2021

Kaleya Smallholders Company Limited (KASCOL)

Sub-surface Drip Irrigation Development Evaluation Project – Pre-Feasibility Report

Project №. AQ21-022

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Airlift yield: This is the yield measured during the drilling process where the water is blown out of the ground using air pressure, hence the term airlift yield. This yield is generally less accurate than the yield derived from a pumping test.

Alluvium: General term for *detrital* material deposited by flowing water.

Aquifer: A geological formation or structure which stores and transmits water and which is able to supply water to wells, boreholes or springs.

Confined aquifer: A formation in which the groundwater is isolated from the atmosphere by impermeable geologic formations. Confined water is generally at greater pressure than atmospheric, and will therefore rise above the struck level in a borehole.

BGR: Bundesanstalt für Geowissenschaften und Rohstoffe, This is a German groundwater institute that has done a number of studies to the geohydrology of the Chongwe catchment and other areas in Zambia.

Detrital: Consisting of loose particles, fragments or grains that have been worn away from rock.

Dolomite: A carbonate mineral composed of calcium magnesium carbonate.

Drawdown: The vertical distance between the static water table and the surface of the cone of depression, which appears when pumping groundwater

ETo: Potential Evapotranspiration, this is the amount of water that can evaporate from a water surface, this is used as a base line and can be converted to actual evapotranspiration for certain crop types.

Evapotranspiration: Loss of water from a land area through transpiration from plants and evaporation from the surface.

Fault: A discontinuity in a volume of rock, across which there has been displacement as a result of rock mass movement.

Hydraulic head: Energy contained in a water mass, produced by elevation, pressure or velocity.

Hydrogeological: Those factors that deal with subsurface waters and related geological aspects of surface waters.

Infiltration: Process of water entering the soil through the ground surface.

KASCOL: Kaleya Smallholders Company Limited

Lithology: The description of the rock type.

m amsl: meters above mean sea level.

m bgl: meters below ground level.

Percolation: Process of water seeping through the unsaturated zone, generally from a surface source to the saturated zone.

Permeability: The ability of a rock or other porous medium to transmit fluids

Porosity: The portion of bulk volume in a rock or sediment that is occupied by openings, whether isolated or connected.

Recharge: The process by which water is added to the groundwater storage in a given period (e.g. from infiltration of rainfall, surface water or lateral groundwater flow).

Specific capacity: The quantity of water a given borehole can produce per unit drawdown.

Specific yield: The amount of water released due to drainage from lowering the water table in an unconfined aquifer ($S_{y =}$ m^3 volume of water/m unit drawdown /m^2 unit aquifer area). The resulting value is a dimensionless ratio between 0 and 1 ($S_y \leq$ porosity). The value for specific yield is less than the value for porosity because some water will remain in the medium even after drainage due to molecular forces. Often the porosity or effective porosity is used as an upper bound to the specific yield.

Static Water level: Refers to the level of water in a well under normal, undisturbed conditions, i.e. a well that is not being affected by pumping. (Also known as "rest water level")

Unconfined Referring to an aquifer situation whereby the water table is exposed to the atmosphere through openings in the overlying materials (as opposed to >confined conditions).

Watershed: A watershed is an area of land that feeds all the water running under it and draining off of it into a body of water. It combines with other watersheds to form a network of rivers and streams that progressively drain into larger water areas. Topography determines where and how water flows.

Yield: Volume of water discharged from a well.

1. INTRODUCTION

Kaleya Smallholders Company Limited (KASCOL) operates a farm, which is located approximately 135 km south of Lusaka, along Livingstone Road, 6 km from the Mazabuka Town CBD. The farm covers an area of about 4,000 ha, with 2,520 ha of arable land (Figure 1). Currently, mainly sugar cane is grown on the farm, with an additional 300 ha of barley and soya on a rotational basis.

Figure 1. Location of the Kaleya Smallholders Company farm

The farm is supplied with water from the Kafue River by Zambia Sugar Plc, the principal off-taker of the sugarcane produce and partner in the farming activities. However, in view of the growing irrigation requirements, there is already a deficit of water. In this light, a project grant has been provided by the Dutch Fund for Climate Development (DFCD). The purpose of the grant is to support a technical assessment for the planned conversion from the current furrow irrigation systems to much more water-efficient drip irrigation systems, as well as a social & environmental study to assess the impacts of this development.

The scope of work for the current Sub-surface Drip Irrigation Development Evaluation Project is defined as follows:

1. ***Technical Literature and Data Review***
   a. Review of all technical studies and proposals to date for KASCOL
   b. Review of all data and systems at KASCOL
2. ***Suitability Assessment***
   a. Assessment of current infrastructure and suitability for the project
   b. Comparative analysis of Irrigation Technologies and their suitability and ROI
   c. Assessment of ROI from other investments in Irrigation infrastructure at KASCOL
3. ***Information Technology and Remote Sensing***
   a. Review of current Information Technology and remote Sensing usage and Scope for expansion
4. ***Energy***
   a. Review of current energy requirements and the possibility of providing resilience with Solar

In addition to the above-mentioned scope of works, an assessment of the available water resources that will feed the proposed irrigation scheme, as well as a corporate government assessment, are to be conducted.

In order to conduct a detailed comparative assessment, different options need to be designed, costed and compared. At this stage, the detailed scope of works for the review of these options is not yet known. The project will therefore be executed in two phases:

- Phase 1 will be a pre-feasibility study to assess the existing data, information and infrastructure, while
- Phase 2 will include a feasibility study with detailed designs of the selected irrigation schemes.

The current report represents the pre-feasibility study under Phase 1 of the Sub-surface Drip Irrigation Development, which will guide the scope of works for the detailed feasibility study under Phase 2.

2. REVIEW OF AVAILABLE DATA AND LITERATURE

2.1 KALEYA FARM AND ENVIRONMENTAL DATA

In this section the environmental information of the farm is summarized. The categories are; farm boundaries, climate, topography, geology, hydrogeology, soil and sugarcane water requirements.

2.1.1 Farm boundaries

A map of the farm boundaries, subdivision and existing dam locations is presented in Figure 2.

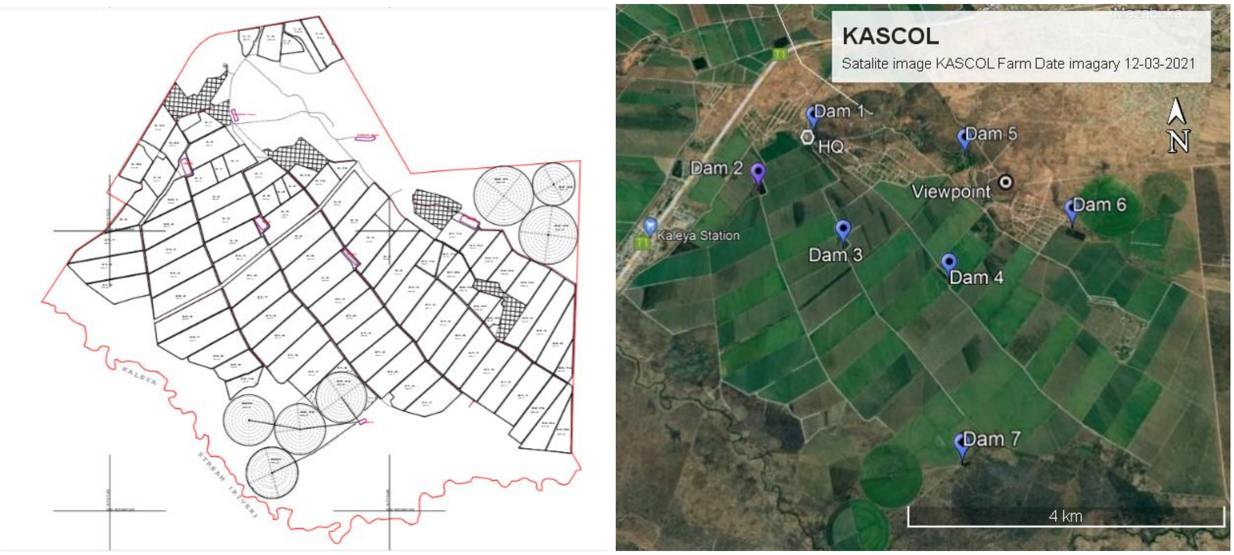


Figure 2. Farm Boundaries

2.1.2 Climate

In the area of KASCOL Estate and its surroundings, three seasons are clearly distinguishable:

1. Mid-April to mid-August, which is cool and dry. Mean day temperatures vary between 14°C and 18°C, with minimum temperatures often falling below 4°C in June and July.
2. The period from Mid-August to mid-November represents the hot and dry season. Mean daily temperatures vary between 20°C and 23°C, with highs up to 32°C in October and November.
3. Mid-November to Mid-April is warm and wet. Typically, the vast majority of the annual rainfall falls during this period.

Data from the three nearest weather stations (at Mazabuka Town, Kafue Polder and Magoye) was collected. Table 1 shows the monthly rainfall around Mazabuka, based on the rainfall measured at these three weather stations, expressed in the categories of low, high and best-estimated rainfall.

Table 1. Monthly rainfall data for Mazabuka (FAO, LocClim)

Precipitation	Best Estimate [mm]	Low Estimate [mm]	High Estimate [mm]
January	184	176	191.9
February	176	155	197
March	68	61	75.1
April	11	0	25.6
May	0	0	2.5
June	0	0	0
July	0	0	0
August	0	0	0
September	1	0.5	1.5
October	16	12.9	19.1
November	101	82.6	119.4
December	211	210.1	211.9
Total	**768**	**698.1**	**844**

KASCOL also recorded their own rainfall data from 2017 onwards (Table 2).

Table 2. Rainfall data recorded by KASCOL, for the years 2017-2020

Month	Mean precipitation [mm]
January	123.2
February	211.8
March	67.0
April	17.2
May	0.0
June	0.0
July	0.0
August	0.0
September	0.0
October	13.4
November	81.8
December	158.3
Total	**672.5**

The recorded data by KASCOL suggests lower mean annual rainfall, when compared with the data from the three Mazabuka weather stations. This difference should mainly be attributed to the fact that the weather stations and FAO data cover a much longer period, while the fact that the recent year 2019 was exceptionally dry weighs heavily on the short-term record for KASCOL, thus significantly lowering the mean precipitation.

2.1.3 Topography

KASCOL Estate is located south of Mazabuka Town and southwest of the Kafue Flats. The elevation on the Estate increases towards the northeast, where it reaches a topographic high of approximately 1,120 m amsl. The slope towards the north-east is relatively steady and constant. The area with the lowest elevation (1,030 m amsl) is along the southwestern boundary, which is formed by the Kaleya River (see Figure 3).

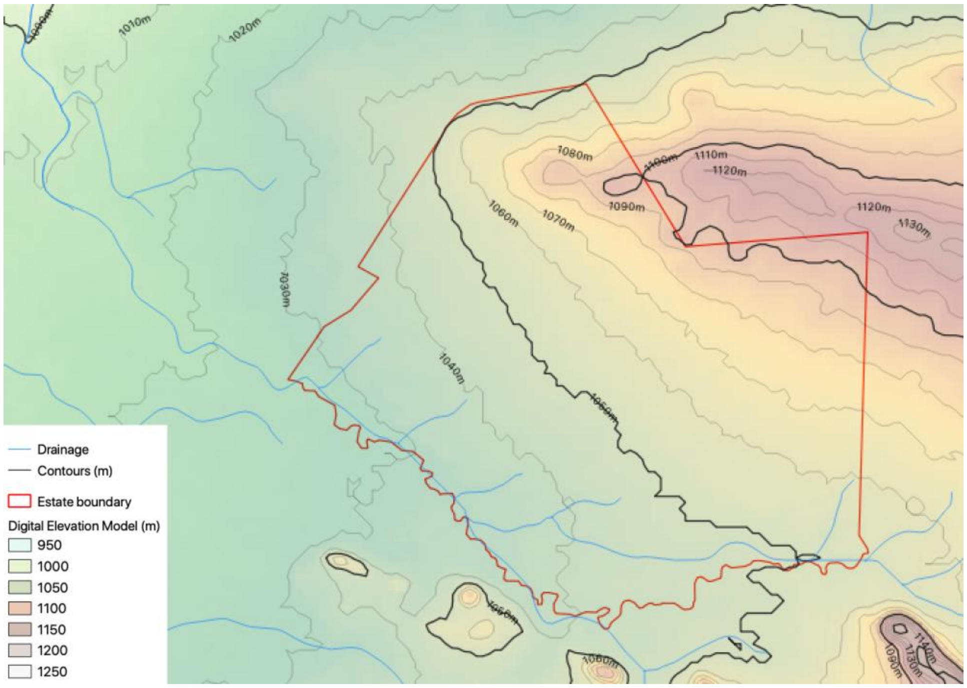


Figure 3. Elevation map of KASCOL estate

Catchment delineation shows that the estate is situated in the downstream part of the watershed of the Kaleya River, a tributary of the Kafue River (see Figure 4). Total catchment area amounts to 570 km^2 and upstream catchment area amounts to 556.8 km^2.

