May Report:

OKWAGAANANA

UGANDA

Team

Amadeo Hachez, An-Sofie Tas, Joshua Beyers,
Lara Helsen, Line Van Bossuyt and Viktor Cockx

Coach

Ignace Pelckmans

2020-2021

Content

AFD Project Okwagaanana
May 2021

Introduction

More than just an organisation, 'Okwagaanana' or "meeting one another" in Ugandan is a meeting of minds premised on the conviction that progress is achieved through social interaction and diversity. By empowering young individuals, Academics for Development (AFD) aims to draw upon enthusiasm and talent to create innovative responses to real-world problems.

The cooperation between Okwagaanana and AFD is rooted in this message of hope and creativity. The goal of the project is to help the Kidiki School in Namwendwa, Uganda, to become financially sustainable and as such, allow it to extend its educational offer to Ugandese students. It is our strongest belief that this project will be as enriching to us as to our Ugandese partners.

At the heart of the project are six driven students, eager to have a lasting impact on the world. Persuaded that a diversity of competences is the key to innovation and creativity, the AFD team is composed of a variety of profiles with backgrounds in physics, engineering, biology, economics, sociology and education. It is our strongest belief that by joining our efforts, we will be able to fill the gap between ideas and action, and have a lasting impact on the Namwendwa community.

This report presents our current situation in realising the Okwagaanana project; how it emerged, what it consists of, and where we, as a team, want to go in the future. As a follow-up to our December report, this report will focus on two elements in order to achieve our main objective, being the financial independence of Kidiki School. More specifically, the report will cover the implementation of a chosen irrigation system and the matching crops.

Enjoy the trip!

An-Sofie, Lara, Line, Viktor, Joshua, Amadeo

Chapter 1. Project summary

1.1 Partner description

After their trip to Uganda and more precisely, the village of Namwendwa, Jos Kuppens and Frieda de Lannoy fell in love with the country. During their first trip in 2006, they met Stephen and heard him talk about his plans for the future and his philosophy: to make structural changes to improve the quality of life in Kamuli district ("I will make Kamuli shine"). He talked about his plans for the Namwendwa Dairy Farmers Association (NDFA), about his the Vocational Training Centre (VTC), the importance he attached to education and the importance of working with a vision: sustainable agriculture, food security, less manual labour, better hygiene, a higher family income, education for boys and for girls,...

Stephen was an example to many: honest, wise, decisive, a man with vision and with attention for everyone who asked him for advice (rich, poor, young, old, woman, man). His vision: "A miracle solution does not exist, but small steps can and will change things a lot" (Stephen, Namwendwa, 2011).

Jos and Frieda returned home, but his words, his decisiveness and his philosophy did not escape their minds. The following year, 2007, they returned and had a long talk with Stephen, asking if they could contribute to his project and that of his friends.

Since that year, Frieda and Jos have returned every year. They decided to support Stephen's project and called their collaboration "Okwagaanana". As a result, a Belgian branch of the already existing project was established. This branch is an autonomous sub-organization of the non-profit organization Don Bosco and is run by volunteers only. It primarily obtains its funding through institutional sponsors, crowdfunding or third parties and collaborations with external partners.

"Okwagaanana'' stands for "meeting each other" and it focuses on three initiatives in the village. The Kidiki Primary and Secondary School is one of them and this will also be the focus in our project. The main goal here is to make the school financially independent and the implementation of an A-level accreditation. The second initiative is the Kyebajja Tobona Women's Group (KTWG). Its goal is to stimulate responsible and efficient microfinancing among the local women and to empower them in general. Third, the vocational training centre's goal is to provide agricultural training for the local farmers (*Okwagaanana*, n.d.). More information about project Okwagaanana is found in Annex I.

1.2 Initial project content

Uganda's educational system disposes of multiple levels of accreditation. An educational institution can award legally recognized degrees for each level up to a specific year of study. The Kidiki secondary school is currently allowed to award legally recognized degrees up to the O-Level, which is equivalent to the fourth year of secondary education. Secondary education in Uganda consists of a total of six years of study. Only with the A-level accreditation can an educational institution award degree for the fifth and sixth years of secondary education.

Obtaining an A-level accredited degree is of primary importance for Ugandan students as this degree allows them to apply to continue study at a higher education institution. Kidiki School's students face significant difficulties to access to A-level accredited institutions in the region, thereby limiting the prospects for further education and a bright future. The main barrier to achieving A-level accreditation at Kidiki secondary School is financial sustainability.

The cooperation between Okwagaanana and AFD aims to solve this issue, as both organisations believe doing so will have a positive and lasting impact on local communities. Besides allowing local students to pursue higher education, A-level accreditation could also attract students from nearby villages. These educated students can thereafter bring back their knowledge and skills to the local villages and contribute to the development of Namwendwa sub county.

By providing the school with solutions to allow more efficient expenses and reach financial profitability, AFD hopes to set the school on the right tracks and ultimately grant it financial independence. This will be done in accordance with social and community concerns in Namwendwa. Local individuals, businesses, communities and other NGOs should all be considered as potential partners in this ambitious undertaking.

Chapter 2. Problem statement & 1st semester research questions

2.1 Local context

2.1.1 Geographical context

Uganda is divided in 134 districts, spread over four geographical regions: North, East, West and Central. The Kidiki Primary and Secondary School of Namwendwa is located in the Kamuli district, in the Eastern part of Uganda. (Government of Uganda, n.d.)

Namwendwa's population is estimated at approximately 35 000 and has an area of 150 km² (Brinkhoff, n.d.). Being a small trading centre in the beginning, Namwendwa has now been transformed into a town council (personal communication). The inhabitants of Namwendwa mostly speak Lusoga, mixed with a bit of Luanda and English. In Uganda, 78 percent of the working population are working in the agricultural sector (Uganda Bureau of Statistics, 2017). The same trend is visible in the district of Kamuli. Over 92 percent of the households are engaged in growing crops or livestock farming and 86 percent grows maize (Uganda Bureau of Statistics, 2017).

The temperature in the Kamuli District typically varies from 16°C to 35°C, throughout the year. The Kamuli District region has an annual bi-modal rainfall that ranges between 900 mm and 1500 mm and has two growing seasons. During the first growing season, most of the rains are received from March to May/June, and in the second one from August to October. Important is that in the second growing season less rains are received than in the first growing season. (Tusiime et al., 2019)

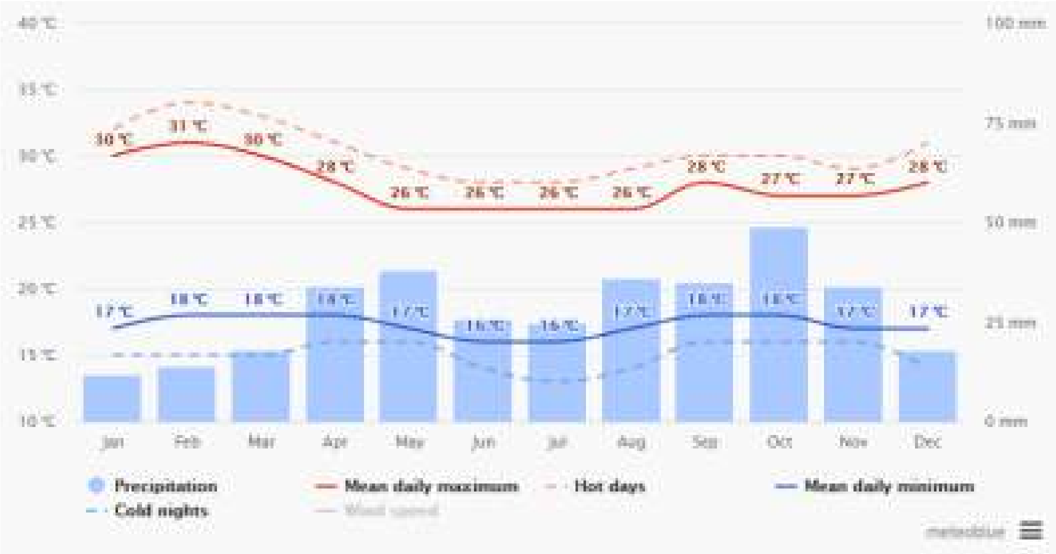

Figure 1: Average temperatures and precipitation. (Meteoblue)

Namwendwa is only a small municipality. Nearby towns are Kamuli, Buyende, Buwenge and Kaliro. These are about 15 to 40 km away from Namwendwa. The closest rivers (Kiko River, Lake Kyoga, Lumbubvri River and Nabigaga River are at a distance of 20 to 40 kilometres. (Google Maps, 2020) As a consequence, such a population has no reliable source of water and therefore faces a challenge during the dry season (personal communication).

