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Kaleya Smallholders Company Limited (KASCOL)

Sub-surface Drip Irrigation Development Evaluation Project – Feasibility Report

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List of Abbreviations

CWR	Crop Water Requirement
DFCD	Dutch Fund for Climate Development
EC	Electrical conductivity
ERC	Estimated recoverable crystal
KASCOL	Kaleya Smallholders Company Limited
MCA	Multi Criteria Analysis
NDVI	Normalized Difference Vegetation Index
ROI	Return on Investment
SDI	Sub-surface Drip Irrigation

1. INTRODUCTION

The current report represents the output under Phase 2 of the Sub-surface Drip Irrigation Development Project - Feasibility Study for Kaleya Smallholders Company Limited (KASCOL). The Feasibility Study follows the previously completed Pre-Feasibility Study carried out in December 2021 (see Aquaquest Report ref. AQ21-022), and its suggested approach, recommended methodology, actions and workplan, as further outlined in Aquaquest's proposal for the 2nd Phase of the study (PAQ22-001).

KASCOL Estate 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 estate, 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. The project has been executed in two phases:

- Phase 1, completed in December 2021, comprised an initial Pre-feasibility Study to assess the existing data, information and infrastructure (see Aquaquest Report ref. AQ21-022), while
- The current Phase 2 represents the actual Feasibility Study with preliminary designs of the selected irrigation schemes.

The report for the Feasibility Study is structured as follows: first, a brief comparative analysis of the existing irrigation systems at KASCOL is conducted, to compare advantages and disadvantages of different technologies (Chapter 2). Subsequently, the recommended design of the envisaged Sub-surface Drip Irrigation (SDI) system is explained (Chapter 3), with a borehole option (Chapter 4), a solar option (Chapter 5), and an additional option for the application of advanced information technology and remote sensing (Chapter 6).

The results of a geophysical survey and exploratory drilling campaign, conducted as part of the Feasibility Study to investigate the borehole option outlined in Chapter 4, are included in two separate reports.

In Chapter 7, three different operation strategies for the SDI system are discussed, based on different irrigation application rates.

In Chapter 8, a Return on Investment (ROI) analysis is conducted for the different operating strategies, taking into account the solar and borehole options. In Chapter 9, the results of the ROI are compared using a multi-criteria evaluation, taking sustainability criteria into account as well. In Chapter 10, a corporate governance analysis is conducted to identify any potential bottlenecks for the future implementation of the project, Finally, in Chapter 11, the key conclusions and recommendations of this study are summarised.

The Aquaquest Project team for this Feasibility Study included the following experts:

- Senior Agricultural Expert: Piet Stevens
- Senior Water Resources Development Expert: Marco van der Plas
- Hydrogeologist / Water Engineer / Project Manager: Frank Meins
- Irrigation Expert: Bram de Vries
- Economist: Glenda Mazakaza
- Electrical Engineer: KVA Power Solutions Ltd

2. COMPARATIVE ANALYSIS OF EXISTING IRRIGATION TECHNOLOGIES AT KASCOL

Three different irrigation systems are currently being used at KASCOL:

1) Furrow irrigation (2280 ha),
2) Center Pivot irrigation (364 ha),
3) Sub-Surface Drip Irrigation (SDI) (153 ha)

Among these, the furrow system, constructed in the 1980's, is the oldest system, while the current SDI system was completed very recently in 2021. The three existing irrigation systems are described in detail in the Pre-feasibility Report (ref. AQ21-022) and their characteristics are summarized below.

2.1 FURROW IRRIGATION

The furrow irrigation system functions correctly and according to its intended design, despite the relatively advanced age of the infrastructure. Currently, 2280 ha of sugarcane are under furrow irrigation at KASCOL Estate. Due to water supply constraints and the fact that operation of the system is relatively labor-intensive, the irrigation application is impeded. Furthermore, the relatively large irrigation intervals (days between irrigation gifts) cause drought stress for the crop, thus limiting the yields.

In general, furrow irrigation systems are characterized by their low scheme irrigation efficiency. For the system at KASCOL, this efficiency is estimated to be 52%, ie. only 52% of the water applied will become available in the rootzone of the crop. The effective irrigation is calculated to be 4.92 mm/day in the best-case scenario (irrigation interval of 14 days) and 2.46 mm when the irrigation interval is 30 days, which is not uncommon.

Comparing these estimated figures for the furrow irrigation system with the Crop Water Requirements (CWR) indicates that the outputs are insufficient for most of the crop cycle. Water use data for the period 2016-2020 indicates an average yearly water use of 897mm, corresponding to an average daily application of 4.27 mm/day, of which 52% (2.22 mm/day) would reach the rootzone and become available for the crop. Based on the water use information of 2016-2020, 466 mm/year can be considered as effective irrigation (water available for crop).

When using the information provided from interviews and considering the applied irrigation scheduling, an amount of 682 mm/year would become available for the crop. Therefore, we can safely say that under furrow irrigation, the amount of water available for the crop varies between 466 mm/year and 682 mm/year (for details see Annex I and Annex II). The total water use, based on 2016-2020 data, is 8,971 m^3/year/ha.

The operational costs of the funnel irrigation scheme are relatively low, as the system does not use electricity, while its depreciation period has already passed, even though it is still in operation and working properly. The water productivity is 7.2 kg cane/ m^3 water applied (from the combined input of effective rainfall and irrigation).

2.2 CENTER PIVOT IRRIGATION

The Center Pivot systems of KASCOL are located in two different locations (with a combined area of 364 ha), which influences their performance in terms of yield. The soil types of the three Pivots located North-East of Dam 6 are shallow and rocky; harvests are comparable with the average yields of the furrow irrigation system. The soils of the four Pivots in the southern part of the Estate are more favorable (deeper soils with higher clay content).

Data received by KASCOL indicate that both Center Pivot systems are currently under-irrigating the crop, causing crop stress and resulting in lower yields, compared with their actual potential. The irrigation records of two Pivot systems indicate irrigation applications between 315 and 708 mm/year, which is well below the CWR. However, the moment of planting might have influenced this information: some data might have been obtained from the rotation where the sugar cane was just planted and required less water, while other data may have been obtained from the second rotation whereby the plant requires more water more water.

Although the Center Pivot irrigation system could potentially provide higher yields compared than the furrow system, available data shows that this has not been the case at Kaleya Estate, due to other factors, such as soil type. The Center Pivot system has higher operational costs, due to the electricity demands and the ongoing depreciation of the system. Water productivity is comparable with the furrow irrigation system. Since a Center Pivot is a complete circle, land use is less efficient, since there is unused space left, which cannot be reached by the rotating sprinklers.

2.3 SUB-SURFACE DRIP IRRIGATION SYSTEM

The SDI System's performance in terms of water use and yield cannot yet be assessed, since it was installed in 2021, while the first lot of sugarcane was planted between 23 October and 13 November 2021 on 153 ha of land. The existing SDI system is designed for a capacity of 8 mm/day, which can deliver the full CWR to the crop 94% of the time. This will not lead to drought stress and a lower yield, due to the good water storage capacity of the clayey soil and the moments when the peak irrigation requirements occur.

The SDI system is driven by 3 pumps with a capacity of 200 m^3/hr each and a total power requirement of 160 kW. As the system uses fertigation (fertilizers are mixed with irrigation water and applied trough SDI system), very high levels of efficiency can be reached.

2.4 COMPARISON OF EXISTING IRRIGATION TECHNOLOGIES

To compare the different irrigation systems that are currently present at KASCOL, a Weighted Multi Criteria Analysis (MCA) tool was developed. The MCA takes different economical and sustainability factors into account and offers a quantitative comparison.

Every factor received a score from 1 to 5, whereby 1 is the least favourable grade, while 5 represents the most favourable. The weighted sum of the economic factors equals that of the sustainable elements, assuming yield is a sustainability factor. This balance results in an equilibrium between economic and sustainability values.

A clear overview of the strong and weaker points of the different technologies is provided in the MCA, which makes it possible to make a quantitative comparison (see Table 1). The MCA solely serves as a comparison tool between the current systems present at KASCOL, based on information provided by KASCOL, observations by the Consultant, and literature research.

It should be noted that both the weight of the different factors and the attributed score can be considered subjective to a certain extent: as a result, different stakeholders may value the criteria differently. Consequently, based on further discussions with KASCOL, and according to its views and priorities, a different weighing and scoring may be applied.

Table 1. MCA of different irrigation technologies

MCA	Factor	Weight (W)	Furrow Irrigation	Center Pivot irrigation	Sub surface drip irrigation
Economical aspects	Turnover	1	2	3	4
	Operating costs	0.5	W x 4 = 2	x 3 =1.5	x 2 = 1
	Investment costs	0.5	W x 4 = 2	x 2 = 1	x 1 = 1
	ROI	2	W x 4 = 8	x 3 = 6	x 3 = 6
Agricultural factor	Yield	1	2	3	5
Sustainability factors	Water saving	2	W x 1 = 2	x 3 = 6	x 5 = 10
	Water productivity	2	W x 3 = 6	x 3 = 6	x 5 = 10
	Chemical fertilizer use	1	1	3	4
	Weighted sum	**10**	**25**	**29.5**	**40.5**

Looking at the weighted sum of the MCA (Table 1), it becomes clear that SDI has a significantly higher overall score, compared with Center Pivot and Furrow irrigation. However, when looking at the individual factors, furrow and center pivot do score higher in some important aspects, such as Operating costs, Investment costs and ROI. Focusing on the sustainability factors, SDI is scoring the highest on every individual factor.

When solely looking at the economic factors, the Furrow system scores highest. The main factors that contribute to this high score are the low operating costs. The furrow system does not need electricity, bulk water supply is relatively affordable, the investment costs are relatively low, and the lifetime of the system is longer. This is evidenced by the fact that the existing KASCOL system is already in operation for 40 years, and still functioning well beyond its depreciation time.

The overall scores for the Furrow irrigation system and the Center Pivot irrigation score are similar (25 and 29.5 respectively). Center Pivot has an advantage over the furrow system when it comes to chemical- and fertilizer use: spraying can be done more effectively using the pivot sprinklers. If all other conditions are the same, the pivots should have an additional advantage over the furrow system in terms of crop yield, due to the better irrigation interval.

Overall, SDI comes out as best possible irrigation system, mainly because of the high scores on the sustainability aspects, combined with the highest crop yield and turnover potential. It is therefore concluded that SDI offers the greatest potential for the coming decades, also considering climate change and the expected increasing pressure on available natural resources. In response, farming practices and technologies should become less dependent on the weather (due to failing rains) and on surface water resources (due to depleted surface water flows and increasingly competing demands), while economizing and optimizing the use of water as much as possible.

In line with the findings from the MCA, this feasibility research will further zoom into the details of the different SDI expansion options and their characteristics.

3. DESIGN AND COSTING OF PROPOSED SDI EXPANSION

The general design of the proposed expansion for an additional 311 ha under SDI is described in this Chapter. However, to avoid pre-empting the outcome of ongoing procurement processes, this design is not specific for any potential brand, make or supplier of irrigation equipment. Instead, the general design provides the advised design criteria and describes the lay-out and pre-liminary costs of a system that matches the requirement. KASCOL can use this information to further fine-tune the specifications, identify the most suitable makes and brands, and engage potential irrigation suppliers.

Since an existing design and quotation by RIVULIS were available during this feasibility study, the cost estimates corresponding with this design were used in the ROI analysis to offer the most accurate insight possible for the purpose of the assessment. It is expected that other irrigation suppliers will be around the same price range, since this was also the experience of KASCOL two years ago, when the SDI for the initial 150 ha was tendered.

3.1 DESIGN CRITERIA

For the design criteria, the optimal conditions for the sugarcane crop have been considered. Since sugarcane is a continuously growing crop, the wetted pattern of the drip-line also needs to be continuous. Considering the clay soils that underlie the selected SDI-expansion fields at KASCOL, an emitter spacing between 40 cm and 60 cm can achieve this with a flow rate of 0.8 to 1.2 litres per hour. Lower flow rates are not recommended, since this will increase the chances of clogging and blockage. For higher flow rates, larger dimensions of pumps, supply lines and related accessories are required, thus increasing the costs of the system rather unnecessarily. Table 2 provides an overview of the criteria advised.

Two rows of sugar cane should be planted per drip-line, making the system more cost-effective, compared with the option of only 1 line of sugarcane per drip-line. Row spacings with this "tramline layout" normally vary between 1.7 m and 2 meters. For uniformity purposes, an average 1.9m spacing has been applied in the calculations. This suggested spacing creates a good plant population and provides sufficient aeration between the rows.

The capacity of an irrigation system is expressed as the number of millimetres per day that the system can supply over the whole command area. After assessing the CWR (Annex I), the peak supply criterion was advised to be 6.8 mm/day, to ensure 92% of the time 100% of irrigation requirements can be met by the SDI.

Only during the hottest period of the year, towards the end of October, the irrigation requirement is higher (with a max of 9.1 mm/day). However, this is not expected to cause stress to the crop since the local clay soil at Kaleya Estate has a high storage capacity. Consequently, the SDI system can completely fill the soil reservoir to capacity, prior to this peak demand in October. During the peak period, the soil moisture content will deplete. However, the soil will still retain enough moisture towards the end of the dry period to enable the crop to take up sufficient water.

After the irrigation water demand peak towards the end of October, the rainy season starts supplying part of the water for the crop and the required amount of irrigation water decreases rapidly. Since the CWR have been determined based on the rainfall data for the period 2017-2021, which had some very dry years, the ‘long term average’ irrigation demands are expected to be lower. Therefore, the design criteria can be considered to take the uncertain climate change and variable weather patterns into account.

Design criteria for the proposed KASCOL SDI System expansion are summarized in Table 2. Annex VI provides the complete list of design criteria and information that KASCOL is advised to share with irrigation suppliers for detailed design and tendering purposes.

Table 2. Design criteria

Crop type	Sugar Cane
Area size (ha)	311
Crop spacing	Continuous
Rows distance (m)	1.9
Row direction	Mainly from East to West
Min. Required capacity system (mm/day)	6.8
Emitter flow rate (indication- open for suggestions irrigation supplier) (l/hr)	0.8-1.2 lph (designer prerogative within this range)
Emitter spacing (range)	0.4 m - 0.6 m (designer prerogative within this range)
Lateral spacing (m)	1.9
Max irrigation time per day (hours)	20
Soil data	Loamy clay 0 - 45 cm; gradually increasing clay content with depth towards heavy clay soil 45 - 100 cm
Effective rooting depth (m)	0.45
Maximum rooting depth (m)	0.95
suggested Irrigation interval	3-5 days
Energy type	Electricity
Water Source	Reservoir (volume 38,800m3) water transferred from Kafue River
Min irrigation zone size	Designer prerogative. Flexibility in irrigation is important: when fields reach field capacity, the irrigation manager should be able to stop irrigating, while on fields that did not yet reach field capacity irrigation should be continued (differences might be caused by crop stage, health, soil type, climatological conditions, exposure, drainage, etc.).
Fertigation	yes, include fertigation option
Filtration	Primary automatic Screen filtration; Block level: semi-automatic filtration

3.2 WATER SOURCE AND COMMAND AREA

KASCOL has selected a number of fields for the proposed SDI expansion of 311 ha. Most of the fields are located in between Dam 6 and the existing 150 ha under SDI. All the selected fields are currently irrigated by one channel which is also fed by Dam 6. After the installation of the new SDI system, this channel would become redundant. In this future scenario, Dam 6 will provide water to the whole SDI area of KASCOL (311+150 = 461 ha), as well as one area that will still be under furrow irrigation with its own supply channel.

The volume of Dam 6 was measured as part of the pre-feasibility study: due to siltation, the current storage capacity is estimated 38,800 m^3. Dam 6 is filled via a concrete channel with a flow capacity of 1.08 m^3/second, which draws water from Dam 5. Therefore, the recharge capacity of Dam 6 is sufficient for the water use of the Center Pivot blocks, the SDI system and the area that will remain under furrow. This is based on the assumption that Zambia Sugar Limited will be able to meet KASCOL's water demand, which has proven to be a challenge in some recent years.

Periods of insufficient supply by Zambia Sugar could be mitigated by the proposed borehole water option (Chapter 4): this supplementary groundwater provision would act as a back-up source that could address emerging supply shortfalls (both expected and unexpected). Through a series of high-yielding production boreholes, KASCOL would be able to ensure that enough water is available at the right times. The water from the boreholes would also be pumped into Dam 6.

The command area for the envisaged SDI expansion is illustrated in Figure 2. The soils in this area are formed by a relatively uniform loamy clay, with increasing clay content towards heavy clay between 40 to 80 cm depth. The fields to the south are underlain by the heaviest clay soils.

It is important for the design to allow maximum flexibility to fine-tune irrigation water supply from field to field, as per actual requirements. In practice, it is possible that certain fields require less or more water than other fields. This can be caused by changes in crop development, local variations in weather conditions (rain, temperature, wind, sun) and exposure, changes in soil, variations in slope and drainage, pests and disease affecting the crop, nutrients in the soil, etc. Consequently, the system design should make it possible to irrigate only a few fields of the entire command area. This can be realised by a proper design with smaller irrigation zones, and the installation of pressure regulators on the system and the pumps that will allow water production or transmission at different discharge rates (i.e., not only at maximum capacity, but also at reduced yield, for instance to irrigate only specific fields, or to irrigate some fields for a limited amount of time, while continuing supply to fields that require more water).

For proper management and enhanced sustainability, the KASCOL team needs to be well-trained on the operation of the system and its different irrigation water supply options. In short, an SDI system will provide optimal growing conditions if the design is geared towards flexibility (factoring in variable supply and demand options), zoned supply options, and ease of operation. While this flexibility may come at a higher investment and operational cost, the benefits are likely to pay off through improved irrigation-efficiency and higher crop yields.

Figure 2. Map of command area for envisaged 311 ha SDI expansion

3.3 PUMPING STATION, FILTRATION AND FERTIGATION

The entire KASCOL area was initially designed for furrow irrigation, and therefore makes use of gravity. This aspect can be used as an advantage, if certain design elements for the SDI system could incorporate part of this existing gravity system. Indeed, this adaptation would reduce costs and make the system more intuitive and practical to use.

Since the water level of the dam is elevated above the fields, water can reach the pumping station by gravity, using the existing gate structure. Close to Dam 6 (Figure 3), the pumping station for the Centre Pivot and the initial 150 ha SDI has already been built, thereby limiting the area that is needed to enhance pumping capacity for the SDI expansion. Moreover, the concrete water reservoir at the inlet of the pumps is too small to facilitate additional intake pumps. However, the channel south of the pump station (to the right of the drawn square in Figure 4) offers potential, as it flows in the direction of the selected expansion area.

Figure 3. Overview Dam 6 and location option pump house

Figure 4 shows a practical alternative option with enough space for a new pump house, whereby water would be supplied from an additional small reservoir along the channel south of the existing pumping station. Part of the existing concrete channel could be part of this new reservoir. For this purpose, one side of the concrete channel should be removed, while the new reservoir is dug out with an excavator and lined with concrete. There will also be room for the filtration and fertigation station next to the new pump house. By aligning these elements in a straight line, pressure loss will be minimized.