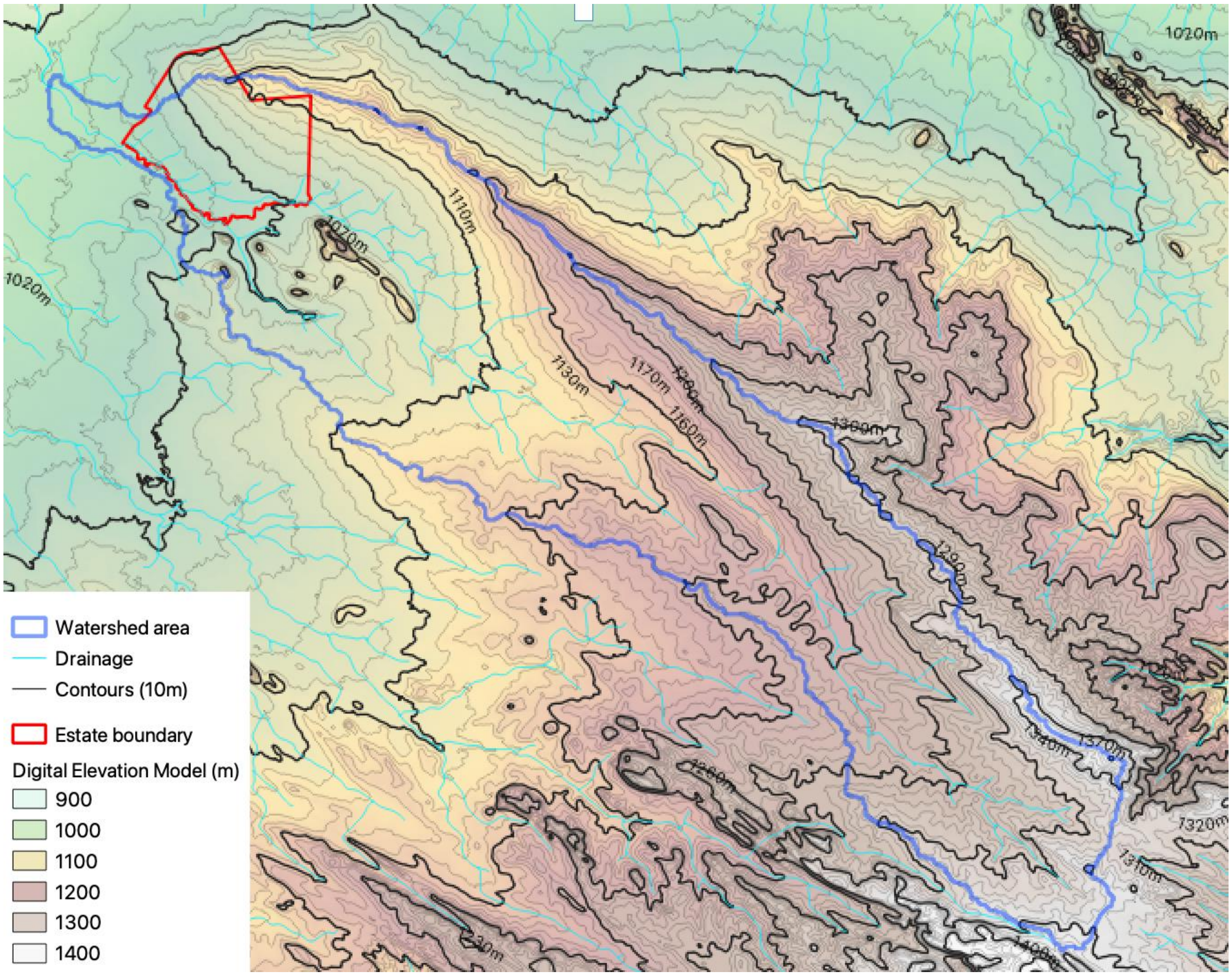


Figure 4. Catchment area surrounding the KASCOL estate

2.1.4 Geology

The area is covered by the 1527 SE Quarter geological map of the Mazabuka Area, 1964, produced by the Geological Survey Department of the Republic of Zambia (Figure 5).

According to the geological map, limestone/dolomite formations are found in the more elevated northern parts of the farm. The central and southern parts of the Estate are made up of alluvium and residual deposits (i.e. hillslope deposits, colluvium). Along the southern perimeter of the estate, quartz-muscovite rocks are exposed in the bottom of the Kaleya River valley, due to erosion and incision. Further east and west, the valley bottom changes to limestone/dolomite formations.

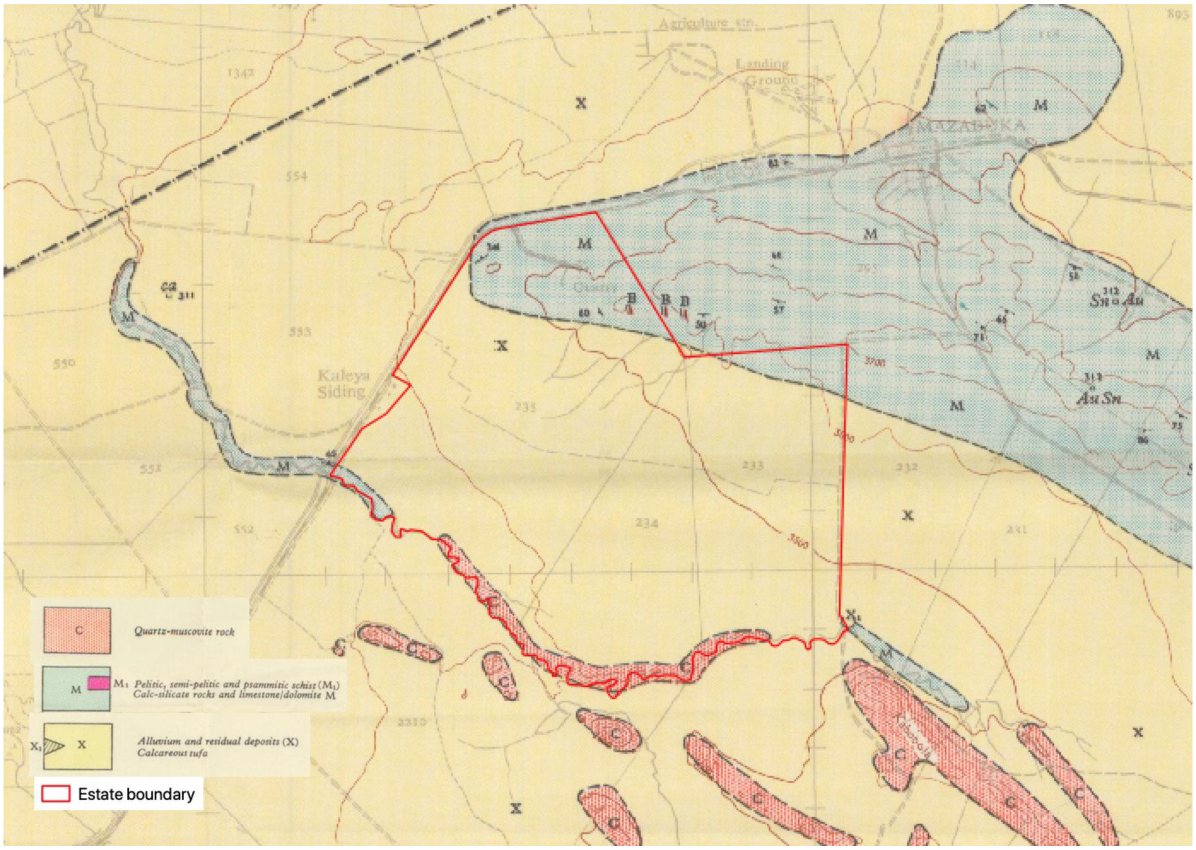


Figure 5. Geological map of the area surrounding KASCOL estate

2.1.5 Hydrogeology

A groundwater map of the area was developed by BGR (Baümle et al., 2007). According to the map (Figure 6), which indicates the aquifer potential around the estate, the general direction of groundwater flow is towards the north-west. The map is based on the geological map, in combination with borehole observations.

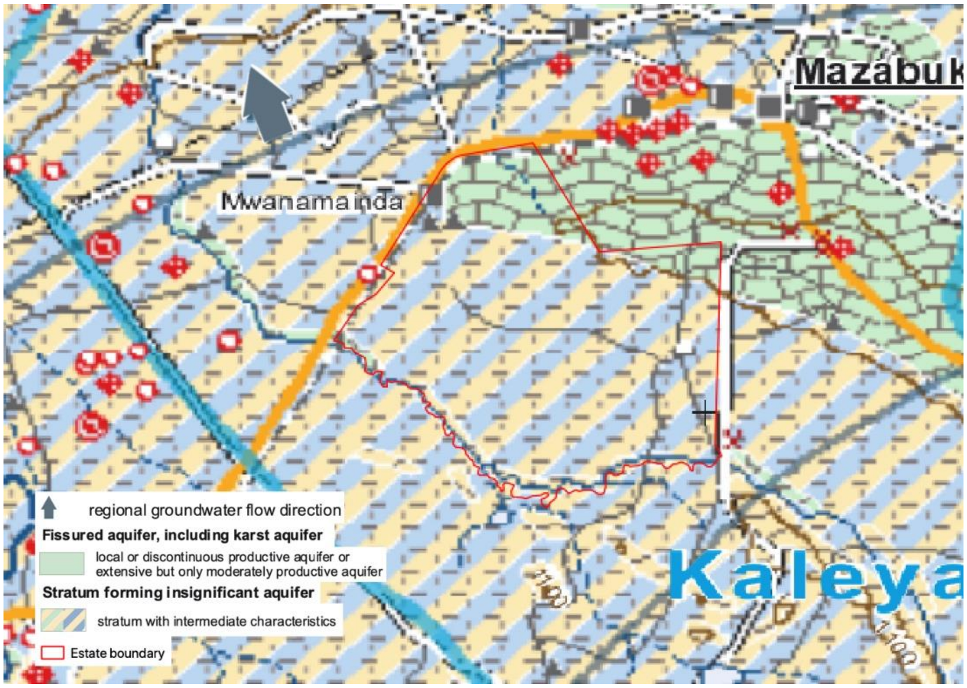


Figure 6. Hydrogeological map of the area surrounding KASCOL estate (BGR, 2007)

The geohydrological map shows potential for a ***local discontinuous productive aquifer or an extensive but only moderately productive aquifer*** in the northern part of the estate, which is underlain by limestone/dolomite. Primary porosity in these formations is generally low, limiting the amount of water that can be stored inter-granularly. Secondary porosity however can be high: dissolved cavities and fractures within the limestone/dolomite can function as great water storage reservoirs. Therefore, the volume of water that exists in the ground is likely hosted mainly within solution cavities and fractures, of which some may extend several kilometers in length. The solution cavities are known to host significant amounts of groundwater. Fractures of 1.0 mm in width already have the capability to transmit high volumes of water. A zone consisting of fractures several cm or greater in width has the potential to support submersible pumping. The challenge is to identify these zones, which are generally not easily recognizable.

Boreholes drilled in this area on the estate have already resulted in yields that look promising. However, only pumping rates are available for these boreholes; important other data is lacking (see Chapter 4.3.1). A detailed assessment of the possible yields in this area requires groundwater exploration and corresponding test pumping.

The central and southern parts of the estate are characterized by ***Strata with intermediate characteristics.*** Relatively shallow sedimentary aquifers are expected within soils, unconsolidated alluvial deposits and colluvium (hillslope deposits).

Alluvial formations normally present favourable conditions for groundwater occurrence: deposits of pure, unconsolidated sands are highly transmissive. However, the hydraulic conductivity rapidly decreases in the presence of clays, even if their portion is small. Heavy clays are impermeable, even though their porosity can be as high as 50%. To evaluate the aquifer potential of alluvial deposits, the thickness and distribution of clay layers is important. Their presence will reduce the amount of recharge and effective storage, and the potential yield of a borehole.

Due to the anticipated mixture of river deposits, soils, weathered residue and colluvium, the texture of the local unconsolidated deposits is expected to be diverse and heterogeneous. In a vertical section, the composition may suddenly change from gravelly to heavy clay. However, clayey textures are expected to be dominant. Hence, while groundwater is expected to occur at shallow to medium depths within these unconsolidated deposits, yields are expected to be relatively low, especially when compared with successful boreholes in the limestones.

2.1.6 Soil information

2.1.6.1 General soil information

Sugar cane prefers fertile deep and well-drained, uncompacted soils that are loamy (less than 40% clay) and neutral (pH around 6.5). Sugar cane roots can grow relatively deep, and relatively shallow soils will inhibit cane growth. The soils on KASCOL estate are classified as Luvisols (a highly weather soil type ideal for most agriculture). Coinciding with the distribution of the limestone/dolomite geological formations, the clay soils in the north and north-eastern parts of the estate (mainly around the 3 northern pivot fields) are filled with large rock fragments and underlain by shallow bedrock. Clay content is relatively low in this area. The center of the estate, where there is furrow irrigation, is composed of relatively deep (up to 2 meters deep) fine loamy clay soils. These soils are most favorable for sugar cane growth. Deep rooting enhances the crop’s drought tolerance and nutrient uptake. The southern part of the estate, where the other 4 pivot fields are located, is composed of shallower loamy clay soils with high clay content, which are consequently less favorable for sugar cane growth.

Due to their less favorable soil environment for sugar cane, part of the northern and southern pivot fields have been replanted with soy bean: 64 out of 164 hectares in the north and 75 out of 200 hectares in the south.

2.1.6.2 Soil analysis

Each year, fertilizers are ordered by KASCOL, based on nutrient shortages in the soil that are examined through soil analysis. The soil analysis conducted in September 2020 shows that the organic matter content is low in the majority of fields and that the acidity of the soils ranges between a pH of 5.96 and 8.36. Although sugar cane tolerates a wide pH range, the alkaline soils of half of the tested fields may affect overall productivity. As phosphorus tends be locked up by calcium in alkaline soils, it becomes unavailable for plants. In fact, ¾ of the fields are deficient in phosphorus. The rather alkaline soils may contribute to a low boron content found on 30 of the 36 tested fields as well.

Total nitrogen concentration in the topsoil across all fields is relatively low. Considering the high nitrogen concentration added through fertilizers, some of it may wash down (to the deep soils), but it should not be ruled out that part of the nitrogen that is not taken up by the crop actually runs off. Water and nutrient losses due to runoff and deep drainage may be better controlled under drip irrigation.

2.1.7 Sugarcane & crop water requirements

To design, assess, or fine-tune irrigation needs, insight in crop water requirements is key. Different methods exist to estimate the crop water requirements. When combining the derived crop water data with the rainfall pattern, a realistic indication can be given. Based on FAO's crop water use calculation tool, CROPWAT 8.0, and the climate data available from CLIMWAT, the peak crop water demand is estimated to be 6.11 mm/day. When taking into account the local rainfall figures, the peak irrigation requirement is 5.73 mm/day. In future, this can be further fine-tuned, using weather data collected by KASCOL. The CROPWAT data is provided in Annex II.

