GmbH.
Text
Philip Oboma Ouma
On behalf of the
AFC Agriculture and Finance Consultants GmbH
Baunscheidtstr. 17 | 53113
Bonn | Germany.

The medium-cost business case for irrigation-fed vegetable production in Northern Uganda.

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List of Abbreviations

AFC	Agriculture and Finance Consultants
BMC	Business model canvas
CAPEX	Capital expenditures
CBT	Community based trainer
CBWRP	Catchment based water resource plan
CSO	Civil society organization
DCO	District commercial officer
DLG	Districts and local governments
DNRO	District natural resources officer
DPO	District production officer
EBIT	Earnings before interest and taxes
EU-DINU	European Union Development Initiative for Northern Uganda
FAO	Food and Agriculture Organization
FG	Farmer group(s)
FMNR	Farmer managed natural regeneration
GIZ	German Agency for International Cooperation
ISO	International Standards Organization
Kg	Kilogrammes
L	Litres
m	Metres
mm	Millimetres
MSMEs	Micro, small, and medium enterprises
NARO	National Agriculture Research Organization
NGO	Non-governmental organization
NU-TEC	Northern Uganda transforming the economy
PE	Polyethylene (a type of plastic)
PDC	Permaculture design course
PVC	Polyvinyl chloride (commonly used plastic)
OA5	Output area five
PRUDEV	Promoting Rural Development in Northern Uganda
Qty	Quantity
Sq m	Square metres
UGX	Ugandan shillings
WHO	United Nations World Health Organization
WRM	Water resources management
WSPP	Water source protection plan

List of Tables, Figures and Boxes

On behalf of: Agriculture and Finance Consultants GmbH (AFC) and GIZ PRUDEV

Author: Hannes Van den Eeckhout

Contributors: The AFC Team (Marty Fokkink, Juliet Akumu and Damasco Rubangakene) and Isaac Okwir (Irrigation equipment expert and dealer)

Pictures by: The AFC Team

1. INTRODUCTION & CONTEXT

While the average rainfall in Northern Uganda is rather high, rains are found to be erratic and more unreliable in recent years. After a heavy storm, one interviewee mentioned:

> ***"Rains are very late this year, and when they come, they come with a lot of power. It's not like before, people have cut too many trees."***

He was right. For inland areas like Northern Uganda, water cycle experts like Walter Jehne argue that *forests bring rain, it's not rain bringing forests*. The water harvesting and holding capacity of forests and wetlands is much higher than that of a mono-crop field or barren land. Think of the temperature difference in a tropical forest (more humid, cooler air) versus when digging on a farm out in the sun.

Two factors are increasing the challenge of producing vegetables in Northern Uganda all year round: climate change and human pressure on nature, mainly deforestation and the invasion of wetlands. **Climate change** threatens to bring longer and more unpredictable periods of drought, more pests and plagues, heavy rains, and flooding. When cutting more trees (deforestation) and invading more wetlands – for rice production, draining wetlands by uncontrolled water extraction, or for other reasons – more soil is left exposed directly to the sun. Rainwater evaporates more quickly and less of it is kept in the soil for plant growth, leaving the soil ever more exposed to continue drying up. **Human intervention in nature** can further accelerate the negative impacts of climate change or, if water management is done well, reduce it.

This is the reason for water harvesting and using irrigation to produce vegetables in Northern Uganda – and the importance of doing so responsibly. Two dry seasons are experienced: the main one runs from December to March generally, the second one from June to August. Therefore, using **manual or mechanical irrigation** provides a strong opportunity to both improve food security and incomes of households in Northern Uganda.

The **Promoting Rural Development** in Northern Uganda (PRUDEV) programme implemented by GIZ since 2017 works in selected districts (Kitgum, Agago, Oyam, Lira, Dokolo, Amolatar, Gulu, Pader and Otuke). The main goal for the programme is: *"the economic development of the rural economy in selected regions of Northern Uganda improved".* Working with district local governments (DLGs), farmers cooperatives and groups, MSMEs, CSOs and other public and private stakeholders, the programme is structured into 5 output areas: i) local economic development, ii) strengthening farmer organisations, iii) market integration, iv) promotion of climate smart agriculture, v) water for production.

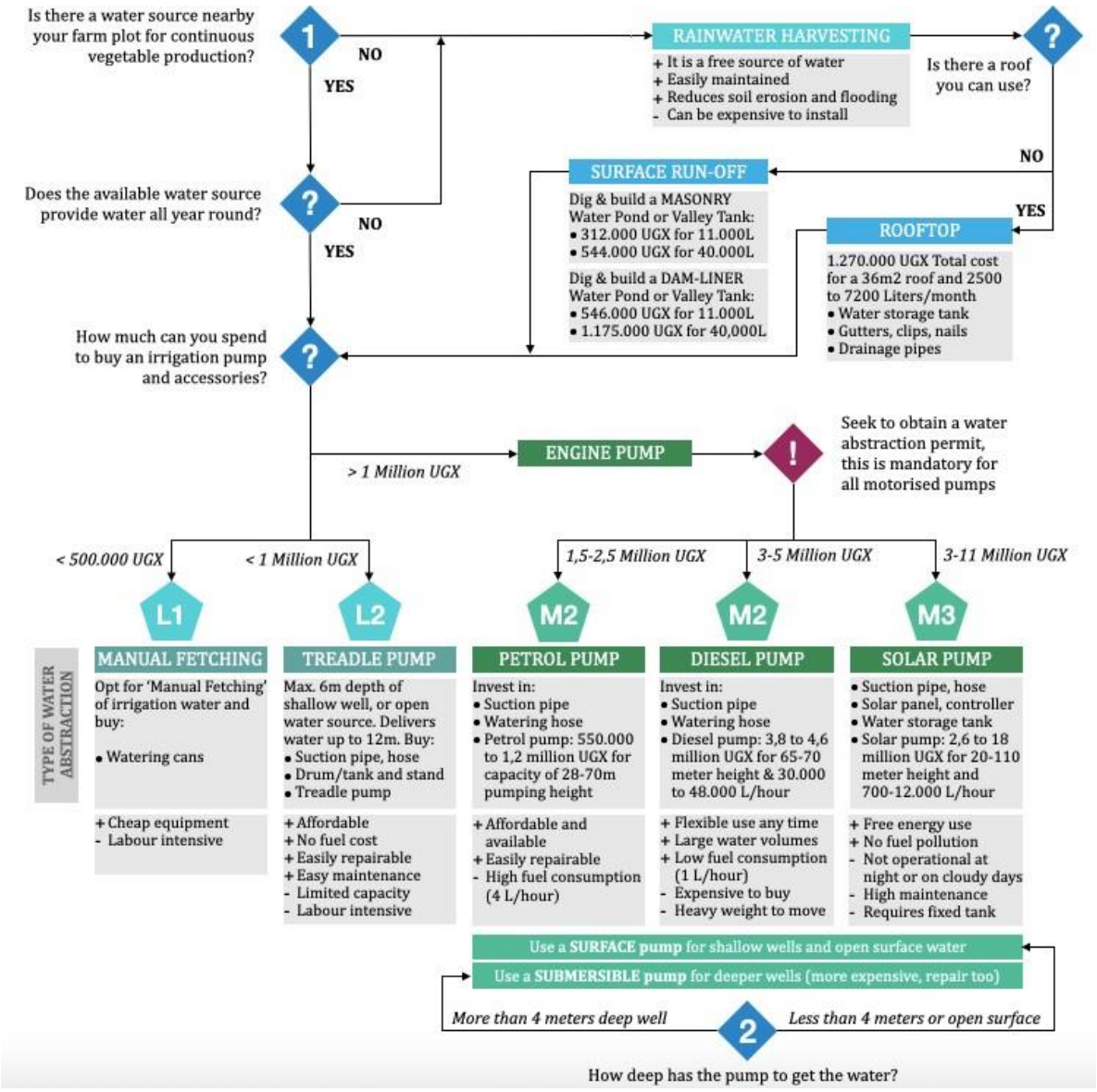
Output Area 5 (OA5) is focused on capacity building and implementing **irrigation-fed vegetable production and sustainable water resource management** (WRM) with smallholder farmer groups in 9 districts. They mainly produce 5 crops: tomatoes, cabbage, eggplants, onions, green peppers (and in some cases, watermelon) for the local and national market. This component, being implemented by Agriculture and Finance Consultants (AFC) since March 2020, works with about 1000 smallholder farmers that are organized in 53 farmer groups. 5 to 40 members come together in those groups to jointly produce vegetables on plots of 1 to 2 acres, using simple irrigation techniques, where the water source is majorly a natural stream, river, or a pond. Seven individual farmers are also included in the project.

This manual aims to demonstrate the **medium-cost business case for irrigated vegetable production** and marketing in Northern Uganda. A low-cost business case, comparing the treadle pump option and manual fetching, is also available. Based on the acquired knowledge, experiences and lessons learnt by the team and PRUDEV (OA5) participants, these guidelines can serve any local government, organization or farmers group in Northern Uganda that plans to **start irrigated agricultural production**.

2. DECISION MAKING CHART

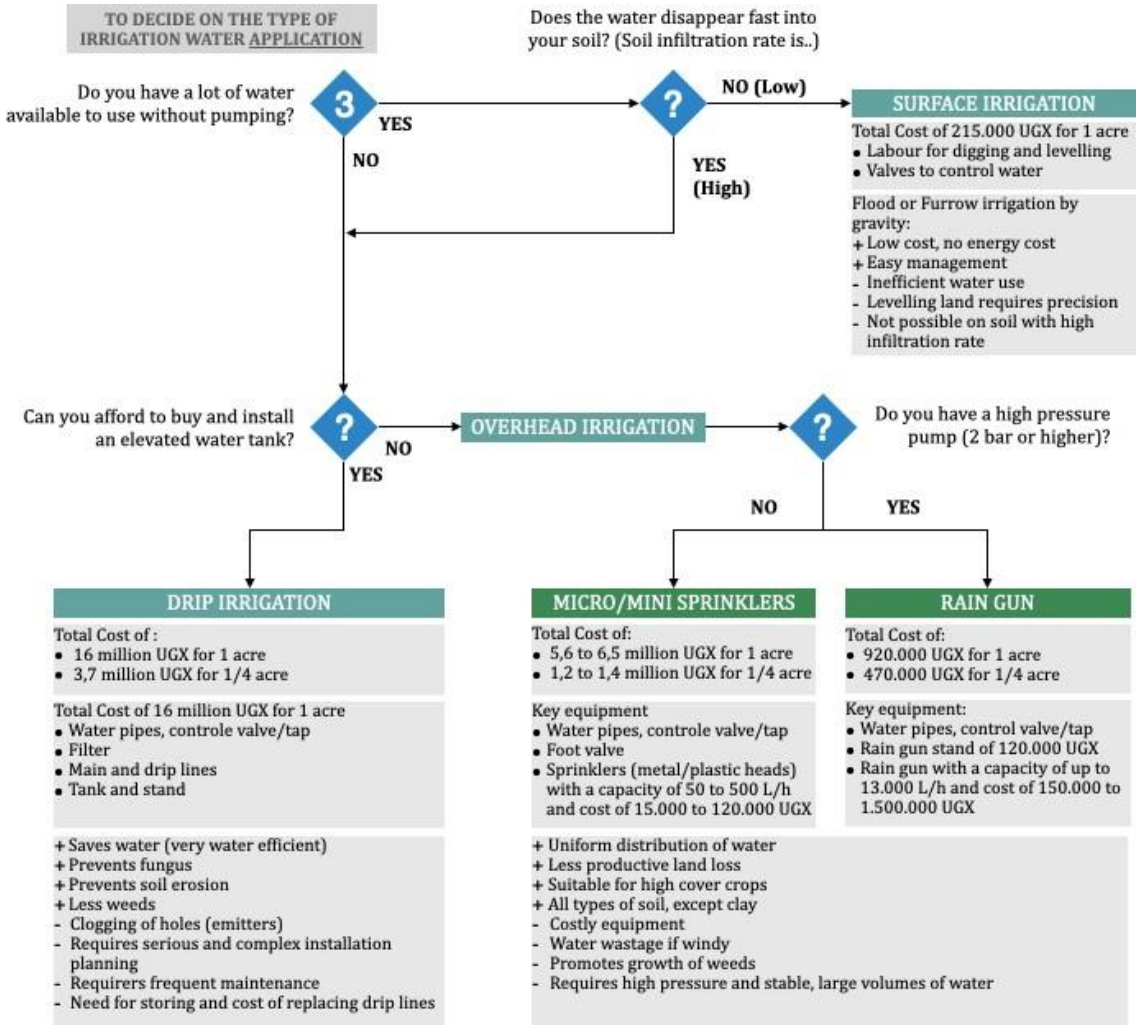
To make a thoughtful decision on what kind of irrigation system to implement as a farmer group or individual, the investment costs for buying the irrigation equipment are decisive. Yet, operational costs (e.g., fuel for running a pump, maintenance, repair, etc.) must also be considered. Other production and marketing related aspects are the same for both low- and medium-cost models. **The decision-making chart below shows the key questions to consider when choosing the best medium-cost solution**. The medium-cost model is presented in this business case. If you want to opt for a low-cost solution, look for that (similar) guide. Start with step 1 to assess your situation.

Figure 1. Decision-making chart on type of water abstraction method.



Follow the decision-making arrows and questions. Continue with step 2 if you plan to invest in an engine pump. Subsequently, decide on which water application mechanism you are going to use with the third step in the diagram below. Note that all prices and costs are provided as a reference. they were noted in 2022 and might be subject to inflation.

Figure 2. Decision-making chart on type of water application mechanism.



These decision-making charts contain a summary of the content laid out in the rest of this document, to get you started quickly. Make sure to refer to the different sections of this manual for more clarity on any of the elements, questions, and information in this overview.

How to use this publication?

This manual aims to present a clear business case for starting – and how to start – your irrigation-fed vegetable production project in Northern Uganda. It is based on field research, interviews and 5 technical reports commanded by AFC on behalf of GIZ-PRUDEV.

- Manual on micro & small-scale irrigation technologies for Acholi & Lango sub-regions in Uganda (by MED6 Agrotech, 2021)
- Water balance report, by Isaac Okwir (MED6 Agrotech, 2021)
- Agricultural Production Market Analysis, by Andrew Muganga (Makerere University, 2021)
- Inventory of agro-input dealers report, by Walter Okol (Agrisol Africa Ltd, 2021)
- Cost–benefit analyses of irrigated vegetable production in northern Uganda (2022)

In case you require more detailed and technical information, please consult these sources.

3. THE BUSINESS MODEL CANVAS

The business model canvas (BMC) below describes a summary of the key aspects and opportunity for a farmer group or individual to start with medium-cost irrigated vegetable production.

BMC for Medium-Cost Irrigated Vegetable Production

1. Unique Value Proposition.

To produce and sell vegetables in Northern Uganda during dry season by implementing a medium-cost irrigation system to improve consumption and income.

2. Customer segments.

Farmers and FGs can sell their vegetable produce to 4 types of customers:

i) Individual households in the community
ii) Households in nearby trading centres, towns, and cities
iii) Stallholders, vendors in those markets
iv) Traders, aggregators, off-takers, intermediaries, called 'Awaro' in Acholi

3. Sales channels.

To sell vegetables one has 3 types of sales channels to target:

i) Farmgate sales
ii) Daily markets: sell directly or to stall holders (mostly women) in rural trading centres and city and municipal markets
iii) Auction markets: sell in bulk to traders on weekly and monthly auction markets

4. Customer relationships.

Farmers and their groups often remain price-takers. To contravene this, they could work more intentionally on their relationships with their customers (and different segments) and explore repeat selling, contract farming, and require credit, input and technical assistance provision.