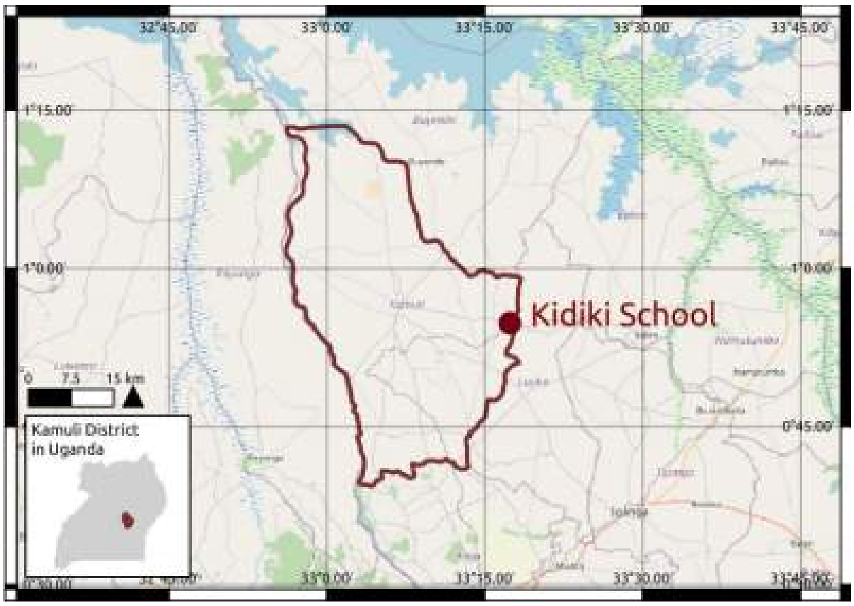

Figure 2: Lokalisation of the Kamuli District and the Kidiki Primary School. (OpenStreetMap)

The Kamuli District has a soil depth of 0-15 cm. Important is the soil textural class, namely sandy loams (SL) and clay loams (CL), which describes the relative proportion of different grain sizes of mineral particles in a soil (Tenywa et al., 1999). In Annex VI a map of the types of soil in Uganda can be found. Frequent irrigation and fertilization are necessary to maintain healthy growth in a sandy loam soil (Thompson, 2018). Besides these sandy loams, there can be found petric plinthosols and ferralitic soil. These are rather acidic soils, which are poor in nutrients, and therefore quite infertile (Kaizzi et al., n.d.).

2.1.2 Current situation Kidiki School

As mentioned above, this project will focus primarily on supporting Kidiki school becoming financially self-sustainable. Hence it is important to understand the current situation of the school more in-depth.

The school is private and started off in 2004 with six students, 11 teachers and two non teaching staff members. Over time Kidiki expanded and currently counts 350 pupils, 20 teachers and seven support staff members. The school receives children from all over Namwendwa and its broader area. (*Background – Kidiki Secondary School*, n.d.)

During the years, also the school's infrastructure expanded. Three new classrooms, a teachers' room, a library and a department for a kindergarten have been added (*Okwagaanana*, n.d.). Some of the pupils attending classes in Kidiki are boarding school pupils. Therefore, one of the buildings provides sleeping accommodation for them. During the day, the pupils are offered meals prepared by the staff. The kitchen is equipped with a single stove which requires a lot of expensive wood. As a result, the kitchen generates many financial losses. Additionally, the school owns six cows and several chickens. During the spring of 2020, school staff succeeded in growing dozens of tomatoes, an achievement which they would like to pursue in the future. Concerning access to (drinkable) water, the school faces significant difficulties. They own one water tank of 10 thousand litters which, when full, can only be used for three days by the students. When empty, the school can access tap water. However, this water source is not reliable since it depends on electricity. Besides, tap water is quite expensive; for 760 liters they need to pay 0,68 euros (3000 shillings) Sometimes, students need to walk 20 minutes in order to reach a water source (M. Walekaki, personal communication, November 17, 2020). Due to periods of drought, growing crops adequately is a big challenge in the area.

At present, the main source of income are the tuition fees the pupils need to pay, which was 158,745.21 shillings (36 euros) each trimester for daily students and 317,490.41 shillings (72 euros) for boarding pupils last year (AFD, 2020). These revenues need to cover a much wider range of costs which consist of salaries, food and fixed costs. As a result, the school runs deficits or at times slightly reaches the break-even point. Besides, it is only able to organise education at the O-level. Since pupils need to accomplish all the six years before starting any further education, the lack of A-level accreditation causes a major limitation to the pupils' future and to the development of the entire region in general.

2.2 Problem statement

The main goal of Okwagaanana regarding the school is to provide qualitative and future oriented education to the youth of Namwendwa. This objective however, is challenged by the lack of sustainable income. Due to the bad financial situation, the school is not able to operate at the A-level. In a local survey, this came out as the main blockade in the development of the whole community. In order to provide the A-level, the school's financial situation needs to ameliorate, especially they need to become financially self-sustainable. Hence this is the main goal of the project.

2.3 First semester research questions

In the December report, we elaborated four main leads that are relevant for this project: crop production, irrigation, the cows of the school and the kitchen. However, in January we agreed not to focus on every lead anymore.

Producing (cash) crops in assistance of an appropriate irrigation system stayed our main goal in the second semester. We already chose tomatoes, onions, eggplants and spinach as suitable crops. Further, this semester we continued with the idea to implement an agroforestry system as we are convinced of the benefits it will provide for the water management, soil fertility and the diet of the students. However, specific trees for the agroforestry were not determined yet. This semester we did research on the types of trees that can be used and how these can be placed between the crops.

In consultation with the local partners, it was decided to use drip irrigation as an irrigation system.. At the beginning of the second semester we got news from the project partners in Uganda that they changed their minds and now preferred a sprinkler irrigation system. After looking through different aspects of this type of irrigation and its costs, we as a team, thought it would be better to continue with our first idea. Frieda supported our choice and we informed the team in Uganda about the advantages of bucket drip irrigation. The high cost for sprinkler irrigation would exceed the budget and starting with bucket drip irrigation would be more feasible. In the future, when the school has become more financially stable, an upgrade to sprinkler irrigation would be very welcomed. The Ugandan team accepted this plan and we started working out the details.

We decided to not further elaborate on the lead about the cows' fodder as the school only has a very small number of female cows that can be used for milk production. We still plan to use the Calliandra fodder shrubs to supplement their hay-diet but we did not look for other improvement as we believe that we can have a bigger impact by focussing on our other leads.

Lastly, as stated in the December report, we wanted to continue working on the findings of the previous Okwagaanana team regarding the kitchen. After many discussions with our partner, we came to the conclusion that at this moment it would be better to focus on increasing the income by implementing the irrigation system. So for two reasons, we are not going to pursue the improvement of the kitchen this year. On the one hand, our partner mentioned that we needed to buy new materials for the kitchen. Since we cannot go to Uganda ourselves this summer, we think it would be better for our partners to look for good materials in his area. On the other hand, our budget is limited and there will probably not be enough left over to finance the irrigation system as well as the kitchen.

Chapter 3. Development and elaboration on research questions

3.1 Crops and agroforestry

Last semester, it was clear after consultation with the local partners that the crops they want to grow are tomatoes, eggplants, spinach (or dodo) and onions. These are cash crops and are thus crops intended for sale, which will provide the school with an additional income. In addition, they will also be used to diversify the diet of the students. Furthermore, we researched which tree species can be used to create an agroforestry system with the crops. Our main goals with implementing an agroforestry system are improving the moisture of the soil, by the shadow they create and improved rainwater infiltration, and enhance the fertility of the soil, by the decomposition of the leaf litter. Additionally, we want the trees to provide either fruits or fodder.

Despite the fact that we are convinced that agroforestry will improve soil fertility in the long term, we are also aware that the effect will not be sufficient in the early stages. After consultation with Michael, Wilson and Julius, it was confirmed that fertilizers will be needed for the cultivation of the crops. We have therefore taken this into account in the budgetary planning and also have the idea of creating a manual that could be a guide in selecting the right fertilizers.

Last semester we already decided that *Calliandra calothyrsus*, a fodder shrub, would be a valuable species to include in the system. The shrub is a nitrogen fixing plant that, as a result, can improve the nitrogen concentration of the soil and has a high protein concentration, making it an excellent fodder supplement (Place et al., 2009). To decide on the fruit trees we first looked into the literature about agroforestry in East Africa to get an idea of the most used tree species. After consultation with the local partners we decided that mango and papaya trees would be the perfect fit, along with the *Calliandra calothyrsus*.

Figure 3: A mango tree (ProductiveProduce)

Figure 4: A papaya tree (Britannica)

Mango and papaya trees (Figure 3 and 4) are commonly used species in agroforestry systems in Uganda (Kyarikunda et al., 2017). In the first place, they are interesting because of the edible fruits they provide. Additionally, they have a few characteristics that make them suitable species for agroforestry. Established mango trees have long taproots which means that they can get their water and nutrients from deep in the soil (Kunhamu & Santhoshkumar, 2012) and thus, will not deplete the upper layer of the soil, on which the crops depend. Full-grown mango trees have large crowns and thus provide a lot of shadow (Kunhamu & Santhoshkumar, 2012). This can be beneficial or non-beneficial depending on whether crops are shadow resistant (spinach) or not (tomatoes, eggplants and onions). The shade provided by the trees can of course also make the working conditions on the field more pleasant for the school staff and students. The decomposition of the leaf litter of the mango trees will also be valuable for a long term build up of the soil fertility (Kunhamu & Santhoshkumar, 2012). Papaya trees are smaller, single stemmed trees and hence provide less shadow than mango trees and therefore, these trees can be a better match with crops that are not shadow resistant. Papaya trees also grow quicker and start producing fruits already after one year (Hessong, 2018), while mango trees need around five years before producing fruits (Grant, 2020). In other words, the two tree species are quite different in shape and growth rate, which is useful for the arrangement of the field as it provides multiple options.