Not only the amount of irrigation water, but also the application depth is important to take into account for sugarcane. The roots of sugarcane can easily reach a depth of 1 meter, and even depths up to 5 meters have been recorded in some plantations. . The deeper loamy fields are expected to hold more water, which could increase the irrigation depth (or duration) but reduce the frequency of the irrigation periods. This will help deep rooting and increase the drought tolerance of the crop. Mainly during the vegetative growth and early ripening stage, when water requirement peaks, longer application depths (by duration) are advised. In the ripening period, irrigation should be significantly reduced to enhance the development of the sugar content. During very hot and dry periods, irrigation with small application depths can be applied.

2.2 FARM FINANCIALS AND OPERATIONS

This section summarizes information provided by KASCOL concerning its financial operations. The provided data will also be used during the second phase of this research to evaluate the different irrigation technologies in more detail and to compare the current data with the expected figures from an envisioned 300ha SDI expansion. It should be noted that the 2021 data is not yet final as the year is still ongoing at the time of drafting this report.

This initial review further includes a rough analysis of the potential to improve 1) the business case (profit maximization), as well as 2) information, products and practices that can assist when agronomic decisions. A summary of the current financial operations by KASCOL is presented in Table 3.

Table 3. Overview of costs KASCOL summarized in eight categories (2021 not complete)

Overview of costs summarized	2016	2017	2018	2019	2020	2021
Staff and labour	K4,291,078.00	K5,907,090.00	K5,858,384.00	K5,640,501.00	K4,989,411.00	K5,365,214.00
Water	K4,500,976.12	K6,865,995.97	K5,568,845.18	K6,442,321.80	K7,083,754.24	K9,705,053.48
Electricity in total	K1,038,977.59	K676,074.61	K1,031,337.66	K1,254,987.25	K1,268,075.11	K2,094,529.69
Farm inputs	K30,343,295.00	K34,677,641.00	K28,762,123.00	K36,508,672.00	K41,617,071.00	K47,221,209.00
Farm machinery	K6,286,604.05	K7,362,370.95	K7,974,373.97	K8,179,611.00	K7,935,211.56	K9,186,396.07
Irrigation infrastructure and equipment	K68,638.89	K383,780.77	K304,455.21	K147,937.41	K215,986.14	K192,804.76
Purchase of cane from individual farmers	K17,977,945.00	K22,500,625.00	K18,988,885.00	K19,907,349.00	K27,688,358.00	K34,603,574.00
All other costs (admin, financing, overhead, etc.)	K14,511,940.35	K12,892,454.70	K18,832,998.98	K16,429,596.54	K20,828,973.95	K11,436,917.00

The three largest costs are in order of importance, the cost of farm inputs, the purchase of cane from individual farmers and the other (admin. etc.) costs: from 2016 to 2021, they together were responsible for 76-80% of the total cost. The most notable trends emerging from Table 3 and Figure 7 are found in the categories of water, farm inputs, electricity, and the purchase of cane from individual farmers. The (running) costs for irrigation equipment is insignificant and far less than for farm machinery (<0.5% versus 6-9% of total cost).

The cost for purchasing cane from individual farmers for onward sale to Zambia Sugar is remarkable. It is not only the second largest cost category after the cost for inputs, but it is in an upward trend as well.

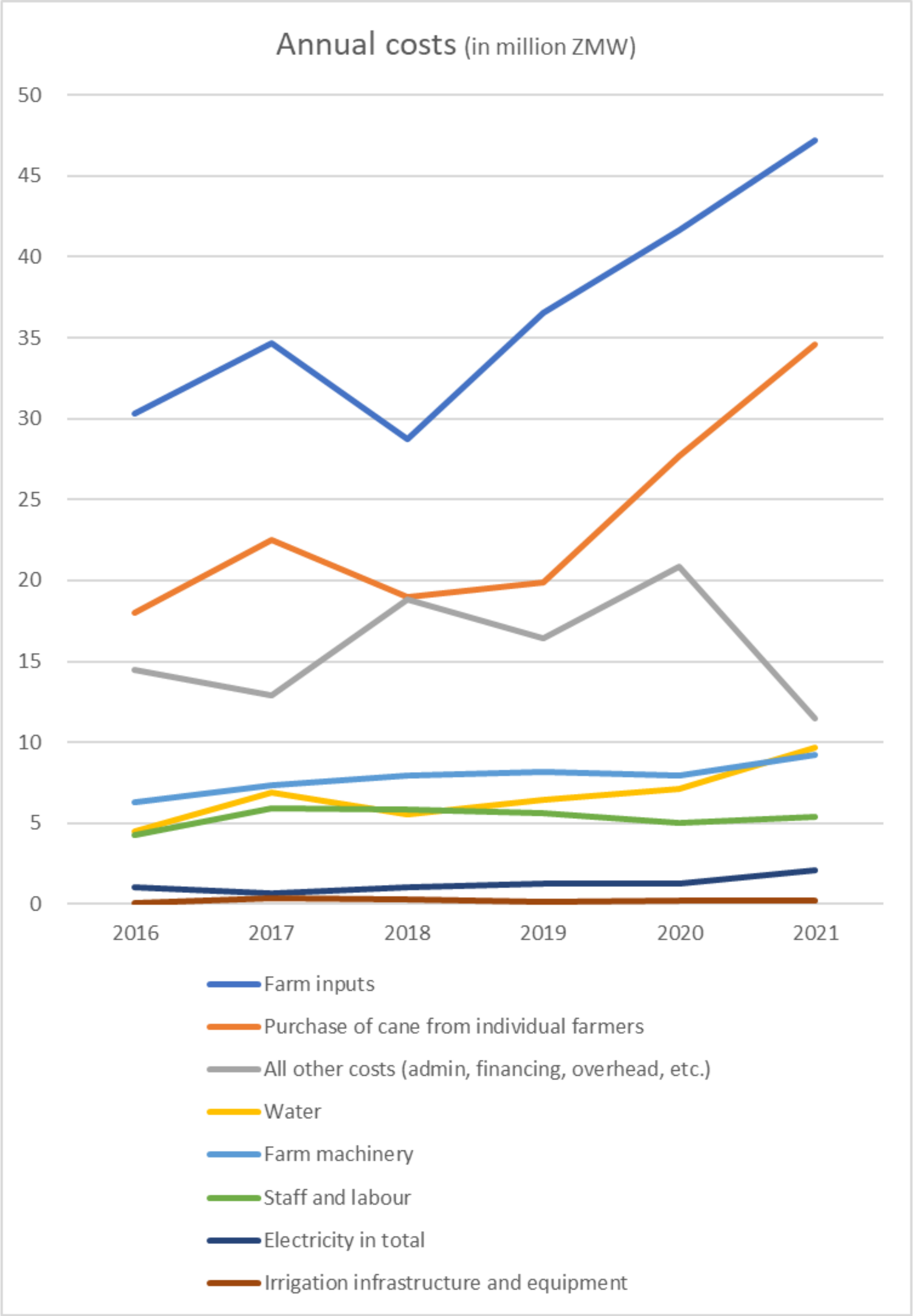


Figure 7. Annual cost trend by cost category

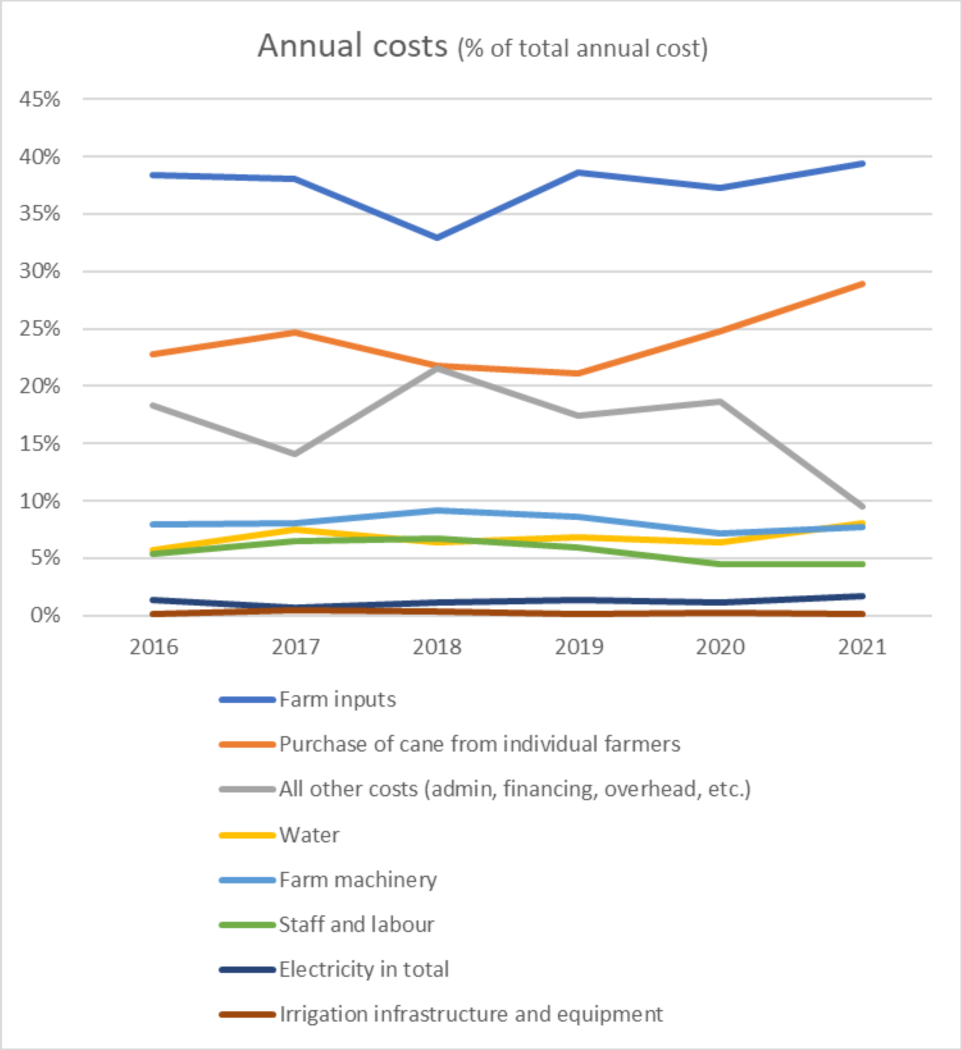


Figure 8. Relative contribution of each cost category to the total annual costs

The water supply costs, also graphically depicted in Figure 9, have increased especially in the last two years, whereby the increase in 2021 is likely attributed to increased electricity tariffs and forex exchange rate fluctuations. The unit rate of a m3 of water (Table 4) has however remained quite constant in the years 2017, 2019 and 2020, whereas in 2016 and 2018 unit rates were lower. In these two years more water was supplied, which could have resulted in a lower cost per unit due to some fixed costs. This however should be further investigated.

Table 4. Unit costs of water per m3

Overview of costs summarized	2016	2017	2018	2019	2020
Water Costs (ZMW)	K 4,500,976.12	K 6,865,995.97	K 5,568,845.18	K 6,442,321.80	K 7,083,754.24
Water Quantity Supplied (m3)	22,272,250	21,376,281	21,845,517	19,658,304	21,693,007
Unit Price (ZMW/m3)	0.202	0.321	0.255	0.328	0.327

The supply of water in 2020 was closer to the requested amount, compared with the preceding years (see Table 6 in Chapter 4.1). In 2021, the demand was met with the requested water volume. With more efficient irrigation, water costs can be reduced.

Figure 9. Costs of water 2016-2021

For the farm inputs (Figure 10), a yearly increase of 10-20% in costs can be seen since 2018. Further analysis is needed to get a clear insight in the factors that contribute to these increased costs. It is however expected that inflation and increased fertilizer prices are major contributors.

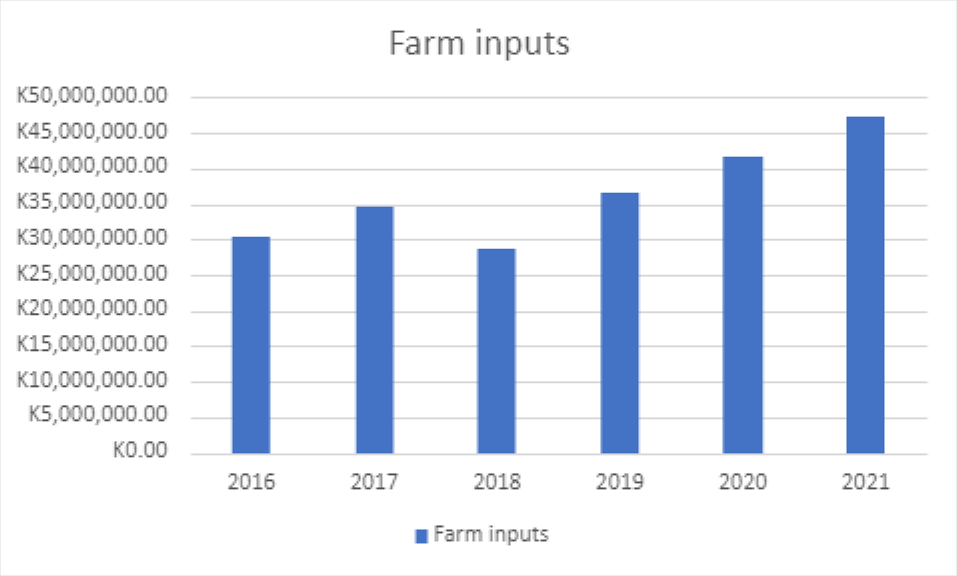


Figure 10. Costs of farm inputs 2016-2021

The electricity costs have also seen a significant increase (Figure 11) over the period 2016-2021. However, electricity as part of overall cost remained low: in 2021, it went up to only 2%.