5. Key activities.

⇒ Investments in irrigation equipment
⇒ Buying inputs
⇒ Preparing the field and irrigated plots
⇒ Planting, weeding, pests/disease control
⇒ Irrigation of the field
⇒ Harvest and post-harvest management
⇒ Commercialization

6. Key resources.

⇒ Irrigation equipment (medium cost) for abstraction: petrol, diesel, or solar pump
⇒ Equipment (medium cost) for water application: spray nozzle, rain gun, or drip irrigation
⇒ Inputs: seeds, pest management solutions, manure, fertilizer + labour

7. Key partners.

The District Production or Agriculture (DPO) and Natural Resources (DNRO) Officers can be key partners for funding and starting an irrigation-fed horticulture project as a farmers group or individual. Farmer groups can work with different key partners: district and local governments, commercial partners like farmer-allied intermediaries (buyers), farmer cooperatives and networks, community-based trainers (CBTs), MSMEs and other private sector actors, financial institutions, communities, and civil society organizations.

8. Costs and Investment Options (1 acre).

The initial costs of investment (in UGX):

- Petrol pump + spray nozzle: 2,2 million
- Diesel pump + rain gun: 6,4 million
- Solar pump + drip irrigation: 21 million

Costs of production for 1 acre of tomato farming with irrigation (in UGX) in one dry season:

- Petrol pump + spray nozzle: 6,8 million
- Diesel pump + rain gun: 6,7 million
- Solar pump + drip irrigation: 8 million

9. Revenue streams (1 acre).

Sales of 1 acre of irrigated tomato production, can provide revenues of 10 million UGX per dry season (farmgate price 100 UGX / fruit).

This largely offsets the total costs of production and farmgate sales and can imply gross profits of 2 to 3,3 million UGX per season. The investment can be recovered in 1, 2 and 11 dry seasons for the petrol, diesel, and solar pump set-ups respectively.

Additional revenues may be generated from renting out irrigation equipment or services.

Box 1. The opportunity to eat better in Acholi and Lango

While food insecurity is a dangerous reality in Northern Uganda, local production of vegetables and fruits all year round provides an opportunity to address this dire situation:

- More than 70% of the people depend on subsistence farming for their livelihood.
- The Acholi region is one of the most food insecure regions in Uganda[1].
- In Northern Uganda, 24% of children under five are short for their age, i.e., stunted.
- One quarter of women of reproductive age, 60% of children under five suffer anaemia.
- Stunting and the nodding syndrome are stringent reasons to consider the food insecurity and malnutrition situation in Northern Uganda alarming[2].

In the Acholi subregion a poorly diversified diet is confirmed with staples representing 41% of the dietary energy consumption. While the proportion of nuts and pulses (28%) is remarkably higher than the national average (17%), high consumption of oils and very low consumption of vegetables are bad news. This form of **'hidden hunger'** is detrimental to mental development, productivity and attaining one's potential: vegetables are consumed frequently but in too small quantities and diversity; nuts and pulses, fruits and milk should be consumed more frequently[3].

In addition, key **food safety concerns** are mainly related to poor post-harvest management, the unsafe and excessive application of agrochemicals, and the use of contaminated water sources for irrigation and post-harvest treatment.

Quite some popular local meals and indigenous plants are contributing to a more healthy and nutritious diet. "Boo, Gnuts, Simsim are already more famous. Pumpkin leaves, akeyo, and some fruits like avocados and mangos have the most potential to become more popular," according to Vivian Aciro, a nutritionist in Gulu. However, the negative perceptions towards (green leafy) vegetables – seen as "poor men's food" while they are highly nutritious – and knowledge loss regarding what food is good and how it should be prepared, limit their positive contribution to healthy diets and eating larger proportions of these healthy, available and affordable foods more frequently.

Considering their potential in terms of desirability, convenience, affordability and accessibility – **the 3 top foods** with potential to contribute to improved health and nutrition are: leafy vegetables (Boo, Akeyo, Malakwang, Sukuma Wiki, Dodo and leaves of pumpkin, cassava, sweet potato), fruits (avocado, mango) and nuts (groundnuts, often mixed with *simsim*, sesame seeds).

Producing these vegetables all year round with irrigation techniques, is a key opportunity to make sure they are available at all times for one's family and community. Direct consumption as the most important market.

[1] Country analysis for Uganda, by the IPC on ipcinfo.org, 2020
[2] The Food Security and Nutrition Assessment in Northern Uganda, by UNICEF and partners, 2019
[3] The (UNHS) Uganda National Household Survey 2016/17, by UBOS, 2018

4. SOCIAL REQUIREMENTS

> ***"Social capital is a primary avenue for farmers to access resources, livelihood and market information; and should be considered as a core component of a market-based approach"***[4].

But what is social capital? We can define it as the strength of the relationships, networks, and forms of organisation (officially established or not) that a group of individuals has to work together effectively towards a common goal, to secure support and find solutions.

In other words, belonging to a farmer group can be crucial to obtain technical and/or financial support for your collective irrigation project, from local government authorities and other key partners. When you have more relationships and stronger connections with individuals working in those support structures, your social capital (and that of the group) is stronger. But what is most important here, is the strength of the relationships within the farmer group and the clarity of the internal rules of engagement and decision-making to manage irrigation collectively.

PRUDEV identified a total of 65 smallholder farmer cooperatives and 5 District Farmers' Associations (Adjumani, Gulu, Kitgum, Oyam and Agago) that work mainly with 15 private sector actors (larger buyers, processors) [5] . This assessment revealed a wide variety in terms of productive, commercial, and organisational capacities of these organisations and mentions the so-called "dependency syndrome"[6]. So, what can you do to build and engage in a strong group of farmers for collective irrigation efforts?

🔎 The answer can be found in the ISO Guidelines for Professional Farmer Organization (ISO-IWA-29, 2019) of which the main aspects are included in this chapter.

4.1 Ownership and collective use of the equipment or infrastructure

Great, you decided to engage with your group in the collective purchasing and use of irrigation equipment to grow vegetables together. Yet, experience shows – and it is well known among farmers – that this collective approach is difficult to manage in reality. To avoid conflict and manage it when it arises, see section 4.5., and always make sure to work as a group when there is a shared need and clear advantage.

AFC technical advisors recommend that immovable infrastructures (e.g., elevated tanks) are only invested in by individual farmers to avoid social conflicts. ***"The shared use has been failing too many times. Land owners can claim the assets as theirs and/or they can deny access to the infrastructure to the group, to give two examples of social problems"***.

When your budget requires teaming up with other farmers to form a group to buy and share irrigation equipment and/or work on a shared farming plot, these are some important guidelines:

- **Set clear rules,** about who can use the shared equipment and when, about what if the equipment breaks down when being used by one member, how to manage fuel costs, transport and storing of the equipment, etc.
- **Divide the plot**, so each farmer can work and grow their own line(s) of vegetables and be accountable. This is more recommended than collectively growing the vegetables, to avoid discussion about the work and revenues that correspond to each member. The members of *Aero Farmers* Group in Minakulu, for instance, signal personal priorities taking over: "***In dry season, members come. But when we work together when it is raining, showing up is a problem. There is a conflict of interest, with other fields to attend."***
- **Save collectively.** Most farmer groups save a portion or all the revenues from the sold produce that has been grown on the collective demonstration plot. That money can be used

[4] ReHope project end-line report, by Mercy Corps/Palladium, 2018
[5] Report on the assessment of Farmer Organizations and Cooperatives in Northern Uganda, PRUDEV, 2018
[6] The dependency syndrome alludes to farmer organisations being (made) dependent on development aid handouts, i.e., they would likely not (continue to) exist or remain operational without outside support.

to either pay for repairs, maintenance or replacing of the equipment, and purchasing next seasons inputs (seeds, fertilizer, etc). Some groups also charge a contribution from the sales of the members' individual plots. The women of *Gene Keni Vegetable Growers* in Kitgum charge an annual member fee of 10.000 UGX, safe after sales from their collective plot, and use the available money for extending affordable loans to the members. Rose underlines, ***"What we save should be bigger than what we share,"*** and in 2021 they used 4 million shillings of their revenues for loans to the 13 members.

As a farmer group, you can learn a lot from each other and set-up a committee to organise taking your vegetables to the market collectively. This chapter proposes a series of steps to avoid any trust issues.

4.2 Organizational structure and performance of a group

The standard on organisational strengthening of farmer organisations (ISO-IWA-29) describes a series of recommendations to build and formalize your farmer group. A more professional organisation will perform better, better serve its members and supply its markets. When growing and selling vegetables together, these are key aspects to work on:

- ***What is your mission?*** What is the final purpose of the group? Sharing a common goal works like glue, holding the group together. E.g., ***"We want to improve the quality, sales, and income coming from our vegetables production".***
- ***Reliable quality***: proper quality management is key to satisfy any buyer's expectations, think about the expected size, cleanliness, packaging, colour, quality testing of samples, safe use of quality inputs, etc. of your produce.
- ***Proper Post-Harvest Management***: post-harvest handling, cleaning, grading, storage, transport, etc. are key to maintain or improve the quality of your sold produce. Think about safety and hygiene requirements and keeping records for traceability.
- ***Consistent supply***: you need to maintain good relationships with key buyers and plan production to continuously meet their demands both in terms of quality and quantity.
- ***Establish a market committee***: the members of Onyede Waribe Farmers Group in Pader explain how theirs works: ***"Two people do a market survey before production, to determine demand and what to grow. Before harvest they go and survey the actual price to sell to the best market. After harvest two more join them to go and sell the group's produce from the shared and from individual plots. This can be two times per week, with 1 weekly meeting to present the results and share the proceeds".***
- ***Formalization***: to build trust with your members and (potential) buyers and other business partners, a formally established organisation is key. The constitution and bylaws of the legally registered entity describe the responsibilities and rights of members, operational policies, a written policy to amend the bylaws, the election process for the regular renewal of leadership, the roles and duties of the board, management and staff, and conflict resolution mechanisms. For the joint buying and using of irrigation equipment, registering as a Farmer Group with a constitution at the subcounty level is recommended. This will also allow accessing support from the local government and specially from its agricultural extension officer.

"We provide backstopping of the registered Farmer Groups: technical assistance on best farming practices, related to the dosage and mixing of chemicals, precaution measures and pointers to market information" – Andrew Okettayot, Agriculture Officer, Puranga subcounty.

🔎 To assess the performance of a farmer organisation, the SCOPE Insight methodology as developed by the Agribusiness Market Ecosystems Alliance (AMEA) can be used. To build inclusive and long-term business relations, the LINK methodology provides a good framework and textbook examples.

4.3 Importance of good leadership

Good, honest, transparent, and empathic leadership can make the difference between a successful and failed or disappointing irrigation project – open communication and including the voices of all members are key to build trust.

The PRUDEV (2018) baseline identified four levels of performance of farmer organisations:

(i) Well-organised, large-scale functional business cooperatives
(ii) Well-organised, medium-scale functional business organisations with many opportunities and challenges
(iii) Unorganised, non-functional cooperatives, both lacking leadership and off-takers
(iv) Organised farmer groups, possessing storage facilities and value addition machines, but functioning below capacity

Organisations in category 3 are often created with financial NGO and/or political support without achieving the cooperative mindset. Category 4 are functioning below capacity as they face similar weaknesses as the previous category. So, *which category does, or can your group belong to? And what needs to change to get there? What do the leaders of your group need to do differently?*

4.4 Representation, inclusivity, and governance

Not all responsibility of how well a group is functioning, lies with the leaders of the group, however. All members carry certain responsibility. As a group you must set clear rules of how you wish to engage with each other and how you want to make decisions together. This is called 'governance'. It is important that everyone (including women, youth) feels represented and included in those decision-making structures.

4.5 Formalization

When purchasing shared irrigation equipment and/or engaging in shared revenue streams, it is important to register your farmers group with its constitution at the subcounty level. This also defines the governance mechanisms (see 4.4) and the organizational structure (see 4.2) and roles of leaders (4.3) and members (4.1).

4.6 Conflict management

> ***"Where 2 or more people are, there have to be disagreements. We resolve them by clear information, transparent communication, meeting regularly and reminding members of our constitution"*** **– James, chairmen of Onyede Waribi Farmers Group in Puranga, Pader.**

The best way to manage conflict is to prevent it. This entire chapter highlights important aspects to avoid negative experiences and conflict within your farmer group regarding the collective irrigation project: choose your group and leaders wisely, define a shared purpose, work out shock-proof (but simple) governance mechanisms, and be clear about what works and what does not in collective irrigation projects.

4.7 Relation of the group with local authorities

The local government authorities – the District Commercial (DCO), Production (DPO) and Natural Resources (DNRO) Officers in particular – can be key partners as their mandate is to support groups like yours in the production and sales of farm produce. The district or subcounty can offer in-kind donations or cash-based support for purchase of tools, irrigation equipment, machines, and facilities for inputs, storage, post-harvest handling and transformation, transport, and office equipment. Or, local authorities can support with capacity building in leadership, organisational and financial management, market access and marketing plans, access to finance, conflict resolution and field extension services. As we have seen, the relational capital of the group and its leaders is key to be identified, vocalise key challenges and activate this kind of support.

4.8 Individual knowledge, attitudes, and practices

Three types of mindset change are important to achieve your goals of improved income and food security as an irrigation collective: building trust, staging youth, and valuing local food varieties. Unfortunately, some stubborn attitudes and practices that go against these mindset shifts persist.

ð *Staging Youth Leaders*

In Uganda, 78% of the populations is under 30 years old. While 400,000 youths enter the job market every year, only 9000 new jobs are created. Close to two thirds of youth (58%) are employed in the agricultural sector.

Access to finance and productive resources – including irrigation equipment! – are mentioned by more than half of the youths as a reason to stop them from engaging more actively in agriculture[7]. On the other hand, youth are often more attracted by more urban jobs as boda driver, rolex vendor, etc. in the trading centres. Therefore, staging youth to take up key (leadership) roles and actively engaging them in the collective irrigation project is an important responsibility and an opportunity to make agri-business attractive for youth. As FAO suggests[8], "The new generations play a vital role as agents of change for the transformation of rural areas and agri-food systems. **Youth can play a pivotal role** in revitalizing local economies, driving innovation, strengthening civil society organizations, managing natural resources, and designing public policies for rural development."

ð *Building Trust*

When deciding to engage in group efforts for farming, sales, or irrigation-fed vegetable production, trust issues are a recurrent topic. ***"Money is not properly accounted for,"*** and lack of transparency and record keeping, are put forward by AFC Advisors to explain these trust issues. See 4.1 and 4.6 for recommendations to work around this.

ð *Valuing Local Nutritious food*

As seen in Box 1, a poorly diversified diet limits food security in Acholi and Lango subregions. The stubborn perception that certain green leafy vegetables (the most nutritious ones) like *sukuma wiki, dodo, boo*, etc. are "poor men's food" reduces their contribution to a diversified and nutritious diet. Both for the members of your farmer group and the population in general, it is recommended to eat these affordable vegetables more frequently and in larger quantities.

[7] Implication of limited access to finance on youth participation in agriculture, Kilimo Trust, 2018.
[8] Rural youth and family farming, by FAO on the Family Farming Knowledge Platform, 2022.

5. TECHNICAL REQUIREMENTS

"Drought or low rainfall" is the number one most mentioned and important constraint to agriculture for food production and availability in Uganda.

