SOSIA
Satellite-based Irrigation Advice

Holland Greentech

FutureWater

Report Phase 2

SOSIA: Small-Scale Open-Source Satellite-based Irrigation Advice

REPORT 240

CLIENT Netherlands Space Office

AUTHORS FutureWater
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Content

List of Abbreviations

AE	Application Efficiency
CFSv2	Climate Forecast System Version 2
CWR	Crop Water Requirements
ETa	Actual Evaporation
ETc	Crop Evaporation
ETref	Reference Evaporation
EUR	Euro
FAO	Food and Agriculture Organization of the United Nations
FW	FutureWater
GEE	Google Earth Engine
GPM	Global Precipitation Measurement
HGT	Holland Greentech
hp	Horsepower
IAT	Irrigation Advisory Tool
K	Kwacha (1K = 0.048 EUR)
LR	Leaching Requirement
LQ	Learning Questions
NSO	Netherlands Space Office
OS	Open-Source
P	Precipitation
R^2	R-squared
RAB	Rwanda Agriculture Board
RH	Relative Humidity
Rsw↓	Incoming Shortwave (solar) radiation
SOSIA	Small-Scale Open-Source Satellite-based Irrigation Advise
T	Temperature
Tair	Air Temperature
ToC	Theory of Change
u	Wind speed at 2-meter height
USD	United States of American Dollar (1 USD = 0.93 EUR)
VWS	Virtual Weather Stations
WaPOR	The FAO Water Productivity Open-access portal
WFP	World Food Programme
WP	Work Package
WTP	Willingness-to-Pay

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1 Project Information

Netherlands Space Office (NSO) launched a two-stage call for innovations based on open-source (OS) geodata aimed at positively impacting food security and sustainable land and water management in Africa. After submitting a successful proposal in the framework of this call, FutureWater (Innovator) in cooperation with Holland Greentech Rwanda (Intermediary) have completed Phase 1 (see report phase 1) and phase 2 of a project which has evaluated the feasibility of SOSIA over the past year, a small-scale open source-based irrigation advisory service. This report describes activities, results and main learning points of the innovation study and explains how SOSIA has contributed to the objectives of the NSO call for innovations.

The SOSIA tool has been developed for smallholder farmers, with the initial user base foreseen in Rwanda and Zambia as both countries served as pilot countries in phase 2. The tool relies on a package that defines so-called Virtual Weather Stations (VWS) to determine an irrigation advice for small and medium scale farmers. The output of the tool is an estimated irrigation duration for different irrigation systems and crop types (Figure 1). The tools can be accessed through online URLs for the Virtual Weather Stations (link)[1] and for the Irrigation Advisory Tool (link)[2]. These links show the base versions of the tool, the final product is only accessible to the intermediary as the embedded database contains user information that should be protected from external parties to be in line with general data privacy regulations.

In Rwanda and Zambia, agriculture is one of the key sectors of economic importance and contributes up to 33% of the GDP. It provides employment for more than 70 percent of the national labour force. Although some Rwandese and Zambian farmers use water efficient irrigation-infrastructures, a large part of available water is lost because of unsustainable use of available irrigation systems, or maximum crop yield is not achieved due to under-irrigation. Both impacts of suboptimal irrigation management are caused by a lack of information on effective irrigation timing, duration, and volumes in relation to crop stage and actual and expected weather conditions.

Figure 1. SOSIA tool showcasing the two main packages.

Irrigation advisory software currently exists primarily for large-scale farms, but for small- to medium-scale farmers it is not feasible to access and utilize these tools. The investment in terms of time, money and necessary technical knowledge is too high for this group of farmers. Advice based on simplified tools such as CROPWAT is available; this is accessible and inexpensive but is not context-specific and therefore leads to suboptimal irrigation advice.

SOSIA aimed to overcome these challenges by making use of the latest state-of-the-art OS geodata to ensure a reliable, location-specific advice which does not require additional knowledge of irrigation practices. During the feasibility stage of this project (phase 1), FutureWater (FW), in close consultation

[1] https://futurewaternl.users.earthengine.app/view/virtualweatherstation
[2] https://futurewaternl.users.earthengine.app/view/sosia-crop-schedule-table

with its intermediary local partner Holland Greentech (HGT) Rwanda, has developed an initial version of the SOSIA tool and ran preliminary tests to assess its feasibility. After successfully trialling the different versions of the SOSIA tool, as this was a continuous process, in Rwanda (and Zambia from phase 2 onwards), SOSIA has shown to assist service providers of HGT with improved information on weather conditions and irrigation water requirements, directly affecting the water use and crop productivity of farmers within the network of HGT. During phase 2 specifically, the tool was further strengthened by adding a hindcast component to the advice. In addition, as mentioned before, the user-base of the tool expanded to HGT Zambia for which a successful launch event was held.

Chapter 1 of this report summarizes the main findings of Phase 1 and 2 of the project. Section 0 describes the individual consortium partners, as well as their synergies and role division. Section 0 presents the project organization and structure specific for phase 2, although relevant findings obtained in phase 1 have been summarized. Subsequently, Section 0 describes the project results regarding technological and economic feasibility, as well insights gained into the expected local impact of SOSIA. Section 0 discusses the main learning questions answered during this innovation project, which were defined at the start of the feasibility stage. Ultimately, Section 0 shows how the originally foreseen Theory of Change (ToC) has ultimately been affected by the activities implemented during this project.

2 Consortium Partners

2.1 FutureWater (Innovator)

FutureWater (FW) has over 20 years of experience in agriculture and water consultancy and product development, quantification of crop water requirements and consumption, agricultural water management including irrigation and drought management, river basin hydrology, and climate risk assessments. FW provides high-quality services around the world by combining scientific research with practical water management solutions. FW uses state-of-the-art quantitative methods in its work for practical solutions in water resource assessments. FW has offices in Wageningen and Cartagena (Spain) and has satellite offices in countries with substantial activities: Maputo (Mozambique), Phnom Penh (Cambodia) and Meru (Kenya).

FW has extensive experience in applying OS geodata to support farmers in African countries (Egypt, Kenya, Mozambique among others), and has a long-standing cooperation with agencies involved in water resources management and agriculture in Rwanda and Zambia. As experts in agro-hydrological modelling, FW typically combines geodata with a modelling approach to evaluate water use and provide advice on water management and crop production.

2.2 Holland Greentech (Intermediary partner)

Holland Greentech (HGT) is developing the next step in horticulture in Sub-Saharan Africa. Since 2015, HGT has been providing an integrated package of agricultural products and services to its customer base. The company represents a group of mainly Dutch horticultural suppliers such as Rijk Zwaan, Koppert, AgroCares, Jiffy and Rivulis in combination with a team of more than 100 experts spread over 12 country offices. HGT's core expertise relates to scaling and growing impact for thousands of farmers, based on the business case of the individual farmer. HGT delivered complete irrigation kits to hundreds of farmers in 2022 and expects to continue to grow strongly in their teams, customer base and service packages over the coming years. In addition, the company is highly experienced in introducing commercial services to the agricultural sector.

HGT has been active in Rwanda since 2015 and has more than 1500 customers across the country, of which over 40 irrigation customers who have purchased irrigation kits. The Zambia office has started in 2018 and has serviced over 500 irrigation clients with drip irrigation, mainly for vegetable crops.

2.3 Role division

With their joint expertise in agro-hydrological service development and the African agricultural sector, FW and HGT have built up ample capacity to make this innovation project successfully achieve its great potential impact on food security and sustainable land and water management in Sub-Saharan Africa.

FW had a leading role in this first phase and second phase, especially in the development of the SOSIA prototype. As the innovation developer, FW took the lead in all work packages, where most of the time was invested in establishing the Virtual Weather Stations (VWS) approach based on OS geodata, its translation into SOSIA, and development of an intuitive graphical user interface which disseminates the information and advice to the user.

As the intermediary, the input of HGT has been instrumental for clarification of the local context and maintaining an active relationship with the (end) users. Under coordination of HGT, the prototype of the tool and the first versions of its results were discussed in-depth with selected farmers in Rwanda and Zambia as well as the HGT staff based in-country. They have overseen the trials in both countries and monitored the use of the tool throughout the innovation process.

Evaluation and reporting of the project activities, including the knowledge component, was undertaken by both parties. The obtained insights are shared with NSO in this report and are shared with the sector through the media channels of both partners.

HGT is the most suitable intermediary to market this innovation since it already has an extensive network of customers for their irrigation products. After developing SOSIA, it can be applied directly by the HGT team to existing customers and/or to design irrigation systems for new customers. As a result, the prototype obtained at the end of phase 1 was successfully scaled up during Phase 2, both inside and outside Rwanda and Zambia.

3 Project Activities Phase 2

In this section, the work performed in each Work Package (WP) to develop the SOSIA tool is presented. Where relevant, a summary of the Phase 1 activities is provided. For each work package, its main goals are described, followed by a detailed overview of activities to address these goals. A complete description of the project activities before commencement of this second phase can be obtained from the Phase 1 report.

3.1 WP 1: Pilot Field Study (trial and demonstration)

Work Package 1 focused on running an effective field trial using the SOSIA tool in Rwanda, followed by an expansion to Zambia. The tool was implemented in several pilot plots, which were monitored by HGT staff. These pilot plots were used to demonstrate the practical implementation of the tool to other HGT staff and interested farmers in the region, as well as served as a first validation on the extent to which SOSIA impacts the farm management. Therefore, close monitoring and evaluation of each of the trial farms and farmers were put in place.

While Phase 1 focused on identifying the users of SOSIA, Phase 2 focused primarily on testing the different versions of the tool in the field. In November 2022 and February 2023, two field trips were conducted to respectively Rwanda and Zambia to evaluate the findings of the farmers and extension-officers regarding the use of the SOSIA advice locally.

The intermediary HGT has a vast team of experts (extension officers, irrigation engineers, etc.) which guided the farmers in the trials. The intermediary is a user of the tool, but they also were interviewed as part of the trials as they translate SOSIA into a tangible and simplified advice used by the farmers (end-users) in Rwanda (Figure 2) and Zambia. These end users of the SOSIA tools have the following characteristics:

Figure 2. HGT extension officer in the field of a client

- Field(s) under irrigation between 0.25 and 10 ha
- Small- and medium scale commercially oriented growers
- Drive towards precision agriculture
- Open to apply new technologies to improve their farm operations
- Values (information) services to improve farming operations.
- Benefits from more efficient water use (e.g., limited water available/pumping costs)
- Owns a smartphone onto which he/ she can receive an irrigation advice or is able to read/ understand a printed PDF provided by the extension officers.

The interviews were only held with farmers that were involved in the trials, for which HGT had made a selection in both Rwanda and Zambia by the end of Phase 1. A total of 10 pilot farmers were involved, 5 in Rwanda and 5 in Zambia. Ultimately, 8 farmers were interviewed by the intermediary over the course of the project as two farmers unfortunately dropped out. In addition, the HGT Zambia office also tested the tool on their own demo plot at the office.

At the start of the 2nd-phase trials, some challenges were faced regarding the rate of adoption of the SOSIA advice in Rwanda. As farmers did not want to commit 100% of their plots of land for testing the advice, the trials got delayed. Luckily, some easy adjustments were applied to the drip infrastructure so

that the SOSIA irrigation trial plot would consist of a few rows within a larger field. The farmers subsequently irrigated the field with his/ her traditional irrigation duration, except for the beds where SOSIA was trialled.

As a hindcast on evapotranspiration and rainfall was included in the SOSIA advice, specific focus during the trials was on validating whether the numbers presented in the tool aligned with observations from the field. Therefore, manual rain gauges were provided to the involved trial-farmers and logs were kept of daily precipitation amounts in mm. Throughout the pilot study, field data was collected from the plots which were used in the quality assessment activities (Section 3.3). Specifically, the irrigation timing and the in-field precipitation measurements were recorded for which the farmers were provided with a printed logbook (Annex 18). An evaluation form was compiled and filled out by HGT together with the farmer at various intervals over the course of the trial period. These logbooks were then used as the end of Phase 2 to validate the data output by the tool with the field measurements of precipitation, and it was checked whether the farmer exactly followed the advice or deviated for whatever reason. For example, Mrs Wood in Zambia (Annex 15) indicated that during the growth stage of her eggplant crop, she sometimes irrigated more as she noticed the soil was drier than what she would like to see. Nonetheless, for her, an irrigation duration reduction of about 50% was obtained for the whole cropping season.

Data on harvest was unfortunately not possible to validate as the farmers only applied the SOSIA advice for part of their driplines, and yield was not monitored separately for the demo and control drip lines. However, qualitatively the farmers stated to not have seen a positive nor negative difference in yield or quality of the harvest.

Also, a general limitation of the trials lied in the season at which they took place. The dry season in Rwanda and Zambia ranges from April-June to October-November. For this reason, monitoring the pilot plots during a full dry season was not possible for the tool, considering the project timing. Fortunately, some farmers were already testing the 1st version of the tool between Phase 1 and Phase 2 of the project, enabling us to measure some impact with the first version of SOSIA in Rwanda. Also, for Zambia the dry period between September and November was covered by the second version of SOSIA. The latest version (SOSIA v3.0), including the hindcasting was tested from December onwards and therefore did not cover the dry season.

3.2 WP 2: Tool Improvements

3.2.1 Status quo after Phase 1

Work Package 2 focused on further developing the prototype into an operational and multi-purpose tool adapted to the needs of the intermediary and end users. In Phase 1, multiple goals were defined for the SOSIA tool, namely:

1) To make OS satellite-based data more accessible to agricultural extension officers and subsequently to farmers, who currently lack access to (open source) remote sensing data for irrigation advisory purposes,
2) To provide state-of-the-art regional weather input data,
3) To present a Historical Crop Schedule, which uses historical Reference Evapotranspiration (ET_{ref}) to calculate daily crop evapotranspiration (ET_c), water volumes and irrigation duration (expressed in minutes) for the whole cropping season.