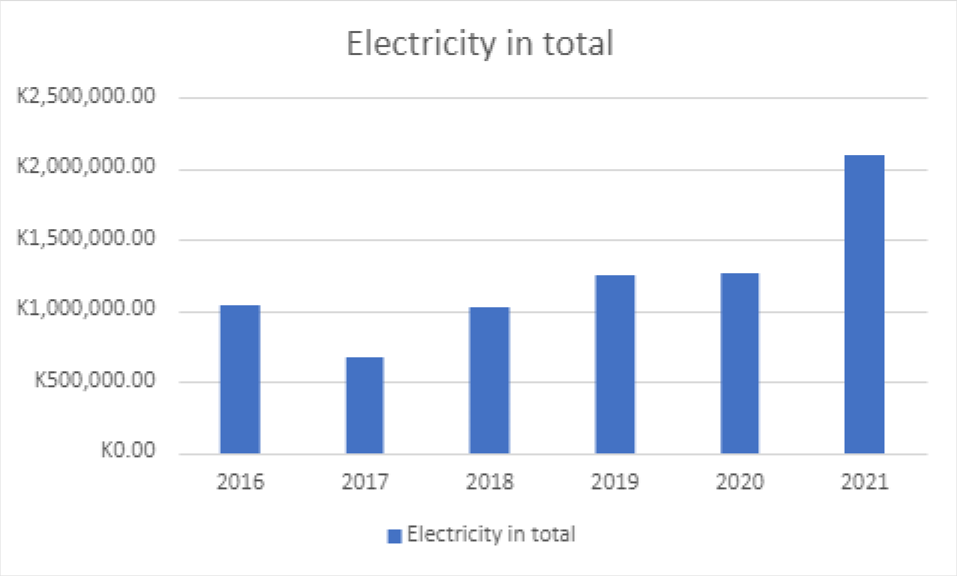
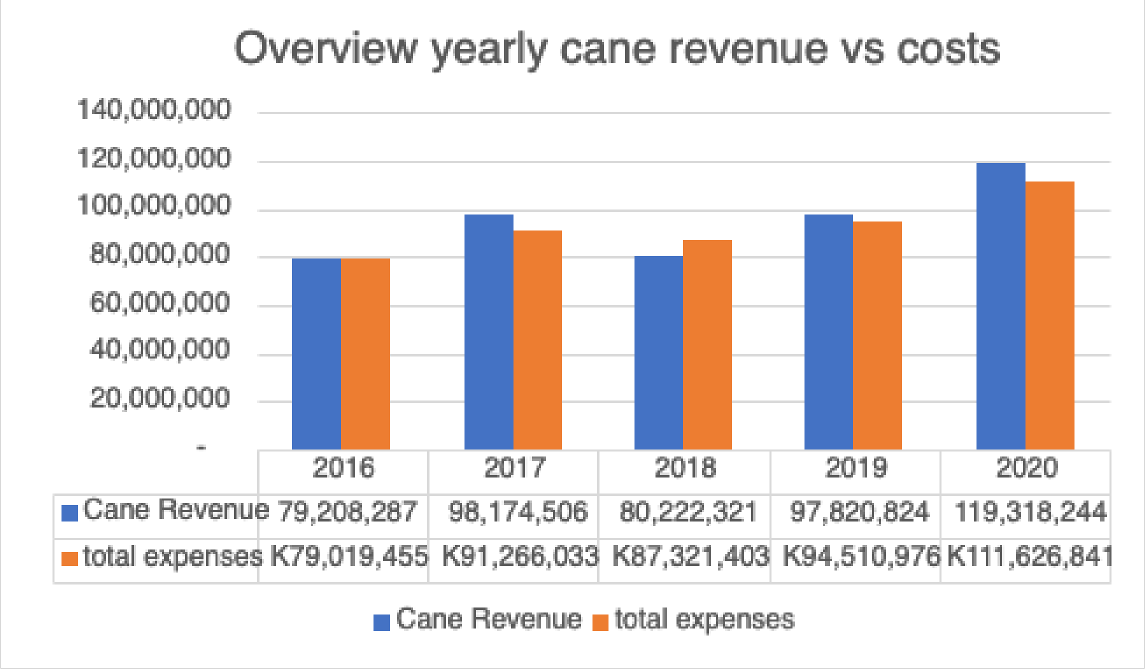


Figure 11. Electricity Costs

The initial research also included a preliminary review of the trend of the yearly revenue vs the yearly costs, derived from the financial data supplied (Figure 12). In general, an increase in both revenue and expenses can be seen. The average margin over the last 5 years is 2.4%, with a high in 2017 of 7.6%. Out of the five years, only 2018 had a negative result (-8.1%).



	2016	2017	2018	2019	2020
Cane Revenue	79,208,287	98,174,506	80,222,321	97,820,824	119,318,244
total expenses	K79,019,455	K91,266,033	K87,321,403	K94,510,976	K111,626,841

Figure 12. Cane revenue and total expenditure

3. ASSESSMENT OF EXISTING IRRIGATION INFRASTRUCTURE AND CAPACITY

3.1 FURROW IRRIGATION SYSTEM

3.1.1 DESCRIPTION OF EXISTING INFRASTRUCTURE

Most of the existing furrow irrigation infrastructure on Kaleya Farm was built in the 1980's, including ductile iron transmission pipelines, (concrete) channels, undershot gates (Figure 13), division structures, and dams. The system appears to be functioning correctly, as designed, and is relatively well-maintained. There are some cracks in the concrete channels that could potentially lead to some water losses. However, it can be concluded that overall, the system works properly and without excessive water losses during the transportation from the dams to the secondary and tertiary channels.

Figure 13. Calibrated undershot gates in open canal furrow irrigation system at Kaleya farm (03-12-2021)

For the majority of the system, syphons (capacity 3.8 l/s) are being used to withdraw water from the concrete secondary and tertiary channels. The syphons discharge the water into (earthen) furrows that have been dug between the rows of sugarcane. The length of these furrows varies between 20 and 500 meters, with an average of approximately 300 meters. For the longest furrows, 2 syphons are being used per furrow to double the discharge rate.

The duration of an irrigation turn depends on, among others, the length of the furrow. An average furrow with a length of 300 meters requires 10 hours of continuous irrigation to be fully irrigated (assuming 1 syphon per furrow). One irrigation team, consisting of 2 workers, operates 18 syphons, and is able to irrigate 2 ha per day. Daily, an average of 2,462 m^3 of water is applied to each area of 2 ha (20,000 m^2), which translates to 125 mm of irrigation.

Depending on the labour force, available water and the season, the irrigation interval varies between 2 and 4 weeks. This means that every field will be irrigated after 14-30 days. When taking an interval of 15 days (best case scenario), the average amount of irrigation is 125/15 = 8.2 mm/day is irrigated. Assuming an efficiency of 60%, 4.92mm/day would become available in the rootzone of the crop. It should be noted that the storage capacity of the soil is not taken into account: depending on rooting depth, this could further decrease the actual amount of water available in the rootzone. When taking into account an irrigation interval of 30 days (worst case scenario), 4.1 mm of water would be applied/day into the field and only 2.46 mm would become available in the rootzone.

The smallholder section of KASCOL also uses earthen tertiary canals that branch into the furrows where the sugarcane has been planted. The farmers manually open and close the furrows, using a hoe. Furrows are generally blocked with mud or soil. To increase the discharge in these earthen canals, multiple syphons are used. During the site visit, 14 syphons were counted that generate a discharge of 53 l/s from the concrete canal into the earthen tertiary canal (Figure 12).

Figure 14. Smallholder section, hybrid of furrow irrigation and flood irrigation

3.1.2 CAPACITY OF EXISTING IRRIGATION SYSTEM

The capacity of the existing dam and channel network is sufficient for effective irrigation of the current furrow system, provided that the main delivery pipeline can supply the requested amounts of water to KASCOL. In this regard, three major limiting factors were identified in this pre-feasibility study:

1) Due to load shedding, other power failures, and limited water availability at the main intake, the actual supply volume is generally lower than the water requirement of the KASCOL Estate. The furrow irrigation system uses approximately 88% of the total amount of water supplied to the farm, the remainder is used for the pivots and existing SDI. KASCOL is therefore limited in terms of the volumes of water that can be applied to the rootzone via the furrow system.
2) Due to the labour-intensive character of the furrow system, whereby the syphons need to be placed manually in every single furrow, the irrigation interval of 15-30 days is far from ideal. During one irrigation turn, 125 mm is applied, of which 40% is lost due to run off, evaporation and deep percolation to the saturated groundwater zone. A furrow system typically also has a non-uniform character (see Figure 15), whereby the crops at the tail end of the furrows receive significantly less water, compared to those near the syphon inlets. The soil water storage will be filled to maximum capacity shortly after each irrigation turn; however, 15-30 days later, the soil moisture content will be too low to deliver the desired amounts of water to the crop. The chances of drought-stress are therefore high, due to the long irrigation interval.

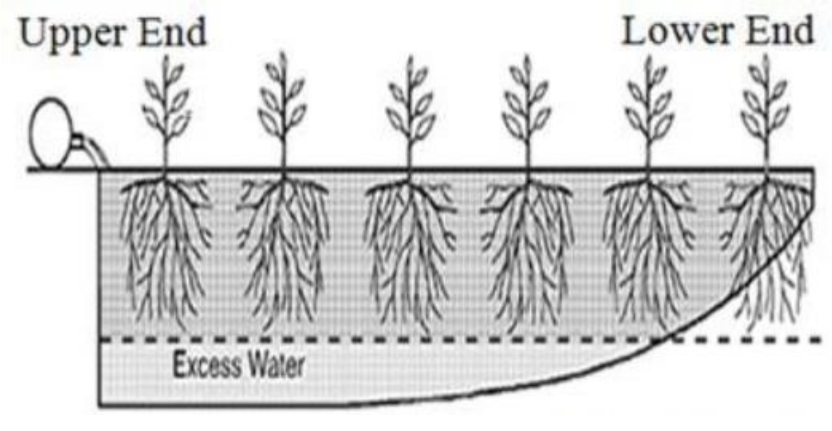


Figure 15. Characteristics of furrow irrigation: non-uniform water distribution

3) Field application efficiency is defined as the ratio of water that becomes available for the plant in the rootzone compared with the water applied on the field: Field application efficiency = Water in rootzone / total water applied on field *100%

> The field application efficiency of a furrow irrigation system depends on several factors, including soil type, slope, length of the furrow, flow rates, furrow dimensions (width, depth and shape), and cut-off time. Field application efficiencies generally range between 25 and 80%; in most situations where long furrows are used (>200m) within clayey soil types, the average efficiency is usually between 50 and 60% (Raine & Bakker, 1996). It is therefore estimated that the irrigation efficiency at KASCOL will also range between 50 and 60%, with potentially lower efficiencies in the smallholder areas, where tertiary earthen canals are being used and flood irrigation is applied. The furrow system also has conveyance losses, evaporation and seepage trough the canal network. For a concrete canal a conveyance efficiency of 95% can be assumed (FAO, AI)

At Kaleya Estate, the scheme-irrigation efficiency can be estimated as follows: Field application efficiency (%) * conveyance efficiency (%)) / 100 = Scheme irrigation efficiency = (55*95)/100= **52%**. It can therefore be concluded that the furrow irrigation system consumes large amounts of water, which limits the effectiveness of the KASCOL scheme in terms of water use efficiency. Especially in times of limited supply availability (see point [1] above) and considering the large irrigation interval brought about by the labour-intensive operations (Point [2]), this will further constrain the yield potential of sugarcane.

The furrow system under its current manual operation has an estimated capacity to deliver on average 4.9 mm of water per day to the rootzone of the crop, if irrigated at an interval of 15 days (see Section 3.1.1). The capacity of the current furrow system is therefore not sufficient to meet the peak water requirement of the crop (5.73 mm/day)

3.1.3 WATER & POWER CONSUMPTION

For the furrow system, electric power is only required for the Zambia Sugar pumps that transfer the water via its pipeline to the dams of KASCOL. After that, the furrow system is designed to solely operate under gravity, making the system very energy-efficient and cost-effective in terms of electricity supply.

In terms of water use, as mentioned above, the furrow system is estimated to use 88% of the total volume of water supply.

3.1.4 OPERATIONAL COSTS

The major irrigation costs can be contributed to the water consumption, of which the cost is significantly higher than the electricity and irrigation infrastructure costs combined (Figure 16 and Figure 8). The staff and labour cost for irrigation can be assumed relatively small as well (being a fraction of the total staff and labour of about 5 million Kwacha annually only).

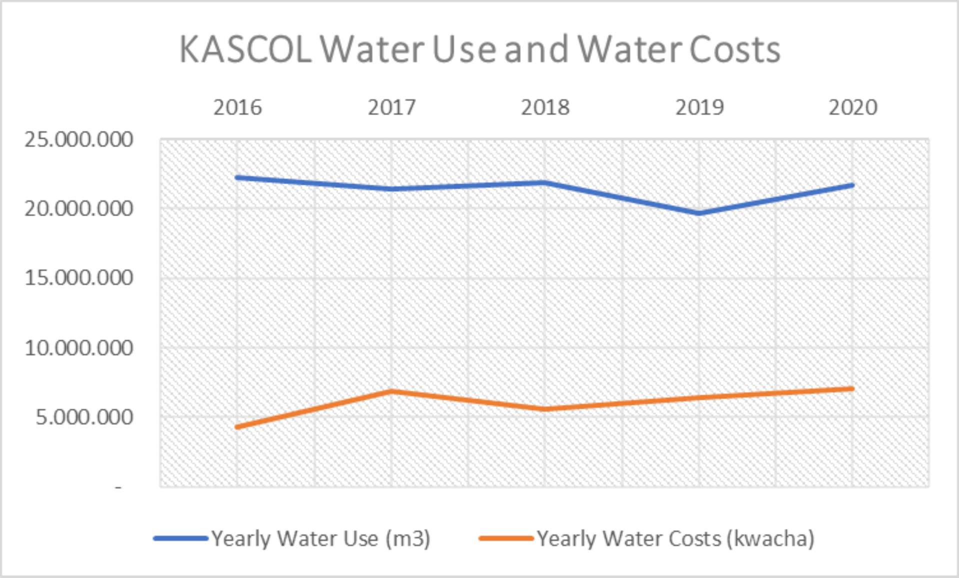


Figure 16. KASCOL water use and water costs 2016-2020

3.1.5 FURROW IRRIGATION: RECOMMENDATIONS & SUGGESTIONS FOR PHASE 2 FEASIBILITY STUDY

With the current data available, it was possible to draw a realistic picture of the general performances of the furrow system and its limitations, tailored to water use and the costs related to its water consumption. During the Feasibility Study planned under Phase 2 of the Project, a more elaborate comparison between (potential) of furrow, pivot and SDI irrigation, as well as a more economical focussed analysis should be done, focussing on the operational costs of the furrow system. This should also include the labour costs for operating the furrow system, fertilizer use (and its efficiency), and other factors.