3.2 The field

3.2.1 The arrangement of the field

This semester we brainstormed about the ideal arrangement of the field. Taking into account the characteristics of the different crops, we made a plan which is shown by Figure 5. The local partners gave us the information that the field is 30 by 60 meters and that the water pump is situated right in the middle. Despite that we are convinced of the benefits of agroforestry, we are also aware of the fact that the results can differ greatly depending on the specific local situation (Rosenstock et al., 2019). Therefore, we opt to try out some 'experiments' with the tree-crop combinations, which can give the school, after a little while, an insight in the best possible arrangements.

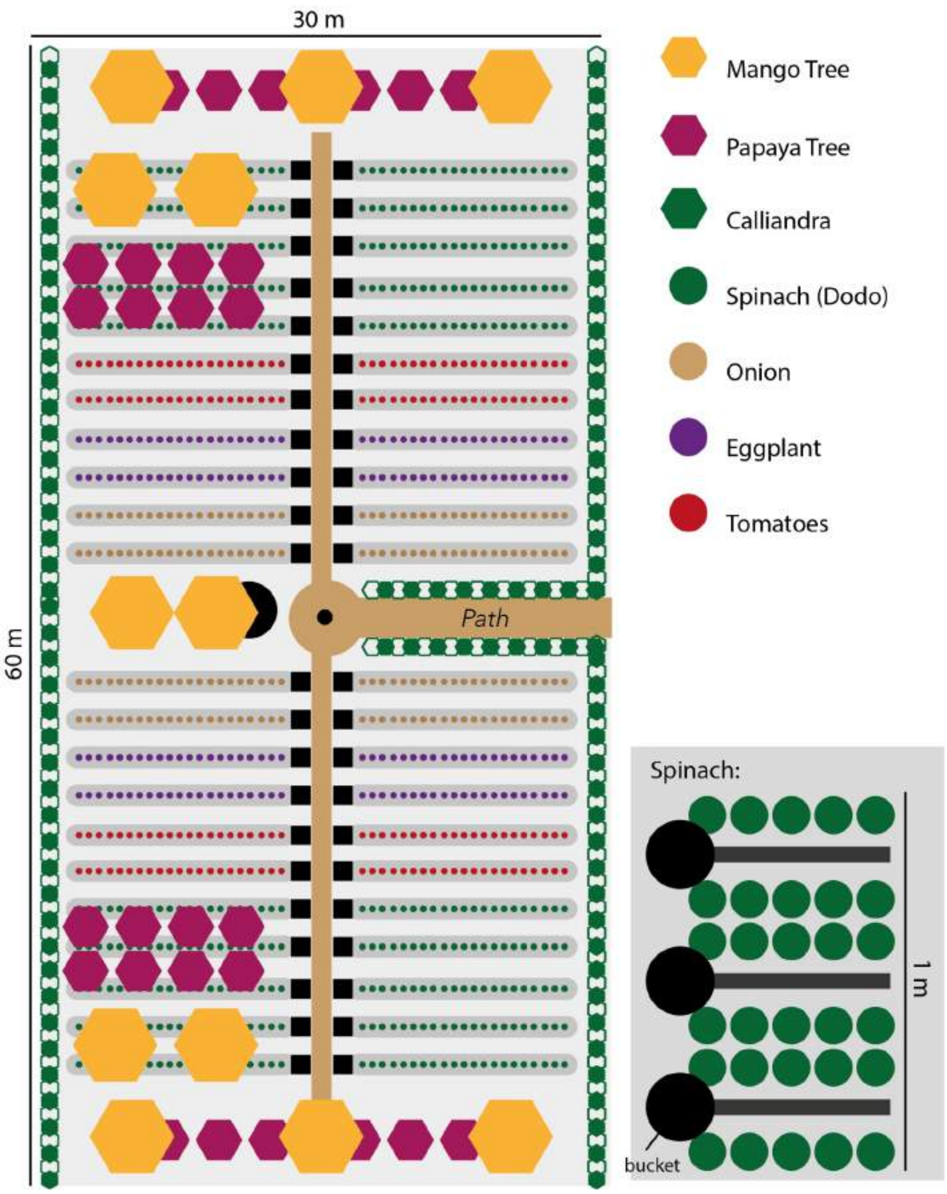

Figure 5: On the left: the arrangement of the field with the water pump in the middle;

On the right: an example (for spinach) of how one row looks in detail.

Spinach is the only crop that is shadow resistant. Therefore, it's the only crop for which we would plant trees in the crop patches. We would place mango trees between one patch and papaya trees between another. This way the school can see, after a little while, if one tree species is more beneficial than the other and continue with that species. The other crops, tomatoes, eggplants, and onions need lots of sunlight to grow and produce fruits. For that reason, we would not recommend planting trees in the patches of these crops.

We would place mango trees at the short edges of the field, leaving 10 meters between each tree as this is the recommended spacing for a full-grown mango tree (Jauregui, 2020). In between the mango trees we would place papaya trees because these trees grow faster than the mango trees. By the time, the mango trees are full-grown and actually need 10 meters spacing in between them, the papaya trees will have already provided fruits for a few years and the papaya trees could be cut to give the mango trees enough space. Next to the 10,000 liter tank, we would also place mango trees to provide shadow limiting evaporation and offering a shade for resting workers

The Calliandra fodder shrubs can be placed at the long edges of the field and next to the path that leads to the water pump, functioning as a fence while also improving the nitrogen levels of the soil. If, after a little while, the crops close to the Calliandra shrubs do better, this is an indication the soil improvement by the Calliandra species is valuable. The school can then decide to place more shrubs also between the crop patches to further improve the growth of the crops. The idea is that these shrubs will be pruned frequently to harvest fodder for the cows, so the shrubs will remain rather small and provide only a limited amount of shadow.

By alternating the different crops the risk of spreading diseases is reduced as many diseases are plant family specific (Geno & Geno, 2001). We think it makes sense to arrange the field in a mirror image. This way every little 'experiment' is done twice giving a more reliable insight if something is actually beneficial (or non-beneficial) and not merely a coincidence.

3.2.2 Planning irrigation, planting and harvesting

To be able to calculate the water demand for each day, which will be discussed in section 3.4, a schedule of when plants are grown and harvested is needed. This growth schedule is made for the upcoming 10 years.

The 4 crops that are grown have different growing stages and times meaning that certain crops can be harvested more each year than others. The different growing periods with their duration in decades (10 days) for the different crops are given in Figure 6, where each period is linked to specific water requirements. Generally speaking, the water requirement starts low during the initial phase, then rises during the development phase to stay more or less constant during the mid phase. During the late phase, water requirement declines and crops can be harvested.

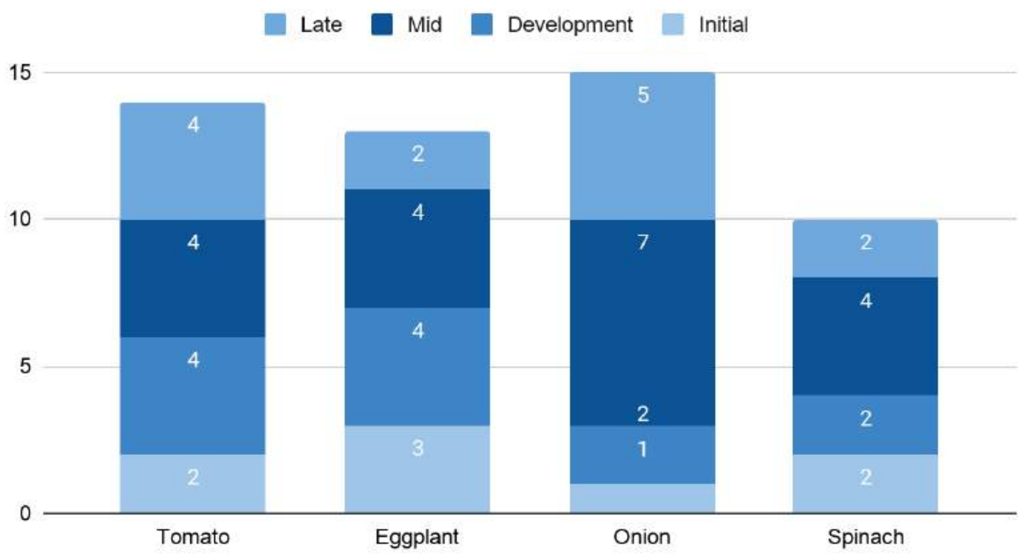

Figure 6: Growth periods in decades per crop

Using the FAO cropwat tool (*CropWat, Food and Agriculture Organization of the United Nations*, 2021), a planning can be made. There are 4 sections of data this tool needs to estimate growing phases. First of all the crop data is needed. This data represents the amount of water a crop will need in optimal conditions and how the crop adjusts to suboptimal conditions. The crop data can be found on the FAO website (*Food and Agriculture Organization of the United Nations*, 2021), or is already at hand in the tool. Secondly, the monthly precipitation is needed which was found on an Uganda weather website (*Average Weather in Kamuli, Uganda, Year Round - Weather Spark*, 2016). On this same website the third section of data, being the environment data (hours of sun, wind speed, incident solar radiation, temperature) , was also found. For the fourth data section the soil information was required. As indicated in section 2.1.1., the local soil is red sandy loam. Hence why the data for red sandy loam, which was at hand in the tool, was used.