This dominant factor is mentioned by 60% of the respondents in Uganda[9]. So, have a closer look at this chapter to set up the technical aspects of your irrigation project as a key opportunity to reduce dependence on erratic rains.

This chapter starts with the methods and equipment for abstracting and applying irrigation water, discusses water availability and sustainable use of water resources, and describes other key aspects of irrigation-fed vegetable farming like inputs, farming practices, production planning, harvesting and post-harvest management.

5.1 Water abstraction

The first technical step to start with irrigation-fed vegetable farming, is to make sure that you have access to a body of water that contains water all year round. If that is not the case, you need to work on water harvesting (see Box 2, and sections 5.3 and 5.4). Then, you want to define the *water abstraction method* you will use. This is the way you will pump the water up from the water source to have it ready to use for irrigation on your farm (for water application, see the next section 5.2).

The medium cost options are all mechanised and using engine pumps: the most affordable is the petrol pump, the most sustainable solution in the long term is the solar pump, and the most powerful one is the diesel pump. Low-cost options (fetching water manually or using a treadle pump) are not detailed in this manual. A lot of factors can influence this decision (plot size, group

[9] The Situation of Food Security and Nutrition in Northern Uganda, by Unicef, UBOS and others, 2019.

constellation, distance to water source, etc.) but your available budget will be the key determinant to decide which type of water abstraction method you will opt for.

First, it is important to note that all engine pumps require a water abstraction permit, regardless of whether you will be using an open surface water source or ground well. You can apply for this permit with the district environmental office or the Ministry of water and environment Regional Office in Lira, after a one-time payment of 450.000 and at a yearly cost of 200.000 UGX.

In the following tables, the technical details and expected costs of each type of engine pump are summarised. If you need to use a submersible pump, you will likely buy a solar one and will need to use a water storage solution. Alternatively, you can buy an electrical surface pump and a fuel generator to power it in case you do not have access to the electricity grid.

(i) ***Surface pump***: this type of pump is most used and uses a hard suction pipe to pump the water from the surface area of the water source. The depth from which it can pump water is usually limited to 6 meters (or less). Therefore, surface pumps are used for open surface water and shallow wells. Its advantages are that surface pumps are usually more affordable, portable (theft), easier installation, repairs and maintenance are less difficult.

(ii) ***Submersible pump***: this type of pump is, as the name suggests, submersed in the water source from where it pumps the water. Therefore, they are commonly used in boreholes and deeper wells (where the surface pump can't reach). The submersed part is more prone to wear and tear and is more difficult to maintain and repair.

Table 1. Solar pump	Technical details
Water source	*All types*
Maximum depth of water level	*6 meters for surface pump; pumping height for submersible pump*
Pumping height	*20 – 110 meters*
Capacity	*700 – 12.000 Litres per hour*
Energy source	*Solar*
Advantages	*Free energy use (no fuel costs) and no fuel pollution* *Operates autonomously (does not need close supervision)*
Disadvantages	*Not performant in appropriate irrigation hours* *Not operational at night or on cloudy days* *Lower capacity (or requires access to the grid for larger volumes)* *High maintenance and very expensive repair costs (technician)* *Requires investment in a fixed tank or water tower*
Investment	*Solar pump 2,6 to 18 million UGX* *+ Suction pipe (100.000 UGX), flexible canvas 90m (270.000 UGX), foot valve (30.000 UGX), basic plumbing tools (150.000 UGX)*

These are the key aspects you need to consider when buying a pump:

- The capacity (the volume of water that can be pumped in litres per hour) that you require.
- For a 1-acre plot of vegetable production, a minimum of 15.000 litres per day is needed on average. For tomatoes, for instance, 1 quarter of an acre (about 1000 square metres, 50 by 20 metres) can contain 2778 plants with a spacing of 60x60 cm (or 0,36 square metres per plant; 1000 / 0,36 = 2778). One plant needs 1,1 to 1,2 Litres per day. So, 2778 plants require 3333 Litres per day, multiplied and rounded upwards this implies 15.000 Litres/day for an acre.
- The maximum depth of the water level: from how deep has the pump to get the water and suction it to the pump? The height difference between pump and water level is usually max. 6 metres (surface pump); if deeper, you will probably require a submersible pump.
- The pumping height: how high do you want to pump the water, counting from where the pump will be located?

Table 2. Diesel pump	Technical details
Water source	*All types*
Maximum depth of water level	*6 meters for surface pump; pumping height for submersible pump*
Pumping height	*65 – 70 meters*
Capacity	*30.000 – 48.000 Litres per hour*
Energy source	*Diesel fuel*
Advantages	*Large water volumes (large field)*
	Low fuel consumption (1L/hour)
	Can be used at any time
Disadvantages	*Expensive to buy*
	Heavy weight to move
	Requires skilled person to repair
Investment	*Diesel pump 2,5 to 3,8 million UGX (low vs. high pressure)*
	+ Suction pipe (200.000 UGX), flexible canvas 90m (630.000 UGX), foot valve (100.000 UGX), basic plumbing tools (150.000 UGX)

- Energy costs: which type of energy is used? Which type of fuel? And how much fuel is consumed per pumping hour? This is the largest part of the operational cost of using a fuel-powered pump. Given fuel costs, this can become a significant (daily) recurrent cost.
- Costs and ease of maintenance and repair. Can you do most of it yourself or do you need a skilled (and more costly) technician for most repairs?
- Additional equipment: Which equipment, spare parts, and tools are included in the cost price of the pump? How much will you need to spend on the additional equipment and tools to operate the pump (spray nozzle, controller, suction pipe, watering hose, etc.)?

Table 3. Petrol pump	Technical details
Water source	*All types*
Maximum depth of water level	*6 meters for surface pump; pumping height for submersible pump*
Pumping height	*28 – 70 meters*
Capacity	*18.000 – 35.000 Litres per hour*
Energy source	*Petrol fuel*
Advantages	*Affordable and available pump*
	Lighter and easier to carry and transport
	Easily maintained and repaired
Disadvantages	*High fuel consumption (4 L/hour)*
	Can overheat, should not be used for a long time / large area
	Can have lower power (lower pressure, shorter distance)
Investment	*Petrol pump 550.000 UGX to 1.000.000 UGX (low vs. high pressure)*
	+ Suction pipe (130.000 UGX), flexible canvas 90m (450.000 UGX), foot valve (60.000 UGX), basic plumbing tools (150.000 UGX)

The main difference between a petrol and a diesel pump is that the diesel pump is more powerful, robust, and expensive. Diesel pumps use significantly less fuel per hour when compared to petrol pumps. The petrol pump is easier to maintain and repair and lighter to move around – which is important when you plan it to be used on different locations and/or by different group members.

5.2 Irrigation techniques

When using an engine pump with good water pressure, the best irrigation techniques you can apply are spray nozzle irrigation (directly on the watering hose), (micro and mini) sprinklers (see table 5 for details), a rain gun (= macro sprinkler), or drip irrigation. A disadvantage of direct hosing is that it is heavy work: "***It is hectic, we need 3 people to carry and move the hose, we sometimes can even fall,"*** say the members of Gen Lacwach Vegetable Growers in Atanga, Pader.

The required pressure is 0.8-1 bar for micro sprinklers, 1-1.2 bar for mini sprinklers, and 2 bar or more for a rain gun to throw the water 20-45 meters (depending on the brand of the rain gun). When connecting these sprinklers directly on the fuel pump (and remaining under the maximum pumping height), these pressure requirements are generally met without any problem. If using a water storage tank, the minimum pressure needed for spray nozzle irrigation, micro- and mini-sprinklers can be attained if the tank is elevated to be 12-15m higher than the field.

The **common advantages** for all sizes of sprinkler irrigation (micro, mini, rain gun) are the uniform distribution of water, the fact that less productive land is lost to space for irrigation equipment, and that they are suitable for high cover crops and all types of soil (except clay). In addition, one can do other things while the field is being irrigated – especially if combined with a solar pump, which unlike the fuel pumps does not need close supervision.

Table 4. Rain gun irrigation	Technical details
Pressure needed	*2-5 bar*
Capacity	*12.000-15.000 Litres per hour* *A 1,5" rain gun is appropriate for a 2" water pump*
Advantages	*Good for fast water application over large volumes*
Disadvantages	*Requires a high-pressure pump (or an elevated water tank situated 30-50m higher than the irrigated area, mostly not feasible)* *Can destroy certain crops (e.g., tomatoes) if spray is not adjustable* *Inefficient water use, water can be lost as run-off rather than permeating into the soil, which might stay dry underneath*
Total investment (average) excluding the pump	*Rain gun, stand, 90m hose pipes, suction pipe, foot valve* • *For ¼ Acre: 1.550.000 UGX (rain gun at 350.000 UGX)* • *For 1 Acre: 2.000.000 UGX (rain gun at 800.000 UGX)*

The disadvantages are the cost of the equipment, water wastage (especially if conditions are windy), the fact that rain guns promote weed growth, and that they require high pressure and stable and large volumes of water.

Table 5. Micro/mini-Sprinklers	Technical details
Pressure needed	*0,8 to 1 bar for micro and 1 to 1,2 bar for mini sprinklers*
Capacity	*Micro: 50-120 vs. Mini: 250-500 Litres per hour per sprinkler* *Sprinklers are commonly 1/4" or 1/2"*
Advantages	*Misty, rainy water delivery over 5-8 metres radius*
Disadvantages	*Nozzle openings can easily block with soil (mainly clay soil)* *Sprinklers require removing and cleaning for efficient operation*
Total investment (average) excluding the pump	*Micro sprinklers (incl. lines, fittings, etc.)* • *For ¼ Acre: 1,4 million UGX* • *For 1 Acre: 6,5 million UGX* *Mini sprinklers:* • *For ¼ Acre: 1,2 million UGX* • *For 1 Acre: 5,7 million UGX*

The details of the costs of investment (these are also called capital expenditures or 'capex') are detailed for each water application method in tables 6, 7, and 8. You are advised to consult a technician or technical manuals referenced in this document to understand the irrigation system design and implicit costs into more detail.

Table 6. Rain gun investment	**Unit**	**Qty**	**Cost/unit**	**1 Acre**	**¼ Acre**
Rain gun (throw radius 20-25m for ¼ acre; 35-45m for 1 acre)	Piece	1	350.000 UGX	800.000 UGX	350.000 UGX
Rain gun stand	Piece	1	120.000 UGX	120.000 UGX	120.000 UGX
Delivery hose (flexible canvas) (90m)	Roll	3	210.000 UGX	630.000 UGX	630.000 UGX
TOTAL	**-**	**-**	**-**	**1.550.000 UGX**	**1.100.000 UGX**

Table 7. Mini sprinklers investment	**Unit**	**Qty**	**Cost/unit**	**1 Acre**	**¼ Acre**
Water pipes (40mm)	Metres	150	4.000 UGX	2.400.000 UGX	600.000 UGX
Main line (50mm)	Metres	100	5.600 UGX	560.000 UGX	-
Fittings	Pieces	10	15.000 UGX	600.000 UGX	150.000 UGX
Control valve / tap	Unit	4	76.000 UGX	304.000 UGX	-
Mini sprinklers (8-15m throw radius)	Pieces	8	56.000 UGX	1.792.000 UGX	448.000 UGX
TOTAL	**-**	**-**	**-**	**5.656.000 UGX**	**1.198.000 UGX**

Table 8. Micro sprinklers investment	**Unit**	**Qty**	**Cost/unit**	**1 Acre**	**¼ Acre**
Water pipes (40mm)	Metres	150	4.000 UGX	2.400.000 UGX	600.000 UGX
Main line (50mm)	Metres	100	5.600 UGX	560.000 UGX	-
Fittings	Pieces	10	15.000 UGX	600.000 UGX	150.000 UGX
Control valve / tap	Unit	4	76.000 UGX	304.000 UGX	-
Micro sprinklers (5-8m throw radius) and raiser and fitter to connect to submain	Pieces	18	36.000 UGX	2.592.000 UGX	648.000 UGX
TOTAL	**-**	**-**	**-**	**6.456.000 UGX**	**1.398.000 UGX**

Drip irrigation on the other hand, is more of a precision irrigation technique that is especially relevant if you have relatively little water available and for crops that are sensitive to oversupply of water and fungus growth.

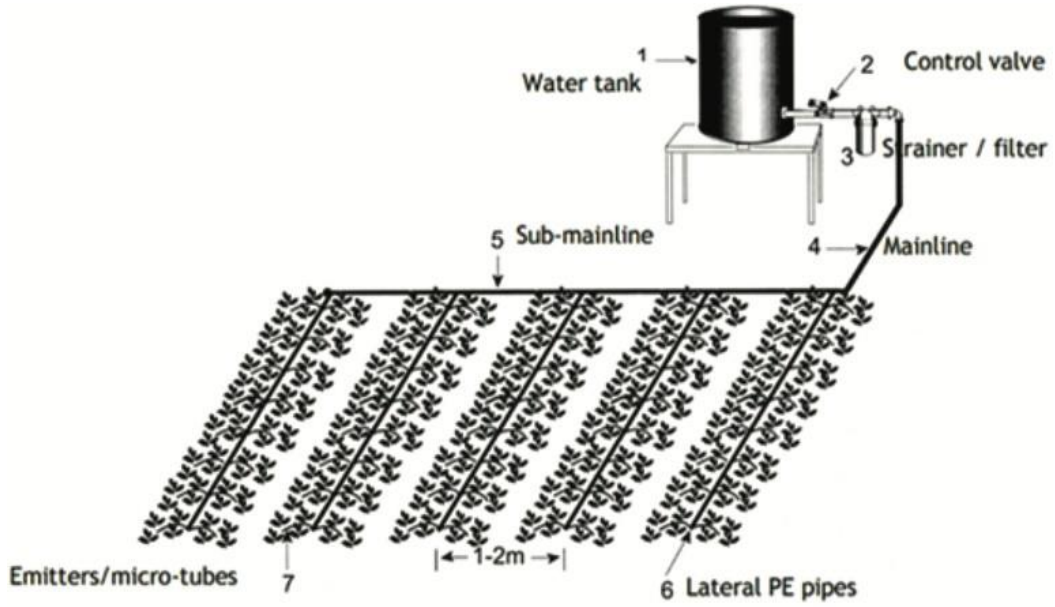
Table 9. Drip irrigation	Technical details
Pressure needed	*Minimal*
Capacity	*1,5-2,5 Litres per hour per emitter (one plant per emitter)*
Advantages	*Saves water, very water efficient* *Prevents fungus and soil erosion* *Less weeds*
Disadvantages	*High initial investment, and cost of replacing driplines* *Clogging of the holes (emitters)* *Requires serious and technical installation planning* *Requires frequent maintenance and appropriate storage*
Total investment (average) excluding the pumping system	• *For ¼ Acre: 3,7 million UGX* • *For 1 Acre: 16 million UGX*

The total average investment costs for a drip irrigation system are presented in **Table 10**. When investing in drip irrigation, the handling and storage (when not in use) of the driplines is key.

Detach, roll, and store them well in a shade (preferably inside), not exposed to the sun that would degrade the plastic quickly and make them brittle. When stored properly, certain brands (e.g., Jane) can last up to 5-7 years.