While doing research on furrow irrigation, different factors were found that significantly influence the field application efficiency. In this light, it could be beneficial for KASCOL to assess how the furrow system can improve its efficiency, for instance with cut- off time trials and (automated) soil moisture monitoring. Also, experiments with different irrigation intervals could result in improved water use and enhanced crop yields.

It should be noted that the optimization of the furrow system is not in the scope of the current consultancy assignment, or the scope of work foreseen under Phase 2. However, based on the above considerations, it is recommended to include a review of the furrow system (and its possible improvement) in the Terms of Reference for the Feasibility Study.

3.2 CENTER PIVOT IRRIGATION SYSTEM

3.2.1 DESCRIPTION OF EXISTING INFRASTRUCTURE

KASCOL operates 7 center pivots which are covering a total of 364 ha (Figure 17). Besides sugarcane, also barley and soybean are being cultivated in a crop rotational scheme. The pivots are supplied by water from Dam 6 and 7. Each pivot has its own electrical pump.

Figure 17. KASCOL Center Pivot irrigated sugar cane field (03-12-2021)

3.2.2 CAPACITY OF IRRIGATION SYSTEM

The 65 ha pivot located next to Dam 6, has a capacity to irrigate a maximum of 7.7mm of water per day, when operating for 24 consecutive hours (Annex I: Pivot irrigation). The standard field application efficiency of a center pivot is 80% (Agier et al, 1996). This means that per day, the pivot system has the capacity to deliver 6.16 mm of water into the rootzone of the crop. Therefore, the pivot system is able to meet the peak irrigation demand of 5.73 mm/day, without the crop experiencing any drought stress (assuming that there is no load shedding and sufficient water can be supplied).

3.2.3 WATER CONSUMPTION

For this pre-feasibility stage, not sufficient information was obtained to give an accurate indication of the water use of the pivot system. However, with the operating records of the pivot system, it will be possible to calculate this. More time is required to digitalize the available data and make this assessment.

3.2.4 POWER CONSUMPTION

To analyse the power consumption of the centre pivot irrigation systems, measurements have been conducted at 3 of the total 7 pivots. The power consumption of the three investigated pivots amounts to 150.4 KVA combined at maximum operating capacity (averaging just over 50KVA per pivot). The total capacity of the transformer that powers these three pivots amounts to 315KVA.

3.2.5 OPERATIONAL COSTS

In this pre-feasibility stage, not sufficient information was available related to operational costs of the pivots. With data about costs of electricity and water use, a more accurate picture can be provided. It is therefore proposed to include this analysis during the second phase of this research (Feasibility Study).

3.2.6 PIVOT IRRIGATION: RECOMMENDATIONS AND SUGGESTIONS FOR PHASE 2 FEASIBILITY STUDY

In order to make a comparison between the different irrigation methods applied on the farm and to assess the benefits and costs of the proposed 300 ha expansion of SDI, more research is needed on the water use and electricity consumption, as well as the costs of the pivot irrigation system. These tasks should be included under the second phase of the Feasibility Study.

3.3 SUB-SURFACE DRIP IRRIGATION SYSTEM (SDI)

3.3.1 DESCRIPTION INFRASTRUCTURE

KASCOL has a very new, fully functioning 153 ha Sub-Surface-Drip Irrigation system (SDI), which was supplied and installed by Green2000 - Metzer in 2021. The sugarcane under the SDI-system was planted in between 23 October and 13 November (see Figure 22). Dam 6 is used as the water supply reservoir for the SDI system: for this purpose, 3 pumps of 55 KW each are installed (Figure 18), which are connected to a 1,000 KVA transformer.

Figure 18. Three pumps for the SDI system (light blue-grey, on right side picture)

The pumping system at Dam 6 is fitted with an automated screen filtration system (Figure 19). After the water is filtered, fertilizers are added in fertigation tanks, using an injection system with a booster pump (Figure 21). From there, the main pipe transports the water to the 153 ha SDI-block, where it is being diverted into the sub-mains. Upon reaching the irrigation zones, the water is again filtered for safety purposes (e.g. cracks in the pipes, debris in the irrigation water, etc.) through a secondary, semi-automatic screen-filter (Figure 20).

After the secondary filters, pressure regulators are placed to control the water pressure. The METZER design states that the pressure in the drip line should be between 10 meter and 32 meter (1 and 3.2 bar). Field tests would be required to test if this designed pressure range corresponds with the realized SDI system.

Figure 19. Main screen filtration system SDI at KASCOL

Figure 20. Secondary filtration station

Figure 21. Fertigation tanks SDI system KASCOL

Figure 22. Germinating cane under SDI

3.3.2 CAPACITY OF IRRIGATION SYSTEM

The SDI system of KASCOL has a designed capacity to deliver 8 mm of water per day. Taking into account a relatively high application efficiency of 95% (due to the extremely efficient character of sub-surface drip irrigation), a daily amount of 7.6 mm is expected to become available in the rootzone of the crop. Therefore, the SDI system can meet the peak water requirements, which were estimated at 5.7 mm/day. Even in years with erratic rainfall, the SDI system will still be able to meet the crop water requirements, provided that the availability of both water supply and electricity forms no constraints.

3.3.3 WATER & POWER CONSUMPTION

Looking at the water-efficient character of the SDI system, different strategies are possible for the operation of the system. In Phase 2 of this assessment, more information and more detail will be provided about the available options: it should be noted that the advantages and disadvantages of the different options are relatively complex with multiple perspectives. Examples of the various considerations and perspectives are: Water use / water saving, Yield optimalization, Water productivity, Profit maximization, and Power consumption.

Due to the ease of operating the system, and the wide range of irrigation intervals possible, it is expected that the crop water requirements can always be met by the drip-irrigation system. The preliminary estimate of required irrigation water to achieve the highest yield is 1,251 mm (ANNEX III). This translates to a total volume of 1,914,030 m^3 of water per year, or 12,510m^3 per ha per year.

The drip-irrigation volume is more than the average water application per ha by KASCOL in 2020 (9,400 m^3/ha). However, this is not surprising, since the furrow system has a lower irrigation capacity than the SDI system, and is unable to meet the crop water requirements of the sugarcane.

To operate the SDI system in a most optimal way, a thorough analysis is needed: this should be included under Phase 2 – Feasibility Study.

3.3.4 SDI SYSTEM: RECOMMENDATIONS AND SUGGESTIONS FOR PHASE 2 FEASIBILITY STUDY

After analysing the available data and assessing the capacity of the SDI system, it is key to include a review of the different available scenarios for the operation of the current SDI system with 153 ha under drip-irrigation, under the upcoming Phase-2 Feasibility Study. This should also entail a detailed assessment of the proposed expansion with an additional 300ha. Due to its high efficiency, it can be concluded that the SDI system does not have to save water.

It is recommended to work out several irrigation-strategies with different scenarios of water use, operating costs, and expected yields. Field experiments should be conducted to trial different scenarios, collect information and analyse the most optimal operating strategy. This should be done as soon as possible, in order to create insight in the profit maximization, viewed from different perspectives of water use, costs, and yields. The findings should be used to align and optimize the current 153 ha under SDI, and to select the most suitable strategy for the implementation and operation of the proposed 300 ha SDI expansion. Based on a careful analysis of these trial results, the system will have the desired benefits for the different stakeholders. To be able to come to this optimal strategy, different measures need to be investigated during Phase 2, including: soil moisture measurements, geo-information, drone technology and field measurements.

In addition, a detailed analysis of the operational costs of the SDI systems (existing 153 ha and proposed 300 ha) should be included in the second phase.

3.4 WATER SUPPLY SYSTEM

KASCOL receives its irrigation water from the Kafue River, via a 25 km long water transfer which consists of an open canal, followed by a ductile iron pipeline which is owned and maintained by Zambia Sugar. The pipeline has a maximum capacity of 130,000 m^3 per day, which is delivered to KASCOL Dam 1 and Dam 5. KASCOL requests certain amounts of water on a weekly basis, based on the irrigation requirements of the whole cultivated area. Zambia Sugar receives this information and adjusts the pumping schedule based on this request. However, the supply-volume does not always meet the amount of water requested by KASCOL. Load-shedding, technical malfunctions and low water levels are mentioned as possible reasons for supply shortfalls experienced during the last years. Chapter 4.1 provides more details on the requested and supplied water volumes over the past 5 years.

Figure 23. Drone imagery, main pipeline to KASCOL (03-12-2021)

After the water is pumped into Dam 1 and Dam 5, the water is sub-divided and distributed over multiple smaller dams on KASCOL. In total, there are 7 man-made dams that supply the furrow systems and the 7 Pivots with water for irrigation. The furrow system is fully based on gravity-flow, while the pivots are being operated with intake pumps from Dam 6 and Dam 7.

A total of 9 drinking water boreholes are situated on the Estate, which are currently used exclusively for domestic purposes. In addition, newly drilled boreholes could provide (part of) the water required for subsurface drip irrigation. This is especially relevant due to the experienced shortfalls of water supply from Zambia Sugar and the Kafue River, as well as the high costs that are associated with this pumped water supply. A review of the existing boreholes is provided in Chapter 4.2.

3.5 POWER SUPPLY

3.5.1 CURRENT POWER SUPPLY SYSTEM

An overview of the current power consumption and existing transformers is presented in Table 5. Power consumption is estimated at 7,657 KWh.

Table 5. Overview of existing power supply and transformers in use

S/NO.	CONSUMER	CONSUMPTION (KWh)	TRANSFORMER SIZE (KVA)
1	OFFICES	358.12	100 KVA
2	FILTRATION	627.22	50 KVA
3	MAIN BOREHOLES	470.4	50 KVA
4	LUNGAE	2324	315 KVA
5	PIVOT 1,2 & 3	1303	315 KVA
6	PIVOT 4,5,6,&7	581	315 KVA
7	MIZINGA	191	200 KVA
8	KALEYA EAST COMPOUND	488	200 KVA
9	STAFF AREA	835	200 KVA
10	KALEYA EAST A/B HOUSES	479	200 KVA
11	NEW TRANSFORMER FOR SDI PUMPS	UNKNOWN	1000 KVA
	TOTAL	**7,656.74 KWh**	**2,745 KVA**

3.5.2 QUALITY ASSESSMENT OF POWER SUPPLY SYSTEM

An assessment has been made of the current state of the power supply system. Findings are presented in Annex IV.

While reviewing the existing power supply situation, it was found that the size of the newly installed transformer (1,000 KVA according to KASCOL) could not be confirmed. It should be noted that a 1,000 KVA transformer would have to be equipped with at least 2 x 500 mm^2 single core cables per phase (8 cables in total), whereas currently, only 1 cable with 4 cores of 185 mm^2 is installed. This cable would be incapable of carrying the loads that a 1,000 KVA transformer is able to produce. In addition, the low-voltage panel should be changed to 1,200A (currently at 800A).

Furthermore, measurements proved that the input voltage of the SDI pumps averaged at 380V, whereas the recommended input voltage for the SDI pumps is stipulated at a minimum of 400V (400V to 690V to be specific). Hence, the pumps are currently running at low voltage. This decreases life span and prevents the pump from reaching its maximum pumping capacity. To fix this issue, the present findings need to be presented to ZESCO, after which ZESCO can raise the tap value on the transformers.

Finally, it was found that electricity-efficiency could be improved and further optimized (resulting in power savings) through installation of a PFC (power factor correction) panel on the main incoming electricity cable. This will lead to a more efficient electricity use by the connected machinery, and hence, to increased efficiency of the pumps as well as lower power supply costs.

3.6 FARM MANAGEMENT

Kaleya Farm has a clear management structure and adequate office facilities at the headquarters. The farm also owns a guesthouse, which is used for external partners and consultants. This gives the farm an open character, while increasing its access to external knowledge and support.

For the current pre-feasibility study, multiple visits were conducted to Kaleya: these enabled the consultants to gain a good impression of KASCOL and its capacity to support the Project with information, assist with the field visits, pin-point different areas and locations of interest, and answer the questions posed by the consultants. This existing capacity should not be undervalued, as it will also be essential in the foreseen Phase 2 of the Project, which aims to go into more detail, with a concrete assessment of the different available options, strategies and scenarios, culminating into a solid advice for the proposed future development of the Farm.

Whilst conducting the review of Information Technology and Remote Sensing (point 3 of the scope of work), it was found that currently, designated KASCOL staff members collect a wide variety of data in hard-copy books. While a lot of valuable data is recorded in this manner, the information is difficult to interpret for external parties. The collection of digital data is a first essential stap towards meaningful analysis and improved decision-making. The translation from the recorded data towards thorough information analysis, decision-making and planning is at this moment limited. This creates a sub-optimal situation, whereby collected data does not come to its full potential, as it remains underutilized. Additional focus or capacity is therefore advised to:

1) Transform the existing hard-copy data collection system into a computerized system (e.g. in Excel) with a digital, well-structured database.
2) Establish and designate a technical team to carry out data analysis and translate the results into information for further dissemination and advice on decision-making and planning matters.
3) Well documented (field) trials are recommended to further increase insights in the cultivation and profit maximization of the farm. The second phase of this research attends to support in this aspect as well.