Setting up the growth planning, the choice was made to let the crops grow throughout the year. This was opposed to the choice of letting the crops grow in their optimal seasons and letting the field lie empty during less optimal seasons. The consequence of this choice is that the water use will not be optimal and can even reach a very high maximum on certain days. The reason for it was the partner specifically indicating that they wanted to use an irrigation system to also grow crops in the dry (less optimal) season.
Between two growths of the same crop, a 10 day period is implemented to clear the field and prepare it for the next growth. The starting date for the growth planning was chosen to be the first of august 2021. This should give sufficient time to set-up and prepare the field during the month of july. A weblink leading to the crop planning can be found in Annex II. The number of harvests per year for the coming 10 years are given in Table 1.

Table 1: Number of harvests per year.

year	*Tomato*	*Eggplant*	*Onion*	*Spinach*
2021	1	1	1	1
2022	2	2	2	3
2023	2	2	3	4
2024	3	2	2	3
2025	2	3	3	3
2026	3	2	3	4
2027	2	2	2	3
2028	3	3	3	3
2029	2	2	3	4
2030	3	2	2	3

The number of harvests varies each year due to the fact that the growing cycle of the crops does not coincide with a calendar year. However, it can be seen that after a few years a period in the number of harvests occurs. This means that the number of harvests can also be predicted for years after the year 2030.

3.2.3 Water demand

The water demand follows out of the crop planning. As mentioned in section 3.3., the crop planning weblink can be found in Annex II. In this crop planning , the water required per m^2 crop for each day for the next 5 years is also given. The reason the required water is only given for 5 years instead of 10 years (like the growth planning) is because of the increasing inaccuracy of precipitation estimates in the future years. Another reason is the possible expansion of the field in 2028, which requires a recalculation of the water requirement. The water needed per row per day and its maximum amount, are also shown in the crop planning. In Figure 7 the maximum amount of water needed per day per row of each crop can be seen. Note that this amount is only needed for a couple of days. To put this last statement in quantitative terms; the water requirement per row per day exceeds 30l for tomatoes, onion, eggplant and spinach during 80, 0, 60 and 280 days respectively, in the upcoming 5 years.

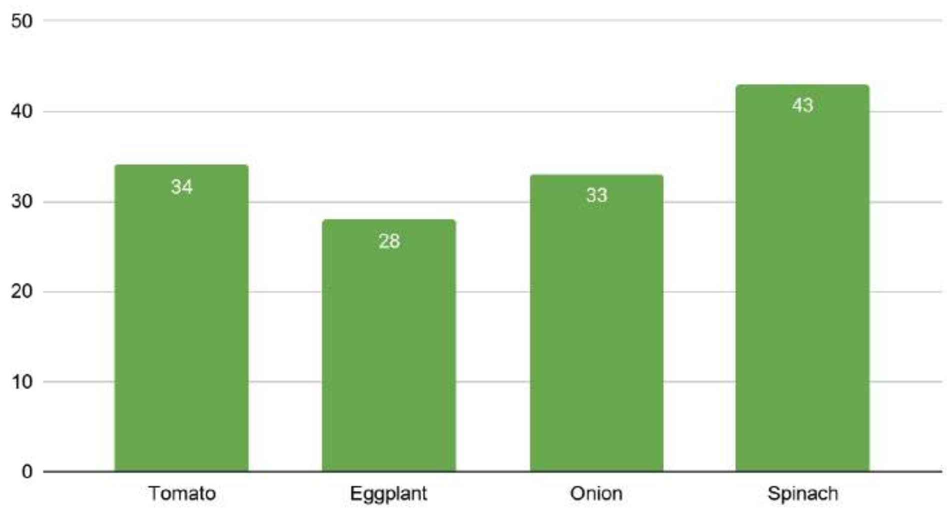

Figure 7: Maximum liters of water required per day per row for each crop

While spinach may have the shortest growth time, it needs the largest maximum amount of water. This means that growth time is not the only criteria that should be evaluated when choosing how much of one crop will be planted. The maximum amount of water required for one day for the whole field (30 by 60 meters) can also be calculated and results in a maximum of 605.16 liters. We can conclude that while these amounts are very achievable, a very well thought out irrigation system and water storage will be necessary. This will be discussed in section 3.3.

3.3 Irrigation

As we started this semester with the news that the project partners wanted to begin with sprinkler irrigation. We started looking into this type of irrigation again. Sprinkler irrigation is a method where water is distributed by overhead high-pressure sprinklers or guns from a central location in the field or from sprinklers on moving platforms. It is easy to set up and there is no requirement of having a lot of sprinklers as the sprinkler is movable. In wind-free conditions and if installed properly, thus in ideal circumstances, water is distributed equally and is frequently applied to the crops. The amount of supplied water can be controlled and the sprinkler can be used for other functions as well, for example using as cooling during high temperatures. Figure 8 shows an example of sprinkler irrigation in practice. The investment cost for purchasing the equipment is high compared to other irrigation systems. Moreover, this kind of irrigation system needs a constant water and energy supply to get high pressure on the sprinkler. Besides, there is a chance of evaporation loss in windy conditions and a chance of water loss when it is high in terms of humidity. As such, this method of irrigation is not so favourable but could be a system used in the future when the Kidiki school is financially stronger. (Civil Engineering, n.d.)

Figure 8: Sprinkler irrigation. Retrieved from Kabunga. (Agriprofocus)

After consulting with our partners in Uganda, we agreed on implementing a *bucket drip irrigation* system to distribute water from the waterpump to the crops. In bucket kit drip irrigation, a 30L water bucket is placed 1m above the ground to provide the required water pressure. At the bottom of the bucket, drip lines are connecting the bucket with multiple drip lines with small holes where water is able to drip out of them. Due to the height at where the buckets are placed, gravitational force pushes water through the drip lines. To prevent evaporation the drip lines are placed under the canopy. The efficient use of water, which is the biggest advantage of this irrigation system enables a farmer to grow vegetables using large amounts of water daily during the crop growing season. Although, a disadvantage using buckets is the fact that it is very labour intensive for large fields compared to other systems like sprinkler irrigation which was for this reason preferred by Michael, Wilson and Julius. To minimize the labour intensity investing in a small pump that provides a pressurized water supply to buckets farther away from the water source would already be a good solution. Which pump, how and where to buy it is still something to discuss in the future as not only we as a team cannot go to Uganda this summer. Figure 9 gives some perspective again on how the bucket drip irrigation system would look like in practice. Several small kit systems can be laid out on a farm to cover a larger area. The drip tapes are placed on a soil surface and plants are planted near the drip outlets to receive maximum benefit.