Google Earth Engine[1] (GEE) was selected as the main platform for developing the SOSIA tool. A main advantage is that GEE, being a cloud computing solution, does not require to have data stored and processed locally. GEE has capabilities for both analysing remote sensing satellite data and visualizing the outputs. Furthermore, it has the possibility to make a dashboard interface for the users, which is easy and intuitive to use. After selection of the platform, various open-source datasets available on GEE were

[1] https://earthengine.google.com/

analyzed to determine their individual and combined applicability for integration into an ensemble of SOSIA data, based on the scope of the service and user needs (Table 1). Datasets that have more recent images available were selected over other datasets due to its applicability for an operational tool, where farmers need recent information. With the identified user needs in mind, the first version of the SOSIA tool was developed.

Throughout Phase 1 (and also in Phase 2) of the project, there has been a need for converting the spatial nature of the OS geodata products to point-based information. Computational routines were developed to process the geodata, each with their own specifications regarding spatial resolution, to support consistent irrigation advice to farmers across Rwanda and Zambia. As can be seen in Table 1, the data is not available on a very small scale, however they are still expected to improve the current situation where farmers rely on national climate data.

Table 1. Overview of weather-related datasets available on Google Earth Engine with in bold-face the data used.

Name data set	Most recent? *	Historical / Forecast	Resolution	P^	ET_0^	T_{air}^	$R_{sw\downarrow}$^	RH^	u^
ERA5 Hourly	28-01-2022	Historical			✓	✓	✓		
WaPOR RET Daily	09-04-2022	Historical	20km		✓				
GLDAS 3 Hourly	13-03-2022	Historical	28km		✓	✓	✓	✓	✓
CFSV2 6 Hourly	10-4-2022	Historical	22km		✓	✓	✓	✓	✓
CHIRPS Daily	28-02-2022	Historical	5 km	✓					
GPM Half-hourly	11-4-2022	Historical	11 km	✓					
GFS 3 Hourly	11-4-2022 (16-day forecast)	Forecasting	27 km	✓		✓	✓	✓	✓
Sentinel-2A	**05-04-2022**	**Historical**	**10 m**						

** Documented on 12-04-2022*

^ P = precipitation, ET_0 = reference evapotranspiration, T_{air} = air temperature, $R_{sw\downarrow}$ = incoming shortwave (solar) radiation, RH = relative humidity, u = wind speed at 2-meter height,

SOSIA 1.0 focused on a Historical Cropping Schedule. In the SOSIA portal, the user (irrigation engineer of HGT Rwanda or Zambia) could generate crop schedules for each of the farmers for each of their specific crop types for a given planting and harvesting date, drip irrigation system dimensions and location of the farmer. The tool was based mainly on evapotranspiration and gave irrigation information based on the water deficiency of specific crop types. Reference evapotranspiration (ET_{ref}) was obtained from the FAO-WaPOR dataset and focused on a 10-year average. The crop-specific Crop Factor (K_c) was derived from the FAO56 handbook for different plant stages. Based on K_c and ET_{ref}, the daily potential crop evapotranspiration (ET_c) was retrieved. ET_c can be used to derive the daily deficit of the plant in mm, which needs to be compensated by irrigation. ET_c was calculated through the following formula:

$$ET_c \left[\frac{mm}{day}\right] = ET_{ref} * K_c,$$

For translation of ET_c into daily irrigation volumes, field-specific information is required. As the advice is specific for one field and one crop only, the dimensions of the field must be known. This information is entered into the tool by the Irrigation Engineer. The area of the field is calculated through the total length of the driplines, number of driplines and bed width.

$$Irrigation\ volume\ \left[\frac{m^3}{day}\right] = \frac{ET_c}{1000}[m] * field\ area\ [m^2]$$

Furthermore, the irrigation duration was derived from information entered by the HGT service provider, such as the flowrate per emitter and the emitter spacing. For pipe flow, the leaching requirement (LR) and application efficiency (AE) are also considered. With this information the total flow of the dripline is calculated:

$$Flow\left[\frac{m^3}{day}\right] = \frac{dripline\ length}{emitter\ space} * flowrate * AE * LR$$

With flow and irrigation volume estimates, the minutes required to irrigate per day are calculated, which constitute the location-specific output of the SOSIA application.

These calculations led to a daily crop schedule for the season of the specific crop, based on 10-year averaged historical evaporation data, derived from the embedded VWS application. The season is specified by the crop, which has specific durations and specific K_c-values for the early-, mid- and late planting stages (FAO56). The crops accounted for in Phase 1 were Habanero Peppers, French Beans, Onions, and Lettuce. These crops were suggested by the intermediate, as most HGT clients who were to be included in the field trials were planting these crops.

3.2.2 SOSIA development Phase 2

In Phase 2, SOSIA was further developed towards a version 3.0 according to the tool development timeline shown in Figure 3. Both technical and user interface improvements were made. Expected technical improvements were outlined in the Phase 2 proposal submitted to NSO. Below, for each of these expected improvements a description is given of the extent to which they were indeed implemented. The expected activities regarding soil water storage and other irrigation methods were eventually not realized in SOSIA 3.0, for reasons explained in the technical feasibility (Section 4.2.3).

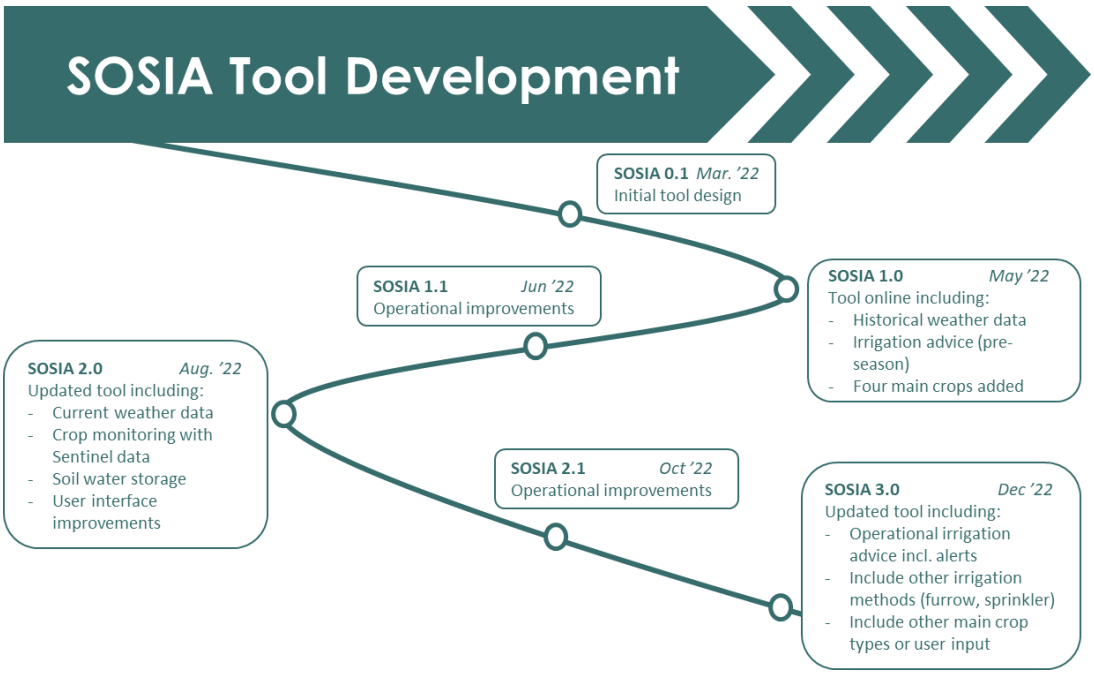


Figure 3. Tool Development Timeline

Uptake of current weather data

One of the most important additions to the tool is the hindcast function, as current weather data is taken into account in this way. In Phase 1, a seasonal crop schedule was shared with the farmers at the beginning of the season, simultaneously with sowing the fields. The historical crop schedule is based on the last 10 years of evaporation data of WaPOR and remains to be the core output of SOSIA. However, since weather patterns are increasingly uncertain with climate change, a need for accounting for the latest weather information was deemed crucial for SOSIA to be relevant. To account for this uncertainty, a hindcasting satellite data product was included in the source code. The hindcasted crop schedule is based on the Climate Forecast Version 2 (CFSv2) product of last week, which consists of multiple bands from which ETref is calculated using the Penman-Monteith formula:

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$ [1]

With this addition, HGT staff can now inform the farmers for which the hindcast shows significantly different irrigation durations compared to the historic advice. In response, farmers will be able to adjust their seasonal irrigation schedules weekly, allowing them to compensate for under-irrigation mostly. The procedure is as follows (Figure 4):

1. A HGT irrigation engineer calculates the seasonal crop schedule for a certain farmer and a certain crop at the beginning of the growing season (day 1).
2. HGT provides the crop schedule to the farmer, either as a printed pdf or via WhatsApp.
3. The farmer irrigates the first week as indicated by the seasonal crop schedule.
4. After one week, HGT-staff checks the SOSIA tool again, but this time the hindcast irrigation advice is selected.
5. The SOSIA hindcast-option calculates the irrigation advice of last week and checks it against the irrigation duration advice for the same period provided in the historical seasonal crop schedule and compares the two values.
6. The Hindcasted Irrigation Advice gives a message to the HGT irrigation engineer. If the hindcasted irrigation advice advises significantly more irrigation minutes than what was advised through the seasonal crop schedule, the application gives the following message: *Warning! Irrigation was **not sufficient** last week. Please irrigate for X minutes extra this week*. If the seasonal crop schedule advised enough irrigation minutes the following message is given: *The irrigation Schedule of last week provided enough water*.
7. Only if the HGT irrigation engineer sees the former message: "*Warning! Irrigation was **not sufficient** last week*", he/she will take action and inform the respective farmer with an update to apply over the coming week over SMS or WhatsApp. Otherwise, the farmer will just follow for that week the advice as outlined in his seasonal advice which he received at the start.

A schematization of this process can be found in Figure 4.

To protect farmers from underirrigation, the highest irrigation advice is chosen. This means that if the hindcasted data gives lower irrigation values than the historical crop schedule, this is not reflected in the advice and the message still reads: *The irrigation Schedule of last week provided enough water*.

Rainfall correction

Correction for rainfall amounts was incorporated for a more accurate depiction of the water balance. Rainfall correction is available for both the historical and hindcasted crop schedule. For the historical crop schedule, the average rainfall of the last ten years for that day is subtracted from the evaporation deficit. For the hindcast, the rainfall of last week is subtracted from the evaporation deficit of last week.

[1] https://www.fao.org/3/x0490e/x0490e06.htm

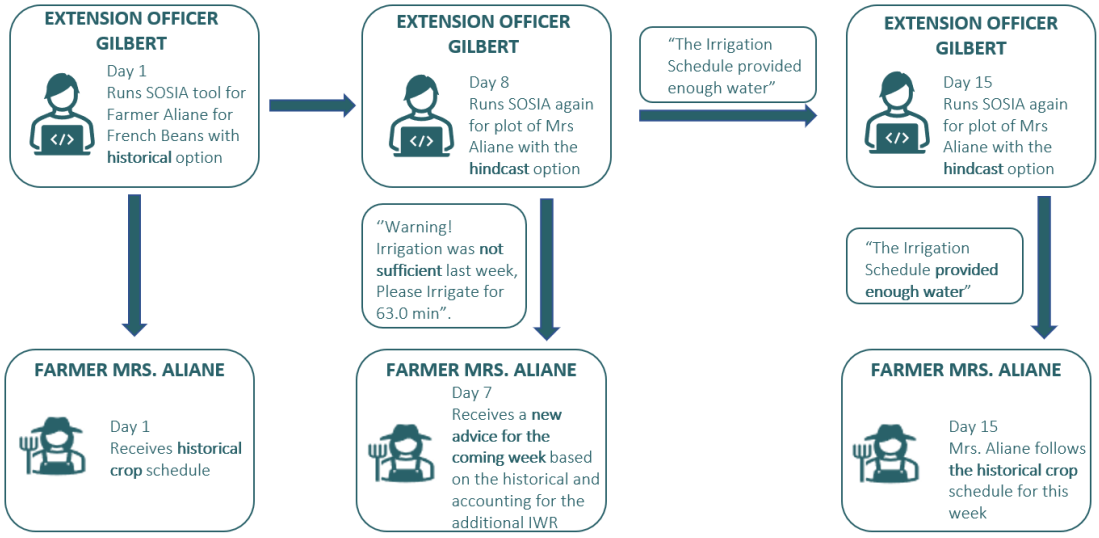


Figure 4. Schematic representation of the operation of the hindcasted irrigation advice

Subsequently, the process of Figure 4 also applies to the advice with rainfall subtraction. For rainfall, the open-source GPM dataset was consulted, which is available in GEE. Furthermore, because rainfall is a very local process and the OS geodata available for rainfall is +/- 11 km, the trial farmers were provided with manual rain gauges and logbooks to validate this critical rainfall component. During the trials the use of rainfall is described by the following procedure:

1. The extension officer calculates hindcasted rainfall using the SOSIA tool.
2. The extension officer asked the farmer for rain gauge information through WhatsApp and compares the rain gauge information to the hindcasted rainfall information.
3. If the rain gauge information and the hindcasted rainfall information were similar, the extension officer subtracts the hindcasted rainfall from the hindcasted evaporation deficit.
4. If the rain gauge information differed significantly from the hindcasted rainfall information, the farmer used a site-specific conversion table to deduct irrigation minutes from the usual schedule. This table accounts for the field size and infrastructure and shows a reduction in irrigation duration (min) per mm of precipitation.