While the proposed solution will very slightly reduce the size of the command area, the advantages in terms of the design, efficiency and ease of operation are expected to outweigh this minor disadvantage.

Alternatively, the area on the North side of the road can be used for the expansion of the pumping facilities. This area has already been graded for the filtration and fertigation station that serves the existing SDI system. However, this is probably a less favorable option, since a new pipe and gate structure from the main dam would be required. Moreover, a whole new reservoir would have to be built in this area, and an additional bend and culvert will be required under the road to reach the command area. This would lead to additional costs, especially when compared with the first-mentioned option along the southern channel.

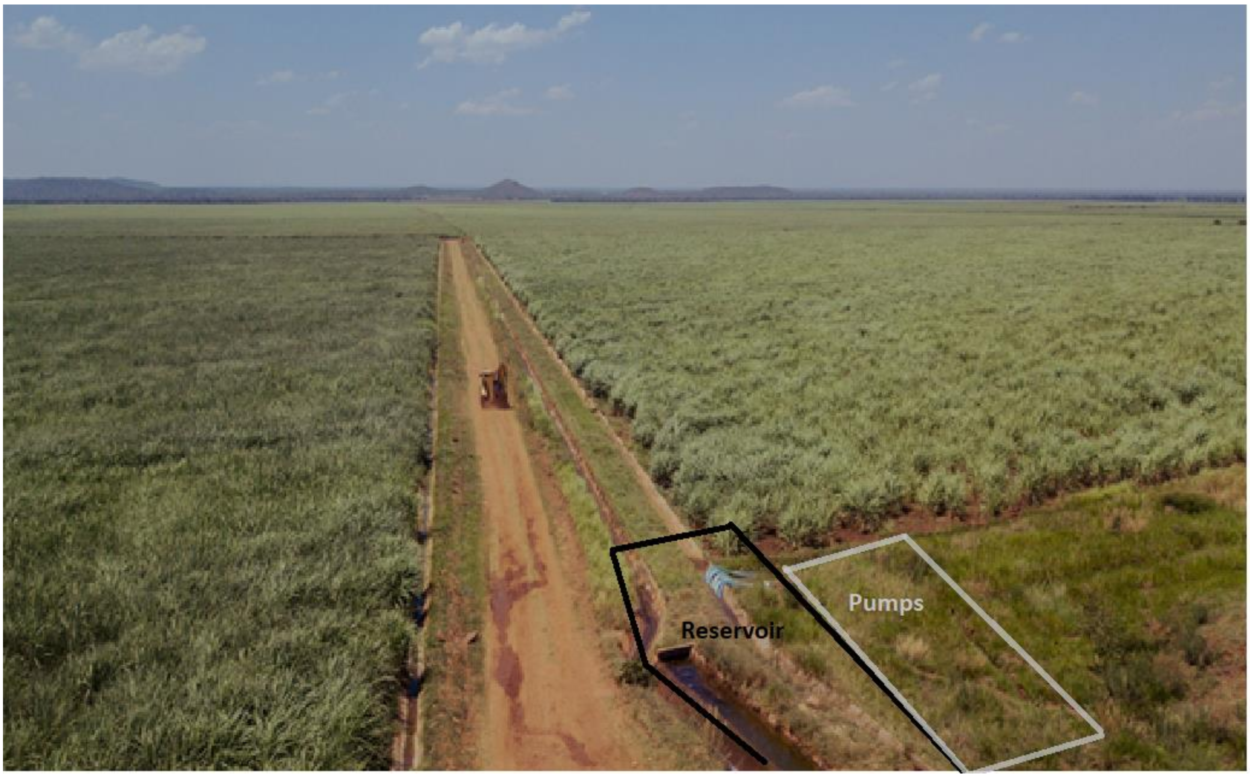

Figure 4. Proposed location pump reservoir and new pump house

Because the drip lines need to be working for an expected lifespan of at least 8 years, and since these are buried under the soil, it is important to minimize the risks of clogging. With an SDI system, it can be difficult to identify clogging problems and even more difficult to unclog or replace the drip lines.

During this study, the water quality was tested: overall, the results indicate that the water is of good quality. Therefore, a primary automatic screen filter system will suffice. In addition, secondary filtration stations are required at block level in case debris enters the pipes: for example, this could happen during construction and/or when other damages within the system would occur. In combination with regular flushing of the drip lines (every 2 weeks), the risks of clogged emitters are significantly lowered. In addition, the quality of the emitters of the drip line is important, in order to minimize clogging risks.

One key-advantage of SDI is the option to fertigate and add fertilizers in an unbeaten and uniform way, thus minimizing leaching and other losses. Different options exist which differ in ease of operation, precision and measuring level. It is advised to select an option that can measure and apply the EC value of the irrigation water to check if the right quantities/concentrations have been used.

An additional advantage is that it would be possible to monitor fertilizer levels per field, thus allowing for tests and trials with different fertigation levels. With these kind of experiments, crop yields under different fertilizer regimes can be compared, finding the optimum levels between fertilizer costs and yields.

Since KASCOL has been cultivating sugarcane for 4 decades with minimum crop rotation, the organic matter and, naturally, the available nitrogen in the soils are very low. The soil tests show this for all fields at Kaleya Farm. It is advisable to use the future fertigation system to add biological products that can support and improve the development of soil life. In combination with other sustainable practices aimed at increasing the organic content of the soil, the application of appropriate fertigation can significantly improve the local soil conditions, keeping them healthy and suitable for cultivation for the coming decades. In short, options to improve soil health are an important added advantage when converting to SDI.

For the envisaged expansion area of 311 ha, an additional pumping capacity of 1,450 m^3/hr is required. It is advised to meet this flow requirement with 6 pumps of approx. 240 m^3/hr at a head of 45-50 meter.

3.4 Electricity Requirements

Looking at the electricity requirements of the 6 main pumps that are needed for the SDI expansion, a new transformer will be required. The existing power cables can be used and do not need replacement to increase capacity. The pre-feasibility report provides suggestions to strengthen the existing infrastructure and improve its safety.

For the SDI expansion, a 315KVA transformer will be needed. This transformer will be able to operate at 330KW, as needed to operate the 6 pumps. The same transformer can take up the solar option that is described in more detail in Chapter 5.

4. BOREHOLE OPTION

During the Pre-feasibility Phase, a preliminary groundwater resources assessment was conducted (see Report ref. AQ21-022). The assessment concluded that, when using the average groundwater recharge scenario, 7,951,299 m^3 of water could be abstracted annually on a sustainable basis. This amount is sufficient to sustain the new 311 ha under SDI in all operating strategies (see Chapter 7). It was estimated that 14 boreholes with a yield of approximately 15 l/s each (i.e., a combined output of 210 l/s) would be sufficient to sustain the development. However, the exact borehole yields that can be attained have to be confirmed through exploratory drilling.

As part of this feasibility study, a geophysical survey was conducted, followed by an exploratory drilling and test pumping programme. At the time of writing, the borehole development was still ongoing; so far, with encouraging results. The geophysical survey and drilling results will be presented in two separate reports.

Preliminary findings after drilling 5 exploratory boreholes (pilot holes PH01-05) indicated that annually three of the 5 pilot holes had a fair yield, ranging between 4-6 l/s (see Table 3). The two best exploratory holes (PH03 and PH04) will be further developed and installed with casing to allow for a pumping test. It is anticipated that after reaming (widening) and developing the production boreholes, these yields will increase.

Table 3: Drilled pilot holes and yield results

Pilot Hole No.	Profile Site No.	Arc 1950 Zone 35 S		Drill Dates	Drilled Depth (m)	Est. Airlift Yield (l/s)	SWL (mbgl)	Water Strikes		
		UTM X	UTM Y					Main (mbgl)	1st (mbgl)	2nd (mbgl)
PH 01	P10S68	577933	8242883	23/2/22	80	4.6	1.55	77	20	58
PH 02	P14S92	578178	8243722	24/2/22	80	0.2	n/a	68	13	68
PH 03	P07S51	577948	8242758	25/2/22	80	5.6	0.18	25	25	28
PH 04	P12S78	576302	8245522	26/2/22	80	6.2	0.95	27	27	46
PH 05	P13S87	576293	8245795	27/2/22	80	1.0	1.50	25	4	25

Based on the preliminary results, it appears that the initial yield estimate of 15 l/s per borehole may have been on the high side: instead, a revised estimate of 10 l/s is more realistic. Furthermore, based on the revised SDI design, the peak irrigation requirement is 6.8 mm/day. For the new 311 ha under SDI, this amounts to 21,148 m^3/day, or 244 l/s, which is about 15% higher than the initial estimated requirement of 210 l/s.

This means that to meet the peak demand, 25 boreholes with a capacity of roughly 10 l/s are required, assuming that all water for the 311 SDI scheme would be supplied solely by boreholes. Based on the quotations of the ongoing programme, a cost break down can be provided for the drilling, as shown in Table 4.

Table 4. Cost estimate borehole drilling

Item	Unit Rate		Quantity	Total	
Additional geophysics	ZMW	30,000.00	1	ZMW	30,000.00
Mobilization driller	ZMW	30,000.00	1	ZMW	30,000.00
Pilot Hole Drilling	ZMW	20,000.00	50	ZMW	1,000,000.00
Borehole Installation	ZMW	175,000.00	25	ZMW	4,375,000.00
Borehole Test Pumping	ZMW	50,000.00	25	ZMW	1,250,000.00
Supervision (10% of total drilling costs)				ZMW	665,500.00
Total				**ZMW**	**7,350,500.00**

As shown in Table 4, the total cost for the drilling and test pumping of 25 production boreholes is estimated at ZMW7,350,500, excluding the installation of pumps and connection works. Following the drilling and test pumping, the boreholes will have to be installed with submersible pumps, and pipelines and electricity will have to be brought to the borehole locations. In Table 5, a breakdown of the estimated costs for the installation works has been provided. It is assumed the water will be pumped from the boreholes directly into Dam 6, or the new reservoir, as outlines in Section 3.3. Since the exact borehole locations are only known after drilling and test pumping, an average distance of 500 m from the boreholes to the reservoir is assumed for this cost estimate.

Table 5. Cost estimate borehole installation

Item	Unit Rate	Quantity	Total
Pump and auxiliaries incl control box (15 kW)	ZMW 209,965.00	25	ZMW 5,249,125.00
Powerlines (per m)	ZMW 262.50	12500	ZMW 3,281,250.00
Water pipelines from BH to dam, incl trenching (per m)	ZMW 100.00	12500	ZMW 1,250,000.00
Total			**ZMW 9,780,375.00**

Depreciation is determined assuming a 20-year period, except for the borehole pumps, which are assumed to have an average lifespan of 10 years. As indicated in Table 6, the total depreciation of the borehole system will be ZMW1,119,000 per year.

Table 6. Depreciation borehole system

Depreciation	Amount
20-years (excl pumps)	ZMW 594,087.50
10-years (pumps)	ZMW 524,912.50
Total	**ZMW 1,119,000.00**

The pumping costs, based on the assumption of 25 boreholes, each pumping at 10 l/s and an average power-supply rate of 1.056 ZMW/kWh, are shown in Table 7. The pumping costs are shown for three different 'Operating Strategies' of the SDI system (OS-A, B and

C), each requiring different amounts of water These operating strategies are explained in detail in Chapter 7.

Table 7. Pumping costs

	Water required (m3/year)	Per BH (m3/year)	Hours of pumping at 10 l/s	Costs per BH/year	Costs total 25 Boreholes per year
OS-A	4,742,750.00	189,710	5,270	ZMW 83,472.40	ZMW 2,086,810.00
OS-B	3,557,062.50	142,283	3,952	ZMW 62,604.30	ZMW 1,565,107.50
OS-C	1,527,258.19	61,090	1,697	ZMW 26,879.74	ZMW 671,993.60

The total annual borehole costs, based on the above calculated depreciation rate and annual pumping costs, and including a 10% contingency for maintenance and other costs, are shown in Table 8.

Table 8. Total annual borehole costs

	Depreciation	Pumping Costs	Contingency / Maintenance (10%)	Total	Total Costs per m3 of water
OS-A	ZMW 1,119,000.00	ZMW 2,086,810.00	ZMW 320,581.00	ZMW 3,526,391.00	ZMW 0.74
OS-B	ZMW 1,119,000.00	ZMW 1,565,107.50	ZMW 268,410.75	ZMW 2,952,518.25	ZMW 0.83
OS-C	ZMW 1,119,000.00	ZMW 671,993.60	ZMW 179,099.36	ZMW 1,970,092.96	ZMW 1.29

When comparing the total costs of water per m^3 from boreholes (as shown in Table 8) with the surface water supplied by Zambia Sugar through the existing pipeline at a rate of 0.286 ZMW/m^3, the borehole water would be 3-5 times more expensive. The advantage is however that KASCOL would no longer be solely dependent on water supplied by an external party, while the boreholes could be used as a supplementary source to fill the experienced supply shortfalls during periods of low supply by Zambia Sugar. In terms of sustainability, this would reduce KASCOL's (over-)reliance on surface water, which is expected to become increasingly stressed in future, due to a combination of climatic change and growing abstractions by other users.

5. SOLAR OPTION

Renewable energy plays an increasingly relevant role all over the world, as efforts are stepped up to reduce reliance on fossil fuels, decrease greenhouse gas emissions, and mitigate the effects on the climate. Moreover, an increase of localized electricity grids is seen, especially on the African continent.

Looking at the growing energy need of Zambia and its dependency on hydro-power dams (and thus, on rainfall), solar energy could become a potentially viable option for KASCOL to reduce the risks and effects of power cuts and shortages experienced from the national grid. Moreover, it could reduce KASCOL's operational costs on the long run. Therefore, this study includes an assessment and advises how solar energy could be utilised to support KASCOL's envisaged expansion of the SDI system.

Considering the total amount of energy required for the new 311 ha under SDI (330 kW), the consultants concluded that solar energy is an option during day-time, whereby the sun can power the pumps directly from a 1 MW solar park. For this solar park, 1-1.2 ha of land is required for the installation of the solar panels.

In order to also irrigate during night-time, or during periods with significant cloud cover, the system will have to be operated using the ZESCO national grid. To be able to operate the 330 kW pumps during the night, solar energy would need to be saved into batteries during the day. However, the associated costs are very high and would by far exceed the benefits, in particular when considering the fact that the new SDI should never be 100% dependent on solar energy. Advanced batteries would be needed, which would make the system very complex and 2-4 times more expensive, compared to a solar park that supplies its energy directly to the pumps (without additional power storage).

The option to design the SDI system based on daytime irrigation only has also not proven to be feasible: in this scenario, the flow rates of the pumps would be unrealistically high and the filter capacity, pipe dimensions and flow rates would become impractical and hard to maintain.

Therefore, a hybrid power supply system, that uses a combination of the national grid and solar energy inputs, is advised and has been worked out in more detail. Under the proposed hybrid option, the costs of the investment in solar power supply are limited. Moreover, under this combined power supply option, it will still be possible to irrigate most of the needed water during the day (using solar power), since the system does not need to run on full capacity most of the times: Kaleya Estate can thus plan its irrigation schedule in a manner that will maximize usage of the solar park.

ZESCO supply should be used during peak demand times, when irrigation is required during the day and night, or when there are insufficient sunshine hours. It should be noted that this will only apply during periods with significant cloud cover or mist, since the solar system is designed to also function during period with slight cloud cover.

Moreover, during periods with cloud cover, the likelihood of rainfall increases, thus generally reducing the irrigation needs.

An ATS switch converter is needed to enable this hybrid system, whereby solar supply will be used during daytime, when there is adequate sunshine. ZESCO will be used when solar power supply is hampered by cloud cover, during peak times, when irrigation must be applied day and night, or any other occasion when the supply of electricity from the solar park cannot meet de demand. Whenever this is the case, the ATS switch will automatically switch to ZESCO supply. Once the power demand reduces again, for instance if some of the pumps are switched off, the ATS will switch back to solar supply.

The design of the solar park has been tailored to supply enough power for the 311 ha SDI under normal irrigation conditions. The solar supply system could also be connected to the pumps of the existing SDI system, or to the pivot pumps, to deliver power on days where the 311 ha SDI would not demand the full amount of power generated by the park. However, any possible connections to these additional pumps are not taken into consideration in this study, since it is focussed on the 311 ha SDI expansion.

The total costs of the recommended 1MW solar park are estimated to be 1,260,000 USD (Table 9). Note that this needs further assessment, final design, and preparation of detailed technical specifications and BoQs at a later stage, so as to finalize the required tender-dossiers and collect technical and financials proposals from potential suppliers and contractors.

Table 9. Cost estimation 1MW solar park

No.	Component	Cost (US$/W)	1MW IPP
1	PV Module	$ 0.78	$ 780,000
2	Inverter	$ 0.18	$ 180,000
3	Cables	$ 0.04	$ 40,000
4	Mountings	$ 0.06	$ 60,000
5	Engineering & Project Management	$ 0.03	$ 30,000
6	Labour	$ 0.06	$ 60,000
7	Miscellaneous/P&Gs	$ 0.11	$ 110,000
	TOTAL	**$ 1.26**	**$ 1.260,000**

6. GEO INFORMATION AND SENSORS

6.1 DRONES AND THEIR APPLICATIONS

The development and the range of possible applications for flying sensors (commonly called drones) have been expanding rapidly over the last decade. The technology has become more accurate, reliable, and affordable, and thus deserves attention for possible applications at KASCOL Estate.

Figure 5. DJI MAVIC flying sensor

Drones can be equipped with different sensors, such as different types of multispectral sensors, Red-Green-Blue light (RGB), regular or high-resolution cameras, and laser equipment. Moreover, drones are available that can, among others, carry chemicals and apply precision spraying. Since the latter is not useful yet for large scale sugarcane farming, the current Feasibility Study excludes this type of drones from the assessment; instead, the study focusses on drones equipped with sensors to collect information that will enable the growers to make data-based decisions.

The proposed drone option that was considered for KASCOL is the DJI Mavic Flying Sensor kit provided by HiView (see Figure 5). This flying sensor is equipped with Normalized Difference Vegetation Index (NDVI) camera, and can therefore make precise crop-stress maps, indicating which fields (or parts of the fields) are stressed. Next to this, it can also capture normal imagery (videos and pictures) that can be used by the Estate's agronomist to assess the situation and take well-informed decisions on the actions that need to be undertaken.

The modified DJI Mavic drone is easy to operate and maintain. However, to apply the drone as effective as possible, it is strongly recommended to include a training package, which can be facilitated by HiView. This package includes:

- Piloting
- Image processing
- Interpretation of the results in field tablet/ map viewing.

More advanced packages are also possible, including assistance in data interpretation and analysis.

Using the advanced drone option, it will be possible to fly the drone on a regular basis over all the fields (e.g. every week or two weeks) to effectively monitor the crops, document the crop development, and to intervene if and as required. When a technical problem occurs (e.g. leakage in irrigation system / clogged drip line, etc) this can be detected at an early stage, due to unusual crop patterns.

An additional feature of the drone technology is highly suitable to monitor impacts and differences in crop development when undertaking trials, e.g. with different water and fertigation regimes. The derived NDVI maps will make it possible to compare and predict outcomes of the trials that have been conducted.