Figure 9: Drip bucket irrigation. (Mapio)

Waterboys (U) Ltd. have adapted drip irrigation technology and developed such a bucket kit for smallholder farmers in Uganda, which caught our attention. The kit comprises one 30-litre bucket (the bucket is part of the kit), and 2 x 10 m of drip tubes connected to a water distribution manifold. The drip outlets in the standard kit are spaced at 30-60 cm depending on the placing space of the crops. Figure 10 shows how this would look like in practice. (Akvopedia, 2013)

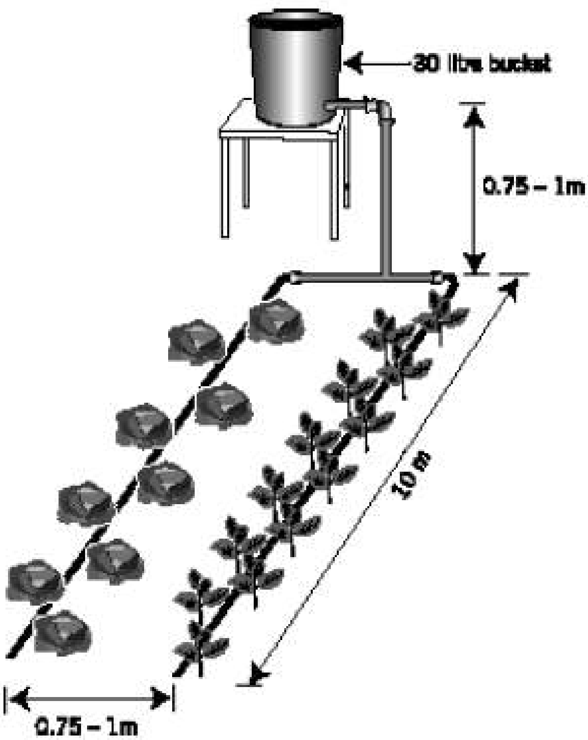

Figure 10: Layout of Waterboys bucket system. (Akvopedia)

The bucket kit system has two 10-m long drip lines and can be used to grow 50 plants such as tomato, eggplant and similar crops requiring a spacing of 60 cm along the plant rows; 100 plants of spinach, tomatoes, dodo and similar plants requiring a spacing of 30 cm along the plant rows; or 300 plants of onions and similar plants requiring a spacing of 10 cm (Akvopedia, 2013). A bucket is placed on a stand at one end of the bed and connected to the drip lines. These bucket kit systems can irrigate 10–20 m², depending on the length of the drip tube and plant spacing. For our field, the buckets will be placed accordingly. The bucket should be filled once in the morning and once in the afternoon to supply 30–60 litres of water to the crop per day, but to get a precise amount of water we refer back to section 3.2.4. Next thing would be best to describe the system components and assembly instructions, which will be explained in the Annex III.

To deal with filtration, since a filter is not included in the kit, the Waterboys bucket kit system requires water that has already been filtered for irrigation. This may not be the case in many rural areas and even in some urban centres. Thus, if the water requires filtration, tie a clean cloth on the mouth of the bucket and always pour the water required for irrigation through it. This cloth should in the regular be replaced by a clean one. (Akvopedia, 2013)

Chapter 4. AFD project impact map

To assess the impact of the project, we must look at the goal setting we have and how the activity leads to the desired impact. By implementing an irrigation system Kidiki will be able to sell cash crops on the market not only in the wet season but also the dry season. This will help them to gain more profit, which they can use to expand their school and obtain A-level accreditation. Firstly, what needs to change? The school needs to lower their expenses and increase its yield. Secondly, for whom? The pupils of Kidiki. They will be able to finish their secondary school once the A-level accreditation is obtained. Thirdly, how much change is created? Not only will all students be able to finish their education, this will also attract more children from the area and further away. To end, we will contribute to taking the first steps towards financial independence. First of all, we have developed a plan for an irrigation system that will help the school to harvest and sell crops all year round. We are also looking for other ways to improve their agriculture system. In addition, we will try to aid in improving the school's kitchen so that costs can be saved and health risks can be reduced.

The first step to completing goals and providing impact is to concretize the problems we face achieving this impact. For this we describe a problem tree, which is a tool that can help you explore the range of root causes behind a social problem – and it can help you identify the ones you may be able to do something about. Thinking about the underlying causes is essential for any impact-driven organisation. We created a problem tree in which we pinpoint these things on Figure 11.

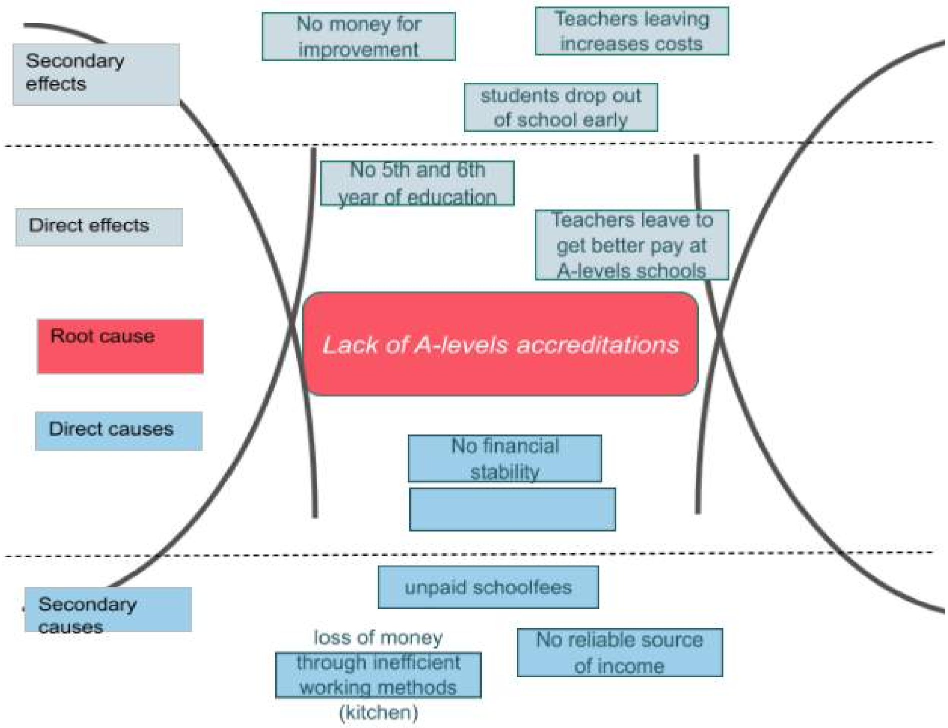

Figure 11: Problem tree pinpointing the root cause of our problem with direct and secondary causes/effects.

The main stakeholders here are the Kidiki staff, pupils and the local community. They consist of 27 staff members, 257 pupils and a rough estimate of 65,900 members of the local community. The input we expect the stakeholders to invest is mostly time and money. We propose a multiple year plan and this requires time and money to build up. The Kidiki staff are the stakeholders who will have to invest the most in this part. These investments made from their side are training for irrigation farming and agroforestry. To improve the farming techniques costs must be made as well. After these initial investments, long and short term outcomes will be achieved. We list the changes the stockholders experience for the different stakeholders below:

- The Kidiki staff:
    - **Short term**: Insights on key irrigation farming skills, own production of crops & fruits from agroforestry, reduced health risks thanks to a better kitchen.
    - **Long term**: increase of financial stability, improvement of nutrition for staff thanks to a variety of meals, A-levels teaching and teaching stability.
- The Kidiki pupils:
    - **Short term**: Insights on key irrigation farming skills thanks to a training book, finishing their education at Kidiki.
    - **Long term**: improvement of nutrition for pupils thanks to a variety of meals, access to higher education after finishing secondary school.
- The local community:
    - **Short term**: access to local farming products, access to new jobs at the farm.
    - **Long term**: Less time spent going to a local farming for food, economic growth in the region, increase of education in the region, children finishing their education.

All these points made in this section are part of the 1st and 2nd stage of evaluating the impact this project provides. In September, after working on the final details of our projects this summer, a new report will be made with the 3rd and 4th stage of measuring the impact the project has. The 3rd stage indicates how the described outcomes are measured, on what scale, what amount of change is measured per stakeholder and how long the outcomes last in terms of years or periods. The 4th stage expresses the relative importance or value of the outcomes, a valuation approach (non-monetary) and the weight of the outcomes.

Chapter 5. Budget statement

To execute this project Frieda and Peter reserved 4,000 euros. This money will be used to buy the planting material and all the materials needed for the irrigation system. Table 2 shows for each item the costs in Ugandan Shilling and in Euro. The prices of the planting materials are retrieved from many calls and chats with Michael, Wilson and Julius. Exact prices of the bucket irrigation kit explained in section 3.2 Irrigation were not found. Therefore, prices of the necessary materials for the irrigation system are based on prices found on Ugandan companies' websites professionalized in irrigation (Graduate Farmer Marketplace, 2021). It is important to note that those prices are obviously not consistent over Uganda. Prices can differ depending on the company where the material will be bought. Although, the ones presented in Table 2 already give a good impression of the costs.

In addition to Frieda and Peter's budget, we also hope to receive a subsidy from the Flemish Government, more specifically from the province of Flemish Brabant. The amount of the grant is a minimum of 15,000 euros and a maximum of 30,000 euros and does not exceed 75% of the accepted project budget. Of course, we take into account that there is no certainty of receiving the subsidy. The application will be submitted between August 20 and September 20, so the payment will be made in the autumn of 2021.

By installing this irrigation system the goal of the project, namely making the school financially independent, cannot be reached immediately. More revenue should be raised and more costs, like the highly inefficient kitchen, should be reduced. To achieve this goal, a broader time period is needed. That's why, like already mentioned earlier in this report, as a team we see this project over a longer period of ten years. To capture the dynamics of costs and revenues of the Kidiki School, a financial model containing all the different sources of income and costs is made in Excel format. In Annex IV an active web link is added that gives access to the model. Annex V provides access to the corresponding manual.