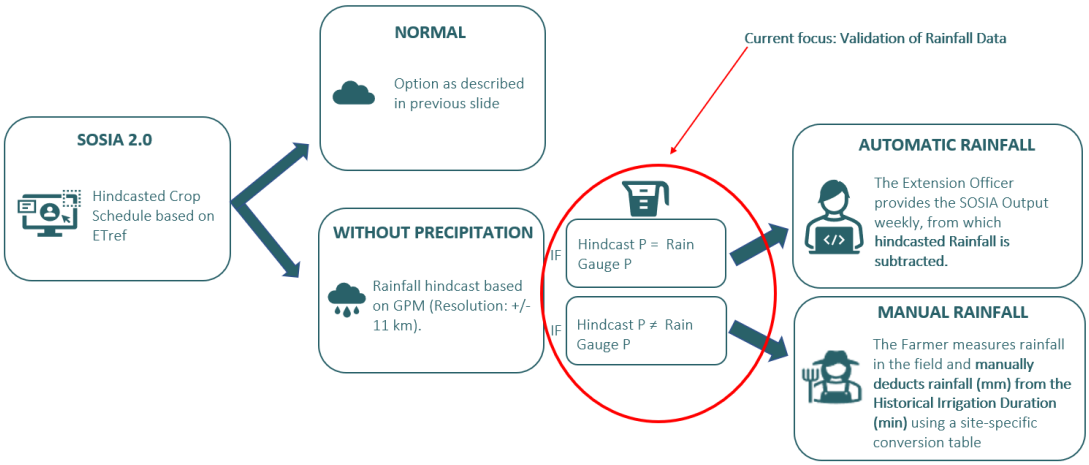


Figure 5. Schematic representation of the rainfall subtraction process using SOSIA

Crop factor calculation through Sentinel-2

The historical crop schedule assumes crop coefficients from FAO-56. SOSIA cannot use averaged Sentinel-2 data for the last 10 years for average crop development, as farmers grow different crops, use a field multiple times a year and use different sowing and harvesting dates every year. Therefore, the FAO-56 values were found to be a good starting point for the seasonal crop schedule. An additional functionality was added which enables to calculate the Kc value through Sentinel-2 for the hindcasted irrigation advice. This was done by calculating NDVI and setting ranges for a minimum and maximum Kc for a crop. Ultimately the Kc is modelled by the following formula:

$$Kc = Kc_{\min} + (Kc_{\max} - Kc_{\min}) * \frac{(NDVI - NDVI_{\min})}{NDVI_{\max} - NDVI_{\min}}$$

Integration of additional crops

In addition to technical improvements, user-friendliness improvements have also been added to the SOSIA tool. Holland Greentech extension officers worked with the app throughout the development process and provided feedback continuously. The first feedback was the addition of more crops and crop groups for which the Kc value does not differ substantially. Ultimately, the extension officers asked for the addition of four other crop categories: Leafy Vegetables, Fruity Vegetables, Pulses and Brassica, which were all added for SOSIA 2.0.

Integration of farmer database

During the tests over the course of Phase 2, feedback was provided regarding the time it took irrigation engineers to fill out the tool. To minimize efforts required for providing input to the SOSIA tool, a database of (for now) trial farmers was added to the backend of the application. A functionality in the interface of the application was added which allows the user to choose a farmer from a drop-down menu. Because the database consists of personal information of different farmers, an extra protection layer was added to the application, to protect the information of the trial farmers. For example, employees of Holland GreenTech Zambia were invited to the SOSIA Zambia application, and the employees of Holland GreenTech Rwanda were invited for the SOSIA Rwanda application. With this, only extension officers that provide the information to the farmers have access to this information.

Operational improvements

Lastly**,** operational improvements were made over the course of the project to ensure the code runs faster. For example, in Zambia it was noticed that the farmer selection drop-down menu reacted very slow compared to the Netherlands, potentially due to different internet settings and available speeds, which was improved on site to enhance the suitability.

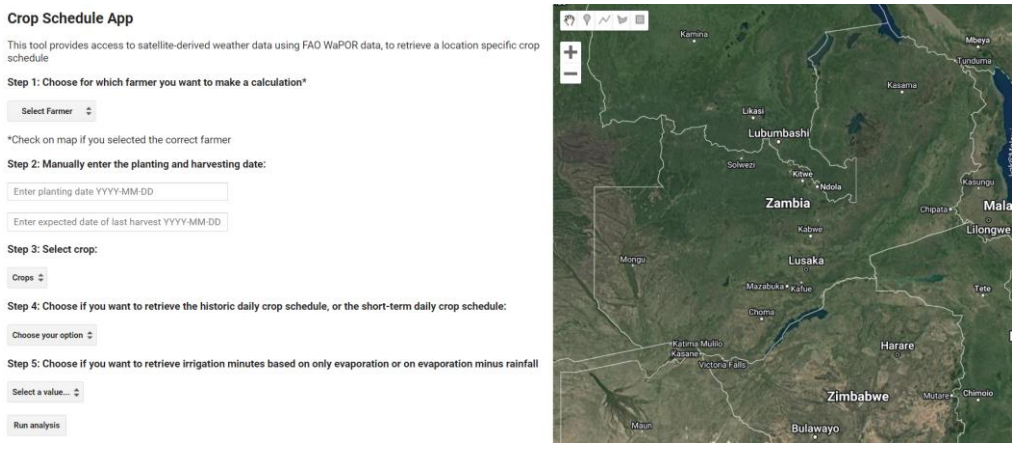


Figure 6. Google Earth Engine Graphical User Interface for SOSIA Zambia

3.3 WP 3: Quality Assessment and Evaluation

Work Package 3 aimed at better understanding the marketability of the SOSIA tool which mostly depends on the quality of the advice provided by the tool and the profitability for end-users to make use of this service. The SOSIA tool was assessed in two manners, farm trials and rain gauge validations. Because evaporation is a hard-to-measure value and not a lot of station data is readily available for both Zambia and Rwanda, the performance of the evaporation deficit advice was based on farmer interviews and irrigation logs. On the other hand, rainfall is a value that is relatively easy to measure with rain gauges, which are cheap and easy to install. Therefore, rain gauges were installed at the sites of the trial farmers, making is possible to validate the rainfall subtraction module of the SOSIA tool.

This work package therefore had 2 main components; first the quality assessment was based on a continuous critical review of the SOSIA output data with observations from the field, either provided by the intermediary or farmer as well as quantitatively analysing some of the monitoring data. The second part entailed an evaluation of the marketability of the tool, thereby focusing on the cost-benefit analysis and revenue models for each of the involved actors (developer, intermediary, farmer).

3.3.1 Quality assessment of the tool

As described in 1.3.2., a hindcast for rainfall was added to the SOSIA application. Because rainfall is a very local process, it was considered important to validate the GPM rainfall product for Zambia and Rwanda. Next to validation, it was important to assess the weekly differences in rainfall information, as the advice is given on a weekly basis. If the products differ a lot but have a high correlation, the GPM rainfall information still could not be implemented in the SOSIA tool as it is pivotal to know the (close to) exact amount of rainfall that has been supplied to the field.

To validate the GPM rainfall product, 8 farmers that participated in the trial were given rain gauges. In the end 4 rainfall records were deemed of sufficient quality to be used. Furthermore, Holland Greentech Zambia also kept rainfall records for a short amount of time and precipitation station data from Kigali Airport was downloaded from NCEI1. Only the hindcasted rainfall is validated, as the farmers kept records for only a short amount of time, mostly between November 2022 and February 2023. Results of this assessment are presented under technological feasibility (section 1.4.2)

3.3.2 Trial farmer (field) results

Most of the activities undertaken to complete this activity have been described under WP1, the analysis and results from the logbooks are presented in section 1.4.1 Impact. Hereto, the activities that have taken place during WP3 cannot be detailed specifically, but results from this work package can be found throughout this report as they are all related to the semi-structured interviews that were held during phase 1 and 2 of this innovation project.

Surveys during phase 1 were conducted to identify the end-users needs (Annex 2, Annex 3 and Annex 4) and during phase 2, to evaluate the impact of using SOSIA. The phase 2-survey was refined after completion of phase 1 with assistance from the HGT staff to better understand the Willingness to Pay (WTP) and to optimally capture the experiences of the app in relation to crop performance.
In addition, the following topics were covered in the surveys:

1. Existing way of operating & scheduling of irrigation
2. Existing gaps in irrigation scheduling
3. Current missing knowledge related to farm management practices
4. Service / information requirements
5. Willingness to pay
6. Crop Performance (in comparison to control plots)

[1] https://www.ncei.noaa.gov/access/past-weather/

7. Willingness to promote the tool to others as an indication of interest.

Summaries of the semi-structured surveys that were held with the farmers during these second phase visits can be found in respectively Annex 14 & Annex 15 for Rwanda and Zambia.

During Phase 2, acceleration of reaching small-scale farmers and achieving impact was conducted in a two-fold approach. The first part focused on achieving an effective field trial and practical demonstration of the SOSIA tool in Rwanda. The experience of the field demonstration and the insights gained from this activity eventually lead to the required information for farmers to understand and adopt the new tool. Assessment of the quality of the information from the SOSIA tool and the economic benefits (cost-benefit analysis) supported the marketing of the service and tool, these are obtained from the semi-structured interview logs which are presented in Annex 14 & Annex 15. The second part is the upscaling and exploitation of the tool to other countries and other clients. Focus was laid on further developing the exploitation strategy that was initiated in Phase 1. Potential users of the tool were identified, and resources were used to launch the tool in Zambia. This specific part is further explained in section 4.3.

The outcome of the semi-structured surveys conducted during this visits (Annex 14 & Annex 15) with the HGT staff and end-users in the first and second phase have been used to further refine the application, so it tailors best to the needs of both the farmer and the intermediary. This resulted in the development of SOSIA v3.0 which was launched on February 4, 2023.

3.4 WP 4: Upscaling and Exploitation

The objective for Work Package 4 was to explore and identify opportunities for upscaling and exploitation. The former would be in the form of a new collaboration with the current intermediary in a new country, the latter aimed at identifying a new intermediary in Rwanda or in another country. Rapidly expanding the number of end-users of the tool would positively benefit the price setting and would improve the business case of the SOSIA tool.

This tool was developed to be universally applicable, especially for small-scale farmers in Africa and the Middle East. This gives an enormous group of potential users to the tool. During the second phase the focus was on further shaping the tool, as the pilots showed at some points there was a direct need for certain adjustments as described under Section 3.2. However, considerable time was also invested in exploring potential new intermediaries as well as scaling the SOSIA tool further within the HGT network to reach more end-users. At the end of phase 1, only HGT Rwanda was using the tool. Over the course of the second phase, HGT Zambia was also involved and a launch event at the end of Phase 2 was held to promote the tool to potential new users as sufficient data and evidence on the use and impact of the tool was gathered, and the tool development had reached a stage at which it was deemed of a sufficient quality as teething problems had been resolved. HGT with their network in other countries launched the tool in Zambia as part of the Phase 2 upscaling activities. Zambia was selected as a next country for launching the tool, due to the large HGT clientele of irrigation farmers. Additional potential HGT countries with similar irrigation farmers are Ghana and Benin. In addition, during the course of the second phase a follow-up project was granted which has allowed for the introduction of SOSIA in Ghana. During this follow-up project, referred to as SOSIA+, the focus lies on further strengthening the scientific background of SOSIA. This means that the tool is further upscaled to Ghana beyond the duration of this project which is perceived as good evidence of the general interest in SOSIA.

Figure 7. Promo Video of SOSIA

The launch event in Zambia consisted of a workshop with HGT staff on the tool and field visits to showcase the tool (Figure 8). A promotion video (Figure 7) and flyer (Annex 17) were made for promoting the event and will be used for further dissemination purposes when introducing SOSIA to new intermediaries. Adding this launch event as part of phase 2 demonstrated the steps that need to be taken

for launching and tailoring the tool to other countries. This experience unveiled both the logistical as well as financial requirements for launching the tool in other countries.

Figure 8. Launch event at the HGT Zambia office in Lusaka on February 4, 2023. On the left, Mrs Phiri who participated in the trials is explaining the main findings she had obtained by using the SOSIA service.

As mentioned previously, the tool is applicable for other countries (in Africa and the Middle East) and was purposely developed to be used by other intermediaries providing extension services towards small-scale farmers. A launch with a new intermediary was also foreseen in phase 2 as part of the exploitation strategy to demonstrate the applicability of the tool for other potential users. Egypt was selected as a country for this activity due to the active network with extension officers in this country following a previous FW project on using geodata tools in a field school setting. In the beginning of Phase 2, the focus on exploitation as well as upscaling was about equal as some critical shortcomings of the tool version 1.0 were not yet uncovered. However, during the first trials in August-September, it became obvious that the current version required some essential tweaks afore introducing it in a new geographical context with a new intermediary. From that moment onwards, focus was put mostly on the current relationship with HGT and predominantly upscaling the tool within their network as they had already established a version of the tool tailored to their needs and it was found best to focus on gathering evidence on the benefits of SOSIA afore introducing an unfinished SOSIA version to new intermediaries. Hence, during the course of the second phase it became apparent that the tool was not yet user-friendly enough for it to be introduced with a new intermediary. Therefore, the organizations originally envisioned in Egypt have not yet been involved because of the slower than expected development process. This is attributed to, among others, the three-tiered communication between FutureWater developers, Holland Greentech extension officers, and the farmers making it close to impossible to fast track the process. In addition, the evidence required to convince a new intermediary of the SOSIA advice was not gathered until later in phase 2 which limited the ability to get the required momentum for introducing the tool with a new intermediary. Fortunately, a follow-up project, namely SOSIA+ has been granted and commenced in parallel to this innovation project for which the SOSIA tool will be launched in Ghana. This shows the potential for upscaling and exploitation of the SOSIA services. In addition, over the course of the second phase, feedback from NGOs within Rwanda and Zambia that showed interest in adopting the tool once finalized has been received and are currently followed-up on.

3.5 WP 5: Project evaluation and communication

The objective of WP5 was to evaluate the different components of this project. It involved the follow-up of the technical assistance workshops provided by BopInc, as well as internal follow-up on progress of the development of the tool and business development. Both the technical innovation and the use and adaptation of the tool for the irrigation engineers and end-users were evaluated.

A total of four field visits were made over the course of Phase 1 and Phase 2. An initial visit to Rwanda in phase 1 took place to identify the needs of both the intermediary as well as the end-users. This visit was from March 22 – 25, 2022 during which various drip irrigation farmers as well as irrigation staff of HGT were consulted. The second visit took place from June 6 – June 14, 2022 and focused on evaluation of the first prototype of the SOSIA tools, with the HGT staff as well as the end-users (farmers). During this field-visit, semi-structured interviews were conducted following the survey questions presented in Annex 7. A third field visit in Rwanda was held from November 7 – 10 2022, during which the updated version 2.0 of the SOSIA tool was introduced with the trial farmers and rain gauges for the precipitation hindcast validation were installed. During this visit, the same but slightly refined (Annex 14 & Annex 15) semi-structured interviews were held with a stronger focus on assessing the Willingness-to-Pay for SOSIA and field observations under the use of SOSIA. Lastly, from January 30 till February 5, 2023, a visit was made to the trial farmers in Zambia thereby conducting semi-structured interviews similar to the questionnaire for the Rwanda visit in November 2022. In addition, a launch event with new potential farmers from within and beyond the current HGT Zambia network was held on Saturday 4 February 2023 during which also national media was present. The launch event took place at the HGT Zambia office in Lusaka. During the event the explanatory videos from the dissemination material (WP4), and a demonstration of SOSIA were showcased to the audience. Presentation by HGT and FW were held to further elaborate the ins and outs of SOSIA to the present farmers and NGO's.