The drones are further expected to be useful in the monitoring and evaluation of the small-holder members of Kaleya. Drone imagery will make it possible to compare the performances of out-growers, measure the exact field sizes, crop stage, potential pests and diseases, etc. This application will make the work of the service providers for the smallholders more effective, as they can more easily detect smallholders that require support in the form of certain interventions.

The cost estimation for this service is worked out in detail in Annex IV and included in the RoI. For the procurement of one drone and delivery of an advanced training option with additional modules, the cost would be approximately USD 11,000.

6.2 SOIL MOISTURE SENSORS AND THEIR APPLICATIONS

To make the SDI system effective and (water and energy) efficient, the supply of water needs to be controlled with information (such as soil moisture content and its distribution in the various fields) to optimize the growing conditions of the sugarcane and ultimately, to enhance the yield.

Stationary soil moisture sensors

KASCOL recently installed soil moisture probes from Irricheck in the existing 150 ha SDI. It is advised to immediately expand this monitoring system to the new 311 ha SDI fields, once installed. After a consultation with Kayimbi Agri ltd, 10-15 additional permanent soil moisture probes are advised to install in the selected new SDI area. Concrete irrigation advice, such as irrigation scheduling, duration of irrigation turns, etc., is provided through the portal/app, which is accessible by KASCOL staff. This is also required to follow certain (deficit) irrigation strategies to further optimize the use of water.

Mobile measuring sensors

Besides the stationary soil moisture probes, soil moisture may also be measured at specific locations, for example to detect or confirm suspected clogged drip irrigation lines or leakages. A mobile sensor can also support the assessment of the uniformity of the water application. Mobile sensors are limited in measuring the moisture only around stationary locations. Therefore, it advisable to purchase one or multiple relatively low-cost hand-held soil moisture meters, which can be carried into the field by agronomists.

While there are many types available on the market, an easy-to-use portable soil moisture scanner that is suitable for this function is the Bluelab Pulse Meter (Figure 6).

Figure 6. Bluelab Pulse Meter

The Bluelab Pulse Meter can measure both soil moisture (%) and electrical conductivity (EC). It is therefore also a convenient tool to quickly assess the EC and check the nutrient concentration (salt level). Measured data is sent to a mobile phone via Bluetooth and can be exported to an Excel spreadsheet for further analysis. It is also possible to see the measured data straight away on the mobile phone in the field. The two pins (Figure 6) can be pressed into the soil at different depts to measure the moisture level at varying places in the soil. Considering the root depth and the nature of the SDI system, the advised depth to measure is 25-35 cm; deeper is not possible with the meter, unless a small hole would first be dug out, after which the soil moisture meter can measure soil moisture at deeper levels, if required.

6.3 GEO- SATELLITE INFO SYSTEM

The application of satellite-based information systems is becoming increasingly common at large-scale commercial farms to monitor crop progress, predict yields, assess the performances of irrigation systems, compare fields, evaluate trials, identify and control pests and diseases, and for many other applications. Currently, weather data and satellite imagery are used to estimate evaporation and identify irrigation needs. Irrigation suppliers such as Netafim and Rivulis offer their own satellite-based services for farmers that use their irrigation products. Netafim uses the software 'Netbeat' and Rivulis offers 'Mana irrigation' and 'Reelview' applications to its customers. These programmes offer similar services such as:

- Crop models
- Use of real time weather data
- Use of recent satellite imagery
- (online) Portals, used to assess the different fields
- Predictive models

It is advised to engage in further discussions with the different irrigation product suppliers to assess the various software options, and the corresponding costs. It is expected that the main irrigation suppliers would provide this service free-of-charge if their system is being purchased by KASCOL.

6.4 WEATHER DATA

The current main weather station at KASCOL does not provide accurate and/or sufficient information for an optimum operation of the different irrigation systems at the Estate. It is therefore advised to invest in a new, modern weather station at a suitable and representative location on the Estate, where data is automatically (digitally) recorded. This will make it more practical for the agronomy team to arrive at the correct irrigation and cropping decisions.

There are different suitable automated weather stations on the market, such as the RMA Weather station (see Figure 7). An RMA Agro weather station consists of a data logger with power supply and a variable set of sensors, which are configured according to the need for data. This station measures the radiation, relative humidity, wind speed and direction, temperature and rainfall. It uses the local mobile phone network and SIM-card to send the information to an online server, where the data is stored for easy access by laptop or smartphone.

Figure 7. Weather station RMA

A simple automated weather system costs around 3000-4000 Euro (going up with enhanced complexity and applications) and is expected to have a life=time of 10-15 years. During this feasibility study, KASCOL already planned to purchase one weather station and it is therefore expected that this new station can be used for the new 311 ha SDI as well.

6.5 DATA, INNOVATIONS AND APPLICATIONS

During the pre-feasibility phase of this research, a lot of data was collected in collaboration with the KASCOL team. The consultancy team noticed that although a lot of data is being recorded by KASCOL staff, it proved to be very challenging to interpret and first digitalize certain data in order to make it suitable for analysis. It is therefore advised to improve on the (digital) data capturing and subsequently, the analysis of this data.

In order to get most out of the data and experiences of KASCOL, it is advised to expand the KASCOL team with one employee, who should be designated to organize the (new) data, oversee the correct and complete recording, and interpret and analyse the data in a format that can be used by the agronomist(s). By doing so, the person with this new function can actively provide required data and give recommendations to the rest of the team, and assist in the identification, execution and management of tests & trials that can create further insights and improve the overall KASCOL operations.

The hiring of such an additional technical employee (e.g. in the job description of 'Data & Innovations Operator') is also included in the ROI analysis of this feasibility study. Alternatively, it is possible to outsource the analysis and recommendations, based on the data collected at Kaleya Estate, by hiring an independent external consultant to further advise as an objective party. Both options (to have the data analysis & application service either in-house or outsourced) have important advantages and disadvantages, which must be considered.

The ROI has budgeted a yearly recurrent cost of ZMW290.000 for this innovation support.

7. SDI OPERATING STRATEGIES

An SDI system offers a considerable number of possible operating strategies, each with its own characteristics. To assess the SDI's feasibility, it is important to first assess the different operation strategies and to create more insight in their strong and weaker points. Subsequently, the overall best strategy can be developed, applied and fine-tuned. This Chapter describes three possible SDI Operating Strategies (OS) that have been assessed and compared as part of this Feasibility Study.

The Operating Strategies considered are separated by differences in irrigation intensity and yield potential:

A) Supplies 100% of the irrigation water requirements: highest yield potential

B) Supplies 75% of the irrigation water requirements (deficit irrigation): medium yield potential

C) Supplies the same amount of effective irrigation as applicable for the existing Furrow Irrigation KASCOL (deficit irrigation): relatively low yield potential

After the detailed assessment of these three potential irrigation strategies in the current Chapter 7, the same comparison method will be used as applied for the review of different irrigation technologies in Chapter 2, using the same sustainability and economic factors. The analysis will be done in Chapter 9, after the ROI-analysis in Chapter 8.

7.1 OPERATION STRATEGY A (OS-A)

The first strategy (OS-A) meets 100% of the irrigation water requirements of the sugar cane. This means that the crop will not experience any drought stress, and in terms of water availability, will not be hindered to achieve its maximum yield. Therefore, OS-A will aim for the highest yield both in tonnage of cane per hectare, as well as estimated recoverable crystal (ERC) levels.

Water

In the optimum OS-A, the total combined water use from effective rainfall and effective irrigation should be 2,030 mm per year (see Annex I - CWR). With an assumed (low) annual effective rainfall of 504 mm (see Annex II – Water use, final Table), the effective irrigation water needed for OS-A equals 1,526 mm.

Converting the irrigation requirements to the envisaged SDI System of 311 ha, an annual volume of 4,745,860 m^3 water is needed, which equates to 15,260 m^3/ha/year. By comparison, the current furrow system consumes 8,971 m^3/ha/year, but is marked by a low irrigation efficiency (see below). OS-A would therefore lead to a 70% increase in water use per irrigated hectare of land. It is important to note that the 15,260 m^3 can be counted as effective irrigation (water directly available for the crop and uniformly distributed in the rootzone) while out of the 8,971 m^3 delivered through furrow irrigation, only 52% would become available for the crop, with a more uneven character due to the method applied (Annex II - Water use).

Assuming that 100% of the irrigation water would be supplied by Zambia Sugar, using the water transfer system that is currently being used for irrigating all other KASCOL fields, the water costs for OS-A have been determined. Based on data provided by KASCOL (Annex II, 2nd Table), the cost of water was extrapolated and estimated for the coming 5 years (2023-2027). This results in an average expected rate of 0.38 ZMW per cubic meter of water. The average annual water costs for OS-A (over the period 2023-2027) are therefore estimated to be 1,789,228 ZMW for the new 311 ha under SDI, or 5,753 ZMW/ha.

Table 10. Water requirement OS-A

OS-A		
Annual Irrigation req.	1,525	mm
	3,110,000	m^2
	4,742,750,000	liters
	4,742,750	m^3
Water costs 311 ha	1,789,228	ZMW/year
water costs /ha	5,753	ZMW/year

Electricity

The SDI system requires electricity to pump water at the right pressure into the system. To be able to pump 4,742,750 m^3 of water, an estimated 1,106,642 KWh is required annually. Taking the average predicted electricity rate for 2023-2027 (Annex III - Electricity), and taking an increment of 5%/year into account, the electricity costs under OS-A will be 1,169,154 ZMW per year for 311 ha under SDI, or 3,759 ZMW/ha/year.

Crop Yield

OS-A aims for the highest yield potential and therefore the crop yield has been estimated from different sources of research on SDI systems. Most of the available research looks at the yield potentials of different varieties and fertilizer regimes. The crop yields reported for sugarcane irrigated by SDI vary considerably, mainly depending on the cultivar, water application, climate, and location.

Extremely high yields up to 180 tons/ha have been reported in some studies (Nyati 2004; Andrade et al, 2017). Nyati (2004) in particular provided useful information to estimate the yield for OS-A, since the trials were executed in Zimbabwe under similar climatological conditions and also with similar clay soil types. Taking the average yields of 10 different varieties over 6 growing years into account, all receiving 100% of the CWR throughout the trial period, a yield of 149 tons per ha is determined. When taking the average ERC of 14.9% into account, this leads to an ERC (ton/ha) of 22.2 (see Table 11). This is significantly (83%) higher than KASCOL's current average ERC, which is 12.15 tons/ha.

Table 11. Estimated yield OS-A

Yield per ha	149
ERC (%)	14.9
ERC ton/ha	22.2
Yield cane for 311 ha SDI	46,391
ERC (tons for 311 ha)	6,912

Water productivity

Although the yield prediction for OS-A is 83% higher than the yield achieved with the existing furrow system, its water productivity is only 2% higher: for OS-A, the water productivity is estimated to be 7.35 kg ERC per m^3 of water, while for the existing furrow systems the ERC is 7.21 kg/m^3 water. This means that for every m^3 of applied water (effective rainfall & irrigation), an almost identical mass of ERC is produced.

It must be noted that the current furrow irrigation is heavily under-irrigated, compared with the CWR that is needed for optimal yields. Thus, with the application of more water under the SDI, the yield per unit of cultivated area increases correspondingly.

Based on the similarity in water productivity, it can be concluded that with 100 ha of sugarcane crop under SDI, a similar total yield would be achieved with the same total amount of water applied to 183 ha of furrow irrigated fields.

7.2 Operation Strategy B (OS-B)

The second strategy assessed in this study (OS-B) takes a deficit irrigation scenario into account, in which the SDI system supplies 75% of the optimum irrigation requirements. Deficit irrigation is a concept whereby crops intentionally do not receive 100% of their water requirements. The main objective of this method is to increase the Water Use Efficiency (WUE) of the crop, by reducing the amount of irrigation water that has only a limited effect on the yield (Kirda, 2002). With deficit irrigation, a potentially higher yield per unit of irrigation water applied can be achieved.

In the light of the increasing pressure on the available water resources at KASCOL, and the enhanced stress on the Kafue catchment in general, it is worth to assess the potential of deficit irrigation, as well as the effects on the different factors of the MCA (i.e., both the economical and sustainability aspects).

Water

The total irrigation water required for OS-B is 75% x 1,526mm (received under OS-A) = 1,144 mm/year (Annex I - CWR). Taking into account a constant effective rainfall of 504 mm/year, the crop would receive a total of 1,648 mm yearly, which is equivalent to 82% of the total water requirements. The crop will thus experience some drought stress in this scenario; however, the extent is limited.

Converting the required amount of irrigation water to the command area of 311 ha under SDI, a yearly volume of 3,557,063 m^3 is required, i.e. 75% of the 4,745,860 required under SO-A. The water use per ha is 11,437 m^3/ha, which is closer to the average water use of the furrow system (8,971m^3/ha). In quantitative terms, the water use per ha would increase by 27%, compared to the existing furrow irrigation system.

Under the same assumptions for the price of water as applied for OS-A, the total water costs for OS-B are estimated to be 4,315 ZMW per ha per year, and 1,341,921 ZMW per year for the whole 311 ha.

Table 12. Water requirement OS-B

OS-B		
Irrigation req.	1,144	mm
	3,110,000	m^2
	3,557,062,500	liters
	3,557,063	m^3
Water costs 311 ha	1,341,921	ZMW/year
water costs /ha	4,315	ZMW/year

Electricity

To pump the 3,557,063 m^3 of water required under OS-B, an estimated 829,981 KWh/year is needed for the 311 ha. This results in an electricity cost of 876,866 ZMW per year, or 2,820 ZMW/ha/year. These costs are estimated using the ZESCO tariffs and an expected price increase of 5% per year in the period 2023-2027.

Crop Yield

To apply 75% of the irrigation requirements is a well-known operation scenario in research on deficit irrigation. Results vary from trials whereby no significant yield reduction was detected, to sources that indicate reductions of about 15% (Dingre & Gorantiwar, 2021; Kirda, 2002; Robertson et al, 1999; Wiedenfeld, 2000). This feasibility study will assume a yield reduction of 12.5%, which is in line with the most common literature findings. To test this assumption, it is strongly recommended for KASCOL to execute a trial at the existing 153 ha SDI system and assess the precise effect of an imposed OS-B on the yield, compared with fields that receive 100% of the irrigation requirements (OS-A). In order to execute such a trial effectively, soil moisture probes are an important tool to include.

Table 13. Estimated yield OS-B

Estimated yield reduction factor	12.5%
Yield per ha (tons)	130.52
ERC (%)	15%
ERC ton/ha	19.45
Yield cane for 311 ha SDI	40,592
ERC (tons for 311 ha)	6,048

Water productivity

The water productivity of OS-B is 7.92 kg ERC/m^3, which is 8% more than under OS-A and 10% more than with the current furrow system. Because effective rainfall is also taken into account in water productivity assessments, the improvement is lower than the % of irrigation water (25%) that is being saved.

7.3 OPERATION STRATEGY C (OS-C)

The third and final scenario assessed in this study (OS-C) aims at a maximum water saving under a more severe deficit irrigation strategy, compared with OS-B. In OS-C, the SDI system will apply the same amount of effective irrigation water into the rootzone as the current furrow irrigation system (466mm/year, see Section 2.1). Because of the high efficiency of SDI (95%), very considerable water savings can be achieved under such a scenario.

Water

Taking the same effective rainfall (504mm/year) and CWR into account as OS-A and B, OS-C is based on a total irrigation amount of 466 / 0.95 = 491 mm/year, which translates to 1,527,258 m^3 water per year for the 311 ha of new SDI. Due to the high efficiency of SDI, this results in very significant water savings compared to the current furrow system, and due to the imposed regime, also in comparison with OS-A and OS-B. While the furrow system consumes 8,971m^3/year, OS-C requires only 4,910 m^3/ year: a 45% water saving.

Table 14. Water requirement OS-C

OS-C		
Irrigation req.	491	mm
	3,110,000	m^2
	1,527,258,190	liters
	1,527,258	m^3
Water costs 311 ha	576,166	ZMW/year
water costs /ha	1,853	ZMW/year

Electricity

Concerning the power use of OS-C, a yearly total of 356,360 KWh is required to pump a water volume of 1,527,258 m3/year, resulting into an annual cost of ZMW 376,490. Expressed per ha of sugarcane, this results in 1,210 ZMW/ha/year, which is only 43% of the power cost under OS-B, and 32% of the power costs under OS-A.

Crop Yield

For OS-C, a slight increase in crop yield is expected, compared with the current furrow irrigated fields. The main reason is not the total amount of effective irrigation, since this is the same under both OS-C and furrow. However, because the SDI allows a flexible operation with shorter irrigation intervals, the growing conditions of the crop are still expected to improve. In combination with the recommended sensor technology, including soil moisture meters, an optimal irrigation schedule can be identified, which should result in a yield increase of 10%, compared with the current furrow system. An increase of 10% is also realistic, looking at the ERC content, as well as the flexibility of the SDI in operation.

Table 15. Estimated yield OS-C

yield ton/ha	114.19
ERC %	13.31
ERC ton/ha	15.2
Yield cane for 311 ha SDI	35,512
ERC (tons for 311 ha)	4,728

Water productivity

In terms of water productivity, OS-C is the highest scoring operational scenario. For every cubic meter of water, 11.5 kg of ERC is produced, compared to 7.92kg/m^3 under OS-B and 7.35 kg/m^3 under SO-A. Therefore, this scenario yields the highest 'crop per drop'.

Because of the deficit irrigation strategy of OS-C, the irrigation water applied compared with the CWR is lowest. Therefore, every unit of water applied results in a greater effect on the yield increase. Compared with the supply of 100% of the irrigation requirements under OS-A, OS-C only provides 32% of the irrigation demands. Looking at the total CWR (also taken into account the local rainfall), OS-C supplies 50%. Normally, a supply that corresponds with the first 50% of CWR will have a significantly larger impact on the yield than the second 50% required to meet the full requirement.

8. RETURN ON INVESTMENT ANALYSIS: SDI

8.1 ROI APPROACH

A detailed return of investment (ROI) approach has been developed in order to create accurate insights into the different financial characteristics of the possible SDI expansion scenarios. For the ROI assessment, predominantly historical data has been used, as provided by KASCOL. This formed the basis to estimate the business case for the years 2023-2027. Trends in the data provided by KASCOL were incorporated, while additional sources such as academic papers, global trends, inflation predictions and exchange rate developments were also taken into account. This Chapter will summarize the findings for the three different operation strategies assessed (OS-A, B and C).

It needs to be noted that this ROI is a forecast for 5 years: it is therefore based on assumptions and predictions. The exact realization of the figures displayed in this feasibility study can be influenced by (among others) external factors; as a result, actual figures may be different from the estimates and the resulting prognosis provided at the current feasibility stage. Nevertheless, the estimations were made as accurate as possible with the data and insights available during this study; in this light, they are believed to be correct to a large extent. This report however does not give a guarantee and the consultants are not responsible for any discrepancies that may occur over the period that was assessed.