Table 2: Costs of irrigation system and planting material

MATERIAL	PRICES	
IRRIGATION		
Water tank (44 units)	1,540,000 UGX	358.90 EUR
Solar Pump System	7,000,000 UGX	1631.39 EUR
Dripping Tubes	1,200,000 UGX	279.67 EUR
Water Reservoir 10,000 liters	3,000,000 UGX	699.17 EUR
PLANTING		
Tomato seedlings	1,898 UGX	0.44 EUR
Eggplant seedlings	712 UGX	0.17 EUR
Dodo seeds	2,965 UGX	0.69 EUR
Onion seeds	1,660 UGX	0.39 EUR
Mango crafted seedlings	60,000 UGX	13.98 EUR
Papaya crafted seedlings	224000 UGX	52.20 EUR
Calliandra seeds	5,560 UGX	1.30 EUR
TOTAL	13,036,795 UGX	3038.29 EUR

Objective of the Model

The financial model allows us to make financial assessments for the project and over different years. The model considers not only the new investments under this AFD project, but also includes the current teaching activities at the Kidiki School. As such, its purpose is to provide a suitable structure for calculating the economic balance of all current and future activities of the School community. More precisely, it helps assessing and forecasting costs and benefits based on concrete information regarding expenses (such as the purchase of goods, transport costs or labour costs) and income (such as fees, sales, subsidies and donations, …).

Structure of the Model

The Model is constructed in a very accessible Excel spreadsheet, clearly indicating the cells where data need to be entered. It is composed of four kind of sheets:

- Sheets labelled “Input School Year x” with financial data on the school activities, with x varying from 0 to 10 (Year 0 is the year 2021)
- Sheets labelled “Fin. Model Year x” with financial data on the project and a copy of the school activities, with x varying from 0 to 10 (Year 0 is the year 2021)
- Sheet labelled “Fin. Model Summary” summarizing the financial data for all 11 years, as from 2021
- Sheet labelled “Indicative Time Table” showing a graph of the main investments, harvests during the period of 11 years, as from 2021

As such the model includes 24 sheets. Except for the “Indicative Time Table”, all sheets are linked to each other. The model can be extended with more years or with more items, if appropriate.

Application of the Model

The Excel spreadsheet is of great interest as a planning instrument since it may be necessary to distribute some of the investment costs over a number of years. For example, the cultivation of the cash crops and the expensive field preparation can be subject to a step-wise approach, by starting with a demonstration or pilot project to test at low cost the efficiency of a number of potential irrigation systems or to compare the yield of different cash crops. On the income side, subsidies may also require more than one year between the preparation of the application, the approval and the first payment. As such, these payment schedules can be introduced in the Excel spreadsheet as well.

A manual has been prepared to facilitate the use of the Model. It is not necessary to be proficient in Excel in order to use the Model.

Origin of the Data

The Model is largely supported by information from Kidiki School Management, i.e. 2021 expenses and revenues from school activities (for the current year 2021), but also by additional data on cash crops, field dimensions and groundwater well specifications. Project design data are from this AFD project. Additional research papers (e.g. FAO reviews, the Technical Manual for the IDEal Micro Irrigation Systems of the American NGO International Development Enterprises) and the consultation of other (commercial) internet sources were needed to fill essential gaps in the information in order to test the Model. These gaps mainly concern unit prices for goods and materials.

Two Ugandan companies (Weis Engineering Ltd and Sprinktech Uganda) were contacted through their webpages for specific quotes on water dripping and sprinkler systems, with however, no response.

Assumptions

Because not all of the input data has been validated by Michael, Wilson and Julius, a number of assumptions have been made in order to test the model with most relevant parameters and values. It is recommended that the model is discussed in detail before doing any actual investments or planning project related activities.

Assumptions on the land surface

The model considers a total field area of 1 acre (0.4047 ha), out of which a surface of 30 by 60 meters (0.1861 ha) would be prepared in 2021 for a pilot field. The pilot field is next to the existing water well. The Model foresees an extension of the pilot field to the full territory of 1 acre after 7 years.

Assumptions on the availability of goods and materials

All equipment and materials including water storage tanks, solar pumps, irrigation systems, pesticides and fertilizers and cooking stove can be bought in Uganda. Also seedlings, seed and small trees for agroforestry will be bought on the local markets.

Assumptions on the pricing of goods and materials

Local prices of purchase of goods and materials (school expenses, seedlings, small trees, labour cost) are provided by the Kidiki School. Pricing of the cooking stove and investment cost for the kitchen extension are copied from the AFD report (2020). Prices of other goods and equipment are from the internet (incl. Graduate Farmer from Kenya and other commercial websites). Prices should be considered as best estimations, but may be subject to change depending on the technical specifications of the goods and materials, and the time of purchase. The model does not consider price fluctuations, nor inflation.

Assumptions on consumables

It is assumed that 200 kg of fertilizer would be needed per ha and per year. The model does not consider costs related to the use of groundwater for irrigation purposes and has not included expenditures for the use of compost (if this would be available as a fertilizer). Compost and water are considered to be free of charge. The new cooking stove may imply a reduction in the consumption of firewood. This has not been taken into account, but can be changed in the model.

Assumptions on the groundwater well

It is assumed that the existing well has a sufficient flow throughout the year (also in the dry season) to produce good quality water to feed the irrigation systems (Figure 12). It was reported that the well is 46 m deep and would allow for a constant flow of 10 m^3/hr. As such, there should be no shortage of water. Depending on the type of crops and trees and layout of the field, the pilot project on a surface of 30 by 60 meters would need about 0.45 m^3 of fresh water per day. The entire field of 1 acre would need 4 times more under the same conditions. The technical aspects of the well (diameter, head, …) would allow to insert a pump for water abstraction for water storage and irrigation.

Figure 12: Installation of ground water well. (Whatsapp Communication)

Assumptions on the irrigation system

The project will make a quick start through the development of a pilot, with a small investment cost. A basic dripping system with a number of water tanks and one solar water pump are to be purchased at the beginning (in 2021), and to be used for the first 7 years (until 2028). After, the remaining of the available territory would be cultivated and a sprinkler system would be installed on the additional territory of the 1 acre.

Assumptions on transport

Transport costs are currently not included but they can be inserted in the calculation sheets.

Assumptions on the repair, maintenance and replacement of infrastructure and equipment

The model allows for expenditures in case of breakdown, repairs, replacement or general maintenance of infrastructure and goods. In the current calculations these costs are not considered.

Assumptions on labour

Currently, limited labour costs are included in the Model (for planting, watering and general management of the field). Specific sales costs are not included in the calculations. Additional labour costs can be inserted (Figure 13).

Assumptions on the type of cash crops and agroforestry

The following plants are foreseen in the Model: tomato, eggplant, onion, dodo (replacing the originally foreseen spinach upon suggestion of the locals), *Calliandra*, mango and papaya. The Model is based on the assumption that the same plants will be grown during the period of at least 10 years. There are provisions in the Model to add other types of plants.

Assumptions on the field layout

The density of the crops (spacing, alternations of the plants, etc.) are based on this AFD project. The following assumptions are made for the density. Per square meter (m^2) there will be 4 tomato plants, 4 eggplants, 20 onion plants or 8 dodo plants. For the mango and papaya trees the Model considers the number as shown in the design (but recalculated by surface). The number of *Calliandra* shrubs are calculated based on the design and with a distance of 0.50 m between each shrub (i.e. 2 plants per m^2).

Assumptions on the harvests

For the four types of cash crops two harvests per full year are included in the model. For the current year 2021 (Year 0) one harvest is taken into account. For the agroforestry other considerations are made. The first harvest of mango is foreseen as from the fifth year. For the papaya the first harvest would be in the second year already. For reasons of productivity, the model foresees two subsequent years of papaya harvest from the same plant, after which the existing plant will be replaced by a new plant. In the year of replacing the papaya plants, no harvest is considered.

Figure 13: Two women in Namwendwa working on the field. (Okwagaanana)

Assumptions on the yields (productivity)

The following data are used in the model, based on own information and internet search: one tomato plant would produce 2.5 kg of fruits; one eggplant would produce four fruits of 1.1 kg in total, one onion would weigh 0.08 kg and one dodo plant would produce 0.1 kg of leaves for consumption. A mango tree would produce about 20 fruits in the fifth year after planting the grafted seedling, and about 50 fruits for the next 5 years. Only after the production would increase to 500 fruits per tree. For the papaya tree 100 fruits are considered in the second and third year. To keep this high productivity, papaya plants would be renewed every 3 years. For the *Calliandra* shrub no such calculations have been made in the model. It is also assumed that there will be no outfall of plants during the growing season due to drought, disease, plagues or other unexpected events.

Assumptions on the sales

Fruits and cash crops will be sold on local markets (Figure 14). *Calliandra* leaves will be used for own usage. The model currently considers that only 50% of the vegetable and fruit products will be sold on the local markets. The other 50% will be consumed within the school community as indicated by our local partners. Upon the installation of the new cooking stove in the extended kitchen, meals could be also prepared for people outside of the school community. The sales of such additional meals can be included in the Model if appropriate.