During phase 1, the first version of SOSIA (v1.0) was evaluated by the intermediary. Secondly, an existing logbook of 1 farmer was checked for consistency with the SOSIA advice. Other irrigation and harvesting records that could be used to validate the tool, were gathered from the end of phase 1 till the end of phase 2. Whereas at the end of the first phase, three pilot fields were established in Rwanda, at the end of phase two a total of 10 farmers in both Rwanda (5) and Zambia (5) were involved in the trials of SOSIA v2.0. Currently, the trials for SOSIA v3.0 have commenced.

Next to the validation over the course of phase 1 and 2, a workshop on how to use the tool was held with the irrigation engineers in Rwanda during phase 1 and in Zambia at the beginning of Phase 2. After preliminary validation and testing of the tool by the intermediates and end-users, a few changes were applied, and SOSIA (version 1.1) was relaunched. At the beginning of phase 2, the focus predominantly lied on updating SOSIA according to the identified gaps at the end of phase 1 after which a new version (SOSIA v2.0) was implemented in the field from October 2022 onwards. Ultimately, based on feedback from the HGT irrigation staff, a database was included in SOSIA v3.0 which reduced the frequency of re-entering the input data for different farms while safeguarding data privacy.

The evaluation of the learning questions, as was continuously accounted for over the course of this project, has resulted in several learnings regarding technical and economic feasibility. During Phase 1, it was emphasized that as the tool was not yet implemented, nor actively used by the end users, the economical as well as impact analysis were yet to be quantified. During Phase 2, this has been possible although still under the limitation of this project duration and the challenges that come with any innovation project.

4 Results

During the project, the SOSIA advisory tool was developed based on input from both the intermediary and the end-users. The results of this innovation project are discussed below according to three guiding principles that were at the base of the project organization: impact, technological feasibility, and economic feasibility.

4.1 Impact

To assess the impact of SOSIA, it is pivotal to establish a clear understanding of the target user group. In the first stage of the project, different Customer Personae (Annex 1) were developed to get an insight in the general profiles of both the intermediary as well as its end user (see Section 3.1). These were initially constructed using the insights of the first field visit and were later improved based on the field visits in Phase 2, during which semi-structured interviews were conducted, and farm visits as well as a co-creation workshop with the HGT extension officer team in Rwanda and Zambia were held. As has become clear during this project, both users are impacted differently, since their initial needs are quite distinct.

4.1.1 Impact end of phase 1

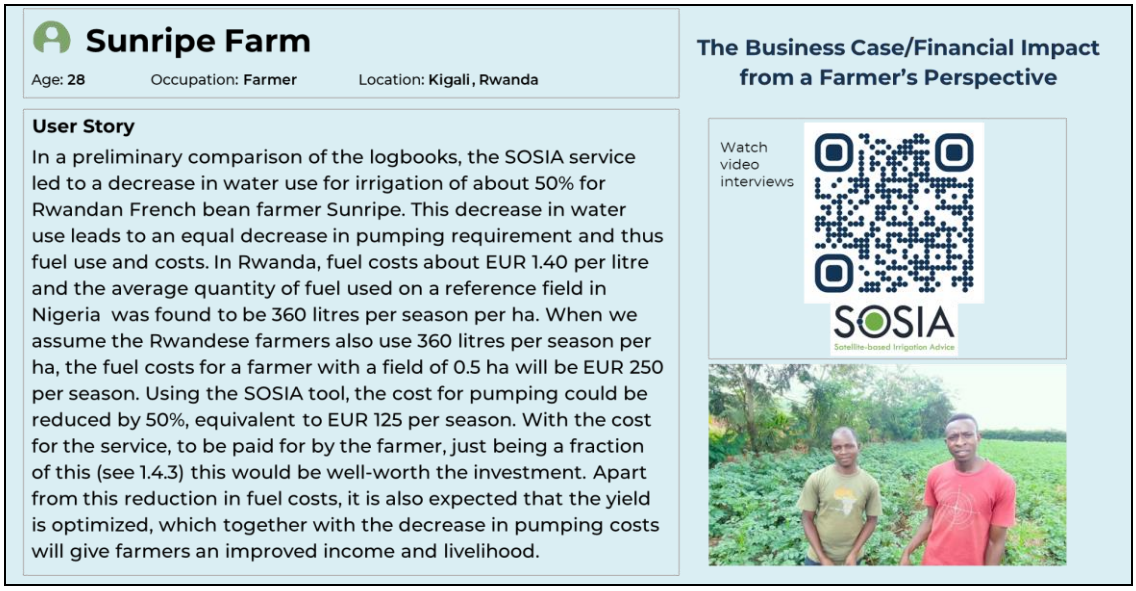
At the end of Phase 1, the SOSIA tool was used by the HGT Irrigation Team in Rwanda. As briefly touched upon above, the actual impact the tool had on crop yield was yet to be evaluated, afore it could be claimed. A short training was given and afterwards everyone was able to use it easily. The first version of SOSIA was received with a lot of enthusiasm, as can be seen from the customer persona (Annex 1), and the attached videos (see QR codes). Some quotes from the HGT workshop in Rwanda on 10 June 2022 confirmed this initial excitement:

- *"This is very simple to use."*
- *"The results are very detailed."*
- *"This will save a lot of time because it is not easy to calculate Crop Water Requirements."*
- *"The result is very accurate because it will use localized data, not outdated climate data or data from a weather station located far from the farm."*
- *"This tool will help me to give a good advice to our clients."*

The first version of SOSIA that was evaluated was complete for the whole crop cycle, farmers could clearly see in the irrigation scheduling that the amount of water increases when the crop matures up until harvesting time. Before SOSIA, farmers relied on day-to day-estimates on how long to irrigate. They did this by looking at the weather: does it feel hot, is there a lot of sun or not? Does my soil feel wet or not? After this assessment the farmer usually decided to irrigate either 30 minutes, 1 hour, 1,5 hours or 2 hours. This led to sub-optimal growing conditions because the crop water requirements were not always met or overestimated. When farmers implement the SOSIA irrigation advise, their yields are seen to be optimized for right amount of (irrigation) water, avoiding excessive water use. The key impact of the SOSIA tools relates to an increased income and livelihood for the farmers and improved sustainable land- and water management practices in the region. Phase 1 was a short duration project which resulted in a successful prototype of the SOSIA tool (version 1.1).

At the end of phase 1, farmers indicated that they would like to test the advice to monitor crop performance and tool-related potential fuel savings. This could only be measured and validated by means of an in-field pilot; due to the mismatch of project duration with the growing seasons, the first pilots had, although commenced, not yet been finalised at the end of Phase 1. Pilot farmers were selected during the second field visit, and were all existing customers of HGT, which allows for a good collaboration during the piloting. One farmer has kept a logbook for two crops (Lettuce and French

Beans) from February till April, which was checked against historical data. Preliminary analysis (Annex 8) on a logbook of applied irrigation volumes for French Beans shows that the advised daily irrigation volumes of the SOSIA-tool consequently are factor 2 lower than currently applied (see Box). This at the time hinted at potential water spillage on field level. However, given the coarse level of detail provided in the logbook, field pilots were still considered to be the best method to evaluate the performance of the SOSIA tools which has taken place during Phase 2.



4.1.2 Impact on Water Savings

During Phase 2, evaluation of the on-field impact of the SOSIA tools has been undertaken, the main insights have shown that the farmers faced no challenges of following the advice after the initial explanation of HGT staff. The farmers were surprised that the advice indicated less irrigation time than they were used to. While following the advice, the farmers also kept records of the realized number of minutes of irrigation, estimation of soil moisture, signs of drought stress and other remarks (Annex 18). No farmers recorded any drought stress on the crops. The observations of the farmers showed that the crop performance of the SOSIA irrigated trial was visually the same as the control field, irrigated under their normal irrigation regime. The farmers were enthusiastic about this water saving, mainly because of the related decrease in electricity / fuel costs. Overall, the farmers did trust the advice since they could see that the crop was performing as expected. Farmers in Zambia seemed to be convinced a bit faster compared to the farmers in Rwanda. For example, one Zambian trial farmer (Mrs Wood) already decided at the beginning of the trial to implement the advice for her whole field instead of the 2 beds that were initially selected. Consequently, the farmers have shown increased interest in using this tool in their daily farm management over the duration of this project, especially compared to the interest they expressed at the beginning of the trials. For most of the farmers involved in the field trials, SOSIA has reduced irrigation water requirements while optimizing yield. In 100% of the trials, the farmers were using less water when applying the SOSIA advise compared to their normal irrigation scheduling. Analysis of the irrigation records indicated that the extent of water saving ranges from 15% to 50%. For example, a farmer in Zambia (Mrs Christine of Chimoko Seedlings Farm) indicated that she usually irrigates her lettuce fields 1 hour in the morning and 1 hour at the end of the afternoon. She was surprised that the SOSIA advise only advised her to irrigate in the range of 50-57 minutes daily. When applying the advice, she did not notice any drought stress in her lettuce crop and the harvest was visually the same for both the demo and control fields (Figure 9).

Figure 9. Video testimonial of Mrs Christine of Chimoko Seedlings Farm.

4.1.3 Impact on Farm Management

Another valuable finding during the interviews was the fact that not all farmers would time their irrigation because they would not know exactly how long is optimal for their crop. Hence, the fact of not knowing crop water requirements contributed to over-irrigation. Not knowing how long to irrigate increases the change that growers mostly over-irrigated for about 1,5 hours to 2 hours. By providing the SOSIA irrigation advise, farmers had an exact number of minutes and were motivated to time this exactly. Therefore, the SOSIA irrigation advise increases the accuracy of irrigation and the commitment to their farm management. Furthermore, during phase 2, it was seen that providing data on the required volume of water can assist farmers in e.g., determining the dimensions for a reservoir and gaining a better understanding on the amount of water applied. Using drip irrigation this insight is often low, because one cannot actually see the amount of water as it gradually drips into the soil compared with other systems such as sprinkler or flood irrigation where the water is more visible.

4.1.4 Impact for Rwanda: local observations

In Rwanda, as the evaluation by the consortium took place just before the mid-term of the second phase, the trial farmers showed interest in further trialling SOSIA afore showing an interest to pay for this service. This feeling was especially felt because of the active rain season at the time, as farmers are mostly looking forward to the field-benefits of SOSIA in a dry season. Also, at the time, there was not yet a price set for the tool in Rwanda so they might not have wanted to fully commit to a paying service for which they had not yet heard a cost. For example, even though the advice resulted in a good yield, they would like to try it again on e.g. other crops and other planting dates. This lack of commitment at that stage could partly be attributed to the wet seasons as farmers were not sure whether their crops sustained because of the SOSIA advice or because of the present rainfall, or because of a combination. Hence, in those cases, it became less clear to what extent the SOSIA advise contributed to the crop performance. However, even in those situations, the farmers indicate to have irrigated less using SOSIA compared to their normal practices, thereby obtaining significant water and energy savings. The set price for the SOSIA advice in Rwanda is 20USD per crop per season. As the price was set at the end of phase 2, surveys taken during the mid-term were not yet specifically tackling the users view on this price setting. As it differs significantly from the price set in Zambia, it will be interesting to further examine how the two price settings compare to one another in the context of the SOSIA advice.

4.1.5 Impact for Zambia: local observations

In Zambia, the first version of the tool (SOSIA v1.1) was tested in the dry months of September and October, which had the advantage as rain did not yet play a role. The trial fields did not show any drought stress and the farmers were positive about the advice. The rains only significantly started in December, at a time during which some of the first trials had come to an end already. It was rather cumbersome for the farmers and the extension staff to follow the trials in the rainy season, as irrigation was not applied consistently with the SOSIA advice, i.e. irrigation was skipped in periods of significant rains. Nonetheless, all farmers indicated that the trial fields were irrigated less in the rainy season as well compared to the rows for which they applied their usual irrigation amounts. Implementing the rain gauges and accounting for precipitation within the SOSIA tool contributed positively to the performance of the trial fields during this period.

At the end of the project, an evaluation was done to capture the experiences of the Zambian farmers over the whole trial period. The farmers were very enthusiastic and experienced significant advantages by using the advice. Water savings, electricity savings and good performing crops were mainly mentioned. All farmers indicated that the advice was very easy to follow and that they trusted its accuracy. The advice would mainly have an impact in the dry-hot season since irrigation is most essential during this period. However, they did see a use for it in the rainy season as well since periods of intermittent droughts are increasing with climate change according to the experience of the farmers. Especially in those periods, it can be challenging to determine how long to irrigate. In general, 4 out of 5 farmers showed to be interested in adopting SOSIA in their day-to-day practices and perceived the initial

price setting of 150 Kwacha (+/- 7.5 euro) per crop per season as a great valuation. 1 farmer showed to be interested in further trialling the tool as there were some miscommunications at the onset of his crop (onion) and how the advice should be used. He saw also that extreme weather conditions (excessive rain/ heat) beyond the SOSIA-advice have had a significant impact on his crop yields. Nonetheless, all farmers mentioned they would definitely promote the use of SOSIA as even for the onion farmer the advice showed that in general the SOSIA advice recommends using less water. Mme Cristine of Chimoko Seedlings specifically stated “If something is good for me, it will be good for someone else. That is why we should share SOSIA”.