8.1.1 CATEGORIES

The ROI assessment divides the costs into different types and categories, as indicated in Table 16. This table provides a description per category to create insight in which costs/expenses have been taken into consideration. The categories were discussed and fine-tuned in close collaboration with the KASCOL team. The costs are all estimated on a yearly basis.

Table 16. Expense categories ROI

Expense type	Expense category	Description
Depreciation initial investment	Depreciation drip lines	Yearly amount accounted for to replace the drip lines every 8 years (before new planting)
	Depreciation SDI main components	Yearly amount accounted for as depreciation of main components (e.g. main pipe lines, filtration station, pumps); linear depreciation model used, lifetime system 20 years.
	Sensors & information technology	Yearly depreciation of expenses related to information, sensors and innovation management. This includes the fee for internal innovation operator or the engagement of an external consultant.
Operating costs	Water use	The costs contributed by the water consumption (assumes all water supplied by Zambia Sugar)

	Electricity (ZMW/kWh)	Yearly expenses of electricity (for ZESCO supply) in situations without solar unless otherwise indicated in report.
	Labour (including maintenance SDI)	Expenses towards labour, including non- irrigation-related work, such as planting and harvesting.
	Farm inputs (fertilizer)	Expenses towards fertilizer application
	Farm inputs (chemicals)	Expenses towards chemicals of pest and disease control
	Weed control	Labour expenses related to weed control
	Other farm inputs	All other farm inputs such as tools, fuel, minor repairs
	Haulage	Costs related to the transport of the harvested sugar cane to processing facility (outsourced to Zambia Sugar)
	Farm Machinery	All costs concerning farm machinery such as tractors, and agri-equipment from KASCOL.
Finance costs	Finance costs	Interest, cost of loan
Others	Overhead (admin, overhead etc)	Contribution towards admin and other overhead costs.

Regarding income, different information is summarized in this Chapter concerning yield (expectations), ERC content, prices, and turnover (Table 17 provides the definitions of the factors assessed).

Table 17. Definitions of yield, turnover and ROI

Term	Description
Yield per ha (ton cane)	The total weight of sugar cane harvested from one hectare, expressed in tons/ha/year
Total yield (ton cane)	The absolute yield for a given area expressed in ton/year
ERC content (%)	The fraction in percentage of Estimated Recovery Crystal (ERC) or sucrose content of the total yield of sugarcane.
ERC (ton/ha)	The mass of ERC, expressed in tons/hectare
Total ERC (ton)	The absolute yield of ERC expressed in tons.
Price per ton (ZMW)	The yearly average price per ton ERC, indicated in ZMW
Turnover/ha (ZMW)	The total turnover generated in ZMW per hectare
Total turnover for 311 ha	Total yearly turnover generated for the command area of 311 hectares
Return of investment (ROI)	$ROI = \frac{(Yearly\ turnover - total\ yearly\ investment)}{total\ yearly\ investment} \times 100\%$ Whereby: Yearly turnover = total revenue in ZMW from 311 ha Total yearly investment = sum of all expenses, including depreciation costs of infrastructure, operational costs, finance costs, and other costs.

8.2 ROI SUMMARIZED

Since farming is characterised by fluctuations in expenses and yields, which also depend on external factors such as weather, the (geo)political situation and economic conditions, the ROI prediction has been developed on a year-to year basis for a period of 5 years. In this section, the average results over the 5-year period have been summarised. The ROI overview in Table 18 provides insight in the average expected ROI for the period 2023-2027 and therefore forms a clear and useful overview of expected average operational costs, while keeping in mind that changes may occur from year to year.

Table 18. Expected annual operational costs (ZMW), averaged for period 2023-2027

ROI analysis per Operation Strategy (OS) – Expected Annual Costs		OS-A	OS-B	OS-C
Depreciation initial investment	Depreciation drip lines	503,676	503,676	503,676
	Depreciation SDI main components	1,547,068	1,547,068	1,547,068
	Depreciation sensors & information technology	416,170	416,170	416,170
Operating costs	Water use	1,789,228	1,341,921	576,166
	Electricity	1,169,154	876,866	376,490
	Labour (including maintenance SDI)	815,159	815,159	815,159
	Farm inputs (fertilizer)	2,393,303	2,127,381	1,861,458
	Farm inputs (chemicals)	200,632	200,632	200,632
	Weed control	200,551	200,551	200,551
	Other farm inputs	945,397	945,397	945,397
	Haulage	4,205,788	3,680,065	3,219,593
	Farm Machinery	1,143,989	1,143,989	1,143,989
Finance costs	Finance costs	1,994,195	1,994,195	1,994,195
Others	Overhead (admin, overhead etc.)	2,410,555	2,410,555	2,410,555
Total		**19,734,865**	**18,203,623**	**16,211,099**

When looking at the depreciation costs, these are the same for the three OS's because the same investment is needed in terms of infrastructure. One could argue that the SDI system will be used less under the OS-B and OS-C scenarios, when compared with OS-A; thus, a longer lifetime of certain components could be envisaged. However, it is expected that this will not create a very significant change: for some mechanical components, it might even be better if they are more frequently used, or for longer periods.

Looking at the operating costs, OS-A has (as expected) the highest costs, followed by OS-B, while OS-C has significantly lower operating costs. Variations in water use, electricity, fertilizer, and haulage costs are the main factors creating this difference in recurrent expenses. Farm machinery, weed control and labour are expected to be independent from the strategy of operation.

The total costs for OS-A and OS-B are relatively close to each other, with respectively ZMW 19.7M and ZMW 18.2M per year: OS-B has 8% lower operating costs (and consumes 25% less water). The costs of OS-C (ZMW 16.2M/year) are 18% lower compared with OS-A. The biggest factors that cause this difference are lower water and electricity expenses under OS-C (due to deficit irrigation) and less haulage (less yield means less haulage costs).

To provide insight in the relative contribution of the different factors per scenario, Table 19 gives the fraction of each factor. It is notable that the 4 major cost factors for each scenario are haulage, fertilizer, finance and overhead costs. In each scenario, the combined costs against these items contributes to over 50% of the total annual expenditure. The depreciation towards the initial investments varies between 12.5% (OS-A) to 15.2% (OS-C), while the relative operating costs are lowest for OS-C (57.6%) and highest for OS-A (65.2%).

Table 19. Relative contributions of cost-factors to total costs per operating scenario

Category	Factor	OS-A	OS-B	OS-C
Depreciation initial investment	Depreciation drip lines	2.6%	2.8%	3.1%
	Depreciation SDI main components	7.8%	8.5%	9.5%
	Depreciation sensors & information technology	2.1%	2.3%	2.6%
		12.5%	**13.6%**	**15.2%**
Operating costs	Water use	9.1%	7.4%	3.6%
	Electricity	5.9%	4.8%	2.3%
	Labour (including maintenance SDI)	4.1%	4.5%	5.0%
	Farm inputs (fertilizer)	12.1%	11.7%	11.5%
	Farm inputs (chemicals)	1.0%	1.1%	1.2%
	Weed control	1.0%	1.1%	1.2%
	Other farm inputs	4.8%	5.2%	5.8%
	Haulage	21.3%	20.2%	19.9%
	Farm Machinery	5.8%	6.3%	7.1%
		65.2%	**62.3%**	**57.6%**
Finance costs	Finance costs	10.1%	11.0%	12.3%
Others	Overhead (admin, overhead etc)	12.2%	13.2%	14.9%

After analysing the expenses for each scenario, the turnover side has been assessed and summarized in Table 20. To create an accurate prediction of the annual turnover, the ERC price for the years from 2023 till 2027 needed to be forecasted. Looking at the ERC prices and the trends between 2016 and 2021 (see Annex VI), it can be concluded that the rates fluctuate considerably from year to year, with the lowest in 2016 (2,439 ZMW/ton) and the highest in 2021 (6,203 ZMW/ton[1]).

[1] The average price for 2021 was not yet finalized by the time of reporting and may still change; however, no significant changes will occur as most of the produced cane had already been sold and the potential impact of the remaining stock on the annual average for 2021 is believed to be negligible.

In general, it is evident that the ERC price follows an increasing trend, which also corresponds with the analysis of global sugar prices. This research extrapolated the ERC price by using the average ERC price for the 4 most recent years (2018 to 2021), with an estimated increase of 10% in 2022 (compared with the previous year 2021) and subsequently averaged the sugar prices from 2018 till 2022 (see Annex VI). The resulting average ERC rate of ZMW 4,781.01 per ton has been applied in the turnover forecast for the next 5 years (see Table 20). While it is expected that this is a realistic estimate, the rate is indeed on the conservative side when looking at the high ERC price of 2021, as well as global trends.

Table 20. Yield and turnover per year

Yield & Turnover per year	OS-A	OS-B	OS-C
Yield per ha (ton cane)	149	131	114
total yield (ton cane) (for 311 ha)	46,391	40,592	35,513
ERC content (%)	15	15	13
ERC (ton/ha)	22	19	15
total ERC (ton) (for 311 ha)	6,912	6,048	4,728
Price per ton (ZMW)	4,681	4,681	4,681
turnover/ha (ZMW)	104,039	91,034	71,159
Total turnover 311 ha	**32,356,218**	**28,311,691**	**22,130,579**

As discussed in Chapter 4, the yields of OS-B and OS-C are lower compared with OS-A, due to the deficit irrigation regime. Evidently, this results in a lower turnover for these two scenarios: OS-A has an expected turnover of ZMW 32.4M/year, while OS-B and OS-C provide an income of ZMW 28.3M and 22.1M/year, respectively. Nevertheless, all three SDI scenarios have higher yields and turnover per hectare than the current furrow irrigation and centre pivot fields of KASCOL.

When assessing the ROI for the averaged business case from 2023-2028, it must be concluded that all three Operation Scenarios form a viable Return of Investment (Table 21) with OS-A being the most attractive option with an ROI of 58%. Though the yearly operational costs are higher for OS-A, the increased crop yield results in a strong ROI prediction. OS-B offers a similar ROI of 50%, while OS-C scores the lowest with an ROI of 33%. Still, OS-C would offer an attractive business case which justifies the investment in the proposed SDI infrastructure from a financial point of perspective.

Table 21. Averaged Annual Return of Investment

ROI	OS-A	OS-B	OS-C
Total annual revenue	32,356,218	28,311,691	22,130,579
Total annual costs	19,734,865	18,203,623	16,211,099
Total profit before tax	12,621,353	10,108,068	5,919,479
Tax (10% of profit)	1,262,135	1,010,807	591,948
Profit after tax	11,359,218	9,097,261	5,327,531
ROI (%)	**58%**	**50%**	**33%**

8.3 ROI YEAR-TO-YEAR

Since it is expected that the business case will further evolve for the coming years, it will be important for KASCOL to have a year-to-year insight on the actual income and expenditure figures, the ROI, and the (updated) cashflow predictions. To this extent, the ROI feasibility analysis includes a detailed year-to-year plan for essential cost categories where significant (price) changes might be expected – thus requiring regular updates of the analysis. It should be noted that not all categories are expected to have significantly changing prices: for these, a constant average was maintained for the years 2023-2027.

In Table 22 and Table 23, the annual ROI forecast is provided. The differences from year-to- year can mainly be attributed to exchange rate fluctuations and inflation, giving rise to increased costs for (among others) agri inputs. The ERC price is kept stable at 4,681 ZMW per ton, since it is not possible to predict which years may have an increment in price and which ones might experience a possible price decrease. Keeping the price on the average forecasted rate for 2023-2027 therefore offers the best insight.

Since the turnover for the 5-year period is kept stable and costs are expected to increase with time, the ROI % decreases over time. However, it is still expected that in the year 2027, all scenarios offer a positive ROI. Furthermore, the application of a stable average ERC rate represents a conservative approach: in reality, it is more likely that ERC prices will increase, thus compensating (either partially or to a full extent) for the assumed price increases over the 5-year period.

Table 22. Year-to-year forecast of expenses (2023-2027)

Year		2023			2024			2025			2026			2027		
ROI analysis : Expected cost of operations, year-by-year, for each Operation Strategy		**OS-A**	**OS-B**	**OS-C**	**OS-A**	**OS-B**	**OS-C**	**OS-A**	**OS-B**	**OS-C**	**OS-A**	**OS-B**	**OS-C**	**OS-A**	**OS-B**	**OS-C**
Depreciation initial investment	Depreciation drip lines	445,948	445,948	445,948	469,039	469,039	469,039	492,130	492,130	492,130	515,221	515,221	515,221	538,312	538,312	538,312
	Depreciation SDI main components	1,369,755	1,369,755	1,369,755	1,440,680	1,440,680	1,440,680	1,511,605	1,511,605	1,511,605	1,582,530	1,582,530	1,582,530	1,653,456	1,653,456	1,653,456
	Depreciation sensors & information technology	416,170	416,170	416,170	416,170	416,170	416,170	416,170	416,170	416,170	416,170	416,170	416,170	416,170	416,170	416,170
Operating costs	Water use	1,555,651	1,166,738	500,950	1,664,546	1,248,410	536,016	1,781,064	1,335,798	573,538	1,905,739	1,429,304	613,685	2,039,141	1,529,355	656,643
	Electricity (ZMW0.87/ kWh)	1,057,937	793,453	340,676	1,110,834	833,126	357,710	1,166,376	874,782	375,596	1,224,695	918,521	394,376	1,285,929	964,447	414,094
	Labour (including maintenance SDI)	654,451	654,451	654,451	726,441	726,441	726,441	806,349	806,349	806,349	895,048	895,048	895,048	993,503	993,503	993,503
	Farm inputs (fertilizer)	1,960,085	1,742,298	1,524,511	2,156,094	1,916,528	1,676,962	2,371,703	2,108,181	1,844,658	2,608,874	2,318,999	2,029,124	2,869,761	2,550,899	2,232,036
	Farm inputs (chemicals)	181,547	181,547	181,547	190,624	190,624	190,624	200,156	200,156	200,156	210,163	210,163	210,163	220,671	220,671	220,671
	Weed control	200,551	200,551	200,551	200,551	200,551	200,551	200,551	200,551	200,551	200,551	200,551	200,551	200,551	200,551	200,551
	Other farm inputs	759,013	759,013	759,013	842,505	842,505	842,505	935,180	935,180	935,180	1,038,050	1,038,050	1,038,050	1,152,236	1,152,236	1,152,236
	Haulage	3,805,708	3,329,995	2,913,326	3,995,994	3,496,495	3,058,992	4,195,793	3,671,319	3,211,942	4,405,583	3,854,885	3,372,539	4,625,862	4,047,629	3,541,166
	Farm Machinery	1,035,166	1,035,166	1,035,166	1,086,924	1,086,924	1,086,924	1,141,270	1,141,270	1,141,270	1,198,334	1,198,334	1,198,334	1,258,250	1,258,250	1,258,250
Finance costs	Finance costs	3,109,015	3,109,015	3,109,015	2,615,998	2,615,998	2,615,998	2,058,589	2,058,589	2,058,589	1,436,786	1,436,786	1,436,786	750,590	750,590	750,590
Others	Overhead (admin, overhead etc)	2,181,249	2,181,249	2,181,249	2,290,311	2,290,311	2,290,311	2,404,827	2,404,827	2,404,827	2,525,068	2,525,068	2,525,068	2,651,321	2,651,321	2,651,321
	Total	**18,732,246**	**17,385,348**	**15,632,327**	**19,206,711**	**17,773,801**	**15,908,924**	**19,681,764**	**18,156,907**	**16,172,560**	**20,162,811**	**18,539,630**	**16,427,645**	**20,655,753**	**18,927,391**	**16,679,000**

Table 23. Year-to-year ROI overview 2023-2027

Yearly ROI	2023			2024			2025			2026			2027		
	OS-A	OS-B	OS-C	OS-A	OS-B	OS-C	OS-A	OS-B	OS-C	OS-A	OS-B	OS-C	OS-A	OS-B	OS-C
Total yearly revenue	32,356,218	28,311,691	22,130,579	32,356,218	28,311,691	22,130,579	32,356,218	28,311,691	22,130,579	32,356,218	28,311,691	22,130,579	32,356,218	28,311,691	22,130,579
Total yearly costs	18,732,246	17,385,348	15,632,327	19,206,711	17,773,801	15,908,924	19,681,764	18,156,907	16,172,560	20,162,811	18,539,630	16,427,645	20,655,753	18,927,391	16,679,000
Total profit before tax	13,623,973	10,926,343	6,498,251	13,149,507	10,537,890	6,221,655	12,674,455	10,154,784	5,958,019	12,193,407	9,772,061	5,702,934	11,700,465	9,384,300	5,451,579
tax (10% of profit)	1,362,397	1,092,634	649,825	1,314,951	1,053,789	622,165	1,267,445	1,015,478	595,802	1,219,341	977,206	570,293	1,170,047	938,430	545,158
Profit after tax	12,261,576	9,833,709	5,848,426	11,834,557	9,484,101	5,599,489	11,407,009	9,139,306	5,362,217	10,974,066	8,794,855	5,132,641	10,530,419	8,445,870	4,906,421
ROI (%)	**65%**	**57%**	**37%**	**62%**	**53%**	**35%**	**58%**	**50%**	**33%**	**54%**	**47%**	**31%**	**51%**	**45%**	**29%**

8.4 COST OF FINANCE & CASHFLOW

Since KASCOL aims to finance the required infrastructure with a loan from DFCD, the finance costs must be included in the ROI assessment. The current assessment assumes that the full amount (100%) for the required infrastructure investment will be financed through a loan. The operating- and overhead costs are assumed to be paid from the existing cashflow of KASCOL.

An assessment was done concerning the finance costs using a 3, 5 and 7 year pay-back period, taking a yearly interest of 10% into account as per Table 24.

Table 24. Loan specifications

Loan specifications	values	units
Payback period requested to assess for	3,5,7	years
yearly interest rate	10%	percentage
Info technology & sensor hardware	6,409	Euro
Initial investment SDI incl Electrical components	1,556,688	Euro
Total required loan	**1,563,096**	**Euro**

The assessment shows that the finance costs for all three pay-back scenarios (3, 5 or 7 years) is a considerable fraction of the total costs for the 311 ha SDI (10-13%). Looking at the turnover that is expected to be generated from the SDI system and the related operational costs, a 3-year payback period is unrealistic without additional investment or cashflow injections. Therefore, it is advised to opt for a 5- or 7-year pay-back period. The 5-year period will create the best business case on the long run, since the total costs of finance are 5 million ZMW less compared to a pay-back period of 7 years.

The forecasted exchange rate for 2023-2027 shapes the amounts significantly, since the initial loan will be in Euros; therefore, the ZMW amount will change in line with actual exchange rate fluctuations. Annex VI gives an overview of the used exchange rates, which are based on data from the bank of Zambia from 2006 onwards, using a linear transgression model.