Table 10. Drip irrigation investment	*Unit*	*QTY*	*Cost/UNIT*	*1 Acre*	*¼ Acre*
Water Tank (5000L vs. 1000L)	Tank	1	-	1.000.000 UGX	320.000 UGX
Stand for the water tank (1m high)	Stand	1	-	1.800.000 UGX	80.000 UGX
Driplines (68 lines of 25m for 1/4 acre)	Metres	1800	1.300 UGX	9.360.000 UGX	2.340.000 UGX
Drip fittings (starter rubber, barb, straight connector, drip end cup; 4 per line)	Fittings	272	1.000 UGX	1.088.000 UGX	272.000 UGX
Drip blank (to connect the submains underground to the driplines)	Metres	40	1.000 UGX	160.000 UGX	40.000 UGX
Distribution lines (main) (PVC 2 inch)	Metres	30	4.667 UGX	560.000 UGX	140.000 UGX
Distribution lines (submain) (PVC 1,5 inch)	Metres	45	3.500 UGX	630.000 UGX	157.500 UGX
Fittings (elbows, t-s, union, connector, etc)	Pieces	17	7.000 UGX	476.000 UGX	119.000 UGX
Control valve / tap	Valves	2	22.000 UGX	176.000 UGX	44.000 UGX
Screen / disc filter	Piece	1	180.000 UGX	720.000 UGX	180.000 UGX
TOTAL				**15.970.000 UGX**	**3.677.500 UGX**

Below a schematic presentation of a drip irrigation system is shown connected to a water tank.



Schematic design of a low-cost drip irrigation system (Source: RCSD, 2008)

5.3 Water availability vs. water demand

When using irrigation to produce vegetables, what you are basically trying to do is to balance the levels of available water to meet the different water requirements (demand) of the plants.

→ Water Availability

The amount of available water can be determined by the sum of the average rainfall and the quantity of water that can be harvested and supplied as irrigation water in times of insufficient rain. If there is a water source closely situated to the field for irrigation-fed vegetable production

that provides water all year round, there is no need for water harvesting. This water source will provide available and accessible water to apply on the field with the methods described above.

If there is no permanent water source close enough to the field, then additional water harvesting efforts will be needed. Rainwater harvesting is a free source of irrigation water, the structures can be costly to install but are easily maintainable, and they usually help to reduce soil erosion and flooding. If natural conditions allow, with a constant flow of water for recharging, then you can have a natural pond without a cover layer.

In case there is no house with a roof nearby that could be used to capture water, it is best to dig and build a water pond to capture surface water run-off. When this water reservoir is larger and machinery is used to build it, it is also called a "Valley Tank". The costs and benefits of a masonry, tarpaulin, and a dam-line water pond or valley tank are presented in **Table *11***.

Table 11. Water Harvesting	*Masonry pond or valley tank*	*Tarpaulin pond or valley tank*	*Dam-liner pond or valley tank*
Capacity of 11.000 L	312.000 UGX	287.500 UGX	545.500 UGX
Capacity of 40.000 L	544.000 UGX	555.000 UGX	1.175.000 UGX
Advantages	Affordable and robust, will last 10-15 years	More affordable, for testing water harvesting before investing in dam-liner	Expensive but durable (0,5-0,8mm can last 5-8 years; 1mm can last up to 15 years)
Disadvantages	Requires technical skill in building	Less resistant, more leakage, not durable Replacement needed after 2-3 years if always containing water	Very expensive repair (technician from Kampala)

For this kind of surface run-off water harvesting, it is advisable to use (existing) channels, road run-off and other natural elements in the immediate environment to enlarge the catchment area (area from which the water ends up flowing into the pond). Also, think about using wire mesh and digging 1 to 3 small ponds at the inlet of the water pond, to trap the rubbish and soil carried by the water and prevent it from filling or damaging the water reservoir. The detailed costs for each of these rainwater harvesting ponds is presented in **Table *12*.**

Table 12. Ponds/valley tank investments	Unit	Qty	Price/unit (in UGX)	Capacity of 40.000 Litres	Qty	Price/unit	Capacity of 11.000 Litres
Dam-liner Water Pond				**1.175.000 UGX**			**545.500 UGX**
Dam-liner	square metres	55	16.000	880.000 UGX	23	16.000	368.000 UGX
Sand	trip	1	80.000	80.000 UGX	1	80.000	80.000 UGX
Cement	bag	3	30.000	90.000 UGX	2	30.000	60.000 UGX
Bricks	trip / pieces	0,5	250.000	125.000 UGX	250	150	37.500 UGX
Tarpaulin Water Pond				**555.000 UGX**			**287.500 UGX**
Tarpaulin	square metres	55	4.727	260.000 UGX	23	4.783 UGX	110.000 UGX
Sand	trip	1	80.000	80.000 UGX	1	80.000 UGX	80.000 UGX
Cement	bag	3	30.000	90.000 UGX	2	30.000 UGX	60.000 UGX
Bricks	trip / pieces	0,5	250.000	125.000 UGX	250	150 UGX	37.500 UGX
Masonry Water Pond				**544.000 UGX**			**311.500 UGX**
Chicken wire mesh	roll	2	60.000	120.000 UGX	1	60.000 UGX	60.000 UGX
Nails	kg	2	7.000	14.000 UGX	2	7.000 UGX	14.000 UGX
Sand	trip	1	80.000	80.000 UGX	1	80.000 UGX	80.000 UGX
Cement	bag	5	30.000	150.000 UGX	3	30.000 UGX	90.000 UGX
Bricks	trip / pieces	0,5	250.000	125.000 UGX	250	150 UGX	37.500 UGX
Waterproof cement	tin	6	5.000	30.000 UGX	3	5.000 UGX	15.000 UGX
Binding wire	kg	5	5.000	25.000 UGX	3	5.000 UGX	15.000 UGX

Alternatively, if there is a roof close to the field and place where you want to put the storage tank, you can use it for rooftop water harvesting. For a roof of 36 square metres anywhere between 2500 and 7200 Litres per month can be collected, in function of the average rainfall in Northern Uganda. The purchase and installation of a water drum, gutters, clips, nails, drainage pipes and a tap or outlet valve to connect to the irrigation system is expected to cost about 1,3 million UGX.

Table 13. Rooftop rainwater harvesting	*Unit*	*Qty*	*Price per unit*	*Total*
Drum reservoir 5000L	Drum	1	1.000.000 UGX	1.000.000 UGX
Gutters	Meters	12	4.333 UGX	52.000 UGX
Clips	Pieces	12	11.000 UGX	132.000 UGX
Nails	Kg	0,5	7.000 UGX	3.500 UGX
Drainage pipes	Meters	3	4.000 UGX	12.000 UGX
Fittings	Pieces	5	14.000 UGX	70.000 UGX
TOTAL Investment	-	-	-	**1.269.500 UGX**

More information on water harvesting and how to design a farm to better *slow, spread, sink, and store* rainfall, can be found in Box 2. For more technical details, the Manual on micro & small-scale irrigation technologies for Acholi & Lango sub-regions in Uganda, developed by MED-6 Agrotech in 2021, can be consulted with GIZ-PRUDEV.

→ Water Demand

The next step is to understand the water demand, the amount of water the different crops that you plan to grow require throughout their growing cycle. Table 14 (Lango subregion) and Table 15 (Acholi subregion) on the next page show the water demand for five popular crops: tomatoes, cabbage, eggplant, green pepper, and onion.

The net irrigation requirement describes the exact water demand of the plant per day. Where it is recommended to irrigate every 3 days (the next time will be on Thursday, if you start on Monday) this means that you will have to supply 3 times the daily water requirement for the soil and plant to absorb the water and use it in the following days. Remember that mulching, covering the barren soil in between your plantlets with dead plant material, is a good way to keep the soil moisturised and avoid excessive evaporation of water by exposure to the sun.

If you find it rains during the waiting days after irrigating, you wait 1 to 3 additional days in function of the intensity of the rain. For instance, if you irrigated on Monday and it rains a lot on Wednesday, the next time for irrigation is on Saturday (Wednesday plus 3 days) instead of on Thursday.

Table 14. Lango irrigation requirements	**Growth Stage**	**Net irrigation requirement (litre/day)**	**Irrigation frequency (days)**	**Total water per irrigation (litres)**
Cabbage	Early stage	0.7	3	2.1
	Development stage	1.1	3	3.3
	Late stage	1.0	3	3.0
Tomato	Early stage	0.5	3	1.5
	Development stage	0.9	3	2.7
	Late stage	0.6	3	1.8
Eggplant	Early stage	0.7	3	2.1
	Development stage	1.0	3	3.0
	Late stage	0.9	3	2.7
Green pepper	Early stage	0.5	3	1.5
	Development stage	0.8	3	2.4
	Late stage	0.7	3	2.1
Onion	Early stage	0.1	3	0.3
	Development stage	0.2	3	0.6
	Late stage	0.1	3	0.3

Let's have a closer look at the example of cabbage (in Lango, Table 14). In the late stage of plant growth, one cabbage needs about 1 litre per day. Given that you will only irrigate again after 3 days, you need to provide 3 litres per irrigation. If you are using a watering can of 9 litres, for instance, this means that you need to use one full can for 3 cabbages, go fill it again and move on to the next 3 cabbages.

Table 15. Acholi irrigation requirements	**Growth Stage**	**Net irrigation requirement (litre/day)**	**Irrigation Frequency (days)**	**Total water per irrigation (litres)**
Cabbage	Early stage	0.5	3	1.5
	Development stage	0.8	3	2.4
	Late stage	0.7	3	2.1
Tomato	Early stage	0.5	3	1.5
	Development stage	1.0	3	3.0
	Late stage	0.7	3	2.1
Eggplant	Early stage	0.7	3	2.1
	Development stage	1.1	3	3.3
	Late stage	1.0	3	3.0
Green pepper	Early stage	0.5	3	1.5
	Development stage	0.9	3	2.7
	Late stage	0.8	3	2.4
Onion	Early stage	0.1	3	0.3
	Development stage	0.2	3	0.6
	Late stage	0.1	3	0.3

→ **Water Balance**

The art of irrigation is in balancing the water demand of the plants with the water made available to them through rain and human-controlled water application.

Warning: In Northern Uganda, farmers that apply irrigation to grow crops in the dry season, tomatoes in this case, are found to be largely underirrigating their plants. The water requirements of the plants were generally not met at all. When studying the actual water needs of the crop, for one case, the tomato required 497mm of water throughout the growing season. A total of 306mm should have been offered to the plant through irrigation and 191mm through rainfall. Growing crops on a quarter of an acre, the optimal yield would have been close to 7500 kg of tomatoes. Yet, the farmer group only harvested 330 kg. In other words, their production efficiency – dividing the actual yield by the maximum expected yield – was very low (merely 5%).

Testing for 4 different locations and farmers in Northern Uganda, the identified efficiencies ranged between 5% and 28% meaning that all farmer groups missed out on a lot of harvest potential and money due to insufficiently balancing the water supply with the plants' water needs (demand).

This is an important warning to apply enough water per plant and sufficiently regular like suggested in Table 14 and Table 15, to get close to the optimal yields and production efficiency close to 100%. These are key points of attention to do so:

1. Know and look for the crop's water requirement per plant per day.
2. Schedule irrigation, every 3 days for instance, and keep to the schedule!
3. Monitor the level of soil moisture actively, look and feel how dry or moist the soil is each day in between irrigation days.
4. Irrigate consistently throughout the different stages of plant development (as indicated in Table 14 and Table 15).
5. When using watering cans for irrigation, learn how to estimate how many plants a 9-litre watering can should water at each stage of growth (see the example above).
6. Use good agronomic practices and fertiliser to optimise plant growth (see 5.7 and 5.8)

Box 2. Applying Permaculture Keyline Design principles for water harvesting

A field, a farm, even a landscape can be designed to increase its capacity for harvesting and storing water. By "walking the water", studying and following how the rainfall obeys to gravity to flow down from the highest point, one learns to understand where the rainwater is flowing, how it is moving on the farm, and how it can be harvested.

Identifying contour lines (lines of the same height) and digging swales (trenches) on these lines will allow for water capture by preventing it to run down and, thus, by reducing erosion. These swales and other permaculture interventions like mulching, "smile gardens", ponds, water-infiltration dams, etc. aim to *slow, spread, sink, and store the water*.

On top of that, building low-cost trellises for growing food crops and providing shade for captured water helps to avoid evaporation. Eventually, the water one manages to keep from running off, sinks in the ground and moisturises the so-called 'soil sponge' in the entire area downstream from where you harvested it.

Farmer Managed Natural Regeneration (FMNR) is another approach to increasing resilience to climate extremes, all while providing food and timber production. In practice, FMNR involves the systematic regrowth and management of trees and shrubs from felled tree stumps, sprouting root systems or seeds. The regrown trees and shrubs – integrated into crops and grazing pastures – help restore soil structure and fertility, inhibit erosion and soil moisture evaporation, rehabilitate springs and the water table, and increase biodiversity. As a result, FMNR can double crop yields, provide building timber and firewood, fodder and shade for livestock, wild foods for nutrition and medication, and increased incomes and living standards for farming families and their communities.

Want to learn more?

Look online for videos like "India's Water Revolution" (series of 6-videos of landscape transformation through water harvesting) and "OSU PDC Course" (an online Permaculture Design Course from Oregon State University); or go to the online FMNR Hub.

5.4 Sustainability and protection of water sources

When using existing water bodies (streams, rivers, lakes, wetlands, communal ponds, and wells) for irrigation, that will only last as long as there is unpolluted water in there. To make sustainable use of the different water sources in Uganda, both in terms of the quality and the quantity of water used, therefore, it is mandatory to obtain a water abstraction permit for all engine pumps (see section 5.1). This is also the reason for not allowing any urban development within 30m from the shores of a river, and 100-200m from the shores of a lake.

From the individual and local level all the way up to the national level, water resource management is a strategic priority to be able to keep on growing irrigation-fed crops now and with future generations. Two challenges are key.

1. **Both lack of rain and excess** (flooding) ask for better soil and rainwater management by improving irrigation techniques, infrastructure, farming practices (mulching, for instance) and water harvesting solutions (see Box 2).
2. **Avoiding wetland encroachment and deforestation** is also key, given the ecosystem services they provide. Wetlands and forests are important water buffers, for storage and filtering water among others.

The Directorate of Water Resource Management of the Ministry of Water and Environment, in its Framework for Water Source Protection Guidelines, warns that "increasing population density and demand for land for agriculture, settlement and industrial establishments has led to the clearance" of those forests and wetlands. ***"The resulting farm bush landscape is poor at retaining and purifying water, and this leads to rapid water runoff, soil erosion and water shortages"***. Even though much of Uganda has a high annual rainfall, with an average of 1200 mm per year, water shortages in the dry season are increasingly common. Protection of water catchment areas, the areas that drain into the water source, is therefore crucial to retain water and to ensure sufficient water supply throughout the year".

While water treatment plants are a must for drinking water supply, it is also in the interest of all Ugandans to make sure that the quality and availability of water being pumped from the environment is the best possible. In addition, the dirtier the water is, the more expensive it will be to clean it with those water treatment facilities (that also will become more expensive in turn). Some key guidelines for water source protection include:

- **Avoid poor farming practices** and deforestation that cause soil erosion and siltation.
- **Bring stakeholders together** and look for 'win-win' situations that improve the livelihoods of everyone in the catchment (= the area where the rainwater falls and drains to the water source).
- **Participatory water resource planning** to relieve emerging conflicts and water scarcities.
- **For any threat to the water quality** of your water source, refer to the local government authorities to see whether a Water Source Protection Plan (WSPP) can be developed with the relevant stakeholders and/or whether a Catchment Based Water Resources Planning (CBWRP, or in short Catchment plan) exists. The staff working on this at the local Water Management Zone office can be a good source of information and advice.
- **When applying for a Water Use Permit**, a WSPP needs to be presented.