The Business Case/Financial Impact from a Farmer’s Perspective in Zambia

During Phase 2, it became apparent that the SOSIA service led to a decrease in water use for irrigation of up to 50% for Mrs Wood in Zambia. She was growing Impwa (African Eggplant) under the SOSIA Advice. This decrease in water use leads to an equal decrease in pumping requirement and thus electricity use and costs as the farm fully relied on electrical pumps. In Zambia, electricity costs are at about 1K per KWh rather inexpensive. Mrs Wood has a small pump of 1hp (horsepower) which uses about 0.75 kWh per hour. Under normal circumstances, she irrigated her crop for about 3.5 hours which meant a total electricity use of 2.6 kWh per day, as the crop remains on the field for about 5 months (150 days) the total seasonal cost is about 394 K or about 19.7 Euros.
With SOSIA, the advice indicated a total duration of 80 minutes per day for 150 days which equals to 200 hours of irrigation. With the pump capacity being equal to 0.75 kwh per hour of pumping, the total electricity usage under SOSIA is 150 kWh which equals 150 Kwacha or 7.5 Euros. From this example, Mme Wood saved a total of 12.2 euros or 244 Kwacha.
With the cost for the service, to be paid for by the farmer, of 150 Kwacha (7.50 EUR), this would be well-worth the investment. Apart from this reduction in electricity costs, it is also expected that the yield is optimized, which together with the decrease in pumping costs will give farmers an improved income and livelihood, and the possibility to increase their crops under irrigation if they were previously limited by their pump capacity.

4.1.6 Impact on the Intermediary

Holland Greentech’s experiences using the SOSIA tool were overall positive. During the testing, feedback was given to FutureWater about glitches in the tool and proposed improvements. The first versions of the tool required to always fill in all data manually which became cumbersome for the extension staff. The last version of the tool allows a drop-down functionality where data of existing clients is saved. This improved the user friendliness. The tool worked stable throughout the testing phase. It was not a challenge for the extension officers to convert the information from SOSIA into the PDF’s. In the beginning of the trials, HGT found out that it was still important to explain the PDF in person to the farmers instead of only sharing it via WhatsApp. This indicates that the model of extension officers using the tool instead of the farmers directly is an effective approach and that direct contact with the farmer is vital for SOSIA’s success. Without the SOSIA-tool, the intermediary, like HGT was not able to give accurate cost-effective irrigation advice to the farmers they work with. ‘A water-saving tap will only save water when switched off at the right time’ the same counts for an efficient drip irrigation system. The business model of HGT, is to supply an integrative package of products and services to create maximum positive impact to their customers. SOSIA offers them a valuable additional service to their existing offerings and equips their extension officers with an easy-to-use tool to provide complete irrigation advice which eases their workload as the current method to estimate crop water requirements is extensive and cumbersome.

Farmers prefer extension services on a variety of topics for them to attain a profitable business case. The SOSIA tool makes it possible for extension officers to guide the farmers in their irrigation practices both in a qualitative and quantitative way. Extension officers of HGT use SOSIA to provide high quality irrigation advise to their clients, something that before relied on a labour intensive and inaccurate process which meant that irrigation specific advice was only provided once during construction of the drip line

infrastructure, independent of the crop, crop stage, harvesting and planting data and the latest weather conditions.

Based on the crop performances of the trials and the feedback from HGT staff and the farmers, it was concluded that SOSIA has a positive impact on the (local) environment. Besides the positive contribution to water availability and reduction of energy use, limiting over-irrigation also leads to optimized growing conditions and reduced fertilizer leaching.

4.2 Technological Feasibility

This section presents the relevant results and insights regarding technological feasibility, which were obtained by implementing the activities described in Chapter 3. Integration of additional crops, creating of a farmer database and miscellaneous operational improvements (see Section 3.2.2) were all successfully realized and have improved compliance of the tool with user requirements. For the other development activities outlined in Section 3.2.2, below sections provide more detailed information on their technological feasibility.

4.2.1 Uptake of current weather data

The SOSIA tool requires the most recent, open-source data to be used for most effective operational decision-making for the farmers, with information to be made accessible through laptop as well as smartphone devices. The use of GEE as the supporting platform enables meeting these fundamental user requirements. However, it also means that options for selecting OS data sources are largely determined by data availability in the GEE catalog.

The availability of open-source datasets was an important factor in making choices in the development of the SOSIA tool, and thus also for evaluating opportunities to incorporate dynamic weather data. To examine the possibilities for delivering an irrigation forecast and integrate current weather data, both the CFSv2 and GFS datasets (see Table 1) were evaluated and the values were compared to WaPOR evapotranspiration data for the same period. Here CFSv2 gave more reliable results than the GFS data, which were in a completely different range than the WaPOR averages. Ultimately the irrigation forecast therefore became an irrigation hindcast in the latest SOSIA version, as the forecasted GFS data were deemed unreliable.

Overall, it was concluded that the integration of recent weather data in the operational advice was successfully achieved based on the available OS data in GEE, though in a somewhat different manner than previously foreseen. In the situation where no reliable field data is available, which is generally the case in Zambia and Rwanda, WaPOR and CFSv2 are considered as a significant improvement for modelling reference evapotranspiration. Adjustments to OS datasets used and their associated licenses are presented in Table 2.

Table 2. Overview of OS geodata products and licenses used for the SOSIA tool

Data product	Licence	Historical Crop Schedule	Hindcasted Crop Schedule
WaPOR	Creative Commons Attribution 4.0 International (CC BY 4.0)	✓	
CFSv2	Creative Commons Attribution 4.0 International License		✓
GPM v6	Open Data. There are no restrictions on the use of this data.	✓	✓
Sentinel-2A	Open Access compliant Creative Commons CC BY-SA 3.0 IHO licence		✓

4.2.2 Integration of rainfall information

As described in Section 3.2.2, another new development within SOSIA has been the uptake of rainfall information in the advice. For retrieving precipitation through open geodata, the Global Precipitation Measurement (GPM) dataset was used. GPM was chosen over CHIRPS, because GPM has more recent data available.

Next to farmer interviews used for qualitative evaluation, also a quantitative evaluation of the rainfall component of the SOSIA tool was done. Farmers in both Zambia and Rwanda were provided with rain gauges. These farmers kept rainfall records. With these rainfall records, the GPM rainfall data was validated. The timeseries of both the GPM and measured rainfall were plotted against each other (Figure 10). Furthermore, summed weekly timeseries were made and for the whole period the average deviation between measured and hindcasted GPM rainfall was calculated Figure 11. Lastly, the summed weekly values were correlated with one another (Figure 12).

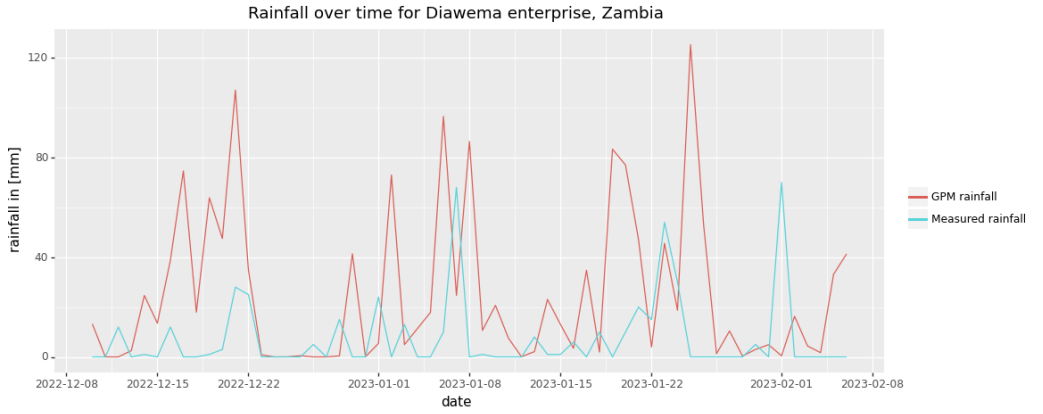


Figure 10. Measured and GPM rainfall over time for the Phiri farm in Zambia.

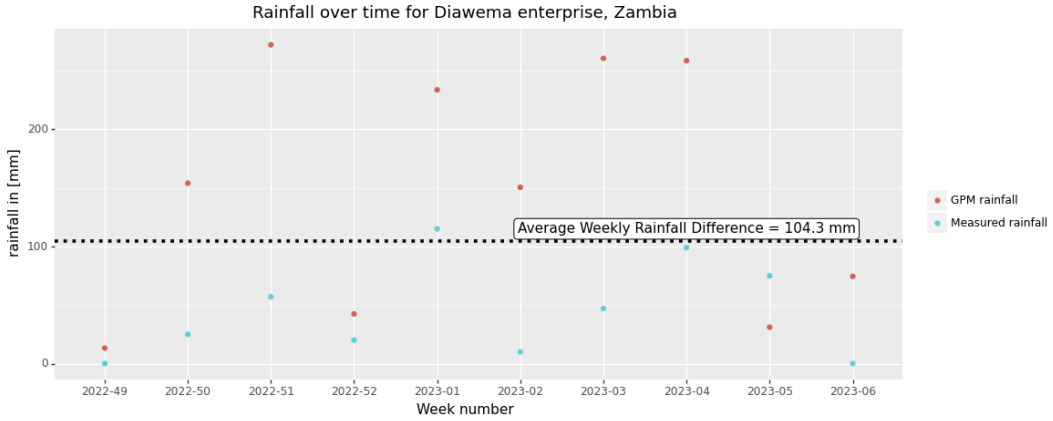


Figure 11. Weekly sum of measured and GPM rainfall over time for the Phiri farm in Zambia.

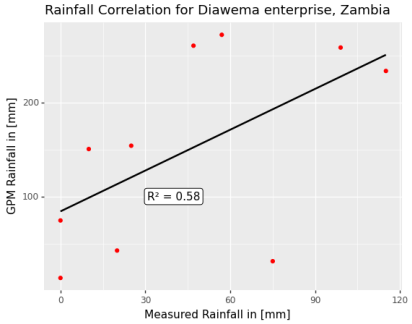


Figure 12. Correlation between summed weekly values of measured & GPM rainfall for Phiri farm in Zambia.

The results of all the validation sites are shown in Table 3. The figures of the Diawema enterprise farm in Zambia show that GPM rainfall is higher than the actual measured rainfall in the field. This was also observed for most of the other validation sites (Annex 13). Although some of the locations tested have a high correlation value, the difference in rainfall values on a weekly basis are too big to be reliable for an irrigation advice. Therefore, a conversion sheet was provided to the farmers in the future which they could use to translate observed precipitation into a required irrigation duration, allowing them to exactly know how much shorter one should irrigate per mm of observed precipitation. These tables are field-specific as they will account for the present irrigation infrastructure and field size.

Table 3. Results of GPM rainfall validation per selected site

Location	Country	Correlation GPM and Measured rainfall (R^2)	Difference in [mm] on a weekly basis
Kigali Airport	Rwanda	0.40	35.7 mm
Sunripe	Rwanda	0.52	11.8 mm
Kayonga	Rwanda	0.62	33.2 mm
Diawema enterprise	Zambia	0.58	104.3 mm
Wood	Zambia	0.73	177.7 mm
Holland Greentech	Zambia	-0.25	208.2 mm

4.2.3 Soil water storage dynamics

Given the uncertainties associated with OS rainfall information at the required spatial scale, it was eventually decided not to operationally model soil water storage. In addition, soil water storage is a complex variable which depends on various input datasets, potentially generating substantial uncertainties in the advice to farmers. With the addition of the soil water storage in the Rwandan and Zambian context, the irrigation advisory would become too complex but also prone to large variations and possible calibration errors, due to the lack of sufficient field data.

Keeping in mind the local context and the need for simplicity, while still acknowledging the importance of reliable rainfall information for sound irrigation advice, it was therefore decided to work with manual rain gauges. When upscaling the SOSIA solution, a rain gauge is something every farmer could be provided with or even make from a bottle, but this is less feasible when soil moisture sensors need to be provided.

4.2.4 Functionality and user-friendliness of the SOSIA tool

Evaluation with the trial farmers conducted under WP5 showed that farmers appreciated the results and especially mentioned that the results are easy to 'read'. The information regarding the number of minutes to irrigate per day and the daily volumes of water required were considered as most valuable information. The results were shown as a print-out and as pdf on a smartphone. All farmers preferred the advice on the smartphone and would like to either receive it via WhatsApp or email, which was accounted for in the development of the SOSIA tool.

From the intermediary's perspective, the SOSIA dashboard is designed to let the irrigation engineer fill in the crucial information that is needed in the calculation, like crop type, planting date and field area. The tool can best be used via laptop to save the outputs easily after which the intermediary will translate the output further into a farmer tailored advice. They can collect and assist clients to collect the required inputs for the tool after which they can process this input data on their laptop to generate an advice. The tool can also be used via smartphone which is considered a pro by the intermediary. When data is entered (or in Phase 2, the farmer is selected) the tool will then calculate ET_{ref}, ET_c, Irrigation Water Volume and Irrigation Duration. The tool will show these in one organized table, which can be exported by the irrigation engineer for further use. In this way the output is flexible and can be easily integrated with existing services from the intermediary. The integration of a farmer database during Phase 2 has greatly decreased the required efforts of the intermediary to provide the necessary input to the SOSIA tool.

The positive feedback received by the trial farmers as well as the intermediary demonstrates that, despite technological challenges encountered during Phase 2, the SOSIA tool v3.0 successfully addresses their needs. This implies that from a technological point of view, it has been feasible to realize improvements to the tool that have increased its impact from various perspectives (see Section 4.1).

4.3 Economic Feasibility

The economic feasibility reviews all kinds of analyses that has happened over the course of phase 1 and phase 2 with respect to the economical aspect of this innovation project. As with all innovations, a new product can only be successful if it has a sound value proposition. During phase 1, a first attempt for this was drafted and it has been further refined within phase 2. In addition to the value proposition, competitor analysis, and market size and selection tools have been examined. Each of these, together with the impact findings presented in section 4.1 fed into the assessment of the Willingness-to-Pay (WTP). As part of this WTP, cost-benefit analyses for both Rwanda and Zambia are detailed and a discussion on the revised business model is presented. As a part of the business case also focusses on exploitation and upscaling, together with the co-developer (HGT) of this innovation project, a license agreement has been signed between both parties. Each of these economical feasibility components, is then summarized in two guiding examples for the two business strategies envisioned by the consortium, a B2B and B2C strategy.