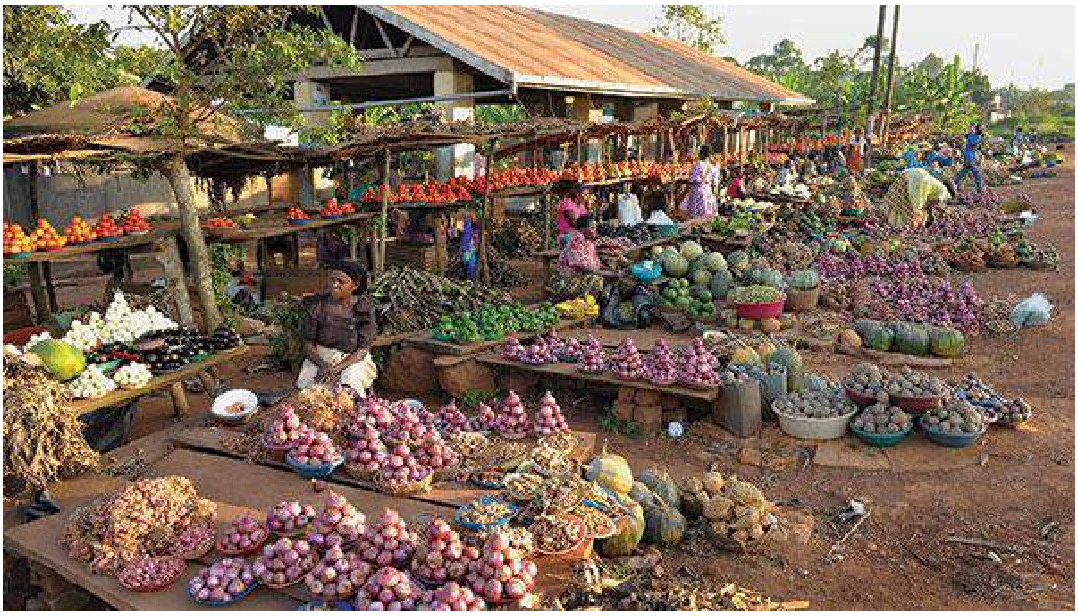

Figure 14: Ugandan market. (Above whispers)

Assumptions on the pricing of products

Pricing of cash crops and fruits are provided by Kidiki School, and complementary internet search. Prices may be subject to change depending on local market conditions, in particular over the time period of 11 years.

Assumptions on the international financial support

International financial support in 2021 from own investment (EUR 4,000) and from subsidies from the Province of Flemish Brabant (EUR 3,000) and in 2022 from the same Province for the amount of EUR 2,000. The financing from the Province will be 75% of the eligible costs. The Model does not include other foreign financial support, but has foreseen the possibilities to enter such information.

Assumptions on the currency exchange rate

Financial data in the Model are shown and calculated in Ugandan Shilling (UGX). The international support is shown in EUR. The Model takes into account an exchange rate of 4.289,15 (date May 7, 2021). For the current calculations, a fixed exchange rate is considered. The rate can be modified in the Model.

AFD Project Okwagaanana
May 2021

First Modelling Results

Based on the 2021 data for the school activities and the project design, a first simulation has been done for the period of 11 years.

Currently, it is foreseen that in the summer of 2021 (Year 0) a number of investments will be made to prepare the area of 30 by 60 meters (or 0.1861 ha) as a pilot field, equipped with a dripping system. This system would also include the installation of one large 10,000 liter water storage tank near the groundwater well and some 44 smaller 100 liter storage tanks, completed with a piping network for watering the beds. One (mobile) solar water pump would be used for pumping the groundwater into the main reservoir and for the further pumping into the smaller tanks. The timely preparation of the pilot field and the purchase of seedlings would even allow for one harvest at the end of the year. Finally, the trees and shrubs for agroforestry would be planted. One labour force is foreseen as from the summer. International financing of EUR 4,000 (own investment) would cover most if not all of the costs, considering the above assumptions. It has been assumed that the successful application for funding from the Province of Flemish Brabant would add EUR 3,000 of financial support. The balance for Year 0, as calculated by the model, would be UGX 20,330,720 (4,714 EUR).

In the Year 1 (2022) additional investments are scheduled. These include the purchase of the cooking stove and the extension of the kitchen building. One full time labour force is foreseen. With the partial (50%) sales from two harvests of cash crops and the additional funding from the Province of Flemish Brabant of EUR 1600 the project would create a small positive result of UGX 1,685,855 (EUR 391). As for all the years modelled, this result should be screened in detail based on a critical review of costs and benefits. A possible measure to increase profits could be the increase of the share of the harvest to be put for sale.

In the Years 2-6 (2023 – 2027) no major investments are foreseen in the model, and also the international financial support would have stopped. During this period the project would be slightly positive still, with a result in the range of UGX 4.1-5.9 million (or EUR 949-1,360) may be expected each year. This profit could be considered as savings for partly financing the new, major investments scheduled in Year 7 (2028), when the full acre would be prepared for cash crops and agroforestry. This upscaling would imply the installation of a (more expensive) sprinkler system, another four 500 liter water storage tanks and the purchase of one additional solar water pump. Because of these investments, there would be a negative result of ca. UGX 20.3 million (EUR 4,702). A detailed screening of the main investment costs (sprinkler system, solar water pump, etc.) and a larger sales proportion of the cash crops would largely mitigate the forecasted losses. In fact, a second well nearby could also compromise the productivity of the existing well. Although the model includes the possibility to budget the fencing of the full acre, this additional cost is not included here. If additional international or other funds could be obtained, then a part of the benefits of the previous years may be also considered to upgrade the school infrastructure or its activities. These choices are to be made by the Ugandan beneficiaries.

In the Years 8 -10 (2029 - 2031) the full field of 1 acre will be operational and productive, and the sales of cash crops and fruits will become more important. The overall positive balances in these years (ranging between UGX 13.3-19.2 million or EUR 3,092-4,443 become more hypothetical however, due to the greater uncertainties (see above under Assumptions). In particular, the maintenance and repair costs may become of increasing importance, considerably impacting the benefits as projected by Model.

Chapter 6. Planning

Unfortunately, we can not go to Uganda this summer to work together with the Kidiki school staff in real life because of the Covid situation. Despite this disappointment, we are still motivated to commit ourselves to the project during July and August, working from Belgium. We will make manuals for the school staff to support them in realising the plans. We plan to make a manual for the irrigation system. We also have the idea to try out a small irrigation system ourselves, which may give us some interesting insights. In addition we will provide a manual on the specific nutritional needs of the crops the school is growing. This manual can be a tool in selecting fertilizers, in the early stages, when the soil improvement through the agroforestry system is not yet sufficient.

References

Academics for Development. (2020, May). May Report: Okwagaanana Uganda. Retrieved from https://drive.google.com/drive/u/0/folders/1ByQiaKbHX2ShNHK_K19lwd3vj42pEbHg

Akvopedia. (2013a, oktober 2). *Layout of Waterboys bucket system* [Illustration]. Akvopedia. https://akvopedia.org/wiki/Waterboys

Akvopedia. (2013b, oktober 2). *Waterboys - Akvopedia*. https://akvopedia.org/wiki/Waterboys

Average Weather in Kamuli, Uganda, Year Round - Weather Spark. (2016). Average Weather in Kamuli. https://weatherspark.com/y/97592/Average-Weather-in-Kamuli-Uganda-Year-Round

Average temperatures and precipitation. (n.d.) Retrieved from https://www.meteoblue.com/en/weather/historyclimate/climatemodelled/ kamuli _uganda_232397.

Background – Kidiki Secondary School. (z.d.). Kidiki Secondary School. Geraadpleegd op 3 november 2020, van https://www.kamulionline.com/kidikiss/background/

Brinkhoff, T. (n.d.). *Namwendwa (Subcounty, Uganda) - Population Statistics, Charts, Map and Location*. City Population. Retrieved 23 November 2020, from https://www.citypopulation.de/en/uganda/eastern/admin/kamuli/SC1478__namwendwa/

Britannica. (n.d.). Papaya: tree and fruit [picture]. Papaya tree (*Carica papaya*) by *Wilfredo Rodríguez.* https://www.britannica.com/plant/papaya

Civil Engineering. (n.d.). *14 Advantages and Disadvantages of Sprinkler Irrigation*. Retrieved 13 november 2020, from https://civiltoday.com/water-resource-engineering/irrigation/289-advantages-and-disadvantages-of-sprinkler-irrigation

Climate Kamuli. (n.d.). meteoblue. Retrieved 23 November 2020, from https://www.meteoblue.com/en/weather/historyclimate/climatemodelled/ kamuli _uganda_232397

Crop Information | Land & Water | Food and Agriculture Organization of the United Nations | Land & Water | Food and Agriculture Organization of the United Nations. (2021). FAO. http://www.fao.org/land-water/databases-and-software/crop-information/en/

CropWat | Land & Water | Food and Agriculture Organization of the United Nations | Land & Water | Food and Agriculture Organization of the United Nations. (2021). Cropwat. http://www.fao.org/land-water/databases-and-software/cropwat/en/