Farmer groups like *Ada Aye Konyi* in Awach use and recommend the following techniques to better protect their water sources for irrigation. ***"Not digging so near the water source,"*** respecting legal distances and buffer zones from rivers and lakes, which often requires additional investment in extra watering hoses. Planting and not cutting trees and shrubs (Mvule, Mahogany, Bamboo) and grass (paspalum) around the source to restore the riverbanks, prevent erosion and increase water retention capacity. Other native tree species like Shea trees, Tamarind, Combretum, Albizia spp, and Prunus Africana are also highly recommended. As the saying goes: "The best time to plant a tree is 20 years ago, the second-best time is now". In addition, they recommend fencing your pond and nearby field: ***"stray animals struggle to drink there and destroy your fields."***

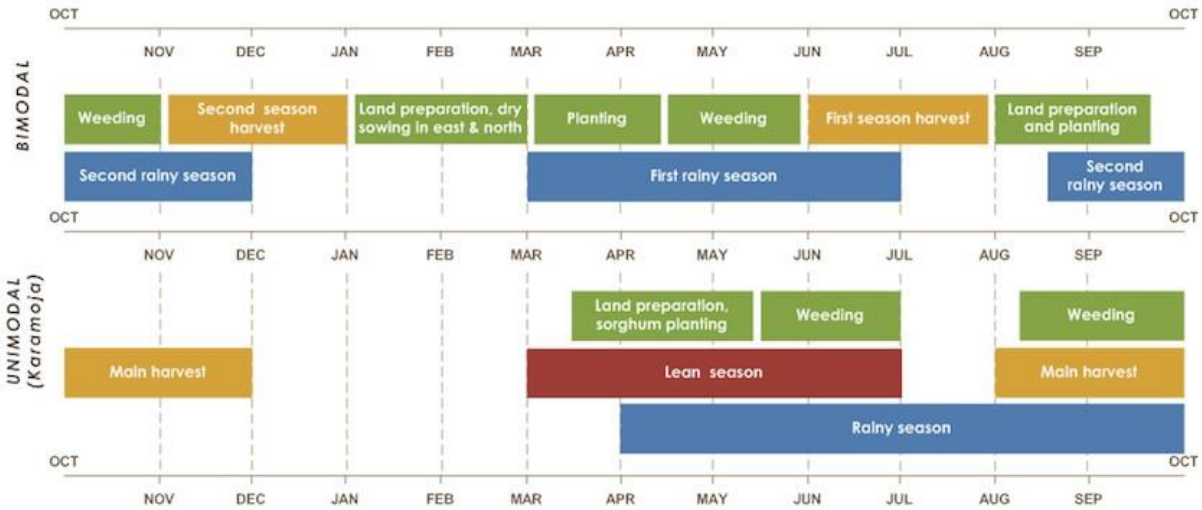
5.5 Planning of irrigated vegetable production season

Up next is the planning of your irrigation-fed vegetable production. Growing vegetables for the market with irrigation provides a good business opportunity during and right after the dry season.

That is the time only other local farmers with irrigation can serve the market (even though they still need to compete with products coming from further away) with these vegetables.

The seasonal calendar in Figure 3, shows a typical year with two rainy seasons in most parts of Northern Uganda. The main dry season runs from December to March; the shorter and less extreme dry season falls in July and August.

Figure 3. The seasonal calendar in a typical year[10]



Considering the time to maturity – the number of days up to harvest after transplanting – the business opportunity window is calculated in Table 16 for 5 selected vegetables with irrigation.

This time window helps to indicate when your irrigated vegetable farming will provide extra business opportunity and better prices (compared to the more abundant, rainy season vegetable farming). Of course, with an irrigation system you are now equipped to grow vegetables all year round in a continuous production scheme – meaning that you should be raising seedlings, transplanting, growing and harvesting at all times, by having different lines or plant beds in all different stages simultaneously.

Table 16. Business window	**Period to maturity (Days after transplanting)**	**Start of growing season**	**End of irrigation-fed sales season**
Tomato	70-85	October	June
Cabbage	60-70	November	May
Green pepper	60-85	October	June
Eggplant	60	November	May
Onion	110-150	September	July

5.6 Site selection and land ownership

Below are the criteria to consider when selecting a field for irrigation-fed vegetables production.

- **Water source nearby**: to irrigate you will need to access a water source that never runs dry. It needs to be situated close to the field to avoid spending too much on pumping the water from far, on distribution pipes and water hoses. If there is no continuous water source available, ask yourself 'Where shall we install our rainwater harvesting infrastructure (pond, valley tank or rooftop)?' See Box 2 for walking the water.
- **Quality of the soil**: look for a fertile soil, with good loose soil structure, for the plants to grow well. Also think about the soil infiltration rate. If the water infiltrates too fast (sandy soil) or too slow (clay soil) certain types of irrigation might become difficult.

[10] Seasonal calendar for a typical year, by Famine Early Warning System Network, December 2013

- ℛ **Proximity to the road**: especially when producing for commercial purposes, the accessibility of the plot by road is a crucial aspect to consider.
- ℛ **Land ownership**: the field must always be accessible and usable to all group members. Solid agreements regarding the ownership and use rights (as a group) need to be in place. Avoid any use of land that might be in litigation or where ownership is not clear.

As discussed in section 4.1, collective irrigation-fed vegetable production can be challenging. Discussion might arise regarding the ownership, the work and the profits related to the harvested vegetables. Therefore, it is recommended to use the irrigation pump and system, if mobile, as a shared resource on individually owned (nearby) plots, have individual lines or plots within a shared field, and/or use a group plot mainly for shared learning and consumption. Formalising your organisation and clear agreements about the ownership and use rights of the land and equipment are crucial. Lack thereof, is often the reason for failure of this group approach.

5.7 Required inputs

> ***"Farmer's access to quality agricultural inputs and how to use it is still a 'bottle neck' to increase their vegetable production, yield and income"[11].***

According to the quoted agro-input research commanded by AFC and GIZ-PRUDEV, farmers' dissatisfaction is mainly related to the quality, prices, and insufficient knowledge in handling of the inputs. The regulation of agro-input businesses is loosely organised, unfortunately, and too few inspectors are on the ground to effectively conduct controls.

- More than half of the farmers (52%) have experienced counterfeit inputs.
- 45% of the farmers never received after-sales service when buying agro-chemicals; considering many of them are illiterate, this might result in dangerous and/or ineffective application of these inputs.
- 42% of the identified agro-dealers in Lango and Acholi subregions, were not registered. They are operating illegally and, thus, ***"putting farmers at risk of being cheated with fake or ungenuine inputs"***.
- 31% of the studied entities were found not to be having an operational license, which is mandatory and issued by the local authorities.

It is recommended to only buy agricultural inputs from agro-dealers that know their suppliers and, preferably, buy from the manufacturers or importers directly. Agro-dealers that also provide after sales services can inform on nursery bed establishment, agronomic practices, planting and fertilizer application, safe and correct dosage, mixing and application of the chemical products. Always wear protective gear when applying agro-chemicals and avoid inhaling or any contact with the product.

To pay good prices and avoid buying counterfeit products, consider teaming up with members of your farmer group to do bulk purchasing of the inputs you will need for the season. The members of *Ada Aye Konyi* Farmers Group in Awach, Gulu, are even looking for a long-term collaboration with their input dealers: ***"they should come and talk about the use of their products. We can agree to make a partial payment and pay the balance at selling time."***

How to identify a genuine input from a fake one? The most recurrent issues are found to be expired seeds, fake fungicide (mancozeb), adulterated or diluted pesticides, fake seeds (that did not germinate), mixed varieties of seeds (look at the purity of the seeds). Knowing and actively paying attention to the following key features is vital when buying chemical agro-inputs.

- ð ***Dosage and frequency of application***: how much should be applied? How frequently? And at which stages of plant growth?
- ð ***Timing of application***: respect pre-harvest intervals mentioned on the containers. Agrochemicals are dangerous to human health and must not be used to prolong shelf life – it does not work, that is a dangerous myth! – or to make products look shinier.

[11] Inventory of agro-input dealers report, by Walter Okol (2021) on behalf of AFC GIZ-PRUDEV

- ð ***Expiry dates***: agro-inputs should not be used past their expiry date. They will be ineffective and/or dangerous to human health. Make sure you buy them with enough time before expiry by always checking. Without it is probably not a genuine product.
- ð ***Authenticity***: make sure the packaging is sealed with a security seal, contains original logos and a serial number, registration number and batch number, the name of the manufacturer and distributor. Always buy at registered dealers and input shops.
- ð ***Health and environmental safety criteria*** (they are usually written on the packaging).

Based on availability, yield, pest and disease resistance, taste, aroma and marketability, common varieties of vegetable seeds preferred by farmers are: Gloria F1 (Cabbage), Red creole (Onions), Long purple (Eggplants), Padma F1 (Tomatoes), California wonder (Green Pepper) and Sukari F1 (Watermelon). All of these are improved varieties, none are local.

For reliable input dealers that supply genuine quality inputs at reasonable prices, look for the larger agro-input shops in the major towns and cities (Gulu, Lira, Kitgum, Pader, Dokolo, Amolatar). Your choice of shop can be based on criteria such as reliability, availability of varieties of stocks, fair prices, and quality of the agro-inputs. Moreover, you can ask for their proof of registration as an agro-dealer and demand to see their active business license.

5.8 Critical good agronomic practices

In addition to quality inputs, soil preparation, nursery beds and the following good agricultural practices are other key **determinants of success** in growing vegetables with irrigation.

- ***Soil preparation***: by integrating compost, organic manure and/or fertilizers into the soil.
- ***Nursery beds***: Before transplanting your plants to the field, it is key to manage the first weeks in a dedicated nursery bed. These are important points of attention:
    1. Monitor carefully for any signs of seed germination.
    2. Remove the cover immediately after seeds start germinating.
    3. Erect shade of around 1.5m above the nursery bed.
    4. Watering: Keep soil moisture condition 'Wet in the day, Dry in the night'; but do not water before germination (usually a couple of days).
    5. Thinning: Control optimum density for healthy growth.
    6. Weeding: Young seedlings are vulnerable to competition with weeds.
    7. Promote root development by breaking hard compacted soil surface.
    8. Prepare the main field in advance to plant seedlings at the right time.
- ***Spacing:*** respect the recommended spacing indicated per plant variety to obtain optimal plant growth and fruits.
- ***Pruning & staking***: is key for plants like tomatoes. ***"Even though this feels like destroying what you already have, it works very well, the quality of the fruits will be better"***.
- ***Mulching***: is important to keep soil moisture, reduces risk of disease infection, reduces weed growth, and to keep plant vigour and prolong harvesting. No soil should ever be left bare and exposed to the sun (as that will kill soil life and turn it into dust).
- ***Rotation***: avoid growing the same crops on the same part of your field year in year out. Rotating between different plants and plant families every growing season, helps to avoid exhausting your soil.
- ***Cover crops***: as a matter of fact, can be capturing and storing certain nutrients (e.g., nitrogen) for your cash crops. Plant the cover crop before, cut it and let it dry, integrate it into your soil and/or use it as mulch.
- ***Mixed cropping***: certain crops can be associated, planted together. Combining maize and beans for instance, the beans will fixate nitrogen in the soil for the maize. Planting rows of onion between your rows of tomatoes, the smell of the onions will naturally deter certain pests from the tomatoes. Boo is nitrogen fixing too, and another good cover crop, often combined with eggplants for instance.

Local, traditional and/agroecological practices that have proven to be successful include mulching, mixed cropping (tubers with legumes, cereals with legumes) and rotational cropping (mentioned above) as well as:

- Planting guard rows: ***"Rows of maize protect the field from pests, they will fly over".***
- Using trap crops: to attract certain pests and, hence, move them away from your cash crops. Research "push-and-pull methods" frequently used in organic agriculture for more information.
- Observation and manual pest removal.
- Using ashes and concoctions for certain pests.

"All are key! You have to apply all of them for bigger fruits", is the final advice of the *Gene Keni* Vegetable Growers in Kitgum when asked which of all these farming practices works best.

Need more vegetable growing information?

This manual aims to present a clear business case for starting – and how to start – your irrigation-fed vegetable production project in Northern Uganda. On behalf of the GIZ-PRUDEV programme AFC also elaborated 5 very hands-on manuals on crop production of tomato, cabbage, egg plants, green pepper, and onion. These manuals provide all the details about:

- Open-pollinated and hybrid seed varieties in Uganda
- Raising seedlings and nursery management (see points above)
- Planting, spacing, water requirements
- Major pests and pest control methods
- Harvesting, value addition and expected profits

In case you require more technical information per crop, please consult these booklets.

Box 3. Health and Regenerative Agriculture

A study of water samples and fruits and vegetables bought from markets in Mbale and Kampala[12], showed widespread excessive use of chemicals and pesticides, water contamination and unsafe handling practices of fresh fruits and vegetables from farm to consumption.

- All 11 food samples tested positive for carbamate contamination (coming from Mancozeb) compared to the maximum allowed residual level, with high concentration being detected in passion fruits (+166%) in green pepper (+58%) and in hot pepper (+48%).
- E-coli and faecal contamination was on average 8 times higher than the recommended levels (of <1000 cfu/mls) for irrigation water by WHO/FAO.
- 75% of the water samples collected tested positive for lead contamination, with high levels of 50-67% above the allowable limit, being detected in swamps, wells, and rivers.
- In the past 3 years, only 4% had tested the water they are using for irrigation.

Another study in Wakiso[13] district highlights similar findings on not respecting recommended pesticide dosage in tomato farming, inadequate personal protection and use of pesticides for wrong purposes (wrongly believed to extend shelf life). This and other research by UNACOH confirm that excessive pesticide use and water contamination form a hazard to both people eating and producing food in Uganda.

Regenerative agriculture avoids the use of agrochemicals to restore the life in the soil. That soil life is crucial to making soil nutrients available to the plant roots. It also improves the soil structure, to create aerobic conditions where the beneficial micro-organisms can thrive and to improve the soils' water retention capacity. Regenerative agriculture is not a certification like 'organic' but it starts from a set of farming principles to ensure the regeneration of the soils, land and ecosystems – as opposed to rapidly depleting them, as is the case with conventional farming practices (excessive use of agrochemicals, over-tilling, bare soils, monoculture, etc.)

[12] Food safety risks in fruits and vegetables supplied in Kampala and Mbale towns of Uganda, By Penguin Agricultural Consultants on behalf of Rikolto, October 2020.
[13] Knowledge, Attitudes, and Practices of Tomato Producers and Vendors in Uganda, by Atuhaire et al., 2016

Regenerative agriculture is a vital pathway to promote human, ecological, and animal health and well-being across the planet: "Agroecological and regenerative farming, support diverse nutrient-rich crops and address the environmental, social, economic and commercial determinants of access to safe, healthy, nutritious, affordable, culturally appropriate diets"[14].

Contaminants in our food supply chains – like bacteria, viruses, parasites and chemical residues or heavy metals, containing endocrine-disrupting chemicals and hormone-growth promoters – contribute to various diseases and illnesses, including micronutrient deficiencies, stunting, wasting, communicable and non-communicable diseases, and mental illness[12]. As one farmer said: "People are tired of all these new diseases arriving".