4.3.1 Value proposition

For farmers who are (potential) precision irrigation users, who want to improve their water efficiency and productivity, the SOSIA service informs them when and how long to irrigate. This enables them to improve the water application to their plants, optimising their (water) productivity. It is unique because it is a new offering in Rwanda & Zambia which fully relies on open source geodata and therefore has a limited cost of operation and maintenance. Our proposition can be trusted because irrigation advice based on geodata, and the subsequent optimized productivity of farmers implementing novel irrigation methods to their farms, has been successful in different regions around the world.

This value proposition, determined using the tool provided by BopInc relies on the following assumptions:

1. Water is widely available.
2. Farmers are willing to pay for the service.
3. The irrigation advise will be provided as a separate advice and/ or included in a set of existing services offered by HGT like seeds, drip irrigation kits and soil testing.
4. Lack of information is the main challenge for farmers related to irrigation scheduling.
5. Farmers are interested to use innovative technologies for improving their water management.

In addition to this value proposition, the innovator, and its intermediary, have what it takes to be entrepreneurial as:

1. FW is a for-profit company that combines state-of-the-are science with practical solutions and has extensive experience with business development in the region.
2. The services of FW are tailored towards the needs of our clients/users.
3. FW relies on innovative technologies which sparks the interest of (pioneering) users (both on the level of the intermediary, as well as on farmer level) and FW is able to translate these to understandable services.
4. FW has experience in working in Africa, Zambia and Rwanda specifically, in projects related to smallholder farmers and irrigation (among others).
5. We have a young, inclusive and diverse proactive team.
6. As the intermediary has a well-established network of customers to which the new service can be offered, no new sales channels are required.

4.3.2 Competitor analysis

Irrigation advisory services have been on the market for some time, but differ greatly in application level and spatial detail. Figure 13 gives an overview of already existing irrigation advice applications and how they relate to the SOSIA tool. It can be seen that existing irrigation advisory tools (e.g. Manna Irrigation, Netbeat, IrriWatch, IRWI, etc.) focus on medium to (very) large areas. A certain paradox is that these services, despite being able to provide a relatively high level of spatial detail, are not accessible or applicable to farmers with smaller areas.

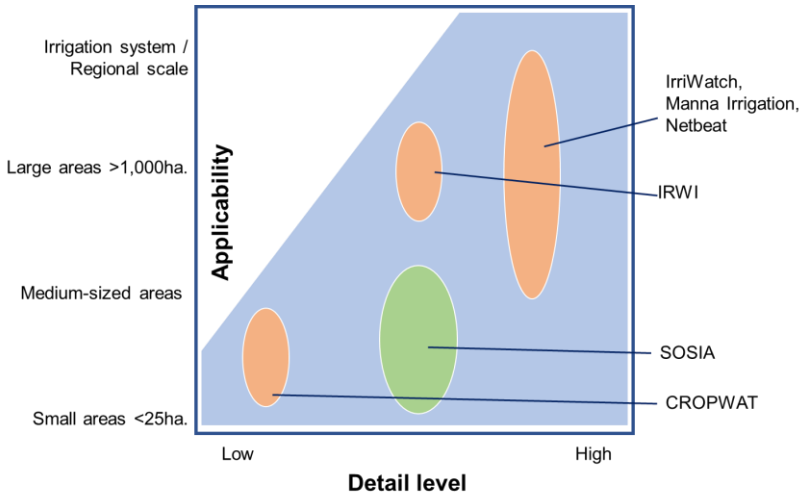


Figure 13. Overview of irrigation advice products sorted by applicability (y-axis) and detail level (x-axis)

In addition to the technical aspects, economic factors play a decisive role in the creation of the market landscape shown in Figure 13. Most of the existing irrigation advisory tools are used by farmers with an area larger than 1,000 ha. Such services are more complex than the SOSIA tool: they use real-time (drone) data, incorporate weather forecasts, groundwater reserves, and are often linked to sensors in the field. Most of these tools are therefore sold to farmers who can finance the investment by the scale at which they grow. The small to medium-sized farmers who are the target group for SOSIA do not have the capacity to use that level of detail cost-effectively on their land. However, this is precisely the target group that determines the sustainability of land and water use on a large scale, and where a large socio-economic impact can be achieved, e.g. 99.8% of the Rwandan areas are grown by small-scale farmers[1]. This requires a solution that is more accurate and accurate than the current CROPWAT 8.0 method.

During phase 1, our innovation has led to a product with low operational costs and therefore ultimately a competitive market price, thanks to the focus on the use of OS data. The service is unique as it is primarily aimed at small to medium-sized food producers, who do not have the financial means to use existing products cost-effectively.

4.3.3 Market size and selection

The SOSIA tool is unique as it is set up in such a way that it benefits two types of users in a two-tiered business model. On the first level, the intermediary using the tool becomes more competitive and more efficient in executing their daily activities, such as providing irrigation services. In addition to the eased process of determining Crop Water Requirements (CWR) the intermediary can also use it internally to optimize the design of irrigation systems of (potential) new clients. Another user group are the farmers directly, who will have a more specific estimation of their CWR, which will optimize their crop yields, while minimizing their fuel/ electricity costs (for pumping groundwater), assuming they are currently over-

[1] NISR (2010). National Agricultural Survey 2008. Kigali: National Institute of Statistics of Rwanda, Government of Rwanda, Rwanda.

irrigating. When under-irrigating now, the CWR can help increase their crop production by applying the right irrigation requirements.

Obtainable market

The obtainable market size of this tool in its current state equals two, that is, as the price draw indicated at the beginning, and because of the early stage of the product development, only **2 intermediaries** have been identified: HGT Rwanda and HGT Zambia. When focusing on the second tier of this business model, i.e., the farmer level, the obtainable market size after phase 2 is around **100 farmers**. These are the farmers who make use of drip irrigation and receive the services offered by HGT Rwanda & Zambia.

Accessible market

HGT has a broad network outside of Rwanda & Zambia as well. Therefore, as can be seen from the mutual business agreement (Annex 9), when upscaling the SOSIA tool, the preference will be given to the current intermediary in case of local presence, and/or in case of absence, a business arrangement between both parties has already been established.

The accessible market, assuming initial expansion solely in collaboration with HGT, consists of **12** intermediaries, as HGT has a physical presence in 12 Sub-Saharan countries. Their customer base of irrigating growers is **800 farmers** in total. As HGT has observed a major increase in the recent demand for drip irrigation technology, and governments are actively supporting and encouraging small and medium-sized farmers to switch to irrigated farming to ensure increased food production, this number is expected to increase substantially over the next few years.

Available market

As the WAPOR dataset only covers the African and Middle Eastern continent, the available market is limited to these geographical locations with the current SOSIA tool, assuming calibration data for each of these countries is available. It is expected that in 2023, a global WAPOR package will be launched, indicating the available market could be drip irrigation farmers worldwide once available[1]. In case the tool is introduced outside of the region where the current intermediary is active, new intermediaries will be identified. These could be either commercial, governmental, or non-governmental agencies. In this way the tool can be upscaled to up to all 66 countries in Africa and the Middle East that are covered by the WAPOR dataset. Assuming one intermediary per country, the available market would be **66 intermediaries**.

In order to obtain a complete estimate for the available market of the second tier, a literature study on general smallholder farming in the region was conducted. The global total of smallholder farmers is approximately 570 million[2]. Of these, about 9% are situated in Africa giving a total of 51.3 million smallholder farmers. In addition, on average for Africa, about 6% of arable land is irrigated[3] which leads to a total available market of **3.08 million small-scale farmers** (<2 ha), which could be served by various intermediary customers. It should be noted that given the expected growth in irrigated agriculture in Africa[2], and because these estimates relate to farms <2 ha, rather than <10 ha which is the applicability of SOSIA, the above-mentioned estimate is potentially underestimated.

[1] https://www.fao.org/in-action/remote-sensing-for-water-productivity/news-and-events/news/news-details/en/c/1603591/

[2] Lowder, S. K., Skoet, J., & Raney, T. (2016). The number, size, and distribution of farms, smallholder farms, and family farms worldwide. World Development, 87, 16-29.

[3] Mango, N., Makate, C., Tamene, L., Mponela, P., & Ndengu, G. (2018). Adoption of small-scale irrigation farming as a climate-smart agriculture practice and its influence on household income in the Chinyanja Triangle, Southern Africa. Land, 7(2), 49.

4.3.4 Willingness to Pay

During the field visit in the first week of the project, a survey was conducted amongst farmers to evaluate their interest in the tool and willingness to pay. From the survey results, it was learned that farmers with a drip system are quite progressive and not afraid to take risks. Most farmers grow cash crops such as strawberries, and vegetables. It was found that 63% of farmers are willing to pay for the service, if it can be proven that fuel/ electricity use can be saved with improved irrigation scheduling. At this point in time, farmers did not see the exact product being offered yet, explaining the slightly low percentage. Therefore, a second survey was done at the end of phase 1. This survey showed that the willingness to pay increased, as a first prototype was presented. For both Rwanda and Zambia, the trial farmers expressed a further interest in obtaining a location specific irrigation advice during the farmer interviews, which has further strengthened the willingness to pay component.

When it comes to the cost, there was general understanding that the exact amount depends on the added benefits of the tool to the farmers' management practices. Farmers mentioned that fuel/ electricity use for pumping is a significant part of their costs of production, and any means to reduce this while optimizing yield is perceived as a good opportunity. The height of the fee would depend on two main factors: i) the improvement of the yield, and ii) the reduction in pumping time and thus a reduction in fuel/electricity and water use.

In the survey, farmers were asked to estimate the amount they would be willing to pay at the end of phase 1. The indicated amounts ranging between EUR 5 and 50, the first being the willingness-to-pay for a single advice for one crop for the whole growing cycle, and EUR 50 the amount a farmer with a larger area would be willing to pay to obtain these extra services for several crops with different planting dates for different fields. At the end of Phase 2, the HGT extension staff in Rwanda and Zambia had separate internal discussions to determine the fee they will charge after the official launch of the service. Rwanda estimated a fee of 20 USD (EUR 18.60) and Zambia a fee of 150K (7.50 EUR). Setting a price during phase 2, allowed for further capturing the willingness to pay component.

For Rwanda, the response to this price setting has not been surveyed as surveys were taken in November 2023. During the launch event, and during the farmers interviews between February 1 – 5 2023, the Zambian price-setting was shared with the trial farmers and launch attendees. The general feedback was positive as the trial farmers found it a fair price for the benefits they have seen after using the SOSIA advice. Mrs Christine of Chimoko Seedlings farm mentioned the ability for her to double her water productivity while sustaining the yield (Figure 9). As she relied on electrical pumping, she explained this price setting was well worth the savings in pumping. During the launch, the feedback was overall positive, especially given the rather sceptical view on the product at first which became apparent during the various chats we had with the attendees. Farmers mostly valued the proven reduction of irrigation time, and the added precision in irrigation practices. It is yet to be seen how many of the attendees will subscribe to the SOSIA advice, however during a show-off-hands, most of the attendees showed interest to adopting to the SOSIA advice after hearing the price setting.

As the price setting between the Zambian and Rwandese extension offices turned out significantly different, Holland GreenTech and FutureWater will keep monitoring the effect of this post-project and schedule an evaluation meeting in 2-3 months' time to investigate the number of SOSIA advises generated to subsequently improve the business cases accordingly. With this information, it will be possible to track whether between these 2 user groups the price significantly affects their willingness to invest in the SOSIA advice. The different price setting for both countries is mostly attributed to the interactions between the HGT staff and the farmers, which is significantly more frequent in Rwanda, which is also reflected by the different costs per sell. For Rwanda the advice costs the HGT office 9 euro/advice whereas in Zambia this is estimated to be only 4 euro/advice. It is yet to be fully understood whether the frequency at which HGT Rwanda interacts for distributing the advice is found necessary for successfully applying the SOSIA advice, otherwise with less frequent visits costs could also shrink.

As discussed below, the agreement between FW and HGT indicates their willingness to sustain the collaboration after completion and introduction of the SOSIA tool. To keep the tool up and running, FutureWater offers periodic service updates, general maintenance, troubleshooting and support. After the 2-3 months of commercial trial, which has officially commenced on 4 February 2023, FutureWater will also have more insight on time and input requirements to maintain the tool. This is vital to come to a future agreement whereby the tool is profitable for FutureWater and Holland GreenTech. Because of a new project in which SOSIA will be further developed (SOSIA+), there is scope for a continuation of tracking the user results and feedback in both Rwanda, Zambia and Ghana, which is the focus area of the follow-up SOSIA project

4.3.5 Cost-benefit analysis Zambia & Rwanda

In Zambia, most farmers use electricity for pumping. Therefore, an analysis based on electricity is provided below, accounting for local electricity rates. It should be noted that electricity is very cheap in Zambia, therefore, the cost-benefit analysis is only valid within the current context. Cost-benefits related questions were included in the interviews with the farmers and a quantitative estimation of the financial benefits was made taken an average submersible pump (1.5 hp) and field size 5000m^2 into account.
The crop African eggplant (Impwa) was chosen since this was a crop on one of the trial farms. Taking the conditions in Zambia into account, one finds a saving of approximately 25 euro over the whole cropping season (Table 4, Table 5) for the 5000m^2 field. It is assumed that for land size ranging between 2500m2 and 5 ha, the electricity cost savings will be in the order of respectively 25 and 500 euro assuming two growing seasons per year per crop.

Table 4 Electricity cost estimation direct pumping from borehole

Description	Value	Unit
litres per unit of electricity	3,090.91	litre/KWH
costs of electricity in Zambia	0.05	euro/KWH
costs pumping per litre	0.000016	euro/litre
total irrigation requirement whole season (SOSIA, taken rain into account)	3,587,250.00	total required litres
Total electricity costs	58.03	Euro

Table 5 Estimated savings when using SOSIA irrigation advice.

Description	Value	Unit
Water saving	1,076,175.00	litres
Electricity saving	497.39	KWH
Cost saving	24.87	Euro

The same cost estimation was done for farmers that use a submersible pump and a reservoir. The calculations of this exercise can be found in Annex 12. These calculations indicate slightly higher energy and cost savings as these systems rely on a minimal of two pumps. One is used to fill the reservoir; the other is used to supply water from the reservoir into the drip system.