Table 25. Year-to-year figures: loan & interest

Year	Payback period	3-year Payback period	5-year Payback period	7-year Payback period
2023	Payback loan year 1	10,363,382	6,218,029	4,441,449
	Interest year 1	3,109,015	3,109,015	3,109,015
2024	Pay back loan year 2	10,899,993	6,539,996	4,671,426
	Interest year 2	2,179,999	2,615,998	2,802,855
2025	Pay back loan year 3	11,436,604	6,861,962	4,901,402
	Interest year 3	1,143,660	2,058,589	2,450,701
2026	Pay back loan year 4		7,183,929	5,131,378
	Interest year 4		1,436,786	2,052,551

Year	Payback period	3-year Payback period	5-year Payback period	7-year Payback period
2027	Pay back loan year 5		7,505,896	5,361,354
	Interest year 5		750,590	1,608,406
2028	Pay back loan year 6			5,591,330
	Interest year 6			1,118,266
2029	Pay back loan year 7			5,821,306
	Interest year 7			582,131
TOTAL		**39,132,653**	**44,280,790**	**49,643,570**

When looking at the suggested 5 year pay-back period and the effects of the loan and interest on the cashflow of the 311 ha SDI system, it is estimated that it is very feasible for KASCOL to pay back the loan over the given period for OS-A and OS-B, while it is not possible for OS-C (Table 27), due to insufficient income. For OS-C the cashflow would be negative by 596,919 ZMW in the initial year (2023); consequently, other sources of income would be needed to compensate for this. For the four subsequent years, the cashflow of OS-C would also be negative, though decreasing each year to a negative 200.000 ZMW in 2027. Therefore, in scenario OS-C, the SDI System would start having a positive effect on the cashflow only after 5 years when the loan has been paid back.

Table 26. Cashflow prediction 5-year payback period - 2023

2023	OS-A	OS-B	OS-C
Preliminary cashflow prediction with 5-year payback period			
Turnover	32,356,218	28,311,691	22,130,579
Expenses (excluding depreciation category)	16,500,373	15,153,475	13,400,454
Loan + interest	9,327,044	9,327,044	9,327,044
Cashflow	6,528,802	3,831,173	- 596,919

Concerning OS-C, the payback period of 7 years would create a more positive cashflow from the start (see Table 27); should KASCOL opt for this scenario, a 7-year pay-back period would be a more feasible option when looking at cashflow.

Table 27. Cashflow prediction 7-year payback period - 2023

2023	OS-A	OS-B	OS-C
Preliminary cashflow prediction with 7-year payback period			
Turnover	32,356,218	28,311,691	22,130,579
Expenses (minus depreciation category)	16,500,373	15,153,475	13,400,454
Loan + interest	7,550,464	7,550,464	7,550,464
Cashflow	8,305,382	5,607,752	1,179,661

Taking a 7-year pay-back period into account, the overall ROI % does remain stable at 55%, 50% and 33% respectively for OS-A, B and C, due to the small yearly interest change. In Year 1, the finance costs would reduce to 1,960,561 ZMW with a 7-year period, which is only 34,000 ZMW less compared to a pay-back period of 5 years.

8.5 Comparisons & insights ROI

All Operation Scenarios provide good ROI scores and can therefore be considered as good potential investments for KASCOL. OS-A scores highest with a 55% Return of Investment, followed by OS-B at 50%, and OS-C with a 33% score. This ROI score takes depreciation and finance costs into account for the years 2023-2027. The finance side was assessed, and the 5-year payback period is feasible for OS-A and AS-B, when looking at the cashflow of the system. OS-C would require additional funds or investment from KASCOL if the loan was to be paid back in 5 years. A pay-back period of 5 years would save 5 million ZMW in interest costs, compared to a 7-year pay-back period.

All operation scenarios do have a positive cashflow prediction with the 7-year loan period; with this pay-back period, also OS-C would not require additional initial investment.

The business case for each OS is expected to improve after the loan has been fully paid back (either after 5 or 7 years), since the finance costs, which range between 10 to 13% of the total annual costs, would be voided. The yearly ROI after the loan has been paid back is expected to increase to excellent rates of 74%, 67% and 50% for OS-A, B and C respectively.

8.6 ROI including borehole water option

If boreholes are used as a water supply for the 311 ha SDI, the ROI picture changes, due to increased investments cost for the borehole development, power supply and piping, as well as increased annual electricity costs to support he operation of the pumps. The updated overview of expenses averaged over the years 2023-2028 is shown in Table 28, with the adjusted costs marked in purple. Electricity costs have significantly increased as compared to the option without boreholes (Table 18). Also, the investments costs and related costs of finance are much higher, while an evident saving on the water use would be made.

Table 28. ROI Costs (ZMW) including borehole option, averaged for period 2023-2027

ROI analysis per Operation Strategy (OS) – Expected Annual Costs with borehole option		OS-A	OS-B	OS-C
Depreciation initial investment	Depreciation drip lines	503,676	503,676	503,676
	Depreciation SDI main components & Solar	2,514,490	2,514,490	2,514,490

	Sensors & information technology	416,170	416,170	416,170
Operating costs	Water use	-	-	-
	Electricity	3,256,929	2,442,697	1,048,795
	Labour (including maintenance SDI)	815,159	815,159	815,159
	Farm inputs (fertilizer)	2,393,303	2,127,381	1,861,458
	Farm inputs (chemicals)	200,632	200,632	200,632
	Weed control	200,551	200,551	200,551
	Other farm inputs	945,397	945,397	945,397
	Haulage	4,205,788	3,680,065	3,219,593
	Farm Machinery	1,143,989	1,143,989	1,143,989
Finance costs	Finance costs	3,093,010	3,093,010	3,093,010
Others	Overhead (admin, overhead etc)	2,410,555	2,410,555	2,410,555
Total with boreholes		**22,099,649**	**20,493,772**	**18,373,475**
Total without boreholes (from Table 18)		**19,734,865**	**18,203,623**	**16,211,099**
Additional cost with boreholes		2,364,784	2,290,149	2,162,376

The additional annual cost with the borehole option is similar for all scenarios, as it ranges between ZMW 2.2M for OS-C to ZMW 2.4M for OS-A. The reduction in costs of water procured from Zambia Sugar is greatest under the high-water usage of OS-A (resulting in a saving of ZMW 1.8M), but the corresponding increase in electricity costs is also highest under this scenario (ZMW 2.1M extra electricity costs). By comparison, the impact is much less for the water-saving schedule of OS-C, which saves ZMW 0.6M on water use, against an increased electricity cost of ZMW 0.7M. Under all 3 operational scenarios, the increase in electricity costs is greater than the financial saving that is made on (externally supplied) water use.

The ROI for the option with boreholes is lower than the option without boreholes (e.g. 42% as compared to 55% for OS-A, and 18% instead of 33% for OS-C). Even though the costs for (external) water use are cut out, the costs for electricity consumption and depreciation of equipment and infrastructure have significantly increased. Nevertheless, the ROI including boreholes still offers a viable business case for OS-A and OS-B (42% and 34% respectively, Table 29).

With a relatively low ROI of 18% for OS-C, it is however not advisable to invest in boreholes under this operational scenario with low water usage.

Table 29. ROI Overview including borehole option

ROI	OS-A	OS-B	OS-C
Total yearly revenue	32,356,218	28,311,691	22,130,579
Total yearly costs	22,099,649	20,493,771	18,373,475
Total profit before tax	10,256,569	7,817,920	3,757,104
Tax (10% of profit)	1,025,657	781,792	375,710
Profit after tax	9,230,912	7,036,128	3,381,394
ROI (%)	**42%**	**34%**	**18%**

After the establishment of borehole water supply system, the additional electricity costs will exceed the savings that are made on water supplied by Zambia Sugar. Therefore, borehole water supply shall not be a cost-cutting measure. Instead, the main reason for considering borehole water supply is to mitigate the risk of over-reliance on a single source of water supply, which is likely to become increasingly unreliable in future. *Inter-alia*, the additional borehole supply would reduce the risk of poor crop development, reduced yields and possible crop failure, associated with potential water insufficiency, which is a significant risk due to enhanced stress on the existing (surface water) supply.

8.7 ROI INCLUDING SOLAR POWER OPTION

When including the solar power design (see Chapter 5), the ROI changes, due to the additional investment in the solar park and the resulting reduction in annual electricity costs, as the power take-off from the national grid would decrease.

Using solar, an estimated 54% of the total energy requirements can be supplied using this renewable energy source, while ZESCO would still supply the remaining 46%. The ROI overview for the years 2023-2027 in Table 30 shows the yearly averaged business case including the estimated additional 1,260,000 million USD solar investment, taking a depreciation of 20 years into account. The highlighted figures are those that are different compared with the costs presented in Table 18.

Table 30. ROI costs (ZMW) including Solar module, averaged for period 2023-2027

<table>
<tr><th colspan="2">ROI analysis per Operation Strategy (OS) – Expected Annual Costs with solar module</th><th>OS-A</th><th>OS-B</th><th>OS-C</th></tr>
<tr><td rowspan="3">Depreciation initial investment</td><td>Depreciation drip lines</td><td>503,676</td><td>503,676</td><td>503,676</td></tr>
<tr><td>Depreciation SDI main components & Solar</td><td>2,824,363</td><td>2,824,363</td><td>2,824,363</td></tr>
<tr><td>Sensors & information technology</td><td>416,170</td><td>416,170</td><td>416,170</td></tr>
<tr><td rowspan="3">Operating costs</td><td>Water use</td><td>1,789,228</td><td>1,341,921</td><td>576,166</td></tr>
<tr><td>Electricity</td><td>520,629</td><td>390,472</td><td>167,653</td></tr>
<tr><td>Labour (including maintenance SDI)</td><td>815,159</td><td>815,159</td><td>815,159</td></tr>
</table>

	Farm inputs (fertilizer)	2,393,303	2,127,381	1,861,458
	Farm inputs (chemicals)	200,632	200,632	200,632
	Weed control	200,551	200,551	200,551
	Other farm inputs	945,397	945,397	945,397
	Haulage	4,205,788	3,680,065	3,219,593
	Farm Machinery	1,143,989	1,143,989	1,143,989
Finance costs	Finance costs	3,444,969	3,444,969	3,444,969
Others	Overhead (admin, overhead etc)	2,410,555	2,410,555	2,410,555
	Total with solar	**21,814,409**	**20,445,299**	**18,730,331**
	Total without solar (from Table 18)	**19,734,865**	**18,203,623**	**16,211,099**
	Additional cost with solar system	2,079,544	2,241,676	2,519,232

Interestingly, the additional annual cost with the solar system is greatest (ZMW 2.5M) under the water-saving scenario OS-C, and lowest (ZMW 2.1M) under OS-A. This is because under OS-A, the solar option results in a significant saving on annual ZESCO power costs (ZMW 0.65M), while under scenario OS-C, this absolute saving is much less (ZMW 0.21K).

Although the costs of electricity are reduced by 55.5% for all Operational Scenarios, the overall ROI is significantly lower compared to the option without solar (see Table 31: 43% as compared to 55% for OS-A, and 16% instead of 33% for OS-C). This is because the investment in solar increases the yearly depreciation of hardware by a relatively large amount of ZMW 1,277,295 and the finance cost by ZMW 1,450,774. On the other hand, the savings on electricity supply are of a much smaller magnitude, as discussed above. Nevertheless, the ROI including solar still offers a good business case for OS-A and OS-B (43% and 35% respectively, Table 31).

With an ROI of 16% for OS-C, it is not advisable to invest in solar with the lower revenues attained by this scenario, and the corresponding smaller absolute savings on electricity costs.

Table 31. ROI overview including solar module

ROI	**OS-A**	**OS-B**	**OS-C**
Total yearly revenue	32,356,218	28,311,691	22,130,579
Total yearly costs	21,814,409	20,445,299	18,730,331
Total profit before tax	10,541,809	7,866,393	3,400,248
Tax (10% of profit)	1,054,181	786,639	340,025
Profit after tax	9,487,629	7,079,753	3,060,223
ROI (%)	**43%**	**35%**	**16%**

8.8 ROI INCLUDING BOREHOLE OPTION AND SOLAR MODULE

When combining both the borehole system and the solar module, the annual electricity costs still increase between ZMW 0.33M for OS-A and 0.11M for OS-C. However, the increases are much less than with the borehole option alone, since the solar system is more actively utilized, now also to power the borehole pumps. Water costs are reduced to nil for all Operational Scenarios, which again results in a saving of ZMW 1.7M for OS-A and 0.6M for OS-C (see Section 8.6).

In a set-up with combined boreholes and solar, the savings on water outweigh the additional costs for electricity, resulting in a reduced electricity-water cost of 1.46M for OS-A and 0.47M for OS-C. In particular under OS-A, this appears to be a sizeable gain. However, the depreciation and finance costs significantly increase, as a large investment of about ZMW 70,711,000 is required. It should be mentioned that, for the solar option, the 1MW solar plant will be able cater for the whole farm (including the existing pivot systems and the new submersible borehole pumps) and not only the 311 ha SDI.

Table 32. ROI costs (ZMW) including borehole and solar options, averaged for period 2023-2027

ROI analysis per Operation Strategy (OS) – Expected Annual Costs with borehole option and solar module		OS-A	OS-B	OS-C
Depreciation initial investment	Depreciation drip lines	503,676	503,676	503,676
	Depreciation SDI main components & Solar	3,791,785	3,791,785	3,791,785
	Sensors & information technology	416,170	416,170	416,170
Operating costs	Water use	-	-	-
	Electricity	1,498,188	1,123,641	482,446
	Labour (including maintenance SDI)	815,159	815,159	815,159
	Farm inputs (fertilizer)	2,393,303	2,127,381	1,861,458
	Farm inputs (chemicals)	200,632	200,632	200,632
	Weed control	200,551	200,551	200,551
	Other farm inputs	945,397	945,397	945,397
	Haulage	4,205,788	3,680,065	3,219,593
	Farm Machinery	1,143,989	1,143,989	1,143,989
Finance costs	Finance costs	4,543,784	4,543,784	4,543,784
Others	Overhead (admin, overhead etc)	2,410,555	2,410,555	2,410,555
Total with boreholes and solar		**23,068,976**	**21,902,783**	**20,535,194**
Total without boreholes and solar (from Table 18)		**19,734,865**	**18,203,623**	**16,211,099**
Additional cost with boreholes and solar system		3,334,111	3,699,160	4,324,095

The combined option of boreholes with solar has the lowest ROI values, due to high investment costs. While the ROI is still fair for OS-A (36%), it rapidly drops to only 7% for OS-C (see Table 33).

It is also important to note that, while reducing over-reliance on a single source and he risk of under-supply (as discussed in Section 8.8), groundwater also comes with a level of uncertainty: even though it is estimated that the additional 311 ha SDI could probably be (largely or fully) supplied by borehole water, the available groundwater resources are not sufficient to extend the borehole supply to the larger farm area of 2,500 ha.

Table 33. ROI Overview including borehole and solar option

ROI	**OS-A**	**OS-B**	**OS-C**
Total yearly revenue	32,356,218	28,311,691	22,130,579
Total yearly costs	23,068,976	21,902,783	20,535,194
Total profit before tax	9,287,242	6,408,908	1,595,385
Tax (10% of profit)	928,724	640,891	159,538
Profit after tax	8,358,518	5,768,017	1,435,846
ROI (%)	**36%**	**26%**	**7%**

9. COMPARISON OF DIFFERENT SDI OPERATION SCENARIOS

After providing an extensive insight in the different characteristics of the three operation scenarios that were assessed, the scenarios will be compared in the current Chapter 9. Based on this comparison, advise shall be given on the most favourable option, after considering the key-economical and sustainability factors.

The Weighted Multi Criteria Analysis also applied in Chapter 2 has been used to compare the OS scenarios. Every factor received a score from 1-5, whereby 1 is the least favourable and 5 the most favourable grade. Note that these scores are relative to each other, and can only be used as a comparison between the options OS-A, B and C. They do not represent an absolute score and cannot be compared with the points allocated in Chapter 2 since different irrigation technologies (furrow, center pivot, and SDI) were compared in that analysis.

The MCA in Table 34 provides insight in the overall scores of the three operational scenarios. Moreover, different factors can be compared relatively to each other.

As observed in Chapter 2, both the weight of the different factors and the attributed score are to some extent subjective and user-dependent: as a result, different stakeholders may value the criteria differently. Consequently, based on further discussions with KASCOL, and according to its views and priorities, different weighing and scoring may be applied, and a different overall result may evolve.

Table 34. Weighted MCA - a comparison of 3 SDI operation scenarios

MCA	Factor	Weights (W)	OS-A	OS-B	OS-C
Economical aspects	Turnover	1	5	4	2
	Operating costs	0.5	W x 3 = 1.5	x 4 = 2	x 5 =2.5
	SDI investment costs	0.5	W x 4 = 2	x 4 = 2	x 5 =2.5
	ROI	2	W x 5 = 10	x 4 = 8	x 3 = 6
Agricultural factor	Yield	1	5	4	2
Sustainability factors	Water saving	2	W x 1 = 2	x 3 = 6	x 5 = 10
	Water productivity	2	W x 2 = 4	x 3 = 6	x 5 = 10
	Chemical fertilizer use	1	4	4	4
	Weighted sum	**10**	**33.5**	**36**	**39**

OS-A, which supplies 100% of the irrigation water requirements, is the lowest scoring scenario with 33.5 points. This mode of operation scores very high on the economical aspects due to its highest yield, and also has the best return of investment. However, its lower score on the sustainability factors pushes it down to third place.

OS-A	Economical Aspects	23.5
	Sustainability Aspects	10

OS-B, which supplies 75% of the irrigation water requirements (deficit irrigation) is ranked second with 36 points: this is caused by its high performance on the economic aspects (close to OS-A). Furthermore, this Operational Scenario scores well on water saving.

OS-B	Economical Aspects	20
	Sustainability Aspects	16

OS-C, which supplies the same amount of effective irrigation as applicable for the existing Furrow Irrigation KASCOL (deficit irrigation), scores highest with 39 points. This high score is mainly owed to its high performance on sustainability, and in particular, its favourable water saving and water productivity aspects. However, OS-C scores lowest when isolating the economic aspects, which may be a concern in terms of expected financial gains and profitability.

OS-C	Economical Aspects	15
	Sustainability Aspects	24

Looking at the weighted sum, the deficit irrigated scenarios OS-B and OS-C score highest and are therefore considered as overall more favourable. For the SDI design option without solar and/or borehole module, OS-C would be most favourable and lowest cost option. When including the solar and/or borehole options, OS-B would come out best, since OS-C would score a relatively poor 1 on the ROI factor.

10. CORPORATE GOVERNANCE

10.1 INTRODUCTION

An assessment was made to determine the company's capability to implement the planned sub-surface drip irrigation investment efficiently and effectively for the desired results (more efficient water use, greater profitability, sustainable and environmental-friendly cane production) under its current organisational and operational set-up. In addition, based on the identified gaps and shortcoming, the assessment provides recommendations on how the organisational capacity could be strengthened.

The following aspects were evaluated:

- Organisation: the company's purpose and structure.
- Staff: expertise and numbers in the various departments (the farm area, technical support services, finance and administration, management).
- Facilities and support services.
- Performance.
- The company's opportunities and risks.

The assessment is based on the following sources of information:

- Data received from KASCOL, including a questionnaire that was prepared for the assessment (Annex VII.a) and submitted to KASCOL management and senior staff who will also be involved in the new SDI system.
- Interviews with KASCOL staff.
- Studies and other information related to KASCOL available on the Internet (the links to the literature used are provided in annex VII.c).