5.9 Harvesting techniques and post-harvest handling

> ***"We take time to plant but when it comes to our harvest, we lose a lot!" – Franko Aliya (Equator Seeds).***

According to Michael Tebere (ICON) for most vegetables and fruits ***"20-30% is wasted on transport, 50% sold and another 20% thrown away on the market."*** FAO highlights that "Fruits and vegetables are highly perishable products, and this can cause high levels of food loss and waste at every step of the value chain, starting at the farms. Given that many fruits and vegetables are consumed raw or uncooked, they may also pose a risk for foodborne illnesses linked to pathogen contamination and food safety risks due to chemical contamination". Therefore, to avoid food waste and provide healthy food, these are key recommendations for harvesting and post-harvest handling:

- **Timing**: harvest products early in the morning preferably (for tomatoes, "***when the dew is gone but it is still cool"***) or in the evening.
- **Respect pre-harvest intervals**: all agro-chemicals must provide clear warnings on pre-harvest intervals. This is the time between the last application of the product and harvesting. The products need a good number of days to be absorbed by the field and go below legally allowed levels of toxicity. Use chemical products only for the use that is stated on the packaging and always wear protective gear. Spraying right before or on harvest day does not prolong post-harvest shelf life – it is a dangerous practice.
- **Quality management**: sorting and grading of the products is key to fetch a good price. The same goes for cleaning and washing (use clean water!).
- **Storage and transport** are key. See below.

> ***"Bringing produce to town with a boda boda is expensive and slow. Due to the bad road conditions, it's the only option and can cost more than a bus ride to Kampala" – Michael Tebere (ICON).***

Considering the road to the market, post-harvest handling is challenging in Uganda: ""Poor roads, remote locations and long distances to major trading centres result in high transportation costs."[15] As a farmer (group), this is what you can do:

- **Equipment for safe transport**: use hard boxes to avoid any damage to your produce (especially tomatoes) during transport. Use closed boxes and bags to avoid any contamination during transport (dust, small stones, faeces, etc.) or from contact with other (food and non-food) products.
- **Cold chain solutions (storage and transport):** while these are still in their infancy in Uganda, as a vegetable grower they could really give you a competitive edge regarding the freshness and quality of your produce.

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[14] Food systems delivering better health: executive summary, by the World Health Organization, 2021; *via* Creating Better Health for People, Animals, and the Planet: Food Systems Insights for Health Professionals, by The Global Alliance for the Future of Food, 2022.

[15] ReHOPE Endline Report, by Mercy Corps & Palladium, 2018.

- **Aggregation and pooling transport**: ***"When bulk buyers are there, we would gather from our individual plots and sell together again,"*** said the farmers of Onyede Waribe Farmers Group in Pader. So, starting from a large and existing demand, ideally an agreement with bulk buyers, organise to plan production, aggregate produce, manage quality and combine transport for the group.
- **One-stop bulking points**: look to access combined services centres (as implemented by the EU-DINU project, for instance) or establish one yourself. These bulking points are aimed to provide quality and quantity in supply. They can cover storage, aggregation, market linkages, producer-buyers negotiation, seasonal planning, access to services and inputs. Training and extension staff can also be included.

5.10 Water and health

As mentioned in Box 3, the quality of water for irrigation and human health are closely connected, especially for vegetables that will (often) be consumed raw, such as tomatoes and lettuce for instance.

For Acholi and Lango subregions, this warning on water quality prevails. On behalf of PRUDEV, four irrigation water samples were collected by AFC and analysed by the Ministry of Water and Environment. Samples were taken from a protected spring in Ngai sub-county (Oyam district), a river in Labongamida (Kitgum), a pond in Puranga (Pader) and lake Kwania in Dokolo district.

The results show that the recommended maximum levels of E-coli and faecal contamination by WHO/FAO (<126 cfu/100ml) for irrigation water were likely exceeded (reported as 'too numerous to count') for the Puranga and lake Kwania samples. Detected levels for E-coli were lower than the recommended maximum levels for the Ngai (82 cfu/100ml) and Labongamida (30 cfu/100ml) samples. For lead contamination the results were around 1,5 mg/L for all samples and probably slightly exceeded the maximum recommended concentration levels (0,1 mg/L).

E-coli was found in all samples and is a potential risk in irrigation water. Hence, the importance of respecting two days between the last irrigation and harvesting time. E-coli contamination is also an important risk when farmers apply animal manure directly as fertiliser. For the use of animal manure, a proper composting process of minimum 3-6 months is key, by then the compost should look and smell like good earth.

6. FINANCIAL & COMMERCIAL REQUIREMENTS

In this chapter the investments and operational costs are detailed to present and analyse the business case for irrigation-fed vegetable farming in Northern Uganda. But, first, the potential market and commercial opportunities are discussed.

6.1 Markets for vegetables

> ***"The 'Awaro', meaning aggregating the best and bringing it together, are feeding the city. These young women market vendors, they source very deeply into the villages the best products to sell".*** **– Michael Tebere, ICON.**

Michael Tebere highlights the dynamic of the Awaro, young female market vendors that leave the main cities in Northern Uganda early in the morning to source quality and locally grown produce from the neighbouring communities and districts. In this section a brief introduction of the different types of food markets is presented, along with their advantages and disadvantages. A study on behalf of PRUDEV, identifies 4 types of markets[16].

a) **Farm-gate markets**: "There are no physical market structures at the farm or home. Traders just come and negotiate with the farmers; they harvest and make payments and take the bought vegetables with them. Farmer groups near non-farm gate markets receive more buyers compared to those far away" *(variable frequency, low variety in products).*

b) **Small daily markets**: "…are located in trading centres usually near the farmer's locations", with "several types of physical market structures": stall in main market structure, commodities on tarpaulins/mats on the ground, small stalls next to shops, or a set of tables in front of retail shops. "They are mostly active in the evening, which makes it difficult for farmers from distant locations to supply their vegetables" *(variable size, more diverse product range but still limited).*

c) **Weekly and monthly auction markets**: "few permanent structures" similar to small daily markets, "usually lined up around the road". "Weekly and monthly auction markets attract many buyers and sellers on the auction days compared to the small daily markets. They also attract traders with relatively larger volumes traded". Large diversity of products. "Traveling traders for vegetables mostly buy in bulk in early morning hours – say between 6:00 am and 9:00 am. This means that farmers who need to sell in bulk need to be there very early" or rather the evening before. Challenges of distance and freshness.

d) **Municipal and city markets**: "For bigger cities like Lira and Gulu, the markets have large modern structures with most trading conducted inside the markets. However, in the evenings, vegetable traders vend on the streets of the town and in the market yard (e.g., in Gulu). In the markets in smaller towns such as Pader, Otuke, and Kalongo, the market structures are small and resemble the weekly markets". Large offer variety, high volumes of sellers and buyers, attracting larger traders and from more distant locations. These markets operate 5am-10pm with a lot of activity in the streets in the last five hours.

The study highlights the following key dynamics for vegetables.

- "**Seasonality**: In general, prices are highest in the months of February, March, and also January and lowest in the months of September, August and October".
- "**Price fluctuations**: In general, vegetable prices tend to be high in the morning and low in the afternoon and evening. Prices are high in the dry season months and low in the wet season months". Unless the market is flooded with certain product, like happened for tomatoes in the dry season of January – February 2022.

[16] Agricultural Production Market Analysis, by Dr. Andrew Muganga Kizito, Makerere University, July 2021.

- ð **Quantity**: "Like prices, the quantities demanded or supplied, or volumes traded in markets in Acholi and Lango sub-regions are not recorded by the market masters nor the district commercial officials".
- ð **Units of measurement**: the study shows a large variety in local units of measurement, 13 in total, including 9 different ones for tomatoes, f.i. the typical heaps of 4 or "Katasa" ("small plastic basin-like container").

Table 17 and Table 18 (based on the forementioned market study) show the different advantages and disadvantages of each market type from a farmer's point of view. They should be self-explanatory. Interestingly, farmers seem to really appreciate farmgate sales, as many advantages can be observed to be at play for this sales channel and disadvantages for the others.

Table 17. Advantages of different market types

		Farmgate	Small Daily	Weekly Auction	Monthly Auction	City & Municipal
1	Better or stronger bargaining power	·				
2	Less strategic actions by traders when sales are at the farmgate	·				
3	Higher prices because of buyer readiness and effective demand	·				
4	High prices (though potentially offset by logistical costs)		·	·	·	….
5	Many buyers and sellers		·	..	·	…
6	High quantities (volumes) demanded.			….	….	….
7	High frequency sales or purchases		..			….
8	Low marketing costs	..	·			
9	Transaction costs: saves time to farmer	·	·			
10	Transaction costs: saves time for selling larger volumes			..		..
11	Quality premiums	..	·			
12	No credit sales	·				
13	No market dues	..				
14	Minimizes price fluctuation risks	..				
15	Enables good record keeping	·				
16	More trust at farmgate markets	·				
17	New contacts and market information generated			·		·
18	Temporary control of perishability, avoiding post-harvest losses	·				

Most of the interviewed farmer groups working with PRUDEV, sell in their community (to neighbours), in the nearby trading centre (via market and/or food stalls), and to the main nearby city (Gulu, Kitgum, Pader, Lira, etc.). The 'Awaro', traders and market vendors play a central role in their sales channels. They either order and get sent the produce via local transport, they come and source at the farmgate, and/or the farmers go and deliver to them.

As also mentioned in Box **4**, **information asymmetry** seems to be dominant in these different market types. Unequal access to information seems to drive unfair price-setting and a large share of the margins and profits ending up with intermediaries rather than with the producers. The recommendations on bulking, production planning and collective sales in section 5.9, are aimed at enhancing a farmer group's capacity to work with farmer-allied intermediaries (see Box 4).

Furthermore, the ReHope end-line report[17] highlights ***"a significant lack of understanding and trust around market pricing between farmers and off-takers"*** and the subsequent need to build relationships and improve methods of communication. Finally, an unexpected market opportunity to explore (practically, legally) could be to provide a mobile vegetables market service, directly selling of the truck on fixed weekdays close to refugee and IDP settlements – areas known as 'food deserts' where fresh vegetables are scarce and prices usually are higher than in municipal markets.

[17] ReHope project end-line report, by Mercy Corps/Palladium, 2018

Table 18. Disadvantages of different market types

		Farmgate	Small daily	Weekly Auction	Monthly Auction	City & Municipal
1	Over bargaining	..				
2	Low or weak bargaining or negotiating power					.
3	Holding at ransom due to lack of ownership of transport					.
4	Limited effective demand	.	..	.		
5	Oversupply in non-farmgate markets		.	.	.	.
6	Too much competition in non-farmgate markets			.		..
7	Fewer buyers	...	.			
8	High transport costs to the market		.	.	....	....
9	Many competing needs (desires) and goods		.	.	.	.
10	High market dues		.		.	
11	Sales on credit		.			.
12	Lower prices at farmgate and small daily markets	..	.			
13	Low Prices according to some farmers' beliefs			.		.
14	Less frequent sales/ purchases			.	...	
15	Collusion and market power					.
16	Lack of storage facilities in small daily, weekly and monthly markets		.	.	.	.
17	Jealousy and conflicts by and with traders in small daily markets		.			
18	Lack of trust in traders in markets		.	.	.	.
19	Price fluctuations in markets		.	.	.	.
20	High transaction costs			.	.	.
21	Traffic police stoppages		.	.	.	.
22	Timing of the markets		.			.
23	General uncertainty (prices, quantities, quality, post-harvest losses)			..	..	.

Box 4. The potential (and contested) role of middlemen

***"Middlemen are the necessary evil. They take on a lot of risk, they are more aware of dynamics of supply and demand, they are better placed for speculation than us, farmers,"* asserts Abasi Kigozi (NARO).**

He is implicitly highlighting a market **information inefficiency and power imbalance** at the farmer level. A report by Bain & Company[18] puts forward strong arguments to strengthen the role of middlemen in working with farmers to build inclusive value chains, as illustrated in Figure 4. "**Intermediaries are farmer-allied** when they invest in enhancing smallholder farmer livelihoods and disrupt traditional, transaction-oriented sales channels, such as traders". "Farmer-allied intermediaries, including producer organizations, aggregators, processors and vertically integrated food brands, can simultaneously achieve a number of critically important outcomes" for the livelihoods of farmers and (urban) consumers. "The intermediary's intent ultimately determines how it engages with smallholder farmers and the degree to which it invests in them. While farmer engagement and investment typically strengthen loyalty and reliability, thereby serving the long-term financial interests of the business, in the near to medium term, they come at a cost and imply a real trade-off with financial performance and returns".

[18] How Farmer-Allied Intermediaries Can Transform Africa's Food Systems, Bain & Company, 2020.

By contrast, an IIED report [19] finds that producers are mostly "contract takers". It calls attention to some limitations of contract farming and producer-buyer contracts, and emphasizes the **challenges** of strengthening the producers' freedom of choice and negotiation power vis-à-vis their off-takers:

- Unequal access to information.
- Monopolistic conditions regarding large-scale businesses or local traders.
- Substantial differences in the scale of activities and lack of collective action.
- Contracts that farmers are not party to — whether downstream in the value chain or in the realm of government — are cascaded onto farmers through the chain of contracts.
- Buyers' choice to set price and reject produce not meeting (undefined) quality standards.
- Contract enforcement remains a recurring challenge in agricultural contracts.

Figure 4 What does a smallholder farmer-allied intermediary do differently? (Bain & Co., 2020)

	Traditional trader	Farmer-allied intermediary
Crop choice	**No signaling of market** supply and demand	**Encourage farmers** to grow crops in demand
Sustainable intensification	**No production support;** no helping farmers improve yields and quality	**Provide access to inputs,** both financial and operational **Facilitate technical assistance** on good agricultural practices
Market access	**Limited frequency and consistency** in volumes purchased Typically **opportunistic relationships** lacking transparency and sharing of economic value	**Commit to predictable,** transparent price and volume **Pay a price premium** to farmers based on quality **Establish high velocity of transactions,** improving farmer cash flow **Set up repeat/long-duration** purchase agreements **Facilitate farmer organization** to reduce transaction costs **Support farmers with storage and logistics,** helping them sell for the best price
Value chain participation		**Facilitate value-add activity** performed by farmers, such as primary processing and increased asset ownership

6.2 Medium cost: petrol, diesel, or solar pump

The required investment for medium-cost motorised solutions like the petrol, diesel, and solar pumps, as well as their benefits and limitations, are detailed in section 5.1. It is important to note that the choice of abstraction method (motorised pump vs. manual fetching or the more affordable treadle pump) will determine the size of the required irrigation budget. The different medium-cost abstraction methods are compared in Table 19.

These are key notes you need to read to understand this table:

- The delivery pipes included are 90 metres long. If the distance from the water source to the plot is small, buying additional delivery hoses might not be required.
- All engine pumps have low and high-pressure models. This determines their capacity (litres/hour) and the head pressure they can deliver.
- Low pressure petrol pumps should have enough pressure to connect to micro/mini sprinklers but might not provide the required pressure for the optimal use of a rain gun. They might overheat when using them for more than 2-3 hours in a row, especially when poor quality motor oil is used, the oil is not renewed regularly, the pump is operated at maximum pressure, or the airways are not cleaned. High pressure pumps are more suitable to connect to sprinklers directly; whereas low pressure pumps with high discharge are more adapted to connect to and fill tanks with.

[19] Contracts in commercial agriculture: Enhancing rural producer agency, by International Institute for Environment and Development (IIED), 2021.

- If the water table is more than 4 metres below the ground, you will likely require a submersible pump. There are no submersible fuel pumps on the Ugandan market, only solar and electric. The latter can only be used in remote areas with a fuel generator. The cost of a generator (1,5 to 2 million UGX) and an affordable electrical submersible pump (0,5 to 1 million UGX) can be better for smaller budgets in this case (before switching to a solar one later, to avoid fuel costs).
- During the right time of day for irrigation (before 9am; or after 5pm) solar pumps can lack capacity (solar power) to be performant. Therefore, in the case of solar pumps, installing a fixed water tower with an elevated thank is recommended. Likewise, as they are solar or electricity powered, submersible pumps are always used to fill a tank, never for direct hosing. Drip irrigation, micro and mini sprinklers can be used with these raised tanks; yet only drip irrigation is really recommended. The pressure will not be high enough to use a rain gun. The elevation of the tank should be based on the specific pressure requirement of the sprinkler heads one buys. The range is from 5 to 7 metres for micro sprinklers. Requiring towers of 12m height and more, even mini sprinklers with tanks are not recommended because of the high cost of installation.