Drip bucket irrigation. (n.d.). [Picture]. Drip bucket irrigation. https://mapio.net/pic/p-100864690/

Geno, L. M., & Geno, B. J. (2001). Polyculture production: principles, benefits and risks of multiple cropping land management systems for Australia: a report for the rural industries research and development corporation. *Rural Industries Research and Development Corporation.*

Google Maps. (n.d.). Google. Retrieved 23 November 2020, from https://www.google.be/maps

Graduate Farmer Marketplace. (2021, 1 februari). *Drip Irrigation Kits and Components*. https://graduatefarmer.co.ke/marketplace/product/drip-irrigation-kits-and-components/

Grant, A. (2020, May, 22). Mango tree not producing: How to get mango fruit. Gardeningknowhow. https://www.gardeningknowhow.com/edible/fruits/mango/mango-tree-not-producing.htm

Hessong, A. (2018, December, 14). What months are papaya trees ready for picking. SFGate. https://homeguides.sfgate.com/months-papaya-trees-ready-picking-63902.html

Jauregui, R. (2020, August, 24). Planting distance between mango trees. SFGate. https://homeguides.sfgate.com/planting-distance-between-mango-trees-58888.html

Kabunga, J. (2016, September 25). Sprinkler Irrigation [Picture]. Retrieved from https://agriprofocus.com/post/57e80572a93f254eb659cdb7

Kunhamu, T. & Santhoshkumar, A. (2012). Mango in agroforestry. Valavi, S., G., Rajmohan, K., Govil, J., N., Peter, K., V., Thottappilly, G. Mango Vol 1 - Producing and processing technology (pp. 395-405). Houstan, U.S.A.: Studium Press LLC.

Kyarikunda, M., Nyamukuru, A., Mulindwa, D., & Tabuti, J. R. S. (2017). Agroforestry and Management of Trees in Bunya County, Mayuge District, Uganda. *International Journal of Forestry Research, 2017.*

Kayuki, K. C., Angella, N., & Musisi, K. F. (2017). 15. Optimizing Fertilizer Use within the Context of Integrated Soil Fertility in Uganda.

Lokalisation of the Kamuli District and the Kidiki Primary School. (n.d). Retrieved from https://www.openstreetmap.org

Ocungi, J. (n.d.). *Ugandan market* [Picture]. Above Whispers. http://abovewhispers.com/2017/01/05/uganda-millions-lost-fire-razes-elegu-market/

Okwagaanana. (n.d.-a). *Okwagaanana*.Retrieved 13 November 2020, from http://www.okwagaanana.be/organisatie01.htm

Okwagaanana. (n.d.-b). *Two women in Namwendwa working on the field* [Picture]. Okwagaanana. http://www.okwagaanana.be

OpenStreetMap. (n.d.). OpenStreetMap. Retrieved 23 November 2020, from https://www.openstreetmap.org/#map=8/50.510/4.475

Place, F., Roothaert, R. L., Maina, L., Franzel, S., Sinja, J., & Wanjiku, J. (2009). The impact of fodder trees on milk production and income among smallholder dairy farmers in East Africa and the role of research.

ProductiveProduce. (2018, August, 21). Mango Trees [Picture]. https://www.productiveproduce.org/articles/2018/2/25/mango-trees

Rosenstock, T. S., Dawson, I. K., Aynekulu, E., Chomba, S., Degrande, A., Fornace, K., Jamnadass, R., Kimaro, A., Kindt, R., & Lamanna, C. (2019). A planetary health perspective on agroforestry in Sub-Saharan Africa. *One Earth, 1*(3), 330-344.

Tenywa, J. S., Nyende, P., Kidoido, M., Kasenge, V., Oryokot, J., & Mbowa, S. (1999). Prospects and constraints of finger millet production in Eastern Uganda. *African Crop Science Journal, 7(*4), 569-583.

Thompson, D. (2018). Characteristics of sandy loam soil. In: Technical report. https://homeguides. sfgate. com/characteristics-sandy-loam

Tusiime, S. M., Nonnecke, G. R., Masinde, D. M., & Jensen, H. H. (2019). Evaluation of Horticultural Practices for Sustainable Tomato Production in Eastern Uganda. *HortScience, 54(*11), 1934-1940.

Uganda Bureau of Statistics. (2017). National population and housing census 2014: Area specific profiles.

Uganda Government. (n.d.). Ugandan Soils [Illustratie]. Retrieved from https://esdac.jrc.ec.europa.eu/content/uganda-soils

Annex I – General background reading

Project Okwagaanana: http://www.okwagaanana.be/

Annex II – Water demand extra's

The weblink for the growth planning and water requirement can be found below.

https://drive.google.com/file/d/1Oc-1FcCgLBrzMMBG1qI5fuJv4p9cP6yn/view?usp=sharing

Annex III – Irrigation extra's

System components and assembly for the Waterboys kit bucket drip irrigation.

System components

- 30-litre bucket
- 2 x 10 m complete drip line
- Manifold to connect
- 2 drip lines.

Assembly instructions

1. Prepare the planting bed 1-m wide x 10-m long.
2. Construct a bucket stand.
3. Lay the pipes. Since all the pipes are already connected, you only need to lay them out on the bed.
4. Mount the bucket on its stand.

5. Connect the manifold to the bucket with a snap-in collar.
6. Connect the two drip lines to the tee.

These components and instructions only apply for two rows of +/- 10m rows of crops. To apply it to the whole field we must just add more buckets and repeat the process.

Interesting links for extra information about assembly of bucket drip irrigation is found in links below:

- https://afghanag.ucdavis.edu/irrigation-natural-resource/files/bucket-drip-irrigation.pdf
- https://www.instructables.com/Gravity-Drip-Watering-System/

Annex IV - Financial Model

The weblink for the financial model can be found below.

https://drive.google.com/file/d/1aw-okUZIraQiidi-oR9C4wUUycQ21urV/view?usp=sharing

Annex V - Financial Model Manual

The weblink for the manual of the financial model can be found below.

https://drive.google.com/file/d/15FajkVem5HAtlveFQ4oKAIKIQO3IGTpQ/view?usp=sharing

Annex VI - Additional Graphs and Figures

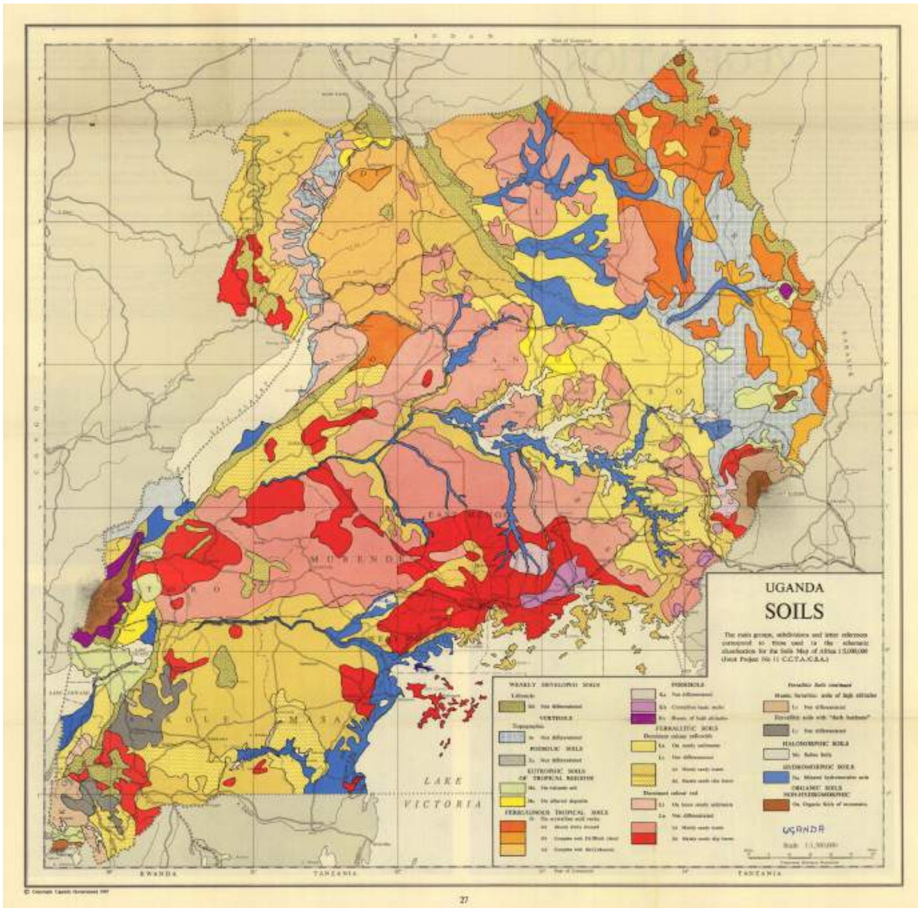

Figure 15: Ugandan soils. Retrieved from Ugandan Government, n.d. https://esdac.jrc.ec.europa.eu/content/uganda-soils. Copyright n.d., Esdac.