The questionnaire sent to KASCOL was for basic information and self-assessment. Following reception of this information (see Annex VII.a), the following staff were interviewed during a one-day visit to the company (also see annex VII.b):

- A group of 6 workers: 2 pump attendants and 4 drip operators. All of them are involved in the recently developed subsurface drip irrigation system of 150 ha (planted for the first time only in November 2021) and will probably also be involved in the new SDI of 311ha.
- Two of the 3 zone leaders (who supervise the irrigation operators and coordinate the work in the fields through their field captains /supervisors).
- The farm manager (the Smallholders & Operations Officer), who is also coordinating the company's share of work for the fields that are leased to individual smallholder farmers.
- Senior management and administrative staff, including the CEO (the Estate Manager) and the Secretary of the company.

Observations

KASCOL's purpose and set-up

The company started 45 years ago and was incorporated as a limited liability company in 1977 under the name "Sugarcane Outgrowers Company Limited". The name was changed in 1981 to "Kaleya Smallholders Company Limited" (KASCOL).

Since its establishment, KASCOL's purpose has been twofold:

- To produce and sell sugarcane.
- To engage smallholder farmers in profitable sugarcane production.

Its setup was the initiative of Zambia Sugar, which had run out of land for expansion of cane production and looked for outgrowers to assist in the cane supply to its processing plant, and the Zambia Government, which made this into a strong rural development case by providing land and involving smallholder farmers in a resettlement scheme. The original shareholders Zambia Sugar Company (at that time still state-owned), Development Bank of Zambia, CDC (Commonwealth Development Corporation), and Barclays Bank formed the company with the intention to sell shares over time to smallholders growers. Currently, the local cane growers, including the smallholders, have significant equity stakes in the company. The Kaleya Smallholders Trust owns 19.5% of the company. ZSC transferred its 25% shares into the Mazabuka Sugar Cane Growers Trust. The Development Bank of Zambia remained a 25% shareholder and Growers Investment Holdings holds 30.5%.

KASCOL is an outgrower company supplying cane to Zambia Sugar under contract, including the cane of its smallholder tenants. Its quota, including the produce from the smallholders, is 300,000 ton per year. The actual volume supplied is slightly lower, in the range of 250-270 thousand tons per year. The deficit is largely attributed to loadshedding by ZESCO, which has affected the available amount of irrigation water.

Currently, there are about 160 smallholders, producing cane on approximately half of the company's land. They co-manage the land under a legally binding Cane Farm Agreement. Each smallholder holds an average of 6.7 ha land for cane production, plus 0.5-1 ha residential space under a 14-year sub-lease. The company supports them with training and extension as well as with farm-inputs and mechanized extension services on seasonal credit. Furthermore, on behalf of the smallholders, KASCOL harvests and sells the cane to Zambia Sugar. Another role of the company is to demonstrate new technologies (such as subsurface irrigation) to and on behalf of the smallholders on the nucleus farm.

Staff competency

The company has 29 permanent staff (of which 11 are in senior positions), 52 permanent staff on a fixed contract (2-3 years), 428 seasonal workers (9 months per year), and 14 temporal staff (on short contract for less than 6 months), plus a harvesting team of 199 seasonal workers (see the organogram in annex VII.f).

KASCOL is managed by the Estate Manager (CEO) and the Finance & ICT Manager, who are supported by 15 permanent administrative staff. The farm (including the farm workshop) is headed by the Smallholders & Operations Officer, who also is responsible for the farming activities at the individual smallholders' plots, and who is supported by 8 permanent staff. The health clinic has 3 permanent staff.

On average, the senior staff has worked about 11 years for the company and about 6 years in their current position. All are well-educated with Bachelor and Master degrees).

While not having a formal strategic gender plan, over the years, the company has slowly increased the number of women employees with the intent to bring their proportion to 40%. Most of the current female employees are seasonal workers (representing about 30% of the seasonal work force). They are usually given duties deemed more suitable for women, such as planting and weeding, and they are not put on night shifts as a measure of protection. Also, about 30% of the junior staff (on permanent or fixed contract) are women. They are mostly in administration, financial accounting and at the clinic. Unfortunately, only few women have risen to a senior position (only 2 of the 11 senior staff, or 18%).

KASCOL has a deliberate policy for staff training, with the expressed objective to strengthen overall performance and facilitate staff to grow in the company. Staff training is a necessary strategy in an environment in which it is hard to find sufficiently skilled and trained personnel. All officers can opt for training in subjects relevant to KASCOL. Courses are financed by the company, but the cost becomes a loan to the employee if he or she doesn't pass. The facility is popular, as testified in Annex VII.e, which gives an overview of recently sponsored courses.

The educational level of the workers ranges from Primary School all the way up to Grade 12. Orientation workshops and meetings with the workers are organised on a regular basis. There is a strong focus on building a spirit of inclusiveness of all employees and enhancing a feeling of togetherness and responsibility throughout the company.

The company recently introduced the position of a Risk & Operations Officer. Purposefully dealing with risks, including increasing environmental risks, is a sign of foresight management and an important step towards risk mitigation and reduction.

As for the installation and running of the new 311 ha SDI system, the company has already gone through a learning curve with the first SDI system on an initial 150 ha of land. It is now in a better position to prevent costly mistakes, including careful planning with the supplier (e.g. installing the pumps and pipes before laying out the drip lines, so to prevent excessive damage by rats when the drip lines remain dry), and it has built a team of 10 drip irrigators and pump operators that are dedicated to the SDI system.

Moving away from furrow irrigation to subsurface drip irrigation will change tasks and potentially reduce labour requirements for the irrigation teams in the field. For instance, there will be less physical irrigation duties (such as closing and opening of gates and valves, moving with pipes, siphoning, maintaining furrows, fertilizing, and ensuring that water properly reaches the entire crop), but more work in scouting and attending timely to problems occurring in the field (such as damaged hydrants, and clogged or damaged drip lines).

In fact, the SDI irrigation operators and pump attendants expressed some concern of possible staff lay-offs within their ranks, but also saw opportunities in being reoriented as scouts and guards of the expensive SDI equipment. One of them mentioned that they are the 'eyes of the company'. Further, precisely calculating the setting of the pump pressures, the timing opening and closing of the hydrants, controlling and cleaning the water filters, flushing of the drip lines, managing the fertigation, and keeping the dams clean will be some of the new responsibilities.

Although the team of SDI irrigators and their supervisors are still learning on the job and fine-tuning the operation of the recently installed 150ha drip irrigation system, all confirmed having learnt to understand it quickly under the initial guidance of the experts who installed it. Importantly also, they professionally appreciated the change from furrow irrigation to drip, as they witnessed reduced crop water needs, less water losses, reduced erosion, and a 3-times quicker and more accurate irrigation performance. This facilitates a more accurate timeliness of the various field operations and a well-growing crop (despite the fact that the 2021 crop was planted too late, due to late delivery of the SDI equipment).

Facilities and support services

The 311 ha subsurface irrigation is planned on land that is currently under furrow irrigated cane production. Other than the irrigation system, including adapted electricity and water supply and accompanied by a service contract with the supplier, nothing much will change with regard to the farming activities. Therefore, the existing equipment and infrastructure, including the maintenance services for it, can be assumed to be adequate with the new SDI system too.

Performance

The company's yield target is 120 t/ha, while 112 t/ha is considered a minimum. So far, at 118 t/ha in 2021, it hasn't reached its full target just yet. However, the yields fluctuated around an average of only 100 t/ha during the previous 5 years (between 92 and 113 t/ha), and therefore, the 118 t/ha is seen as a good achievement.

A better buffer against a fluctuating market and an increasingly risky climate could be achieved if yields would be higher (as targeted) and if production costs could be reduced: these are aspects that the company is very mindful of. The combination of a currently reasonably good yield and a good price has strengthened KASCOL's financial position. This improved financial capacity also guided the decision to invest more in additional fields under SDI (rather than extending the 7 ha sprinkler and over 350 ha pivot irrigation systems, which gave challenges).

The cost of water is about 17% of the total cost of production. Installing technologies such as SDI will help reduce this cost factor, as well as the costs for inputs (especially fertilizer) through their more efficient use, and for labour (e.g. for weeding). However, as is the experience so far in the 150 ha already brought under SDI, the cost of electricity is likely to go up significantly, as a result of the high-pressure pumping needed when using drip lines as opposed to furrow irrigation.

The fact that yields lag slightly behind the target is not due to lack of financial support of the farming activities. The farm manager confirmed having the full support of the financial department. Cane productivity has the priority. Furthermore, the team is youthful, with a zeal to work and an expressed and evident eagerness to learn, not wanting the new 150 ha drip irrigation to fail. Staff turn-over is low, which is an indication that people are content in their job.

While sugarcane has remained the dominant crop, KASCOL has diversified into soybean and barley as well. It has also started venturing in macadamia production and fish farming. These diversions from its core business may be ways to spread risks, as well as a possible fallback once KASCOL meets its cane delivery quota (300,000 tons/year) with Zambia Sugar Company. Moreover, with soybean, it has introduced crop rotation on land that needs rehabilitation from continuous cane production. Further, the company has an afforestation programme and considers investments in solar power.

Over the years, KASCOL has proved to be a successful governance model for increased and sustainable smallholder participation and ownership. Key to this was its ability to build social capital. An important driver of this success, apart from the lucrativeness of the industry and a well-guided development agenda of the government, seems to have been the interdependency of the stakeholders (e.g. KASCOL being dependent on water from Zambia Sugar, Zambia Sugar being dependent for expansion on land provided by the government and additional production to supply its plant, the smallholders being dependent on KASCOL's services and income from sales by KASCOL to Zambia Sugar) that forced them to solve their issues together. This set-up of interwoven and common interests has also organised the smallholders into a serious and competent partner.

Opportunities and risks

Opportunities:

- A well-developed and rewarding value chain with players in the public and private sector that over the years learnt to effectively cooperate.
- Zambia Sugar Company being a strong player in the market, a reliable off-taker of cane and a good service provider.
- Accessible technologies and knowhow to build resilience and grow.

Risks:

- Increasing water shortages, not only due to climate change, but also due to inefficiencies in land and water resources management in general and increased demand by different water users due to population increase and economic development. This particularly affects the Kafue Basin, on which densely urbanised and industrialised areas such as Lusaka and the surrounding areas with large, irrigated farms are relying for their fresh water as well as their largely hydro-power-generated electricity.

- Price fluctuations and worldwide shortage of inputs and energy due to adverse international developments (currently e.g. COVID-19 and the war in Ukraine).
- KASCOL's dependency on Zambia Sugar Company for all of its irrigation water.
- KASCOL's dependency on Zambia Sugar Company as a single buyer of its cane and for determining its value.

Conclusions and recommendations on corporate governance

- KASCOL is a well-established and profitable company with several decades of history, which is being run by experienced, qualified and committed staff. The fact that it is still vibrant today is in itself a prove of strength. Investing in new technologies and dialogue with stakeholders have been important parts of its strategy to respond to challenges.
- KASCOL has been able to maintain and to a large extent comply with its two-fold purpose: profitable cane production and smallholder participation. This social model, rather than flat-out aiming for financial gain alone, has proven to be valid and sustainable for a large group of smallholder farming households.
- In addition to the urgency for more water-efficient crop production technologies, due to the relatively high cost of water as well as the outlook of increasing water scarcity, the current combination of fairly good yields and a good price may have convinced KASCOL to invest in the SDI system at this stage.
- Although the company as well as its smallholder tenants have proven to be able to achieve acceptable cane yields, they still have remained somewhat below target. To overcome this gap, investing in SDI equipment alone will not be enough.
- Along with investing in a more modern irrigation system, the company should further explore ways to modernise its agricultural expertise. Specifically, expanding its know-how in water management, precision irrigation and sustainable soil management will be indispensable to meet the yield targets and to remain cost-effective under increasingly demanding environmental conditions. Promising young graduates in the required fields should be selected carefully, and will still need to be groomed for their usefulness to farm management. Letting them work to improve their practical farming skills and build their confidence should be part of the learning process. Ideally, a new group of technical staff will join together with the installation of the new SDI system, so they can be attached to the supplier's experts.
- Along with strategic improvement of the company's expertise, continuous refining and investing in monitoring of the farming and financial results is required, as well the appropriate practical use of information and results in management and (investment) planning. The reliability of the system and the decision taking for improved irrigation precision should continuously be optimised.
- Therefore, as mentioned in Chapter 6 of this report, investing in relevant monitoring equipment, such as for collecting weather data and monitoring soil moisture, will prove beneficial, as long as the existing HR and systems to process the data into useful information can cope with it.

- The company may consider procuring basic laboratory equipment, including a refractometer, for monitoring the sugar content of the cane delivered to the Zambia Sugar Company.
- Attention for staff training and inclusiveness should continue. A strong focus on developing skills is advised, including among the workers. The beginner's mistakes made with the installation and application of the initial 150 ha SDI system will provide very useful lessons. Exposure visits to cane growers who have successfully advanced with subsurface irrigation could be another efficient way to learn skills.
- While SDI should lead to higher yields, it will be important to manage the overall costs, as some of them are expected to go up considerably (such as the electricity bill for pumping, maintenance costs, the costs of keeping the irrigation water clean, depreciation of the new infrastructure and equipment, as well as the financial costs due to loans for investments).
- A gender-balanced work force, including at higher staff level, is not only fair but also considered business-smart. Therefore, a more outspoken gender strategy for achieving this goal seems welcome.
- The company has an adequately large work force. In fact, with an expansion of the area under drip irrigation, there might be an excess of irrigators. As well as possible, these should then be prepared for other duties in the company, or for an alternative livelihood.
- A certificate could be issued to the workers in the field after they have been (re)oriented, in recognition of them having successfully learnt and applied new knowledge and skills.
- For improved scouting and guarding the facilities and communication between the drip attendants and the pump operators, the decision taken by the company to provide the irrigation teams in the field with radios and, for the night shift, with reliable torches and a shelter, is important. Management is advised to instruct the farm workers and tractor drivers to accept the authority of the irrigators whose task it will be to protect the hydrants and drip lines etc. against accidental damage. Consequently, the irrigators must be empowered and enabled to guide their colleagues accordingly.
- The need for the irrigation water to be free of dirt and algae requires constant attention to the dams. Putting dam liner will be a useful investment.
- With increasing scarcity of water in the Kafue catchment and as a result of KASCOL's new ability to save water thanks to the SDI system, the company may need to accept a reduction on its water right, and aim at a more sophisticated planning and use of the SDI system, e.g. by using deficit irrigation and/or by developing groundwater sources (borehole drilling).
- The use of drip irrigation will significantly reduce water run-off and may reduce deep percolation. Consequently, less water may be available to recharge the aquifer, which may affect down-stream water users over time. This aspect might,

therefore, become a point of attention for the Water Users Association, of which KASCOL is a member.

11. CONCLUSIONS AND DISCUSSION

11.1 CONCLUSIONS

To conclude, it is feasible to transform the 311 ha of existing sugarcane fields that are currently under furrow irrigation to a water-efficient SDI system. The existing dam and power lines have enough capacity for the SDI expansion. A new transformer, pumping reservoir and pump-filtration-fertigation station are still required at close proximity to the existing Dam 6. The clay soils present at the selected 311 ha are highly suitable for the SDI system and are expected to perform well. However, it is advised to improve the soil-life by adding organic matter and applying soil-life-enhancing methods to the fields. SDI can help to enhance this and further optimize the sugarcane cultivation.

The Return on Investment analysis shows that the SDI system is a sound investment from an economical point of view. The three different operating strategies that have been analysed (i.e. OS-A with 100% of the CWR, OS-B with 75% of the CWR, and OS-C with a larger deficit and an effective water input that is equivalent to the existing furrow irrigation) have an ROI of 58, 50 and 33% respectively. These ROIs apply under the assumption that no additional solar or borehole options are included. When both the borehole and solar options are included, the ROI reduces to 36, 26 and 7% respectively, due to increased investment costs (and relating finance costs and depreciation).

For OS-A and B, a pay-back period of 5 years is advised: this can be supported by the cashflow forecast. For OS-C, a 7-year pay-back period is advised, as the 5-year period can not be supported by the resulting cashflow.

When comparing the different scenarios on multiple factors, using a weighted MCA, the deficit irrigation scenarios OS-B and C are the best options to consider, when no solar or borehole modules are included. Using a deficit irrigation strategy lowers the total volume of water required on the fields and increases the water productivity. Water productivity is considered as a real water saving.

Geo-information and sensors will make it possible to operate the SDI system most optimally, thereby creating the best growing conditions for the crops under the chosen operation strategy.

OS-C, which is the highest scoring scenario from a water use perspective, is not expected to score high enough on the ROI when adding Solar or Borehole modules. This is due to the very high depreciation and finance costs, while at the same time, the yield and income is relatively low compared to the other options, but also in absolute terms and in relation to the high depreciation and finance costs. Furthermore, under OS-C, the electricity costs after the installation of the solar module do not reduce to a significant extent in relation to all other costs involved.

The assessment on how solar energy can be best included in the SDI system indicates that this renewable energy source is a feasible option when supplying 54% of its electricity demands. Though it is a significant investment with a great impact on the depreciation- and finance costs, it proves to still offer a good business case for OS-A & B. Being less dependent on the national grid is an added advantage, since load-shedding is a risk factor that can jeopardize the optimal operation of the system and subsequently its yield.

After designing and analysing the SDI, taking the three scenarios assessed into account and valuing both economical and sustainable aspects, OS-C is most favourable without solar and borehole option. OS-B is performing best after including solar or the borehole option, or both.

KASCOL seems to have the commercial drive as well as the organizational set-up, competence and position in the industry needed for successfully developing the planned 311 ha of subsurface irrigation and making it profitable. Further, the company looks sufficiently motivated by environmental concerns to invest in technologies such as the envisaged SDI and other inputs that will be beneficial to its operation. Also, KASCOL's successful role of integrating a significant number of smallholders in the business and being a role-model for them makes it an attractive development partner.

11.2 DISCUSSION

The initial phase of this feasibility study consisted of collecting and organizing data required to give an 'as accurate as possible' insight in the feasibility of the SDI system. Data was used from KASCOL and from external sources. Though a lot of valuable information was collected that helped to get a good understanding of, among others, water use, and cost and income figures, a translation towards the future was required in order to get insight in the ROI feasibility.

Different methods were used to estimate the data for the years 2023 till 2027. As a rule, relatively conservative estimations were made, for example, for the ERC price and the water costs. However, the forecasts remain estimates and can differ from the reality. This is an important realization when looking and interpreting the figures of this report. It is therefore advisable to keep a safe certain margin into account, even if the pre-assumptions have been largely conservative. In this light, there may be a need to update the forecasts with actual figures, as soon as these become available, to review the accuracy of the predictions, and to fine-tune the financial models, if and as needed.

When looking at the outcomes of the ROI, it can be positively concluded that there is significant room for the viability of the new 11 ha SDI system. Even in situations where the actual costs increase will be more than forecasted, or in the unlikely event that sugar prices drop due to unforeseen (global) situations (the opposite trend appears to be more probable), the SDI system can still be a profitable option for KASCOL. The design's resilient character against climate change by taking, for instance, poor rainfall into account, further decreases the risk of yield losses, while making KASCOL increasingly climate-smart.