Table 19. Medium cost water abstraction	*Investment*
Low-pressure petrol pump (total)	**1.340.000 UGX**
High-pressure petrol pump (total)	**1.790.000 UGX**
Purchase of a low-pressure petrol pump	*550.000 UGX*
OR purchase of a high-pressure petrol pump	*1.000.000 UGX*
- Suction pipe (10m) (2 inch)	*130.000 UGX*
- Delivery hose (flexible canvas) (90m) (2 inch)	*450.000 UGX*
- Foot valve	*60.000 UGX*
- Basic plumbing tools	*150.000 UGX*
Low-pressure diesel pump (total)	**3.580.000 UGX**
High-pressure diesel pump (total)	**4.880.000 UGX**
Purchase of a low-pressure diesel pump	*2.500.000 UGX*
OR purchase of a high-pressure diesel pump	*3.800.000 UGX*
- Suction pipe (10m) (3 inch)	*200.000 UGX*
- Delivery hose (flexible canvas) (90m) (3 inch)	*630.000 UGX*
- Foot valve	*100.000 UGX*
- Basic plumbing tools	*150.000 UGX*
Low-pressure solar pump (total)	**3.150.000 UGX**
High-pressure solar pump(total)	**5.050.000 UGX**
Purchase of a low-pressure solar pump	*2.600.000 UGX*
OR purchase of a high-pressure solar pump	*4.500.000 UGX*
- Suction pipe (10m) (1-1,25 inch)	*100.000 UGX*
- Delivery hose (flexible canvas) (90m) (1-1,25 inch)	*270.000 UGX*
- Foot valve	*30.000 UGX*
- Basic plumbing tools	*150.000 UGX*
Submersible low-pressure solar pump (total)	**4.270.000 UGX**
Submersible high-pressure solar pump(total)	**7.270.000 UGX**
Purchase of a submersible low-pressure solar pump	*4.000.000 UGX*
OR purchase of a submersible high-pressure solar pump	*7.000.000 UGX*
- PE Delivery pipe underground (15/30m)	*45.000 UGX*
- PE Delivery pipe to tank above ground (15m) (1-1,25 inch)	*45.000 UGX*
- Foot valve	*30.000 UGX*
- Basic plumbing tools	*150.000 UGX*
1000L tank and wooden stand for solar pumps (¼ acre)	**400.000 UGX**
- Purchase of the 1000L water drum	*320.000 UGX*
- Elevated stand for 1000L water drum (wood) (drip only)	*80.000 UGX*
5000L tank and stand for solar pumps (1 acre)	**2.800.000 UGX**
- Purchase of the 5000L water tank	*1.000.000 UGX*
- Elevated stand for 5000L water tank (masonry) (drip only)	*1.800.000 UGX*

6.3 Irrigation technique

After deciding how you will bring the water from the source to the field (abstraction), the next step is to decide which irrigation technique (application) you will use: watering cans, direct hose pipe, spray nozzle, sprinklers, rain gun, drip irrigation. The medium-cost options laid out here are direct hosing with the fuel pumps and a spray nozzle, drip irrigation, micro or mini sprinklers, and the rain gun. See sections 5.1 and 5.2 for details.

Table 20. Medium-cost water application (excluding costs of pumps)	*¼ Acre*	*1 Acre*
Direct hosing with spray nozzle	**375.000 UGX**	**375.000 UGX**
- Purchase of spray nozzle	*375.000 UGX*	*375.000 UGX*
Drip irrigation	**3.678.000 UGX**	**15.970.000 UGX**
Rain gun irrigation	**1.100.000 UGX**	**1.550.000 UGX**
Mini sprinkler irrigation	**1.198.000 UGX**	**5.656.000 UGX**
Micro sprinkler irrigation	**1.398.000 UGX**	**6.456.000 UGX**

6.4 Other production and marketing costs

Besides mentioning the financial costs of abstraction and irrigation equipment, we also need to cover the operational costs of the inputs (seeds, fertilizer, etc.), labour, fuel, post-harvesting and sales. For these seasonal, operational costs for inputs and labour, we will distinguish between variable costs and fixed costs.

⇒ **Variable costs**: are costs that increase (or decrease) when we produce on unit more (or less). Seeds, labour for weeding or irrigation, transport costs for bringing produce to market, etc. are good examples of costs that vary (variable costs) for every extra unit of production. In our example, as yields can fluctuate, we consider the number of cultivated plants as a unit. If you go from growing 1000 plants to 1100 plants (+10%), for instance, variable costs will increase with 10% as well.

⇒ **Fixed costs**: remain the same every period (month, quarter, or year) regardless of producing any additional (or even zero) units. Paying for the yearly water abstraction permit, for instance, or paying (ourselves) a monthly salary, airtime to follow-up with customers, renting a store, etc. are all fixed costs as they will not change when producing 1 plant more or less.

In Table 21, the main variable production costs for cabbage, eggplants, onion, and green pepper are presented for your reference. This information comes from the PRUDEV crop manuals for Community Based Trainers.

Table 21. Variable costs for 1 acre of production (in UGX)	Cabbage	Eggplants	Onion	Green pepper
Seeds	264.000	24.000	180.000	45.000
Fertilizer (DAP & CAN)	594.000	432.000	810.000	594.000
Insecticides (systemic & contact)	185.000	80.000	160.000	185.000
Fungicides (preventive & curative)	190.000	70.000	190.000	70.000
Labour	1.000.000	1.000.000	1.000.000	1.000.000
Irrigation labour and fuel costs* (2-3 times weekly)	240.000	360.000	360.000	360.000
Sum of variable costs	2.473.000	1.966.000	2.700.000	2.254.000

** Fuel costs obviously depend on which type of irrigation is used and will vary. The crop manuals refer to an average for diesel pump irrigation.*

In this manual the business case is focused on irrigation-fed tomato farming as an interesting example. Therefore, find a more precise overview of all variable and fixed costs in *Table 22*. It is important to note that this includes labour costs, even though this cost is often not considered by farmers.

Table 22. Variable and fixed costs for tomato production	Unit	Qty	Price/unit (UGX)	1 Acre (UGX)	1/4 Acre (UGX)	Details
Fuel costs: Petrol pump + spray nozzle	*L*	*84*	*6.000*	*504.000*	*126.000*	For 1 Acre: 12 weeks; 2 times per week; 3,5 L each (28.000 L with efficient pump)
Fuel costs: Diesel pump + rain gun	*L*	*60*	*6.200*	*372.000*	*93.000*	For 1 Acre: 12 weeks; 2 times per week; 2,5 L each (33.333 L with efficient pump)
Labour irrigation: Solar pump + drip irrigation	*Hours*	*48*	*1.250*	*120.000*	*60.000*	For 1/4 Acre: 12 weeks; 2 times per week; 2 hours each, 1 person; 1 Acre times two
Labour irrigation: Petrol pump + spray nozzle	*Hours*	*144*	*1.250*	*720.000*	*180.000*	For 1/4 Acre: 12 weeks, 2 times/week; 2 hours each; 3 people
Labour irrigation: Diesel pump + rain gun	*Hours*	*48*	*1.250*	*240.000*	*60.000*	For 1/4 Acre: 12 weeks; 2 times per week; 1 hour per week; 2 persons
Weeding: drip irrigation	*Days*	*1,5*	*10.000*	*15.000*	*3.750*	Weeding only 1 time if mulched
Weeding: other forms of irrigation	*Days*	*6*	*10.000*	*60.000*	*15.000*	Weeding only 1 time if mulched
Seeds (hybrid)	Grams	50	17.000	850.000	212.500	
Nursery beds (labour)	Days	4	10.000	40.000	20.000	
Preparing the field (Ox ploughing)	Acres	1	80.000	80.000	20.000	
Planting (6 labour days/acre)	Days	6	10.000	60.000	15.000	
Mulching	Days	6	10.000	60.000	15.000	
Staking / training (materials)	Acres	1	60.000	60.000	15.000	For 1 Acre: 12 rolls of strings (12x5000), 1 role of binding wire (90.000), 0 for poles
Staking / training (labour)	Days	10	10.000	100.000	25.000	
Fertiliser (DAP & CAN)	Kg	240	5.000	1.200.000	300.000	
Fertiliser (Labour)	Days	6	10.000	60.000	15.000	
Insecticides (systemic & contact)	Litres	3	40.000	120.000	30.000	
Fungicides (preventive & curative)	Litres	15	20.000	300.000	75.000	
Pest and disease management (labour)	Occasions	6	40.000	240.000	60.000	3 times for pests and 3 times for diseases
Pruning	Days	3	10.000	30.000	7.500	
Harvesting	Basins	526	2.000	1.052.000	263.000	10.000 plants per acre divided by 19 plants to fill a basin (285 fruits for a basin)
Cost of sales at farmgate (loading labour)	Days	6	10.000	60.000	15.000	
Other cost of sales (transport, time, bags, etc.)	-	-	-	-	-	Sales at farmgate are analysed to standardize; add costs of transport, labour, bags, etc. when selling elsewhere
Tot. variable costs: Petrol pump + spray nozzle	-	-	-	**5.596.000**	**1.409.000**	-
Tot. variable costs: Diesel pump + rain gun	-	-	-	**4.984.000**	**1.256.000**	-
Tot. variable costs: Solar pump + drip irrigation	-	-	-	**4.447.000**	**1.151.750**	-
Water abstraction permit (1-time initial fee)	Year	1	450.000	450.000	450.000	Only for engine pumps (diesel, petrol, solar)
Water abstraction permit (yearly)	Year	1	200.000	200.000	200.000	
Maintenance: new engine oil for Petrol pump	Litres	1,5	8.000	12.000	12.000	Replace once a month (or when dark); 0,5 Litres each time
Maintenance: new engine oil for Diesel pump	Litres	3	17.000	51.000	51.000	Replace once a month (or whenever dark); 1 Litres each time
Maintenance: new spark plugs Petrol pump	Season	1	10.000	10.000	10.000	Replacing the spark plugs once every season maximum
Maintenance: labour for fuel pumps	Season	1	25.000	25.000	25.000	1 time labour of a technician required (20-30 thousand UGX)
Repair costs (lumpsum) for engine pumps	Season	1	100.000	100.000	50.000	Depends on intensity of use, pump type, distance to town, etc.
Land (renting near water source)	Season	1	100.000	100.000	25.000	For 4 months (1 acre, 1 season)
Depreciation*: Petrol pump + spray nozzle	Season	1	Table 23	335.833	260.833	
Depreciation*: Diesel pump + rain gun	Season	1	Table 23	765.000	557.500	
Depreciation*: Solar pump (surface) + drip	Season	1	Table 23	2.786.429	842.500	
Total fixed costs: Petrol pump + spray nozzle	-	-	-	**1.232.833**	**1.032.833**	
Total fixed costs: Diesel pump + rain gun	-	-	-	**1.691.000**	**1.358.500**	
Total fixed costs: Solar pump + drip irrigation	-	-	-	**3.636.429**	**1.567.500**	

*The depreciation can also be considered the amount the farmer (group) needs to put aside to make sure to have saved enough to replace the irrigation equipment by the time it has reached its expected end of life. See Table 23 for the details on how this amount was calculated.

Table 23. Yearly depreciation of the investments (capital assets)	*Investment 1/4 Acre*	*Investment 1 Acre*	*Lifetime in years*	*Yearly depreciation 1/4 Acre*	*Yearly depreciation 1 Acre*
Petrol pump (low pressure)	1.340.000 UGX	1.790.000 UGX	6	223.333 UGX	298.333 UGX
Diesel pump (low pressure)	3.580.000 UGX	4.880.000 UGX	8	447.500 UGX	610.000 UGX
Solar pump (surface, low pressure)	3.150.000 UGX	5.050.000 UGX	10	315.000 UGX	505.000 UGX
Spray nozzle	375.000 UGX	375.000 UGX	10	37.500 UGX	37.500 UGX
Drip irrigation (incl. tank and stand)	3.692.500 UGX	15.970.000 UGX	7	527.500 UGX	2.281.429 UGX
Rain gun	1.100.000 UGX	1.550.000 UGX	10	110.000 UGX	155.000 UGX
Mini sprinklers	1.198.000 UGX	5.656.000 UGX	8	149.750 UGX	707.000 UGX
Micro sprinklers	1.398.000 UGX	6.456.000 UGX	8	174.750 UGX	807.000 UGX

6.5 Potential revenues

To assess the business case of irrigation-fed vegetable farming, we need to know the expected yields of production and use an average price to estimate potential revenues. See Table 24. While it is highly recommended to produce a wide range of vegetables and crops (mixed and rotational cropping, see section 5.9) on the same field, these potential revenues are calculated per crop[20].

Table 24. Yields & Revenues	*Tomato*	*Cabbage*	*Eggplants*	*Onion*	*Green pepper*
Plant spacing	100x40 cm	60x60 cm	100x50 cm	20x10 cm	100x40 cm
Plants/acre of cultivation	10.000	11.111	8000	125.000	10.000
Number of fruits/plant	15 (3x5)	1 head	8 flowers	60 gr/bulb	9 flowers
Farmgate price/fruit (UGX)	100	1000	125	2000 /kg	167
Sales per plant (UGX)	1500	1000	1000	2000 /kg	1500
Optimal yield per acre (fruits)	150.000	11.111	64.000	7500 kg	90.000
Optimal revenues per acre (UGX)	15.000.000	11.111.000	8.000.000	15.000.000	15.000.000
Expected revenues per acre (67%)	10.000.000	7.444.000	5.360.000	10.000.000	10.000.000

Note that the expected yields per acre were put at 67% of the maximum yield under optimal conditions (as published on the packaging of the seeds). This might seem low, but it is a good measure to calculate and set realistic return expectations. As mentioned in section 5.3, another PRUDEV study showed that even with irrigation equipment and good levels of training, farmers generally tend to undersupply irrigation water as compared to the plants' water needs. This resulted in measured yields of as low as 5% to 28% for four farmer groups in Northern Uganda.

Onions and green pepper seem to be generating as much revenues as tomatoes yet are produced less. Onions have been imported from other parts of the country historically, post-harvest handling might also be a challenge (curing and sorting), and market demand lower. Please note, that these potential revenues are directly related to the sales of the irrigation-fed vegetables. Providing services to vegetable growers (inputs on credit, renting irrigation equipment, etc.) and the innovative business ideas in Box 5, can also be a good source of income in rural communities.

[20] All data comes from the Training Manuals for CBTS, published by AFC under the GIZ-PRUDEV programme.