Weather station

The current weather station and data collection should be improved:

- The location of the Evaporation-pan (Figure 24) is close to a tree, and existing buildings that can influence the accuracy. When visiting the weather station, sprinklers were also operating to irrigate the lawn. Chances are high that the sprinklers will sometimes also ‘irrigate’ the E-pan, leading to underestimated evaporation-figures; furthermore, the sprinklers will influence the moisture content of the air, potentially influencing (i.e. reducing) the evaporation measurements. Furthermore, E-pan measurements are recorded in ‘cups’, after which no translation is made into evaporation depths or volumes.
- Part of the sensors of the weather station were not in good shape, influencing the accuracy. When assessing the data, gaps exist in (among others) the rainfall data, making it less useful for analysis. Digital storage of weather station readings (in Excel) would significantly help in the application of the data. It is thus recommended to modernize the weather station; more information on the proposed improvements will be provided during Phase 2 of the Feasibility Study.

Figure 24. Evaporation pan

Soil Moisture

For the three existing irrigation systems (furrow, pivot and SDI), the installation of automated soil moisture sensors would open a new window in the assessment of optimum irrigate times, intervals and volumes. Both mobile and stationary soil moisture probes could be considered. Phase 2 will include the presentation of concrete options for soil moisture measurement and management, which would benefit the irrigation scheduling of KASCOL significantly.

4. WATER RESOURCES ASSESSMENT

This chapter entails a preliminary assessment of the current surface water system, as well as the groundwater system that is present on the Estate. The aim of this assessment is to provide information that can aid in the decision-making on the right strategy for the different water supply options for both the existing and enhanced SDI system.

A site reconnaissance visit was conducted on 2 and 3 December 2021, guided by Mr. Meja (farming operations assistant) of Kaleya Farm. The purpose of the visit was to gain a general impression of the farm area, to assess the existing surface and groundwater systems, and to map the existing boreholes.

4.1 WATER DEMAND AND SUPPLY ASSESSMENT

Water demand and supply over the last 5 years is shown in Table 6 below. Structurally, about 17% less water was supplied than requested. However, in 2021, Zambia Sugar was able to supply KASCOL with all the water that was requested. This has resulted in increased cost for water use over 2021 so far.

Table 6. Water requested by KASCOL and water supplied by Zambia Sugar for the period 2016-2020

Year	Request [m3]	Supply [m3]	Deficit [m3]	Deficit [%]
2016	25,685,856	22,272,250	3,413,606	13.3
2017	25,804,170	21,376,281	4,427,889	17.2
2018	25,784,216	21,845,517	3,938,699	15.3
2019	26,248,689	19,658,304	6,590,385	25.1
2020	25,361,580	21,693,007	3,668,573	14.5

4.2 SILTATION IN WATER SUPPLY DAMS

The water supplied by Zambia Sugar is pumped into reservoir 50 WEST (or Dam 1) and 50 EAST (or Dam 5). Water from Dam 1 is distributed over Dams 2, 3 and 4, while water from Dam 5 is pumped into Dam 6. Dam 7 receives run-off water as return-flow from the furrow-irrigated fields.

Over time, siltation takes place as sandy and clayey material accumulates in the dams. Field measurements have been conducted to measure the current depth of the dam reservoirs, as well as the sedimentation within the reservoirs. This data has further been used to estimate the storage capacity of the dams after siltation. Results are presented in Table 7.

Table 7. Area, maximum storage volume, siltation and maximum storage volume after siltation in the 7 dams

		Dam 1 (50 WEST)	Dam 2	Dam 3	Dam 4	Dam 5 (50 EAST)	Dam 6	Dam 7	Total
Area	(m2)	8430	24565	22030	14080	14400	29370	6030	118905
Max. volume before siltation	(m3)	17000	37950	27900	21000	27930	47904	No data	179684
Estimated siltation	(%)	21%	12%	11%	6%	18%	19%	0-5%	-
Max. volume after siltation	(m3)	13430	33396	24831	19740	22903	38802	12000	165102

Slash-and-burn tactics have been applied to remove vegetation accumulated within the dams once a year, in order to try and control the build-up of sediment and plant material. No dredging has taken place in the past. This has contributed to decreased storage volumes of the dams due to siltation (Table 7), which are generally in the order of 10-20%.

4.3 GROUNDWATER ASSESSMENT

4.3.1 EXISTING BOREHOLES

All known boreholes on the estate were mapped (see Figure 25). The boreholes are almost exclusively situated along the intersection between the dolomite/calcite formation in the north-northeast and the alluvial deposits in the center of the estate.

Figure 25. Map of existing borehole locations

The existing boreholes are used for domestic purposes only. An overview of the borehole depth, pump capacity (in horsepower), size of the casing and maximum pumping rate of the installed pump is presented in Table 8 below.

Table 8. Overview of existing boreholes

S/no.	Borehole Name	Depth	Pump capacity (horse power)	Size of Casing	Pumping rate (L/s)
2	Main Borehole-2	50	6.5 HP pump	8"	20
4	Recreation Club	50	5 HP pump	4"	7.5
5	Mizinga compound	50	3 HP pump	5"	4.55
7	Tuyake borehole	50	3 HP pump	8"	4.55
8	Group 2 Borehole	50	5 HP pump	8"	7.5
9	Group 2 Borehole	50	5 HP pump	8"	7.5
10	Group 3(b)	50	2 HP pump	5"	2.72
11	Group 4(a)	50	1 HP pump	5"	1.3

Yields range from moderate to high, with an average of 6.95 l/s. It should be noted that, on basis of a pumping rate of 20 l/s from a 6.5 horsepower pump, it cannot be concluded that such a borehole would be able to provide a sustainable yield of 20 l/s, either during peak demands or throughout an entire year.

4.3.2 ASSESSMENT OF GROUNDWATER POTENTIAL

As mentioned before, an accurate assessment of the possible and sustainable yields in this area requires a more detailed groundwater assessment, corresponding test pumping, and analysis of the results. In this section, a preliminary assessment has been made, based on the limited amount of currently available data and information on groundwater resources.

4.2.2.1 General remarks

An initial assessment of the groundwater potential within the farm and its upper catchment area was made. Due to the lack of good local data, a largely theoretical approach was used, based on parameter values from relevant literature, to arrive at a ‘first cut’ or preliminary estimate of the available groundwater resources for the different geological units. These first estimates should be refined once more detailed data for the area becomes available.

A detailed quantitative assessment requires sufficient lithological data, collected during borehole drilling, in conjunction with data collected during hydraulic testing (test pumping).

Estimations of the available groundwater resources for each of the main lithological units underlying the farm and in the upper catchment area were made under ‘*dynamic*’ (as opposed to ‘*static*’) conditions:

- Static conditions consider the volume of water held as storage within each of the lithological units that can be penetrated by a borehole and withdrawn by pumping. An estimate based on static conditions is often not sustainable, as it does not take into account the important factor of aquifer replenishment. Borehole abstraction without replenishment means that the water is effectively being “mined” and progressively depleted, until no water could be left at some point in the future.
- Dynamic conditions, on the other hand, are used to estimate the amount of water available for the replenishment of each unit through recharge from rainfall, infiltration of stream water, or groundwater inflow from neighbouring areas. This is a more sustainable approach, which generally aims to ensure that the imposed abstraction does not exceed the volume of replenishment.

The calculated volumes of available water obtained from the dynamic aquifer conditions are estimates only. While not 100% accurate, these estimates do give a fair indication of the approximate potential abstractions, and the general possibilities and limitations of groundwater utilization. The figures on groundwater resources do not guarantee that these resources will indeed be available from random drilling efforts. The ability to abstract water in relation to its availability depends critically on the successful siting of boreholes. This requires details from remote sensing analysis, comprehensive and good quality geophysical measurements, and exploratory drilling at the most promising sites.

4.2.2.2 Dynamic Groundwater Recharge (DGR)

The replenishment of the groundwater resource is calculated using a variation of the rainfall infiltration method. The method estimates the amount of rainfall that penetrates into the ground to actively replenish (recharge) the confined aquifer. Soil texture (percentage of sand, silt and clay) is the major inherent factor influencing infiltration. Most of KASCOL Estate is covered by clayey soils. Depending on the amount and type of the clay minerals, some clayey soils develop shrinkage cracks as they dry. The cracks are direct conduits for water entering the soil, causing clayey soils to have high infiltration rates under dry conditions, and at the initial onset of rains. Where cracks do not occur, clayey soils have low infiltration rates.

On the other hand, the presence of crops such as sugar cane results in a dense network of roots with a higher level of soil disturbance in comparison to pristine conditions (Cheong, 2013). This creates more macropores in the soil, leading to higher surface infiltration of water.

In pristine environments, the main contributor to infiltration is precipitation. On KASCOL Estate however, the presently applied furrow irrigation will provide an additional contribution to the replenishment of the groundwater store. Under furrow irrigation, the additional percolation of water towards the saturated zone will be greater than under the more efficient subsurface drip irrigation regime. This adds some uncertainty to the total amount of future infiltration and the corresponding groundwater replenishment.

Typically, recharge is quantified through analysis of long-term water level measurements or through the application of the Soil Moisture Deficit Model (SMD). Due to the influencing factors stated above, and in the absence of actual infiltration data, three scenarios with a recharge coefficient of 0.02, 0.07 and 0.15 have been assumed that represent low, average and high estimates of recharge, based on related literature (Cheong, 2013; Heeren, 2015, Hennings, 2012; Raposo, 2012).

The dynamic recharge (DR) is calculated as follows:

DR = F * A * Average Annual Rainfall

Where:

DR = Recharge from rainfall

F = Recharge coefficient

A = Area of Computation for recharge

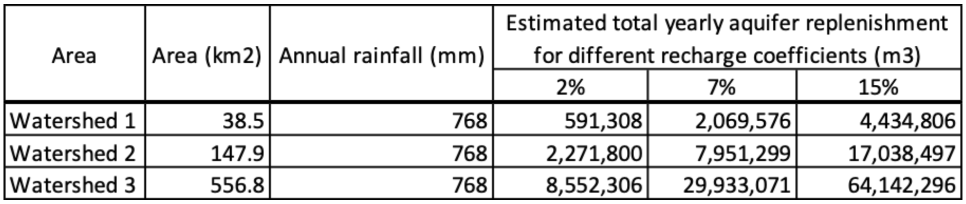
4.2.2.3 Results

The total available groundwater resource has been assumed to be equal to the Dynamic Groundwater Resource, without relying on the Static Groundwater Resource. As stated above, there are three different scenarios with three different recharge coefficients. Since upstream groundwater use by other communities or farms is difficult to determine, the groundwater recharge has further been calculated for three contributing watershed areas with different sizes, which are:

1. Worst case, with small catchment area: The catchment area within the estate boundaries
2. Intermediate scenario with medium-sized catchment area: The catchment area consistent of alluvium and residual deposits
3. Best case with large catchment area: The entire catchment area

The results are presented in Table 9.

Table 9. Total available groundwater for different scenarios



Area	Area (km2)	Annual rainfall (mm)	Estimated total yearly aquifer replenishment for different recharge coefficients (m3)		
			2%	7%	15%
Watershed 1	38.5	768	591,308	2,069,576	4,434,806
Watershed 2	147.9	768	2,271,800	7,951,299	17,038,497
Watershed 3	556.8	768	8,552,306	29,933,071	64,142,296

The annual water requirement for 300 ha of additional land irrigated using subsurface drip irrigation is estimated at 1,251 mm annually (or 3,753,000m^3). This volume can be met with groundwater supply in the following recharge scenarios:

- The high replenishment scenario of 15%.
- The average replenishment scenario of 7%, with a medium- or large-sized catchment assumption, whereby groundwater replenishment upstream of the estate boundaries is not completely consumed by neighboring farms and communities in that area, thereby also contributing to the replenishment of the groundwater on KASCOL estate. The scenario with a medium replenishment rate of 7% and some interception of groundwater flow by upstream users is in fact the most likely situation applicable to KASCOL Estate.
- The low replenishment scenario of 2%, when assuming an unlikely scenario that at least 44% of the replenished groundwater generated over the entire catchment area flows downstream into KASCOL estate.

In the worst-case scenario, with an assumed low replenishment rate of 2% and replenishment only available from within the boundaries of the KASCOL Estate, only 50 ha can be sustainably irrigated. This area decreases further when groundwater use for domestic purposes on the estate is continued. In this case, additional water sources (namely, surface water from the surface water system already in place) will have to be utilized to meet the large water requirements of the proposed farming activities.

It is important to recognize that irrigating 1,251mm annually using SDI is estimated to meet the optimal sugar cane water requirements. Since optimal sugar cane requirements under the current furrow irrigation system are not met, the current furrow irrigated fields actually consume less than 1,251mm annually. It thus follows that 1,251mm of irrigation annually is estimated to be the absolute maximum when using SDI.

As proposed under section 3.3.4, different scenarios should be trialled to collect information, compare the available options, and analyse the most optimal operating strategy. The outcome of these trials could be that irrigating with less water is part of the optimal operating strategy. With 1,251mm annually being the maximum amount of irrigation, and with the likelihood that the final irrigation amount will be less, it is expected that the groundwater replenishment (in the medium replenishment and medium catchment scenario) is indeed sufficient to provide 300 ha of subsurface drip irrigated fields with water from additional boreholes on the Estate.

Due to the absence of field data, it is advised that, in order to confirm the findings in this study, groundwater levels are monitored from an earliest-possible stage, when the choice is made to use groundwater for irrigation purposes. Finally, it is also advised to gain additional information on the recharge coefficient and groundwater replenishment dynamics throughout the catchment area.

4.3.3 VIABILITY OF GROUNDWATER EXPLORATION PROGRAMME

The estimated water supply necessary during peak irrigation for the 300 ha SDI to be developed, equals approximately 200 l/s. When assuming that boreholes with an average yield of 15 l/s (currently among the highest pumping rates of the existing boreholes) can indeed be established and also yield those volumes on a sustainable basis, a total of 14 new boreholes would be required. Groundwater research and aquifer testing has to be conducted in order to assess whether sustainable yields of 15 l/s can indeed be supported.