The three operation scenarios that were included in this research show interesting differences in the MCA and give a good first direction on how to operate the SDI system. For each of the OS, it is now broadly known what can be expected in terms of economical and sustainability factors. However, the interpretation and evaluation of these factors (and therefore, the final ranking of each operational option) may greatly vary, depending on the priorities and interests at stake.

More operating scenarios are also possible, for instance with different irrigation regimes and different fertilizer applications. Therefore, it becomes clear that, to optimize and keep improving the sugarcane cultivation from different perspectives, additional trials and innovation remain important. These trials, tests and reviews will not change the overall feasibility of the SDI expansion, but should be applied, while the new system is already in operation. It is recommended that KASCOL introduces different trials and data collection on e.g., costs of production, water use and yields. Results and findings should be constantly used to keep fine-tuning its operations.

The insights of this report should be considered as a starting point on how to operate the system in a smart and beneficial way. However, until tested and proven, this might not be the most optimal situation: in any case, deficit irrigation needs to be further fine-tuned and optimized towards the exact situation at KASCOL. This should be one of the main objectives of data collected and analysed by KASCOL over the coming years. If the findings are applied correctly, and with enhanced knowledge and innovation, the system will become more and more beneficial for KASCOL in terms of economical and sustainable benefits.

Although the factors that were taken into account in this research (MCA & ROI) were discussed with KASCOL and compared with other research done to assess the feasibility of several OS-options and infrastructure developments, it is possible that not all factors that are valued by different stakeholders were included.

Furthermore, since the MCA is a tool to compare different characteristics, and weights are somewhat subjectively assigned to these different aspects (making some aspects more important than others), every stakeholder will value the different elements and their importance differently. The current MCA was valued based on 50% economical and 50% sustainability importance. When stakeholders value this differently, it is highly likely that the scores of the three operation scenarios will change.

With the method developed in this research, it would still be possible to extend and review the analysis by e.g. internal review by KASCOL, as well as additional stakeholder interviews to determine which factors weigh most for different stakeholders. In fact, this approach with a full MCA-review is strongly recommended, in order to align the analysis closely to the views of KASCOL, the smallholder members, and other stakeholders in the development.

The yield expectations applied in this study are based on existing data from KASCOL, combined with literature research on SDI systems with comparable characteristics. However, the resulting estimations are partially based on other locations with other weather patterns, water regimes, and soils. It is therefore possible that KASCOL's actual future yield will be somewhat different, compared with the figures used in this analysis. Overall, a fairly close match between the forecasts and the actuals is expected since the historical yield data from KASCOL served as a solid baseline of what is achievable and what is to be expected. Under the right operation and application of the new SDI system, the likelihood of significantly improved yields is high, as has been demonstrated and proven in a large number of trials and publications.

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ANNEX I – CROP WATER REQUIREMENTS

Crop and Irrigation Water Requirements are key for the design and assessment of an irrigation system. In this feasibility study, the Crop Water Requirements (CWR) and Irrigation requirements for KASCOL Estate are calculated. For this method, different data sources were used, such as rainfall data collected from 10 stations at KASCOL for the period 2017-2021 (Table 35). The average rainfall received by the KASCOL stations within this period was 659 mm.

Table 35. Mean monthly rainfall 2017-2021 collected from 10 stations at KASCOL

Month	Rainfall (mm)
January	146
February	221
March	56
April	19
May	0
June	0
July	0
August	0
September	0
October	11
November	69
December	137
Sum	**659**

It should be noted that the rain recorded at KASCOL falls below the 'low' estimation of FAO (698 mm/year) for the same area. Therefore, this feasibility study takes a 'worst case' scenario into account concerning rainfall. It is likely that there will be years and seasons with higher rainfall, whereby less irrigation water is required. For example, KASCOL recorded relatively high rainfall of 824 mm in 2017.

Besides rainfall, different (climatological) parameters have been used in Table 37 to calculate the crop-specific Evapotranspiration (ET_C), which is the sum of crop transpiration and evaporation from soil surface. The ET_C is calculated by multiplying the open pan ET_o (see Table 36) with a crop coefficient k_c. The effective rain and the irrigation requirements are calculated assuming a 100% efficiency. As shown in Table 37, the average daily irrigation requirement over the year is 4.1 mm and the peak daily water requirement is 9.1 mm/day at the end of the month October (i.e. the final 10-day period of the month).

Table 36. Weather input (LocClim, Mazabuka)

Month	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	°C	°C	%	km/day	hours	MJ/m²/day	mm/month
January	18.1	28.3	91	259	7.4	22.1	129.38
February	18.1	28.5	92	251	7.7	22.2	116.52
March	16.2	28.8	85	277	9.6	24.0	144.53
April	13.8	28.7	83	320	10.8	23.4	136.83
May	10.0	27.1	76	337	11.2	21.3	133.67
June	8.5	25.2	71	346	10.8	19.4	119.99
July	7.3	25.1	74	380	10.9	20.1	124.02
August	9.6	27.7	59	432	11.5	23.1	176.76
September	13.3	31.3	52	475	11.4	25.7	224.25
October	16.5	33.0	51	475	11.2	27.2	257.65
November	18.1	31.5	66	389	8.2	23.1	189.67
December	18.1	28.8	85	320	7.4	22.0	140.99
Average	**14.0**	**28.7**	**74**	**355**	**9.8**	**22.8**	**1,894.26**

Table 37. Evapotranspiration, effective rainfall and irrigation requirements

Month	**ETc (mm)**	**Effective rain (mm)**	**Irrigation Req. OS-A (mm)**
January	169	112	57
February	153	143	10
March	185	51	134
April	177	19	158
May	166	0	166
June	135	0	135
July	123	0	123
August	97	0	115
September	124	0	124
October	253	11	242
November	246	61	184
December	186	107	79
Sum	**2,011**	**504**	**1,526**

ANNEX II – WATER USE AND COSTS

Data based on water data 2017-2020 provided by KASCOL

Overview of costs summarized	2016	2017	2018	2019	2020
Water Costs (ZMW)	K4,500,976.12	K6,865,995.97	K5,568,845.18	K6,442,321.80	K7,083,754.24
Water Quantity (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
hectarage	2451.8	2359.4	2410.4	2381.4	2308.7
Water quantity (m3/ha)	9084	9060	9063	8254	9396
Water average (in mm)	908	906	906	825	940
effective irrigation (mm) (scheme irrigation efficiency 52%)	472	471	471	429	489
total yield ERC (tons)	29,632	24,963	30,821	31,563	25,418
Water productivity (KG ERC/m3 water)	1.330	1.168	1.411	1.606	1.172
Cost water (ZMW/ton ERC)	152	275	181	204	279
average yield (ton/ha) 2016-2020	100.97				

water cost estimations	costs ZMW/m3	water costs OS-A (ZMW)	water costs OS-B (ZMW)	water costs OS-C (ZMW)
2021	0.29	1,358,765.46	1,019,074.09	437,549.03
2022	0.31	1,453,879.04	1,090,409.28	468,177.46
2023	0.33	1,555,650.57	1,166,737.93	500,949.89
2024	0.35	1,664,546.11	1,248,409.58	536,016.38
2025	0.38	1,781,064.34	1,335,798.25	573,537.53
2026	0.40	1,905,738.84	1,429,304.13	613,685.15
2027	0.43	2,039,140.56	1,529,355.42	656,643.11
average 2023-2027	**0.38**	**1,789,228.08**	**1,341,921.06**	**576,166.41**

Water costs for different OS using water costs data from KASCOL. The average of 2023-2027 (0.38 ZMW/m^3 of water) is used for the forecast in the feasibility study.

Average water use 2016-2020: 8,971.65 (m3/ha)

Assuming irrigation season April-Oct (7 months or 210 days)

8971 m3/ha *1,000/10,000= 897 mm/year

897/210=4.27 mm/day on average

Furrow irrigation: based on interviews and irrigation schedule

<u>2-week interval</u>

7 months (april - oct)	2 weeks interval;
14	irrigation turns
125	mm per irrigation turn
1,750	mm per year (best case scenario) of which 52% would become available for crop)

<u>4-week interval</u>

4 weeks interval	
7	irrigation turns
125	mm per irrigation turn
875	mm per irrigation turn worst case scenario

Comparing the two methods described above, we can assume that on average the furrow irrigated fields will be irrigated approximately every 4 weeks and that the 2-week interval can be more considered as an 'ideal' scenario for the furrow system. Due to contains described in the pre-feasibility study, this cannot be achieved in practice.

Water productivity- water use aspect

Comparing the two approaches used to calculate the water use of the furrow system, the option using the water data from 2016-2020 is considered the most accurate in relation to calculating water productivity, We have the harvest data and the water use covering the mentioned period and thus can determine the water productivity (expressed as kg of cane/ m^3 of water use (rain + irrigation). In this calculation 897 mm is used as irrigation and the effective rainfall of 540mm (based on rainfall data KASCOL).

Detailed Crop water requirements, KC Factors ETC, Eff, Rain & Irrigation requirements

Planting date: 08/08/2022

Decade	**Stage**	**Kc**	**ETc**	**ETc**	**Eff rain**	**Irr. Req.**	**Irrigation requirement daily**
		coeff	mm/day	mm/dec	mm/dec	mm/dec	
1	Init	0.9	4.6	13.8	0	32.2	3.22
2	Init	0.4	2.28	22.8	0	22.8	2.28
3	Init	0.4	2.52	27.7	0	27.7	2.77
1	Deve	0.41	2.88	28.8	0	28.8	2.88
2	Deve	0.54	4.1	41	0	41	4.1
3	Deve	0.69	5.41	54.1	0.1	53.9	5.39

Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.	Irrigation requirement daily
1	Deve	0.84	6.92	69.2	1.2	68	6.8
2	Deve	0.99	8.52	85.2	1.8	83.4	8.34
3	Deve	1.15	9	99	8	91	9.1
1	Mid	1.28	8.95	89.5	15	74.5	7.45
2	Mid	1.3	8.19	81.9	20.7	61.3	6.13
3	Mid	1.3	7.43	74.3	25.7	48.6	4.86
1	Mid	1.3	6.57	65.7	31.9	33.9	3.39
2	Mid	1.3	5.77	57.7	37.6	20.1	2.01
3	Mid	1.3	5.65	62.1	37.5	24.6	2.46
1	Mid	1.3	5.57	55.7	36	19.7	1.97
2	Mid	1.3	5.41	54.1	36.2	17.9	1.79
3	Mid	1.3	5.4	59.4	40	19.5	1.95
1	Mid	1.3	5.4	54	48.1	5.9	0.59
2	Mid	1.3	5.39	53.9	53.4	0.5	0.05
3	Mid	1.3	5.61	44.9	41.3	3.6	0.36
1	Mid	1.3	5.83	58.3	25.3	32.9	3.29
2	Mid	1.3	6.04	60.4	14.2	46.3	4.63
3	Mid	1.3	6	66	11.5	54.5	5.45
1	Mid	1.3	5.95	59.5	9.3	50.2	5.02
2	Mid	1.3	5.91	59.1	5.5	53.6	5.36
3	Mid	1.3	5.8	58	3.7	54.4	5.44
1	Late	1.29	5.66	56.6	0.1	56.4	5.64
2	Late	1.25	5.37	53.7	0	53.7	5.37
3	Late	1.2	5.05	55.6	0	55.6	5.56
1	Late	1.15	4.74	47.4	0	47.4	4.74
2	Late	1.11	4.44	44.4	0	44.4	4.44
3	Late	1.07	4.27	42.7	0	42.7	4.27
1	Late	1.02	3.96	39.6	0	39.6	3.96
2	Late	0.98	3.73	37.3	0	37.3	3.73
3	Late	0.94	4.15	45.6	0	45.6	4.56
1	Late	0.9	4.6	32.2	0	32.2	3.22
				2,011.4	**504**	**1,525.9**	

	OS-A	
Irrigation req.	1,525.00	mm
	3,110,000.00	m2
	4,742,750,000.00	liter
	4,742,750.00	m3/year

	OS-B	
Irrigation req.	1,143.75	mm
	3,110,000.00	m2
	3,557,062,500.00	liter
	3,557,062.50	m3/year

	OS-C	
Irrigation req.	491.08	mm
	3,110,000.00	m2
	1,527,258,189.62	liter
	1,527,258.19	m3/year

ANNEX III – ELECTRICITY COSTS

Data received from KASCOL (ZESCO invoices)			
	kWh	Costs	ZMW/kWh
Apr-21	1,148	2,425	2.11
Feb-21	1,151	2,357	2.08
Aug-21	54,463	45,995	0.84
Dec-21	48,529	41,312	0.85
Jun-21	57,451	47,842	0.83
Mar-21	1,204	4,056	3.37
May-21	21,837	20,012	0.92
May 2021-2	9,203	10,920	1.19
Nov-21	50,443	44,091	0.87
Nov 2021-2	19,506	17,660	0.91
Oct-21	56,466	46,745	0.83
Oct 2021-2	32,542	29,608	0.91
Sep-21	65,728	52,349	0.80
Sept 2021-2	50,237	42,090	0.84

	kWh	Costs (ZMW)
Total	469,908	407,462
average cost per kWh (ZMW/kWh) in 2021	0.87	

pumping hours	yearly irrigation water	required hours of pumping	number of full days (24hrs) pumping with 6 pumps	average (2023-2027) assuming 5% increment	costs/ha
OS-A	4,742,750.00	23,713.75	164.68	1,169,154.17	3,759.34
OS-B	3,557,062.50	17,785.31	123.51	876,865.63	2,819.50
OS-C	1,527,258.19	7,636.29	53.03	376,490.49	1,210.58

ANNEX IV – GEO-INFORMATION AND SENSORS

Training on Flying Sensors (drones with dedicated cameras for agriculture and forestry)

The training is composed of three parts,

1. Piloting: manual & automated flights, camera control, safety management
2. Image processing: stitching, preparing orthomosaics, crop stress mapping
3. Interpretation of the process results and in field tablet map viewing

Costs

a. Training
   - Basic (5 days), Pilot skills and basic processing & interpretation - $ 3300
   - Advanced (10 days), Pilot skills and advanced processing & interpretation - $ 6600

b. Flying Sensor kit - $ 2700

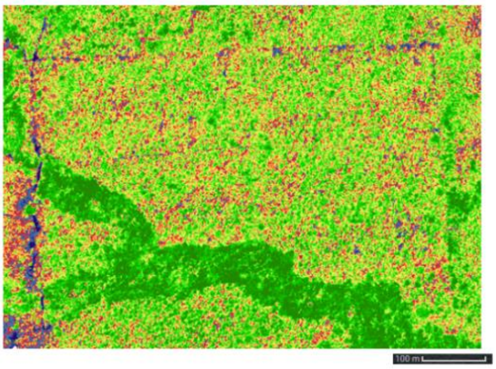
For both training options it is necessary to procure a Flying Sensor kit. The kit contains a Flying Sensor (modified DJI Mavic drone), batteries, charger, backpack, tablet, tablet holder. The kit will be propriety of the off-taker.

Accommodation and transport costs are not included in the cost indication,

Extra options

- Performing flights, NIR en RGB capturing (gpr 3-5 cm) per 100 ha - $ 700
- Image processing basic, Making orthomosaic (NIR en RGB) per 100 ha - $ 500
- Image processing advanced I, NDVI mapping per 100 ha - $ 250
- Image processing advanced II, Making DEM (without GCPs) per 100 ha - $ 500

Background



Teak Plantation in Ghana, RGB and NDVI crop stress map

Derived products of FS images and their relevant applications:

Description	*Example applications*	*Resolution*
Ortho RGB	Overview image Visual inspection Deriving inputs for biophysical model	Max GSR: 2 cm Common GSR: 10 cm
Ortho NIR	Input for NDVI	Max GSR: 2 cm Common GSR: 10 cm
NDVI map	Vegetation stress diagnosis Assessment land degradation (LD) maintenance Assessment bare soil Input for biophysical model	Max GSR: 2 cm Common GSR: 10 cm
Land cover map	Vegetation classification Forestry Land use / land cover change assessment Input for biophysical model	Max GSR: 2 cm Common GSR: 10 cm
DEM	Damage inspection LD volume assessment Evaluating SLM practices / terracing Input for biophysical model	Max x-y res, 5 cm; z res, 5-10 cm Common x-y res, 10 cm; z res, 10-20 cm
3D model	Visualization / dissemination Inspection tool for decision makers	Max x-y res, 5 cm; z res, 5-10 cm Common x-y res, 10 cm; z res, 10-20 cm
KMZ /KML	Localization in Google Earth Visualization / dissemination	Max x-y res, 5 cm; z res, 5-10 cm Common x-y res, 10 cm; z res, 10-20 cm

ANNEX V – DESIGN CRITERIA 311 HA SUB-SURFACE-DRIP IRRIGATION SYSTEM KASCOL

Crop type	Sugar Cane
Area size (ha)	311
Crop spacing	Continuously
Rows distance (m)	1.9
Row direction	Mainly from East to West
Min, Required capacity system (mm/day)	6.8
Emitter flow rate (indication- open for suggestions irrigation supplier) (l/hr)	0.8-1.2 lph designer prerogative within this range)
Emitter spacing (range)	0.4 m – 0.6 m (designer prerogative within this range)
Lateral spacing (m)	1.9
Max irrigation time per day (hours)	20
Soil data:	Clay-loamy 0 cm -45 cm increasing clay content till clay soil 45 cm-100cm (see figure 1)
Effective rooting depth (m)	0.45
Maximum rooting depth (m)	0.95
suggested Irrigation interval	3-5 days
Energy type	Electricity
Water Source	Reservoir (volume 38,800m3) water transferred from Kafue River (see figure 2,3), location pump see KMZ file, other side of the road from figure 2,3,
Min irrigation zone size	Designer prerogative, Flexibility in irrigation is important, when fields reach field capacity they should be able to stop irrigating while fields that did not reach field capacity yet can continue irrigating, (differences might be caused by crop stage, health, soil type etc)
Fertigation:	yes, include fertigation option
Filtration	Primary,-automatic Screen filtration, Block level-semi-automatic filtration

Available Water Quality Report

SCHOOL OF ENGINEERING
CIVIL ENGINEERING DEPARTMENT
ENVIRONMENTAL ENGINEERING LABORATORY
P.O Box 32379, Lusaka

PHYSICAL/CHEMICAL EXAMINATION OF WATER

Attn : Aquaquest
Lusaka
Sampled by : Client
Receipt date : 08.12.2021
Report date : 09.12.2021

Laboratory Results

Parameter	**Kaleya Dam**	ZABS Guideline (Maximum Permissible value for drinking water)
pH	7.86	6.5- 8.0
Total Dissolved Solids (mg/l)	155	1,000
Total Suspended Solids (mg/l)	3.8	-
Total hardness (as mg $CaCO_3$/l)	140	500

Tests carried out in conformity with " Standard Methods for the Examination of water and Wastewater APHA, 1998".