In Rwanda, fuel pumps are often used to pump water into drip irrigation systems. This changes the picture of the (financial) benefits compared to electricity since the operating costs of fuel pumps is considerably higher than for electricity powered pumps. Taking the same field size of 5000m^2 into account and an average fuel consumption of 180 litres per season[1], a farmer spends 250 euro on pumping. Assuming a 30% reduction of pumping due to the SOSIA irrigation advise, a farmer can save, 75 euro per season / 150 euro per year per field/ crop. Assuming an area under cultivation between

[1]Jekayinfa, S.O., Ogunshina, M.S., Oke, A. M., Ojo, O.I (2018). Irrigation and drainage energy requirements for irrigation water supply of selected schemes in Nigeria, Misr J. Ag. Eng., 35 (2): 571 – 586. DOI: 10.21608/mjae.2018.95798

2500m2 and 5ha with 2 growing seasons per year, a financial saving between 75 euro and 1.500 euro per crop can be achieved.

4.3.6 Revised revenue model

In the development of a sustainable revenue model, insight in the advantages for the farmer was of paramount importance. A balance needed to be found between the benefits for the farmers, the costs of the maintenance of the tool and the willingness to pay for the end user. Looking at the duration of the project, a first insight in willingness to pay and a good insight in the advantages for the farmers were establish. The irrigation extension staff proposed a first fee that will be implemented for the next 2-3 months. After this testing period, FutureWater and Holland Greentech will evaluate the results and make the necessary adjustments in the fees for the farmers as well as the maintenance license fee. Both parties strive to, with the insights of this additional commercial testing period, find a balance between maintenance (requirements), costs, and willingness to pay. All this in order to keep creating positive impact with the developed tool. Ultimately striving for establishing a sustainable revenue model for all parties involved.

From an economical viability perspective, different strategies were thought through off which a project-based tailoring per new intermediary was found to be the ideal business case for FutureWater. This would translate as follows; for every new intermediary, a certain extent of tailoring is expected. From a technical perspective this entails setting up a user group on the GEE platform to prevent data and privacy leaks among intermediaries, tailoring the database input requirements based on the type of irrigation schemes, adjusting the crop selection drop-down to be specific for the clientele of the new intermediary, and making sure the application runs smoothly. In addition, if the intermediary is interested in accounting for rainfall as well, rain gauges and translation tables at field level will be generated for each end-user. To make sure these changes can be applied successfully, a project-based fee for each new intermediary is preferred rather than a significant license fee that would have to cover for these tailoring activities as it very much depends on the size of clientele envisioned. However, a license fee will still be charged annually to each intermediary officer to ascertain SOSIA updates, bug fixes and general maintenance requirements. As the technical development stretched over the full duration of the second phase, the months after the official finalization of this price draw will be used to further measure the requirements in terms of license fee. This is necessary as from a developer perspective, the license fee mostly depends on the maintenance requirements which again depends on the rate at which new end-users are adopting the SOSIA advice through HGT.

For both Rwanda and Zambia, different pricing schemes are introduced and were initially determined by the local HGT staff as they are most experienced with the end users. For Zambia, the SOSIA advice will cost K150 (7.5EUR) per crop per season in Zambia and in Rwanda the same advice is charged at 20 USD (18.6 EUR). Both prices were set by the local HGT staff without intervention of the project team which makes for an interesting case to further study the effect of pricing on end-users adopting the SOSIA services. During the coming months, the effect of this will be quantified under the security of the newly granted SOSIA+ project in Ghana.

The principal revenue model designed in phase 1 still holds after completing phase 2 whereby the advice will be commercially sold by the intermediary to the end user, both as a separate irrigation advise as well as part of e.g. irrigation hardware and fertilizer advise. FutureWater will charge a maintenance fee to Holland Greentech and will create revenue by receiving a 15% of the net-income that HGT realizes with the advisory sales. Hence, the revenue model for FW is based on selling the tool to intermediaries on the one hand and receiving a commission on sales completed by the intermediaries to their customers.

The SOSIA tool is an ideal complement to the services that the intermediaries currently offer (Annex 10) and the experience of providing soil advice provides a good foundation to develop and fine-tune an effective model for the SOSIA tool. From the intermediary perspective, two sales strategies have been identified that allow for SOSIA to be used in an economically viable and sustainable way:

1. Complete irrigation kit: The service becomes part of a complete irrigation package consisting of: Design, purchase and installation of the irrigation kit, training and advice using an irrigation schedule, originating from the SOSIA tool. For this, farmers pay a one-off and recurring fee.
2. Separate irrigation advice: The SOSIA tool is used for a separate service for a (recurring) fee. The farmer determines the crop and the date of planting, after which a tailor-made advice is provided to the farmer. Since the irrigation advice can vary greatly per location, crop and season, the farmer is advised to request a new irrigation advice for each crop and field. Based on an average crop cycle of 3 months, this leads to 3 to 4 irrigation recommendations per farmer per year. If a farmer has multiple fields with multiple crops, this number can increase further.

For FutureWater, the potential business cases identified are two-fold from which both parties will profit. This is ascertained via the license agreement established and put in practice during phase 1 of this project. The following revenue models are considered:

1. B2B: FutureWater (Innovator) tailors SOSIA to a new context, intermediary, etc. on a project basis and an annual license fee is applied to cover for operational and maintenance costs.
2. B2C: FutureWater (Innovator) gains on the business between intermediary and end-user through an annual license fee and commission based on Holland Greentech turnover.

4.3.7 Exploitation strategy

The tool is developed to be universally applied, especially for small-scale farmers in Africa and the Middle East. This gives an enormous group of potential users to the tool. During phase 2, the SOSIA tool was. launched in Zambia after the first successful pilots in Rwanda had come to an end. The launch event, that was organized in Zambia, showed what is required (in logistics and finance) for launching the tool in other countries. The financial requirements for such a launch and training event are included in the revised version of the revenue model as they are part of the service costs of the tool.

A launch with a new intermediary was also foreseen in phase 2 to demonstrate the applicability of the tool to other potential users. Egypt was selected as a country for this activity due to the active network with extension officers in this country following a previous FW project on using geodata tools in a field school setting. However, as the development of the tool took longer than originally planned for, and as both FutureWater and Holland Greentech would not feel comfortable introducing an unfinished and half-validated tool in a new context, the focus on exploitation of SOSIA during phase 2 was minimized as the strengthening and the co-development of the SOSIA tool was prioritized. Nonetheless, specific attention during phase 2 was given to creating dissemination materials such as flyers, promo videos and user stories that can and will be used for effectively exploiting the business opportunities that will be explored with SOSIA in the near future.

HGT will promote the SOSIA service in their basket of products and services. The promotional material and the launch will help to create awareness amongst farmers in Rwanda and Zambia, and beyond.

4.3.8 Intermediary license agreement

To make arrangements regarding any future income generated by FutureWater or the intermediary of this project, Holland Greentech, with regard to the SOSIA tool, a licence agreement was made. With this agreement the financial aspects related to services sales are now well-arranged. Furthermore, it still provides the freedom to FutureWater to offer the tool to any other intermediary service providers and does not only depend on Holland Greentech as intermediary. The license agreement specifies the primary usage rights to Holland Greentech in these countries where they are already active, in other countries FW is allowed to distribute the usage rights of the tool to any other organization willing to pay for it. Before entering into an agreement with the interested organization, Holland GreenTech has the first right to match the proposed payment by the organization willing to make use of SOSIA.

Furthermore, it was agreed that HGT shall pay FW an amount equal to 15% of the gross amount invoiced on sales, leases or other transfers of the tool directly to customers. FW will maintain, update and/or further develop (features of) the tool, upon payment of additional fees that will be determined in mutual agreement between both parties. When selling the service to other businesses, the net sale will be divided 60-40% between FW and HGT in countries where HGT has a physical office. In other counties this division is 85-15%. When not the service provided by the tool but the complete tool (and its intellectual property rights) itself are sold to any organization, the division is also 60-40% between FW and HGT. With this agreement the financial aspects related to service sales are now well-arranged. Nonetheless, it still provides the freedom to FW to offer the tool to any other intermediary service providers and does not only depend on HGT as intermediary. The signed license agreement is attached to this report in Annex 9.

4.3.9 Example business cases for Rwanda and Zambia

Figure 14 gives a schematic overview of the business model of the SOSIA tool for both Rwanda and Zambia as business case-studies. Since most intermediary business models are based on a long-term relationship with farmers (many returning customers for seeds, irrigation, etc.), it is expected that the number of end-users of the SOSIA tool will grow as fast as the number of farmers of intermediaries.

Due to the excellent upscaling opportunities of the tool to the ten other countries where HGT currently has branches, and other countries where other intermediaries will be sought, the number of customers is expected to increase from 40 in year 1, solely in Rwanda, to 1,280 in year 6 after the development shared across the whole HGT network.

With an average selling price of EUR 18.6 per sale and an assumed average of 2 growing seasons per year during which 2 fields/ crops are cultivated for the Rwandan Business case, the benefits of this tool increase from 2,976 euros in year 1 to 95,232 euros in year 6. To achieve these numbers, training and demo sessions and awareness campaigns for farmers are planned. The costs for the intermediary to perform the sale are estimated to be approximately EUR 9/sale, which will be monitored the first months of offering the SOSIA service commercially. Costs to update the tool when needed, perform maintenance, troubleshoot in case of bugs, and update the database are set at a fixed rate of 500 euro per intermediary per year and is charged as a license fee. Currently 2 intermediaries are associated to the SOSIA tool, hence the total cost sums up to 1,000 EUR. By year 6, all of the 12 intermediaries are assumed to be associated with SOSIA, the fixed license cost for the intermediaries will then sum to 6,000 EUR. On top of that, a fixed annual fee of 800 EUR for PR, training and dissemination activities is accounted for. None of these fees include further developments of the tool which will be done on a project bases in case of a new intermediary. For this specific project with the current intermediary HGT, a follow-up project, namely SOSIA+ has commenced already, therefore no additional costs for tailoring the SOSIA tool for the current intermediary are foreseen. Since the tool will only use OS geodata, the other operational costs are minimal and do not depend on the number of users. The total costs amount to 3,080 euros in year 1 to 47,760 euros in year 6. For Rwanda, in the first years after the development phase, a (relatively small) loss is incurred, after which the profit will increase to approximately EUR 47,472 in year 6.

For Zambia, a similar calculation was made. Due to the significantly lower price setting of 150K or 7.50 EUR, the expenditures are also less. For example, the cost of providing the advice to one farmer is estimated at 4 EUR per sell. Also, for dissemination and training, a fixed annual contribution of EUR 400 is accounted for. The license fee to FW and the number of advices each farmer purchases per year are similar for both cases. For Zambia therefore, the tool will have a minor loss the first 3 years and will have a profit of 11,520 EUR by year 6.

It should be noted that both examples are just for indication as in reality both intermediaries are part of the same Holland Greentech pool. Considering the low SOSIA cost for Zambia, and a higher cost in Rwanda (ranging between 7.50 EUR and 18.60 EUR per crop per season), it is expected that over 6

years, when all 12 HGT country offices are involved, the profit is likely to be within the range of 11,520 EUR to 47,472 EUR.

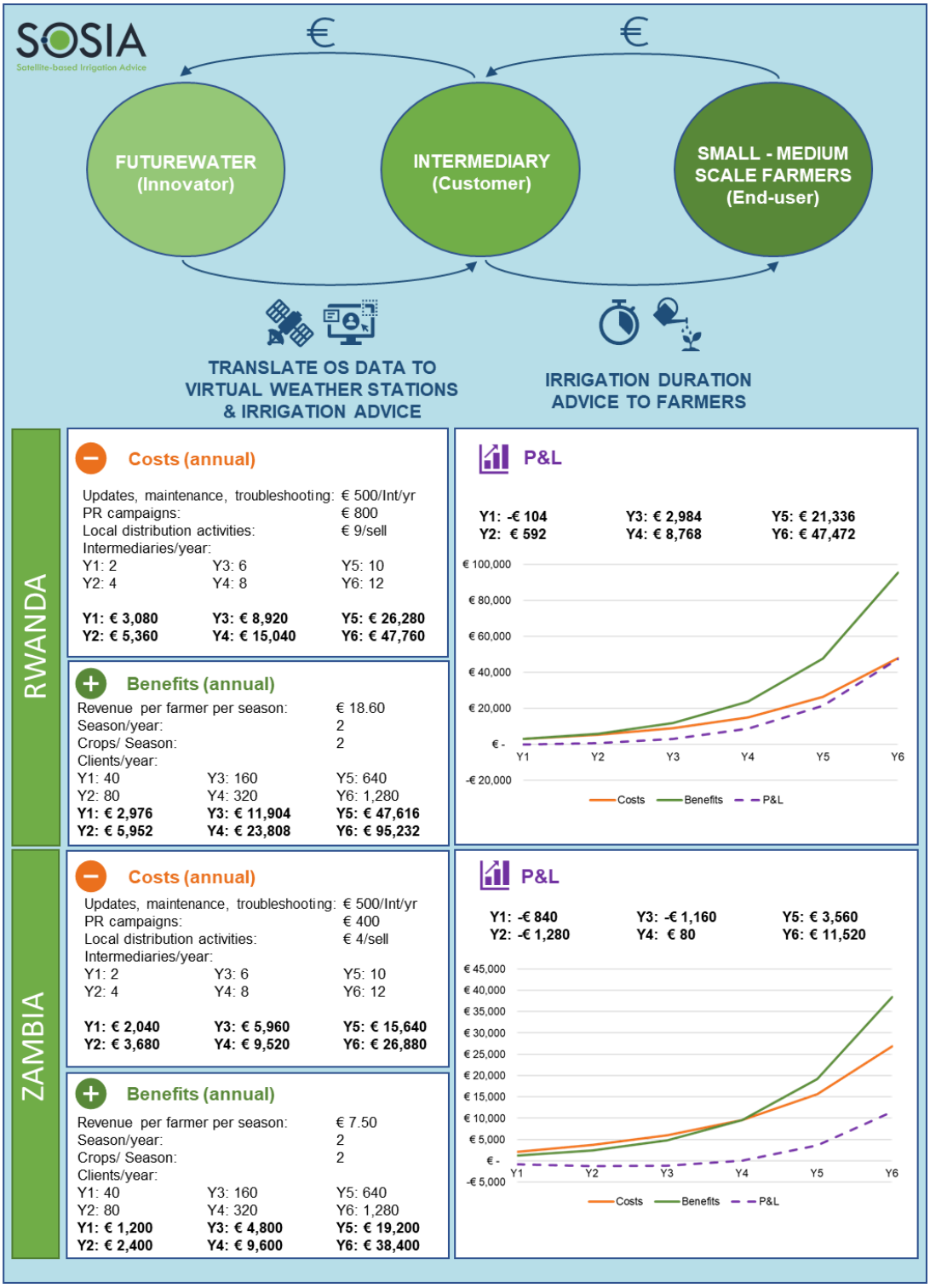


Figure 14. Napkin calculation showing expected revenues and costs in the years following successful completion of the development phase of the innovation.