Box 5. Innovative Business Models

Developing services for vegetable growers provides a key opportunity to build inclusive business models all while addressing key challenges for emerging irrigation farmer groups and providing them with better conditions for production and sales. *Who will step up to develop these service models?*

- **Irrigation as a service:** farmers do not want pumps and expensive equipment on their farm, they need water on their fields when there is not enough rain. In other words, for every locality, irrigation hours (or a given quantity of litres per hour) could be sold to farmers as a service. The advantage with this pumping-as-a-service is that farmers do not need to invest in equipment nor worry about fuel costs, repairs, maintenance, or labour. There are no upfront payments, no need to take a loan, you simply pay by the hour. Agriworks Uganda is among the first to offer this service already**.**
- **Solar drying as a service**: certain vegetables, herbs and fruits can be better conserved and enjoyed when they are dried. Yet buying a solar dryer is expensive. To access this kind of value addition and keep larger margins for the farmer, offering them solar drying as a service (visiting each interested farmer group once every month with mobile solar dryers, for instance) would be very innovative.
- **Cold chain solutions**: better cold transport and storage at the market can substantially improve farmers margins and reduce post-harvest losses. This includes products like insulated boxes with icepacks, refrigerated vehicles, or cold storage as a service solutions. ColdHub is working on an inspiring model in Nigeria.
- **A one-step bulking and service centre:** as mentioned in section 5.9.

6.6 Potential returns and break-even period

First of all, it is important to highlight that more expensive and advanced irrigation technologies are not always the best solution for any farmers group. The available water quality plays a role, for instance, drip irrigation doesn't work well with water with high levels of particles presence and may require additional investment for filtration and/or imply higher maintenance costs.

There is no 'best' irrigation solution. What is best for you as a farmer (group) depends on a lot of conditions specific to your field reality: distance to the water source, type of water source, height difference, depth of the water table, soil type, water purity, etc. As suggested by the members of the Aero Farmers group in Minakulu, ***"choose the right equipment in function of your available budget and also adopt cheaper solutions".***

Table 25 shows which combinations of pumps and irrigation water application systems are commonly used (✔) and for which cases we will conduct the gross profits and break-even calculations (marked with the green checkbox ☑). The latter are presented in Table 26. The gross profits – also known as EBIT, earnings before interests and taxes – are calculated by comparing the expected revenues from sales (Table 24) with the expected costs (Table 22).

Next, we can calculate the break-even period – the time to recover the initial investment – by comparing the gross profits per season against the total investment in irrigation equipment, both water abstraction (Table 19) and application (Table 20). Naturally, farmers can also use their irrigation equipment for dry spells in other periods of the yearly weather cycle, but then irrigation might be less frequent, and all costs would vary. Therefore, in Table 26 everything is presented on a per dry season basis.

For 1 quarter of an acre under tomato production, using a petrol pump with a spray nozzle provides (small) positive returns. Both for the diesel pump + rain gun set-up and the solar pump with drip irrigation, the investment does not seem profitable for an area as small as one quarter of an acre (returns are negative). Slightly increasing the area to about 1105 and 1176 square metres respectively would allow for reaching break-even for these cases – this means the marginal profits are large enough to cover the fixed costs and, thus, your profits (or loss) are zero.

Table 25. Water abstraction and application combinations	Manual fetching	Treadle pump	Petrol pump	Diesel pump	Solar pump
Furrow irrigation	-	-	✓	✓	✓[21]
Direct hosing	-	✓	✓	✓	-
Direct hosing with spray nozzle	✓	✓	✓	✓	-
Bucket-and-Drip set-up	✓[22]	✓	*[23]	*[22]	*[22]
Drip irrigation	-	✓	✓	✓	✓
Micro Sprinkler irrigation	-	✓[24]	✓	✓	✓[25]
Mini Sprinkler irrigation	-	✓[23]	✓	✓	✓[24]
Rain gun irrigation[26]	-	-	✓	✓	-

As we have seen before, the calculations and results in Table 26 are based on a lot of assumptions: proper maintenance of the pumps, quality of the available water, distance to the source, good agricultural management, close follow-up of the irrigation scheme, but also the types of pumps (low pressure, more affordable models in this case) and the estimated lifetime of the pumps and equipment, among others.

For the case of 1 acre of tomato farming, positive returns are observed for all engine pumps. The treadle pump is not an option here, as it would require too much treadling hours a day to deliver the estimated 15.000 Litres water needed for an acre.

Given its higher capacity, the diesel pump + rain gun option becomes more profitable than the petrol pump + spray nozzle for 1 acre. For both set-ups the time to recover the initial investment (or repay a zero-interest loan), is only 2 or 1 years (dry seasons).

Given the high investment costs, both in a decent solar pump and in the driplines and fixed water tower, the solar pump + drip irrigation combination would require 11 years to recover the investment. The cost of storing water (pumping it into the water tower tank to slowly release it via the driplines) seems to be prohibitive to make the solar set-up profitable in these conditions of relatively low acreage and low-intensity management. The fact that the performant hours (9am to 5pm) of solar pumps are not appropriate for direct irrigation, requires storage and, thus, excludes direct hosing and the rain gun. However, it is important to note that the solar + drip irrigation case is profitable for 1 acre, requires much less labour in irrigation and weeding, and provides independence of fuel prices.

It is important to highlight that Table 26 does not consider any investment that might be required for water harvesting. If applicable, it is necessary to add these investment costs in your calculations and include their depreciation in the fixed costs.

When looking at continuous production, the irrigation equipment can actually be used for 3 cycles per year. In other words, going through the production process from seeds to sales 3 times (technically it could be done 4 times in a year with tomatoes) would provide an opportunity to recover the investment in less than a year for the fuel pumps and less than 4 years for the solar and drip installation – assuming that all other variables are kept constant, including the irrigation needs and related costs during other wet-season parts of the year (these costs are supposedly lower in 'wet seasons' and, hence, the potential profit margins are likely to be higher).

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[21] Depends on the capacity of the pump, as this inefficient application method requires a lot of water.
[22] The bucket-and-drip set-up is good for a backyard garden, not for use on a collective plot or close to the water source if it is far away from home; the risk of theft or vandalism is too high.
[23] This combination is possible in theory but would make very inefficient use of the pump's capacity.
[24] Moving with 1 or 2 sprinklers on the treadle pump maximum.
[25] With a solar pump an elevated water tank is needed. This can work for micro sprinklers (5-7m height), but for mini sprinklers the required height (12+ metres) makes the needed water tower(s) very expensive.
[26] The rain gun is appreciated for its cost-effectiveness. However, with low soil permeability farmers find they suffer from a lot of water run-off. This makes it difficult to determine the applied amount of water and requires more pumping and higher fuel costs.

Table 26. Gross profits & break-even point for Tomato production with irrigation	¼ Acre 3 months	1 Acre 3 months
Expected revenues from sales (at 67% of optimum)	*2.500.000 UGX*	*10.000.000 UGX*
Total variable costs: Petrol pump + spray nozzle	*1.409.000 UGX*	*5.596.000 UGX*
Total variable costs: Diesel pump + rain gun	*1.256.000 UGX*	*4.984.000 UGX*
Total variable costs: Solar pump + drip irrigation	*1.151.750 UGX*	*4.447.000 UGX*
Marginal profits: Petrol pump + spray nozzle	1.091.000 UGX	4.404.000 UGX
Marginal profits: Diesel pump + rain gun	1.244.000 UGX	5.016.000 UGX
Marginal profits: Solar pump + drip irrigation	1.348.250 UGX	5.553.000 UGX
Fixed costs: Petrol pump + spray nozzle	*1.032.833 UGX*	*1.232.833 UGX*
Fixed costs: Diesel pump + rain gun	*1.358.500 UGX*	*1.691.000 UGX*
Fixed costs: Solar pump + drip irrigation	*1.567.500 UGX*	*3.636.429 UGX*
Total investment in irrigation solutions		
Petrol pump + spray nozzle	1.715.000 UGX	2.165.000 UGX
Diesel pump + rain gun	4.680.000 UGX	6.430.000 UGX
Solar pump + drip irrigation	6.842.500 UGX	21.020.000 UGX
Expected gross profits per season (EBIT)		
EBIT Petrol pump + spray nozzle	**58.167 UGX**	**3.171.167 UGX**
EBIT Diesel pump + rain gun	**-114.500 UGX**	**3.325.000 UGX**
EBIT Solar pump + drip irrigation	**-219.250 UGX**	**1.916.571 UGX**
Number of dry seasons to recover the investment?		
Petrol pump + spray nozzle	**30**	**1**
Diesel pump + rain gun	**-**	**2**
Solar pump + drip irrigation	**-**	**11**
Minimum area under production to make profit	**Square metres**	**Acres**
Petrol pump + spray nozzle	958	0,28
Diesel pump + rain gun	1105	0,34
Solar pump + drip irrigation	1176	0,65

- The marginal profits are the expected revenues minus the variable costs (for 1 unit, the price per unit minus the variable costs per unit). These are used to cover the fixed costs.
- The area under production to break even is calculated by dividing the marginal profits by the fixed costs (converting to square metres in the ¼-acre case). It shows how much area should be cultivated approximately (under these cost assumptions) to reach break-even (which means zero profits or loss).
- The EBIT (earnings before interest and taxes) is calculated as expected revenues – variable costs – fixed costs.
- The number of dry seasons to recover the investment is calculated by dividing the total investment by the EBIT per dry season.

6.7 Record keeping and financial management

Finally, AFC provides some key financial advice regarding record and bookkeeping[27]. To be able to assess the above business case for your own reality, and finetune projections in the future based on real-life data from the first cycles, it is important to keep the following recommendations into account. Moreover, they will help to increase the accountability to members, trust in the organisation and/or creditworthiness.

- Keep written records of every purchase and sale.
- Also note down on a daily or weekly basis how much inputs have gone into the production process, even when they were not paid for (e.g., labour, agro-inputs, fuel, etc.)
- Learn how to use these records to know the trend (increasing/decreasing) of sales as compared to previous seasons, to know how much cash is spent and available from your budget, understand the costs per product, and know which crops provide you more profits for less work/costs.
- Set goals for sales per week, month and season; compare your results against these targets to learn how to plan more precisely for the future and decide what to do differently next period to get closer to target.
- Make a budget for all costs you can plan for next season. At the end of each month and season, compare the actual costs against the budget you had made to learn and readjust accordingly for the next periods.

As the saying goes, ***"all models are wrong, but some are useful"***. The above calculations will not present an exact version of reality. What is most important, is that the information is proportionate to the costs one can expect to incur in Northern Uganda, for starting and deciding on an irrigation-fed vegetable growing project, and that the projections and budget can be used to learn and adapt accordingly after running the first and consecutive cycles of production.

[27] Business planning with the business model canvas, by Oliver Schmidt, AFC, 2022.

7. CONCLUSIONS AND RECOMMENDATIONS

> ***"Most field crops like maize, soybeans, groundnuts, and sorghum, have died because of the drought. The only hope for income generation are the vegetables at this point"*** **– Andrew Okettayot, Agriculture Officer, Puranga subcounty, in the July 2022 dry spell.**

It is needless to say that climate change has increasingly detrimental effects on agriculture in Northern Uganda. That is why water harvesting is so important – especially by planting, not cutting, trees and regenerating soil life to build the 'soil earth sponge' – so that any delay in rains or drought periods can be covered with irrigation solutions.

> **"*We now have money*" – Member of Ada Aye Konyi commenting on the benefits of irrigated vegetable growing.**

The case for irrigation-fed vegetable farming is overwhelmingly positive as we have seen – as long as the irrigation schedule is applied strictly to meet the water needs of the plants and achieve good yields. The social, technical, and financial requirements to do so are laid out in this document. There is no "best" water abstraction (pump) and water application (irrigation) mechanism. There is only a combination of both that is most adapted to the circumstances of each farmer (group): type of and distance to the water source, soil conditions, financial means, etc.

7.1 Challenges and lessons learned

Key challenges relate to agricultural methods, depleted and infested soils, and poor quality and performance of chemical agro-inputs. Especially for tomatoes and plants of the Solanaceae family.

> ***"The chemicals have failed for bacterial wilt. Hybrid seeds too. We followed the instructions for Kalsan of the agro-input dealer, but they give you any information just for their business"*** **– Nyeko Collins, community-based trainer, Good Luck farmers group in Bungatira, Gulu.**

Information asymmetry and lack of trust in markets plays an important role. Not all market vendors and "Awaro" can be trusted. ***"When they are supposed to pay the remaining balance after 2-3 days they start complaining about the products being rotten and such things, they refuse to pay"*** says Collins. As indicated in section 6.6, building strong commercial relationships and working with farmer-allied intermediaries can be a key success factor.

Farmers see the benefits of producing and selling (more) collectively. Yet, confidence in the leadership and trust within groups, can be a challenge. In addition, the shared use of irrigation equipment in a kind of rotational calendar for their individual plots, pushes the members to a staged production and, hence, they might not have enough produce available for bulk selling.

The invasion of wetlands does not only endanger the replenishment capacity of the local water table, but it is also a means of unfair competition: ***"We compete with those sneaking into the wetlands, they are pushing down the prices. Before we didn't, but now we protect the wetlands, because water is life!".***

Finally, to restore soil life, improve its water harvesting capacity, and assure irrigation water quality, all while securing liveable farmer incomes, regenerative farming practices are paramount.

> ***"We are in need of organic solutions because prices of agro-inputs have gone high. Chemical fertiliser has doubled from 2500 UGX/per kg in 2017 to 5000 now!"*** **– Nyeko Collins.**

> ***"Inorganic fertilisers are deteriorating the soils. We are trying to mitigate climate change by conservation farming. That is protecting the soil and adding organic manure to improve soil fertility."*** **– Odongo Bob, Aero Farmers in Minakulu, Gulu.**

7.2 Best practices and recommendations

This manual concludes with recommendations *for farmers by farmers* in Acholi and Lango subregions. *What would they recommend to a farmer (group) that wants to start with irrigation?*

- Irrigation is hard work. ***"You are not supposed to be lazy as a vegetable farmer".***
- ***"There is good money in vegetable production"***. But you also must have money to start and invest in doing it.
- ***"Get an engine pump and start with hose pipe or hand irrigation".*** If you cannot afford a fuel pump, then start with a treadle pump and use it to bring the water from the source to a drum and from there fill your watering cans to reduce time.
- ***"Start with what you have and persevere."*** The Gen Lacwach Vegetable Growers in Atanga, Pader, would like to have a borehole with a submersible pump, but first plan to extend their hand-dug water harvesting ponds for now. ***"Create a water source, the one you can afford."***
- Training. ***"Invest in knowledge first, before investing in equipment"***. ***"You need to be technical, have both agronomic skills and for maintenance of the irrigation equipment"***.
- Field trials: types of seeds, varieties, new inputs, adding organic manure, regenerative farming practices… you can test all of them for their effectivity before deciding where to invest and applying them to all your crops. ***"Plant the crops that your land can support".***
- Select varieties in function of the yield, resistance to pests and diseases, and market demand.
- Keep records to know your loss or profits. Record costs of inputs, (paid) labour, transport, sales, and of who owes you money.
- ***"As a beginner, first hire irrigation equipment and learn. Start on a small plot and expand it with time"***. One farmer, for instance, started on 3 acres, and the work was too much and the capacity of the pump too low.
- ***"Decide what to plant in function of what the market demands"***. When choosing products, varieties, even quantities, first look for the market, and plan for transport costs. ***"Start from the market and then work backwards. Who is going to eat my cabbage?".***
- ***"We have to combine better quality with larger quantities and a consistent supply to be ready whenever they give the call***" (staged production for continuous supply).
- Selling more does not necessarily equal higher profits. "***You need to rush so your products don't get spoiled. The buyers know that, so your price is lower. So, it is better to sell consistently but in smaller quantities"***.
- ***"It is very important to be part of a group to get to know many people with different ideas and learn from each other".***
- ***"As a group we can produce more, learn more, work less, waste less time, and it is easier to get a market for our products."***

For More Information, contact:

Promoting Rural Development in Northern Uganda

c/o Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices Bonn and Eschborn, Germany

giz_prudev@giz.de

PRUDEV – Promoting Rural Development in Uganda - giz.de