The estimated costs for groundwater investigations, including geophysical siting and the development and test-pumping of two successful boreholes amounts to approximately 30,000 USD including a provision for low yielding boreholes that are not developed. The costs for additional boreholes amounts to approximately 10,000 USD per borehole. The estimated total cost for siting, development and construction of 14 new production boreholes would thus amount to approximately 150,000 USD. Furthermore, additional costs should be factored in for pumping equipment, power supply installation, electricity consumption of the boreholes, construction of water infrastructure between the boreholes and irrigation pumps, and maintenance costs for the entire system.

4.3.4 MAINTENANCE OF THE DAMS AND WATER CONVEYANCE CHANNELS

Significant siltation has occurred in the dam reservoirs. In the current situation, the diminished capacity of the dam reservoirs (with volumes reduced by 10-20% due to siltation) has not reportedly been a limiting factor in the amount of water available for irrigation. Under maximum subsurface drip irrigation, with quantities of 1,251mm annually, the total volume of irrigation water would increase with 9% at most.

It is therefore strongly advised to monitor whether the reduced reservoirs volume is significantly limiting the amount of water available for irrigation. If this is indeed the case, it is recommended to conduct maintenance through dredging and cleaning of the existing dams to free up extra storage volume.

5. PROPOSED IRRIGATION DEVELOPMENT

5.1 LOCATION FOR THE NEW DRIP IRRIGATION DEVELOPMENT

The location selected for the SDI system (see Figure 26) has been assessed as a suitable location due to its proximity to Dam 6. The proposed new 300 ha SDI system will have a peak water demand of approximately 18,000 to 20.000 m^3, which is equivalent to approximately 50% of the total dam storage of 38,800m^3 (see Section 4.1). Including the estimated peak demand of the existing 153 ha (9,000m^3), approximately 10,000 m^3 would still be available for the furrow and pivot systems connected to Dam 6. Confirmation is needed concerning the daily recharge possible to Dam 6.

Two essential questions to be resolved relating to Dam 6 are: Is it possible to recharge Dam 6 sufficiently to be able to supply enough water for 453 ha of SDI, plus three centre pivots? Can the storage capacity of Dam 6 be increased by increasing the hight of the spillway (this could indeed be very cost effective, but needs to be worked out in detail)?

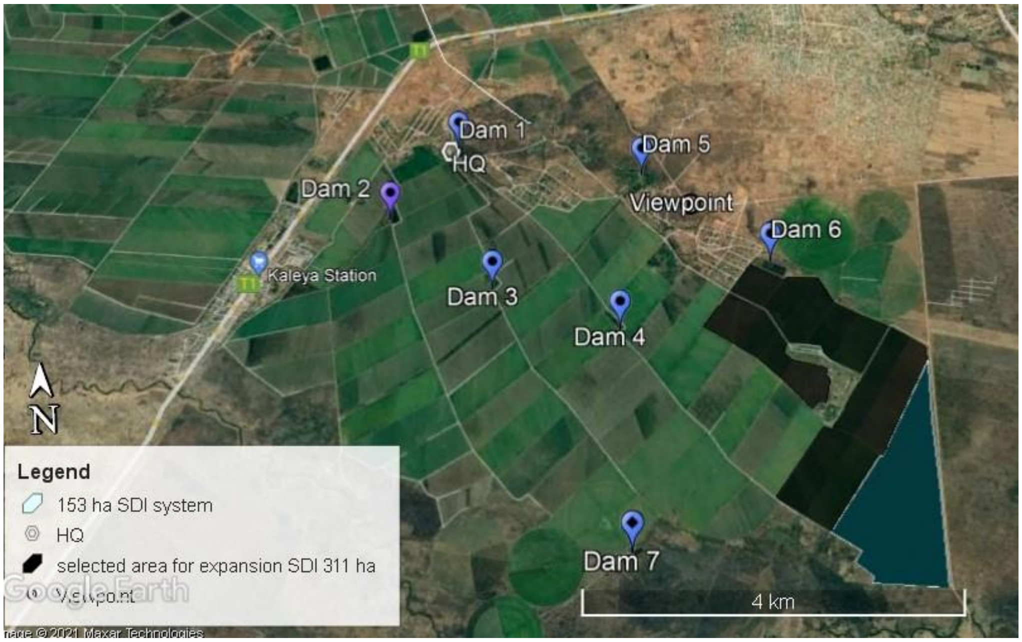


Figure 26. Location of the existing 153 ha SDI system (blue) and selected area for 311 ha expansion (dark green)

5.2 REVIEW OF WATER SUPPLY OPTIONS

Based on the groundwater assessment, sufficient groundwater replenishment to provide the required volume of groundwater for 300 ha of SDI is likely to be available. Hence, exploring the possibility of additional boreholes to abstract groundwater for irrigation supply appears to be a viable option.

An estimated total of 14 additional boreholes would be required to provide enough water for irrigation during the dry season peak demand. This would leave KASCOL less dependent on the sometimes erratic and insufficient water supply from Zambia Sugar. However, the cost of groundwater exploration and the development and construction of 14 boreholes are significant. In addition, the cost of constructing the necessary electrical and water infrastructure, as well as maintenance of the entire system, should be factored in.

If KASCOL considers the use of boreholes for irrigation water supply to be a viable option on basis of the findings thus far, it is proposed to include a financial analysis comparing the full cost (pre- and post-construction; investment and operational costs) of borehole water supply versus surface water supply in Phase 2.

Due to the water efficient nature of Subsurface Drip Irrigation, the current surface water system with piped water supply by Zambia Sugar will be able to provide the sufficient water for all irrigation purposes. This is in the assumption that a) 300 ha of SDI will replace 300 ha currently under furrow irrigation and b) the theoretical maximum volume of 1,251mm annually is irrigated. Using the current water supply system in place comes with the huge benefit of no additional investment requirement to meet the water demand.

For the above reasons, Aquaquest advises that the current surface water system is probably the most suitable water supply option to meet the future irrigation demands.

5.3 DIFFERENT POWER OPTIONS

The currently available capacity of the newly installed transformer amounts to 850 KVA (150 out of 1000 KVA used by 3 SDI pumps). The available KVA on Transformer Nr. 5 (also situated in the electric compound at Dam 6, which is the most suitable location for providing the newly installed SDI pumps with power) equals 165 KVA (150 out of 315 KVA in use).

When adaptations are made to the 1,000 KVA transformer as described under Section 3.5.2, all 6 additional SDI pumps required to irrigate 300 ha of field can be powered by this single existing transformer. It should however be verified that the capacity of this transformer indeed equals 1,000 KVA.

A detailed cost analysis of the different power supply options (ZESCO and Solar power) should be included in the Feasibility Study under Phase 2.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

For this first pre-feasibility phase of the proposed SDI development evaluation, technical data and relevant information was collected during visits to Kaleya Farm and discussions with the KASCOL Staff. Important insights were gained on the farm, its operations, available data and technical information, current practices and processes, as well as on the ideas and plans for future developments and improvements.

This Pre-feasibility report offers a preliminary analysis and evaluation of the available data (for overview of data received, see Annex V), and the different options of improved infrastructure, services and processes that are required to support the proposed development. The Pre-feasibility study is a first step towards a more detailed evaluation of the different irrigation technologies during the upcoming Feasibility stage, as well as the steps that are required to expand the SDI system by 300 ha.

This report also identifies the current knowledge gaps and points of attention that will be included in the second phase of this research. Technology implementation such as the design, installation and operation of an SDI system has many angles that need to be considered beforehand to work optimally. Findings of this Pre-feasibility study are summarized below:

- Water demand of the proposed 300 ha SDI system approximates 18,000 to 20,000 m^3. Information on the maximal recharge volume into Dam 6 should lead to confirming the capacity of this reservoir to supply water for the 453 ha of SDI irrigated fields and the 3 center pivot fields. If necessary, the storage capacity could be increased through raising the spillway.
- Aquaquest advises that the current surface water system is the most suitable water supply option to meet the future irrigation demands, as this system provides enough water for the new 300 ha SDI system and estimated costs for groundwater exploration and borehole development and construction are significant (see Chapter 4.3.3). A financial analysis comparing the full cost (pre- and post-construction; investment and operational costs) of borehole water supply versus surface water supply could further narrow down the decision-making.
- The current available capacity of transformers in the electric compound at Dam 6 is enough to provide the newly to be installed SDI pumps with power. It should however be verified that the capacity of this transformer indeed equals 1,000 KVA.

The system development of 300 ha of new SDI needs to consider the sustainability and optimalization of the water and electricity supply, the soil, the crop, the revenues, and the operating costs. Furthermore, environmental factors need to be taken into account, especially with regard to water use. The system design will consider the different available options, with a wide range of future scenarios in mind.

The first phase of this research offered the Consultant an adequate insight into the plans and visions of KASCOL, as well as into the range of available data and technical information. Furthermore, it provides a sound base on which to ground the advice concerning the envisioned SDI expansion in the second phase (the Feasibility Study), approached from different perspectives and including Return of Investment considerations.

6.2 RECOMMENDATIONS

The focus during the current pre-feasibility stage was to assess the existing data, technical information, and infrastructure, and to gain a better insight of the components that will provide the input for a detailed evaluation of the envisioned 300 ha SDI system expansion. The previous chapters already provide initial insights and summaries of the available data provided by KASCOL and collected by Aquaquest. For the Phase 2 Feasibility Study a wide variety of topics and activities are suggested. This chapter will highlight these key-action points that are required in the Feasibility Study.

Key-action points required in the Phase 2 Feasibility Study:

1) The development and assessment of different scenarios for the application of the new 300 ha SDI system, with a clear overview and appraisal of the various advantages and disadvantages for every scenario. This includes:
    a) An assessment of irrigation requirements based on weather data collected by KASCOL.
    b) An analysis of estimated crop yields with different volumes of water applied through SDI.
    c) Recommended application and quantities of fertilizers, in relation to profit maximization.
    d) Details of proposed field trials for SDI system for optimizing the operating strategy.
    e) A desk study on optimal application depths, as well as irrigation intervals for SDI.
    f) A field study of application depths at existing SDI system.
    g) A Depth of Rootzone assessment (which can be done in existing furrow system).

2) A Return of Investment analysis, which will be based on the data supplied by KASCOL, supplemented with literature research, estimated inputs and extrapolations. This includes:

   a) Clear insight in electricity requirements, based on measurements, experiences and data for the existing 153 SDI field.
   b) An estimation of electricity needed per unit of water and calculation of energy costs for different operational scenarios.
   c) An estimation of maintenance requirements and their costs.
   d) The depreciation of the SDI system.
   e) An estimation of the turnover for different operating scenarios.
   f) Comparison between the ROI of SDI, pivot and furrow systems. Note:
      i) More accurate information is needed on the yield potential of the pivot system to enable reliable comparison. Research based on existing literature is required. Current pivot data yields are influenced by several factors (soil type, planting schedule, pests, estimated data), making it hard to quantitatively compare.
      ii) Comparison with furrow system: include water use, fertilizer use, electricity consumption, other operating costs, yields/turnover.
   g) Aspects and impacts of SDI that cannot be captured in the ROI, e.g. effects on Kafue catchment. Note:
      i) Using different operating scenarios SDI (different water quantities applied).

3) Proposed development of appropriate information technology and remote sensing systems, suitable to optimize the use of SDI will also be included in the Feasibility Study. This includes:
   a) Advice on soil moisture technology options.
   b) Drone information and application potential.
   c) Geo-information services based on satellite information and other remote sensing tools.
   d) Weather data – weather monitor possibilities.
   e) Digitalization possibilities for data recording (e.g. mWater).
   f) Data management, dissemination and usage: Ideas on how to analyze recorded data & options of trials; application of data analysis in decision-making and planning processes

4) The capacity of Dam 6 to sustainably supply water to 453 ha of SDI and three center pivots should be reviewed in the Feasibility Study. This includes:
   a) Assessment of the maximum recharge capacity of water into Dam 6. Note:
      i) If necessary, increasing the volume of Dam 6 in order to provide more water storage and lower the required recharge capacity could be investigated through increasing the height of the spillway.

5) Due to challenges experienced with electricity supply over the past years, alternative sources (including solar energy) will be explored and worked out, which will be

complimentary to the current power supply infrastructure that was assessed during this initial phase. This includes:

a) Verification of capacity of newly installed transformer (1000 KVA) and adaptations to the 1,000 KVA transformer as described under Section 3.5.2 of energy requirements for 300 ha SDI and electrical infrastructure.
b) A review of the possibilities of solar energy development, including cost indications of the different power supply options (both ZESCO and Solar power).

Additional key-point, subject to KASCOL decision-making:

Alongside the proposed key-action points to include in the Feasibility Study, it is up to KASCOL whether the estimated cost of groundwater exploration and borehole development & construction (under section 4.3.3) have raised interest in the further pursuit of investigating whether this water supply source is long term cost-effective in comparison to the current surface water supply system in place. This would include into the Feasibility Study:

a) A financial analysis comparing the full cost (pre- and post-construction; investment, operational and maintenance costs) of borehole water supply versus surface water supply.
b) Drilling of two pilot boreholes in order to confirm that yields of 15 l/s can be achieved sustainably.

Discussion on all the key-action points is welcomed in order to confirm the final outline of the Feasibility Study.