UNIVERSITY OF ZAMBIA
SCHOOL OF ENGINEERING
09 DEC 2021
DEPT. OF CIVIL

Tested by: D. Mkandawire ………. Checked & Approved by: Joshua Liyungu………………….
Lab. Technician Lab. Manager /Co-ordinator

Figure 8 soil profile

Figure 9 option location pump house though space limited, undershot gates plus canal on left side blue square will not be used anymore after installing SDI

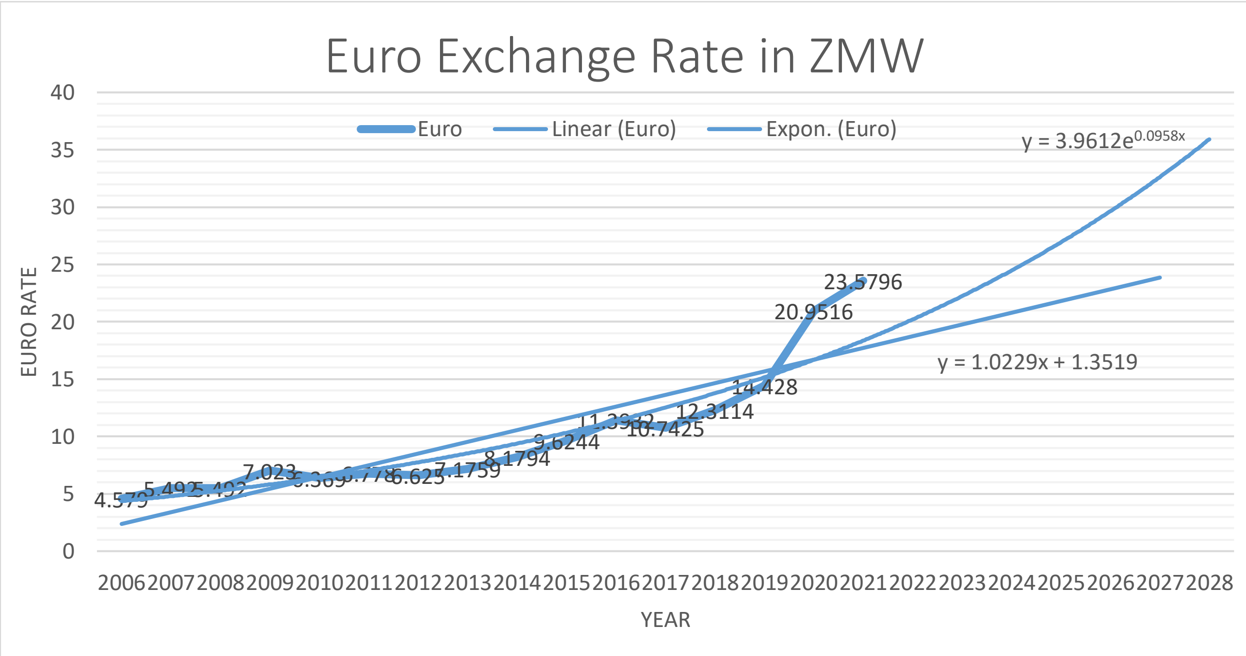
Figure 10 overview dam and option location pumphouse though space is limited

Figure 11 part of the selected fields to be transformed towards SDI irrigation, Currently irrigated by furrows,

ANNEX VI – RETURN ON INVESTMENT ANALYSIS

Year	Price per ton ERC	Source
2016	2,439,03	Data Kascol
2017	3,313,14	Data Kascol
2018	3,213,63	Data Kascol
2019	3,385,11	Data Kascol
2020	3,780,00	Data Kascol
2021	6,203,00	Data Kascol
2022	6,823,30	Based on 10% increase compared with 2021

Average of 2018-2022 = 4,681,01 ZMW / ton ERC



Year	USD:ZMW
2023	19.89
2024	20.92
2025	21.95
2026	22.98
2027	24.01
2028	25.04
2029	26.07

Exchange rate predictions based on Bank of Zambia data and linear trendline

ANNEX VII – CORPORATE GOVERNANCE ASSESSMENT

Annex a. Questionnaire with answers provided by KASCOL

Annex b. List of KASCOL staff interviewed in 8 interviews (in order of time)

Annex c. Literature consulted

Annex d. Development Bank of Zambia Impact Data Records received from KASCOL

Annex e. Overview of staff training 2020-2022

Annex f. Organogram

Annex a. Questionnaire with answers provided by KASCOL

1	**Fill in columns C, D, E, etc. per individual senior staff member. Only for those that will be involved in the new SDI system, whether in the fields, the workshop or the office at technical, administrative, financial or management level. Fill in separately per senior staff member, add columns if needed.**											
	Senior staff member:	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
a	What is the current main function of the staff member?	Estate Manager	Finance Manager	Smallholder & Operations Officer	Risk & Operations	Management Accountant	Human Resources	Financial Accountant	Executive Assistant	Zone Leader	ICT Administr ator	Zone Leader
b	How many years has the staff member been in that function?	8	5	2	4	5	5	3	12	11	7 months	11
c	What other function(s) are being carried out by the same staff member (if any)?				Projects Management							
d	How many years has the staff member been employed at KASCOL?	12	5	8	15	9	11	3	23	13	7 months	32
e	Is the staff member employed full-time of part-time?	Full Time	Full Time	Full Time	Full Time	Full Time	Full Time	Full Time	Full Time	Full Time	Full Time	Full Time
f	Is the staff member male or female?	Male	Male	Male	Male	Male	Female	Male	Female	Male	Male	Male
g	What is the highest educational level of the staff member?	Masters	Masters	Degree	Master	Degree	Degree	Degree	Diploma	Diploma	Degree	
h	Is the current level of education, skills and experience sufficient for the function(s) assigned to staff member?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
i	Which (if any) on-the-job or company-provided in-service training did the member of staff receive?			Management training		Management training						

2		**Fill in for the group of supervisors (only those that will be involved in the new SDI system)**	
	a	What is the total number of supervisors involved in the SDI system?	3
	b	Of this total, how many are female?	None
	c	What is this group's average number of years of experience as supervisors at KASCOL?	
	d	What is the minimum educational level in the group?	Diploma
	e	What is the maximum educational level in the group?	Master's Degree
	f	Which (if any) on-the-job or company-provided in-service training did they receive?	Management training

3		**Fill in for the group of workers (only those that will be involved in the new SDI system)**	
	a	What is the total number that will be involved in the SDI system?	10
	b	Of this total, how many are female?	TBA
	c	What will be their tasks?	General work
	d	What is this group's average number of years of experience at KASCOL.	5-years
	e	What is the minimum educational level in the group?	Primary School
	f	What is the maximum educational level in the group?	Grade 12
	g	Which (if any) on-the-job or company-provided in-service training did they receive?	Business Understanding Program

4		**Fill in for the casual workers (only those that will be involved in the new SDI system)**	
	a	What is the total number of casual workers (only those involved in the SDI system)	20
	b	Of this total, how many are female?	TBA

5		**Does the company have any concrete plan to hire more women?**	
	a	If yes, for which function(s)?	Yes, Checking on leakages in drip lines.
	b	If yes and if there is a target number, what is this target number of new positions for women?	40% of Est.

6	**The major implications of the new SDI system - staff and work force requirements**						
a	Is the current capacity of the staff ad work force overall adequate for introducing and running the new SDI system (possibly with some simple adaptations)?	Yes					
	If not, so the capacity of the staff and work force need to be adjusted,	*What are the changes in the existing functions?*	*What number of new staff is needed in these existing functions?*	*Which new functions are required, and how many staff is needed for each of these new functions?*	*Which extra tools, equipment and/or infrastructure is needed (apart from the planned SDI system itself)?*	*Which changes in remuneration and other conditions of service will be needed, for which functions?*	
b	For the management and administration functions/responsibilities:						
c	For the technical and agricultural functions/responsibilities:						
d	For the functions and responsibilities of the supervisors:						
e	For the functions and responsibilities of the permanent workers:						
f	For the functions and responsibilities of the casual workers:						

7	**The major implications of the new SDI system - knowledge and skills training requirements for the:**	*Agricultural and technical senior staff*	*Agricultural and technical supervisors*	*Agricultural and technical workers*	*Financial staff*	*Management and administration staff*
a	For a satisfactory knowledge level of the staff and work force:	Calibrations for chemigations and fertigation, replacement of pipes, drip lines.	Calibrations for chemigations and fertigation, replacement of pipes, drip lines.	reading of meters and pressure gauge, connecting and replacing pipes, drip lines and	System literature Inventory management and provisioning for automatic, manual and insurance items to support the system.	Placement and training of staff, support staff and shopfloor workers

b	For a satisfactory skills level of the staff and work force:	how to operate the system, and cleaning of filters.	how to operate the system, and cleaning of filters.	cleaning of filters at the field	System literature Inventory management and provisioning for automatic, manual and insurance items to support the system.	Placement and training of staff, support staff and shopfloor workers

8	**The major implications of the new SDI system - other changes and solutions**	
a	What (if any) are the required other changes or solutions, only those relevant for the introduction and running of the new SDI system?	

9	**SWOT analysis of KASCOL as far as relevant for adapting to and running the new SDI system, by component:**	*Farm operations*	*Own technical support services*	*Finances and financial management*	*Management and administration*
a	Strengths: company traits that contribute to an effective and efficient introduction and operation of the new SDI system. Fill in for each of the four mentioned company components.	Dedicated workers to the drip system only	in house and outside training of staff	Established accounting department spanning finance, accounting, procurement and stores	Established Management team, HR Function
b	Weaknesses: company traits that make an effective and efficient introduction and operation of the new SDI system challenging. Fill in for each of the four mentioned company components.	Dependence on Zambia sugar for water and on ZESCO for power.		Specific system costs knowledge is wip	Yet to adopt a formal structure for the section
c	Opportunities: positive conditions or developments outside the company that can strengthen a successful introduction and operation of the new SDI system. Fill in for those of the four mentioned company components that would be affected by it.	improved water supply and electricity	training of staff to have more technical know-how.	A great opportunity to realise precision cost management	Opportunity to streamline operations
d	Threats: risky conditions or negative developments outside the company that can hamper or even prevent the introduction or successful operation of the new SDI system. Fill in for those of the four mentioned company components that would be affected by it.	prolonged load shedding	outward migration of trained staff.	Unknown extent of cost exposure in running the system	Higher pay rates for skilled labour

10	**Any other observations**	

Annex b. List of KASCOL staff interviewed in 8 interviews (in order of time)

Interview	Interviewee(s)	Function
1	Kelvin Mwiinga	Risk & Operations Officer
2	Austin Hayumbu	Irrigator
	Cutwell Muleya	Irrigator
	Honest Kayombo	Irrigator
	Sternley Chingumbe	Irrigator
	Ernest Jalabani	Pump attendant
	Meselina Nyendwa	Pump attendant
3	Oscar Meja	Zone leader
	Lawrence Kayomba	Zone leader
4	Mutinta Chilala	Human Resource Associate
5	Maybron Nansayi	Smallholder & Operations Officer
6	Muimui Mufana	Estate Manager & CEO
7	Percy Simunika	Finance & ICT Manager, and company Secretary
8	Alex Sinyama	Management Accountant
	Jerry Nyambe	Financial Accountant

Annex c. Literature consulted

https://eprints.whiterose.ac.uk/141050/1/Journal%20of%20Development%20Studies%20Author%20Accepted%20Version.pdf

https://thedfcd.com/2021/07/22/the-dfcd-partners-with-zambian-cane-sugar-grower-to-make-its-irrigation-climate-smart/

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www.illovosugarafrica.com/media/documents/socio-economic-impact-report/Illovo-Impact-Report-Zambia-Dec17.pdf

www.jstor.org/stable/pdf/resrep18063.9.pdf?refreqid=excelsior%3A36efe8d4cde120c34cb86b375b7199d1&ab_segments=&origin=

www.wwf.nl/wat-we-doen/aanpak/internationaal/Dutch-Fund-for-Climate-and-Development/zambian-cane-sugar-grower

Annex d. Development Bank of Zambia Impact Data Records received from KASCOL

IMPACT DATA RECORDS

Project Name	KALEYA SMALLHOLDERS COMPANY LIMITED
Date of Data Capture	APRIL – DECEMBER 2021

1. Employment Data

Direct Jobs	Male	Female	Low/Semi Skilled		Youths (Under 36)	
			Male	Female	Male	Female
Total Number of Full Time Employees	66	12	49	5	18	4
Total Number of Part Time Employees	634	91	99	3	181	33
Total Full Time Employees (PTE = 0.5FTE)	66	12	49	5	18	4

Entrepreneur(s) Under 35 years of Age at Investment Date (Y/N)	N
Number of Women in Senior Management	N
Percentage of Shares Owned by Women Entrepreneurs	N

2. Industry Specific Data

Impact Data	Recorded Data	Applicable industry
Number of Customers Served Directly	119	All industries
Number of Customers Served Indirectly	3,500+	All industries
Number of Farmers /Primary Producers /Suppliers Supported	160	All industries
Number of Patients Supported	2,272	Healthcare
Number of Students Supported	990	Education

3. Financial Information

Annual Financials

Income Statement and Balance Sheet Provided by Client (Y/N)	Y
Time Period of Latest Annual Financial Statements	31/03/2021

Management Accounts

Income Statement and Balance Sheet Provided by Client (Y/N)	Y
Period of Latest Management Accounts	30/11/2021

4. Validation		
	Business Owner/Manager	**DBZ Portfolio Manager**
Name	MUIMUI MUFANA	
Signature		
Date	22/12/2021	

Comments

- Direct Customer base includes housing tenants, trade, others.
- Indirect Customers base includes catchment areas.
- Part time Employees on seasonal employment i.e. April – November 2018.

Annex e. Overview of staff training 2020-2022

KALEYA SMALL HOLDERS COMPANY LIMITED **TRAINING FOR THE PERIOD 2020-2022**

Fully sponsored study by the company

NAME	JOB TITLE	DEPARTMENT	SPONSORED COURSE
Kelvin Mwiinga	Risk & Operations Officer	Finance	Risk Management
Alex Sinyama	Management Accountant	Finance	Master in Finance Accounting
Jerry Nyambe	Financial Accountant	Finance	Master in Finance Accounting
Shadreck Chiwala	Human Resource Assistant	Human Resource	Bachelor of HRM
Moses Mumba	Payroll Accountant	Finance	Master in Finance Accounting
Gelson Mwale	ICT Support Administrator	Finance	Bachelor of Science in Computing
Audrey Meja	Accounts Assistant	Finance	Bachelor of Accounting and Finance
Oscar Meja	Zone Leader	Agriculture	Bachelor of Agricultural Business Manage
Theo Mulumbu	Buyer	Finance	Certificate in Purchasing & Supplying
Vinordy Mudenda	Stores Keeper	Finance	Advanced Certificate in Purchasing & Supplying

Other trainings

Training on Dove personnel and payroll

NAME	JOB TITLE	DEPARTMENT
Mutinta Chilala	Human Resource Associate	Human Resource
Shadreck Chiwala	Human Resource Assistant	Human Resource
Esnart Chisenga	Agric Information Assistant	Agriculture
Moses Mumba	Payroll Accountant	Finance
Gelson Mwale	ICT System Administrator	Finance

Zambia Institute of Purchasing & Supply training

NAME	JOB TITLE	DEPARTMENT
Kelvin Mwiinga	Risk & Operations Officer	Finance

Procurement sensitization training

NAME	JOB TITLE	DEPARTMENT
Theophilus Mulumbu	Buyer	Finance
Vinordy Mudenda	Stores Keeper	Finance

Training on optimizing human capital

NAME	JOB TITLE	DEPARTMENT
Mutinta Chilala	Human Resource Associate	Human Resource
Shadreck Chiwala	Human Resource Assistant	Human Resource

Training on food value chains

NAME	JOB TITLE	DEPARTMENT
Percy Simunika	Finance & ICT Manager	Finance

Pensions & Insurance training

NAME	JOB TITLE	DEPARTMENT
Mutinta Chilala	Human Resource Associate	Human Resource

Shadreck Chiwala	Human Resource Assistant	Human Resource

Supervisors training for Field Capitao

NAME	JOB TITLE	DEPARTMENT
Pardon Namwakili	Field Capitao	Agriculture
Titus Mweemba	Field Capitao	Agriculture
Muyoywa Mafenyeho	Field Capitao	Agriculture
Edward Chabwe	Field Capitao	Agriculture
Jolophan Njobvu	Field Capitao	Agriculture
Milner Siawala	Field Capitao	Agriculture
Anthony Mulenga	Field Capitao	Agriculture
Vien Chilala	Field Capitao	Agriculture
Whyclif Miyoba	Field Capitao	Agriculture
Simon Kalibaliba	Field Capitao	Agriculture
Charity Siabeenzu	Field Capitao	Agriculture
Johonny Namaloya	Field Capitao	Agriculture
Brian Mutondo	Field Capitao	Agriculture

Sage evolution accounting software skills training

NAME	JOB TITLE	DEPARTMENT
Theo Mulumbu	Buyer	Finance
Moses Mumba	Payroll Accountant	Finance
Audrey Meja	Accounts Assistant	Finance

ZIPS training

NAME	JOB TITLE	DEPARTMENT
Kelvin Mwiinga	Risk & Operations Officer	Finance

Training on dove personnel and payroll

NAME	JOB TITLE	DEPARTMENT
Mutinta Chilala	Human Resource Associate	Human Resource
Shadreck Chiwala	Human Resource Assistant	Human Resource
Esnart Chisenga	Agric Information Assistant	Agriculture
Moses Mumba	Payroll Accountant	Finance
Gelson Mwale	ICT System Administrator	Finance

Drip Irrigation training

NAME	JOB TITLE	DEPARTMENT
Maybron Nansayi	Smallholder & Operations Officer	Agriculture
Mosses Siyoyo	Senior Zone Leader	Agriculture
Oscar Meja	Zone Leader	Agriculture
Lawrence Kayombo	Zone Leader	Agriculture
Ernest Jalabani	Pump Attendant	Agriculture
Meselina Nyendwa	Pump Attendant	Agriculture
Cutwel Muleya	Irrigator	Agriculture
Honest Kayombo	Irrigator	Agriculture
Kyson Bbakala	Water Coordinator	Agriculture
Sternley Chingumbe	Irrigator	Agriculture

First Aid and Chemical handling Training

NAME	JOB TITLE	DEPARTMENT
Maybron Nansayi	Smallholder & Operations Officer	Agriculture
Mosses Siyoyo	Senior Zone Leader	Agriculture

Oscar Meja	Zone Leader	Agriculture
Lawrence Kayombo	Zone Leader	Agriculture
Ernest Jalabani	Pump Attendant	Agriculture
Meselina Nyendwa	Pump Attendant	Agriculture
Cutwel Muleya	Irrigator	Agriculture
Honest Kayombo	Irrigator	Agriculture
Kyson Bbakala	Water Coordinator	Agriculture
Sternley Chingumbe	Irrigator	Agriculture

Training by South African Sugarcane Research Institute

NAME	JOB TITLE	DEPARTMENT
Maybron Nansayi	Smallholder & Operations Officer	Agriculture
Lawrence Kayombo	Zone Leader	Agriculture
Oscar Meja	Zone Leader	Agriculture
Esnart Chisenga	Agric Information Ass	Agriculture

Annex f. Organogram