7. REFERENCES

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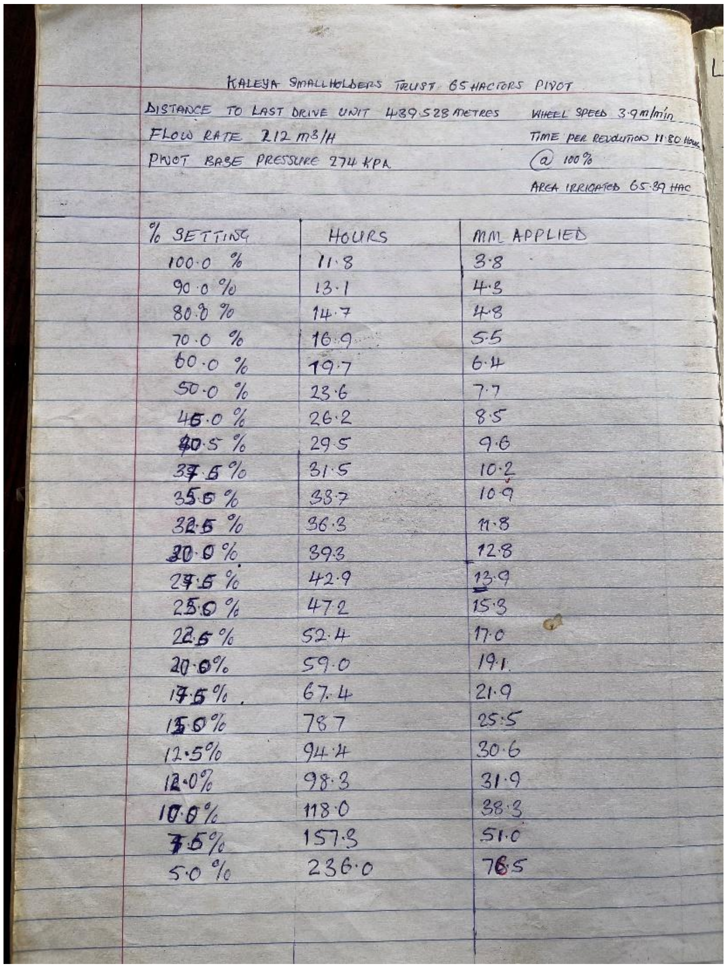
ANNEX I – PIVOT IRRIGATION DATA

Max capacity in mm per hour: 3,8/11,8=0,322

Max capacity in mm per 24hrs = 0,322 * 24 = 7,73



KALEYA SMALLHOLDERS TRUST 65 HACTORS PIVOT

DISTANCE TO LAST DRIVE UNIT 439.528 METRES

WHEEL SPEED 3·9 m/min

FLOW RATE 212 m3/H

TIME PER REVOLUTION 11·80 HOURS @ 100%

PIVOT BASE PRESSURE 274 KPA

AREA IRRIGATED 65·39 HAC

% SETTING	HOURS	MM APPLIED
100·0 %	11·8	3·8
90·0 %	13·1	4·3
80·0 %	14·7	4·8
70·0 %	16·9	5·5
60·0 %	19·7	6·4
50·0 %	23·6	7·7
45·0 %	26·2	8·5
40·5 %	29·5	9·6
37·5 %	31·5	10·2
35·0 %	33·7	10·9
32·5 %	36·3	11·8
30·0 %	39·3	12·8
27·5 %	42·9	13·9
25·0 %	47·2	15·3
22·5 %	52·4	17·0
20·0 %	59·0	19·1
17·5 %	67·4	21·9
15·0 %	78·7	25·5
12·5 %	94·4	30·6
12·0 %	98·3	31·9
10·0 %	118·0	38·3
7·5 %	157·3	51·0
5·0 %	236·0	76·5

ANNEX II – CROPWAT

max ETc (mm/day)	6,11
max irrigation (mm/day)	5,73

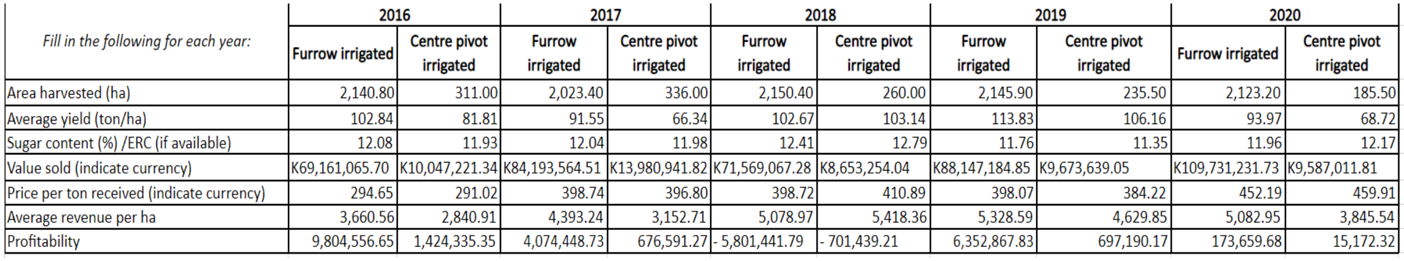
Weather date CLIMWAT, location Choma (most approximate location to Mazabuka) assumed planting date cane: 15 sept. When rain data is digitalized from KASCOL, we can adjust the crop water and irrigation requirements tailored to the location of Kaleya Farm.

Max KC factor 1.27

Month	Decade	Stage	Kc coeff	ETc mm/day	ETc mm/dec	Eff rain mm/dec	Irr, Req, mm/dec
Sep	2	Init	0,86	5,69	34,2	0	22,8
Sep	3	Init	0,4	2,76	27,6	1,5	26,1
Oct	1	Init	0,4	2,95	29,5	4	25,5
Oct	2	Deve	0,43	3,33	33,3	5,7	27,6
Oct	3	Deve	0,57	4,06	44,7	12,6	32,1
Nov	1	Deve	0,73	4,58	45,8	20,1	25,8
Nov	2	Deve	0,87	5	50	26,4	23,6
Nov	3	Deve	1,02	5,53	55,3	32,6	22,6
Dec	1	Deve	1,16	5,96	59,6	40,6	19
Dec	2	Mid	1,27	6,11	61,1	47,7	13,5
Dec	3	Mid	1,27	6,04	66,4	47	19,4
Jan	1	Mid	1,27	5,95	59,5	46,1	13,4
Jan	2	Mid	1,27	5,85	58,5	46,6	11,9
Jan	3	Mid	1,27	5,77	63,5	44,4	19,1
Feb	1	Mid	1,27	5,69	56,9	42,7	14,2
Feb	2	Mid	1,27	5,6	56	41,2	14,8
Feb	3	Mid	1,27	5,71	45,6	35,6	10
Mar	1	Mid	1,27	5,81	58,1	29,6	28,5
Mar	2	Mid	1,27	5,91	59,1	24,4	34,7
Mar	3	Mid	1,27	5,79	63,7	19,3	44,4
Apr	1	Mid	1,27	5,67	56,7	13,4	43,4
Apr	2	Mid	1,27	5,56	55,6	7,8	47,7
Apr	3	Mid	1,27	5,46	54,6	6	48,6
May	1	Mid	1,27	5,37	53,7	4,2	49,5
May	2	Mid	1,27	5,28	52,8	1,8	51
May	3	Mid	1,27	5,09	56	1,3	54,7

Jun	1	Mid	1,27	4,9	49	0,8	48,2
Jun	2	Late	1,25	4,64	46,4	0	46,4
Jun	3	Late	1,21	4,54	45,4	0	45,4
Jul	1	Late	1,16	4,37	43,7	0,1	43,6
Jul	2	Late	1,12	4,23	42,3	0	42,3
Jul	3	Late	1,07	4,51	49,7	0,1	49,6
Aug	1	Late	1,03	4,79	47,9	0,1	47,9
Aug	2	Late	0,98	4,98	49,8	0,1	49,7
Aug	3	Late	0,94	5,23	57,5	0,2	57,3
Sep	1	Late	0,89	5,43	54,3	0	54,3
Sep	2	Late	0,86	5,69	22,8	0	22,8
					1866,5	604	1251,1

ANNEX III – REVENUE DATA



Fill in the following for each year:	2016		2017		2018		2019		2020	
	Furrow irrigated	Centre pivot irrigated	Furrow irrigated	Centre pivot irrigated	Furrow irrigated	Centre pivot irrigated	Furrow irrigated	Centre pivot irrigated	Furrow irrigated	Centre pivot irrigated
Area harvested (ha)	2,140.80	311.00	2,023.40	336.00	2,150.40	260.00	2,145.90	235.50	2,123.20	185.50
Average yield (ton/ha)	102.84	81.81	91.55	66.34	102.67	103.14	113.83	106.16	93.97	68.72
Sugar content (%) /ERC (if available)	12.08	11.93	12.04	11.98	12.41	12.79	11.76	11.35	11.96	12.17
Value sold (indicate currency)	K69,161,065.70	K10,047,221.34	K84,193,564.51	K13,980,941.82	K71,569,067.28	K8,653,254.04	K88,147,184.85	K9,673,639.05	K109,731,231.73	K9,587,011.81
Price per ton received (indicate currency)	294.65	291.02	398.74	396.80	398.72	410.89	398.07	384.22	452.19	459.91
Average revenue per ha	3,660.56	2,840.91	4,393.24	3,152.71	5,078.97	5,418.36	5,328.59	4,629.85	5,082.95	3,845.54
Profitability	9,804,556.65	1,424,335.35	4,074,448.73	676,591.27	- 5,801,441.79	- 701,439.21	6,352,867.83	697,190.17	173,659.68	15,172.32

ANNEX IV – POWER SUPPLY ASSESSMENT

1.0	Transformer (Newly installed) Problem: Earthing In case of lightening, with the two joined earthing's connected the discharging current would go to the transformer instead of the intended underground path. Solution: detach the two earth wires connected to each other, one from the transformer body and the other from the lighting arresters from the pole. Replace the connecting clamps nodes with more permeant exothermic connection. Measure the earthing resistance if it ZESCO standard.
1.1	Transformer (newly installed) oil leakage: Problem: leaking oil from the transformer. The leakage is not controlled could cause the oil level to drop beyond the minimum protective level and expose the windings causing the transformer to trip or losing the windings. Solution: Reseal the transformer plate to close the leakage and prevent any further losses of transformer oil with a material that is oil corrosive resistant to prevent it from reoccurring. Then top up the transformer oil to the commended level.
1.2	Transformer 1(315KVA 11/0.4KV); lighting protection Problem: transformer unprotected Solution: ZESCO to install arresters to the transformer.
1.3	Install danger signs on both transformer
1.4	Put a lockable gate and new fence on the transformer number 1
1.5	Transformer 1 Earthing (315KVA 11/0.4KV) Problem: transformer earth cable missing. The transformer earthing or grounding is used to provide a relatively low-impedance path to ground, thereby maintaining the system neutral at or near ground potential. It limits the magnitude of transient overvoltage when restriking ground faults occur. Also provide a source of ground fault current during line to line ground faults.
1.6	Transformer 1 (315KVA 11/0.4KV) oil leakage Problem: transformer oil leakage from the HT windings. Oil will drop beyond recommended level. Solution: ZESCO to work on the leakage.
1.7	Check and inspect the DB'S and Panels
1.8	Check and inspect and make corrective maintenance.
1.9	Clean the transformer sites surrounding area of plant growth and dead plants.
2.0	Undertake extensive load testing for the pumping system and the irrigations system for both the existing 150 hector drip irrigation and the overhead pivot irrigation system to find out exactly how much power each system uses.
2.1	With the information collected design a stand -alone solar system plant to supply power to the 450 -hector drip irrigation system as an alternative (daytime) power source when ZESCO is unavailable.

ANNEX V – TECHNICAL ASSESSMENT DATA RECEIVED BY CONSULTANT

DATA	**INPUT BY**	**STATUS**
Company registration Data	Coordinator	Received
Board data & company documents	Coordinator	Received
General Organisation structure	HR	Received
Staffing	HR	Received
Casual workers per year	HR	No Data
Qualifications & Specialisms	HR	Received
Contracts with Illovo	EM/FM	Received
Other Service providers	FM	No data
Relationships with govt, donors, for technical/financial support	EM/FM	Received
Service contract with farmers	EM/FM	Received
General farm plan	**AGRIC**	
Size in ha of cane under; furrow, Drip, & Pivots	SOO	Received
Calendar; replanting harvesting, rotation	SOO	Received
Fertilizer application methods for each type of irrigation	Zone leaders	Received
Fertilizer input in (kgs/ ha) for; basal, top/% N & other fertilizers	SOO	Received
Size in ha for other crops	SOO	Received
Soil analysis (latest results)	SOO	Received
Yearly Break down of Costs -overall costs; labor, water, electricity, farm inputs,	Management Accountant	Received
Sugar cane production costs (*cost of cane production only)* Total field(ha)	M A	Received

-Farm labor -water -Electricity -Farm machinery All other Direct costs		
Annual Sugarcane Results over years; furrow & pivots	**AGRIC/ACCOUNTS**	
Harvested Area (ha)	SOO	Received
Average Yield(ton/ha)	Management Accountant	Received
Sugar Content	MA	Received
Value sold(currency)	MA	Received
Price per ton received	MA	Received
profitability	MA	Received
Annual Incomes (from other crops)	**ACCOUNTS**	
From service contracts	MA	No data
From other sources	MA	No data
From individual farmers	MA	No data
General questions		
Trends	MA	Received
constraints	EM/ FM	Received
Company plans	EM/FM	Received
Water Resources Data	**AGRIC/ACCOUNTS**	
Pumped volumes from Nakambala	SOO	Received
Cost of water invoiced Yearly	MA/FA	Received
Storage capacity & dimensions(dams)	SOO/Zone leaders	Received
#Boreholes+ drilling records	SOO/Zone leaders	Received what was available, but incomplete.
Pumping capacity for Boreholes	SOO/Zone leaders	Received
Geophysical survey reports	SOO/Zone leaders	No Data

Available geological data	SOO/Zone leaders	No Data
Estate boundary (GIS/Google Earth)	SOO/Zone leaders	Received
Irrigation (operation) Data	**AGRIC**	
# Workers Forming one furrow irrigation team -irrigated area per team -Salary per worker	Zone leaders	No data
Average furrow irrigation interval	Zone leaders	No data
Irrigation Records -when fields were irrigated -how long	Zone leaders	Received
Available data on maintaining the canal systems	SOO	No data
# Workers to operate one pivot	Zone leaders	No data
Pivot operation data	Zone leaders	Received (same data as point 3)
Average pivot irrigation Interval	Zone leaders	No data
Power consumption per pivot system	Electrician	Received
Weather data	Zone leaders	Received
Sub surface Drip Irrigation System Data -Salary per SDI employee -Source of fertilizer; soluble/granular -fertilizer prices; soluble & granular	SOO/FA/MA	No data
Power data Layout -Transformer Details Consumption Breakdown	Electrician	Received
Dam Dredging Cleaning	Buyer/ SOO	Received