For the above example, the license agreement will have the following effect for the profits of the innovator and the intermediary respectively:

1. B2B: FutureWater (Innovator) tailors SOSIA to a new context, intermediary, etc. on a project basis and an annual license fee is applied to cover for operational and maintenance costs.

Step 1 B2B Business Case

Potential clientele: NGOs in agriculture, Government bodies, Agri-Consultancy, Irrigation Infrastructure Suppliers.

Scenario: 2 new organizations using SOSIA per year
➔ Project based tailoring of SOSIA to context: 10,000 EUR (20 days)
➔ Commercial yearly SOSIA license (indication): 500 EUR
Yearly turnover: 21,000 EUR

Forecast for 5 years to 2 new organizations per year.
Tailoring = 10 x 10,000 EUR = 100,000 EUR
License = [5 yr *2 Int *EUR 500] + [4*2*500] + [3*2*500] + [2*2*500] + [1*2*500] = 15,000 EUR

Total = 115,000 EUR turnover FW

Division FutureWater and Holland Greentech (over net sales to other organizations)
1. Countries where HGT has a branch / involvement HGT: FutureWater 60%, HGT 40%
2. Other countries: 85% FutureWater and 15% HGT

2. B2C: FutureWater (Innovator) gains on the business between intermediary and end-user through an annual license fee and commission based on Holland Greentech turnover.

Step 2 B2C Business Case

Clientele: Intermediary Holland Greentech to Farmers
Scenario:
1. 200 SOSIA end-users paying 7.50 EUR per crop/advice/field for Zambia.
2. 200 SOSIA end-users paying 18.60 EUR per crop/advice/field for Rwanda.

Annual turnover:
[200 x 2 (seasons) x 2 (crops/season) * 7.50 EUR] + [200 x 2 * 2 * 18.60 EUR] = 20,880 EUR HGT

Yearly **fixed fee** to Future Water: 500 EUR * 2 intermediaries = 1000 EUR per year
Yearly **flexible fee** to Future water 15% of HGT turnover: 15% of 20,880 EUR = EUR 3,132 per year

Example for 5 years with 400 customers over 2 HGT branches
EUR 20,880 * 5 years = 104,400 EUR turnover HGT over 5 years
5 x 1000 EUR = 5,000 EUR **fixed** income FutureWater over 5 years
EUR 3,132 x 5 = 15,660 EUR **flexible** income FutureWater over 5 years

Turnover HGT = 104,400 – 15,660 – 5,000 = 83,740 EUR
Turnover FW = 15,660 + 5,000= 20,660 EUR

5 Knowledge Component

5.1 Overview of learning questions

Overall, activities under the Phase 1 knowledge component have led to valuable insights related to the development of digital services in the context of sustainable agriculture and water management. Knowledge development has been guided by a set of pre-defined Learning Questions (LQs): The learning questions can be found in Annex 5, a detailed overview of the LQ per stage of the project can be obtained from the Learning Question Workbook (excel).

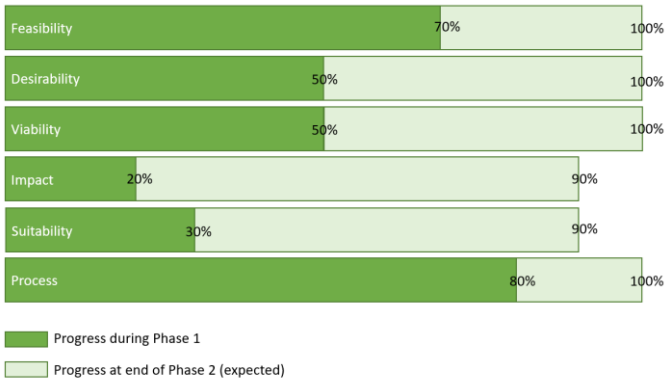


Figure 15. Estimated progress towards answering the Learning Questions during Phase 1 and Phase 2 of the competition. LQs under the category "The Unexpected" are excluded, since these by definition cannot be planned or foreseen.

Due to the phased structure of the competition, not all answers could be fully answered by the end of the first phase. Since Phase 1 focused on development, testing of feasibility and initial prototyping, LQ categories such as Feasibility and Desirability were more extensively addressed than others, such as Impact and Suitability.

Phase 2 involved further optimization of the service by more extensive demonstration to the end user, during which further knowledge was developed. However, all LQs already led to interesting and useful new insights at the end of Phase 1, these are now further elaborated where applicable. Figure 16 schematically represents the **progress that was made and the expected progress towards fully answering all LQs** at the end of Phase 2. It is therefore an indication of the current stage of the learning process associated with SOSIA development and piloting. Not all LQs are fully answered at the end of Phase 2, since continuous learning is expected e.g. concerning the (long-term) impact that will be achieved by implementing the service, and regarding unforeseen learnings that will take place along the way. During phase 2, it became clear that some of the projections made regarding progress on the LQ were still too ambitious (i.e. desirability and viability), during the mid-term meeting at the end of 2023 the following progress wat noted (Figure 16, left). At the end of phase 2, it was noted that not all of the learning as foreseen could be completed. As pointed out in Figure 16 (right), Viability was reduced to 90% as it was found particularly difficult to estimate the maintenance cost upfront. This is further explained in the specific viability section below.

Below sections provide a synthesis of key insights that were obtained during the project. These go beyond learning points that are only relevant to the specific SOSIA service, and relevant learnings are discussed in the broader context of geodata initiatives which aim to support food security and sustainable use of land and water resources in agricultural systems. Annex 5 presents a word-copy of the BopInc Learning Excel sheet with tracked answers for each of the learning for phase 1, for the additional learnings obtained during and after phase 2, the excel worksheet should be consulted.

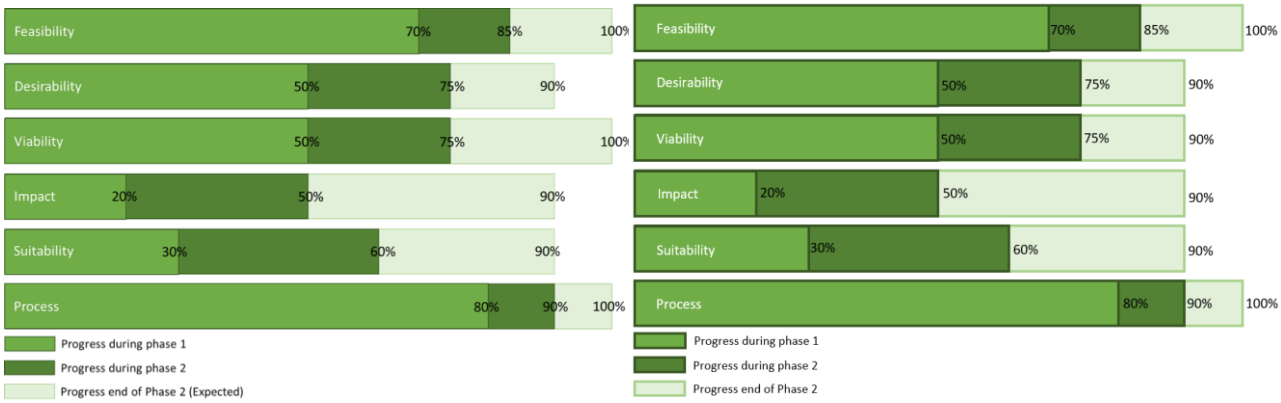


Figure 16. Left, learning progress by mid-term phase 2. Right, learning progress at end of phase 2.

5.2 Feasibility

A technical challenge in using open geodata, particularly when integrating multiple datasets, is the need for downloading, processing, uploading and managing large amounts of data. These activities do not only require considerable resources, but also pose technical risks of failure along the complex chain of activities. During Phase 1 development and testing activities, it was learned that the use of a cloud computing platform (in this case Google Earth Engine - GEE) is an effective way to minimize these risks. Data can be accessed and processed in the cloud, and no major storage space or high-speed computing infrastructure is needed.

In addition, it was found during Phase 1 that an important technical challenge relates to the need for having a tool that fits a collaborative, agile framework for developing a geodata-based service in close consultation with the end user. It was learned that the use of GEE, especially given the ease with which configuration and functionality can be modified, is very suitable for supporting agile development processes and assessments of fit-for-purposeness for future other users. Changes to the source code of the application directly reflected in a visual change to the graphical user interface, which can immediately be evaluated by the user.

However, during phase 2, it became apparent that the use of GEE limited the improvement of the user-friendliness of this tool given the limitation of strictly abiding to freely available data, and thus platforms. As the HGT staff pointed out during phase 2 that the frequency of inputting the data for different farmers was too labour intensive, the idea of creating a database for each intermediary was born. This database would contain all the fixed data for each farmer for each of his fields. However, within GEE, the database extensions all came at a significant cost we could therefore not consider for this project. Hereto, a tailor-made solution to this limitation was drafted to define a database within the script, however this has taken considerate time and is to be seen as a temporarily solution as it also will become too labour intensive on the developer-side once the tool reaches more users.

A generic learning point relates to the availability of local calibration data, which is a typical challenge for developing advisory services based on OS geodata. Satellite-derived data in general have the greatest added value in contexts with limited ground data. During this project, we learned that this issue can be mitigated, at least partly, by making use of OS data products from renowned international organizations, which have been scientifically published and undergone extensive validation and quality control mechanisms. These include for example WaPOR data, which have been developed and tested particularly in the African context.

Further insight into the issue of output validation was obtained during phase 2 as the field pilots undertaken in Rwanda and Zambia showed for all farmers similar yields under the SOSIA irrigation durations, however that is related to the advice based on an evaporation deficit. In the process of

identifying and selecting datasets appropriate for advising on precipitation, major limitations were found with forecasting datasets. It was soon realized that the spatial resolution of the forecasting datasets on precipitation was too coarse to effectively represent local conditions. Additionally, for precipitation and evapotranspiration, the bias obtained from the forecasted data with respect to the historical data was too large, and bias-correcting these datasets in an operational tool was considered sub-optimal. Hereto, a focus on hindcasting was preferred as it allows to say something about last week without adding too much uncertainty to the advice (4.2). In addition, the hindcast is only used to advice in case too little water was applied and will not be used to reduce the irrigation advice if over-irrigation would have taken place in the preceding week, it therefore only focusses on restoring potential soil water losses (Figure 4). As precipitation was added by means of a hindcast, data was needed to validate the spatial resolution with the in-field observations. Hereto, each of the involved trial-farmers was provided with a manual rain gauge from which results were read and logged on a daily basis. These field observations were then cross-checked with the hindcasted rainfall data output by the SOSIA advice. The results indicated that hindcasted rainfall data is not of sufficient quality to be used directly in the determination for irrigation application duration. Therefore, it was concluded that in order to account for rainfall, farmers using SOSIA will be supplied with a field-specific table that allows them to convert measured rainfall (mm) into a duration that can be subtracted from their daily irrigation duration reading. Training will be provided by HGT to inform and train farmers on this methodology.

Hence, an important technical learning relates to the limitations to the level of spatial detail that can be achieved with some OS products, which are developed on a global or continental scale and thus are not delivered with spatial resolutions in the same order of magnitude as field sizes. The main learning from the intermediary and end user feedback is that the added value of these services should be seen in the perspective of the current situation, where essential data are lacking. The level of improvement from the OS geodata-based services is considered significant, despite the aforementioned limitations. Furthermore, the use of (open) geodata also allows for developing a service that provides information that is consistent in both space and time. This allows for comparing current conditions to historical conditions, thus enabling detection of trends and anomalies, as well as facilitating comparison between fields, farmers, and crops.

As OS geodata are produced by renowned knowledge institutes that are generally transparent about the processing steps that are involved, there is, however, also a certain risk of continuity as some of the products are generated within projects that may end at some point. This risk is mitigated by our service in several ways:

- Our service is designed to be flexible, allowing new or better products to be added as input data to the tool in the future. Dissemination of OS geodata is a major trend, and more and improved relevant products are expected to come available over the next years.
- We make use of 5-6 different OS geodata sources to compute the virtual weather station data, where multiple datasets are consulted to compute individual meteorological parameters. By diversifying the inputs, the impact of future gaps in the ensemble of input data is minimized.
- The strength of FW as a company is its focus on the interface between research and consultancy. The company has strong ties with the scientific community and is therefore aware of new and upcoming data products that can be used to improve the service.

This is considered a learning point that is relevant to all operational services for the agricultural sector which are based on OS geodata.

5.3 Desirability

5.3.1 Challenges faced by farmers

The Rwandese & Zambian farmers served by HGT face several challenges in their daily farm operations. Although the target farmers invested in efficient irrigation methods, a gap of knowledge exists in how much water to apply and thus how long to irrigate for. Currently the duration of irrigation is done by guess work, looking at the weather (no measurements, no data, no weather stations). The economic benefit for

a farmer, to supply the right amount of water at the right time to the crop is that the crop will perform better which results in higher crop yield per m^2, less pest pressure (a vigorous crop is more resistant), improved soil life (optimal soil moisture content benefits soil life), water saving and more importantly: economic saving due to decreased fuel use, since the far majority of farmers are using petrol pumps and fuel prices are currently increasing rapidly. Based on the survey results presented in Annex 2 and Annex 3, the latter is considered by the farmers as the most important gain of optimal irrigation advice.

Comparing the first results obtained at the end of phase 1 of SOSIA with irrigation records retrieved from a farmer in Rwanda indicated that the farmer currently irrigates more than necessary (Annex 8). The advised daily irrigation volumes of the SOSIA-tool consequently are factor 2 lower than previously applied by the farmer. This indicates that, by implementing the SOSIA advice, less water would be used, and fuel would likely be saved. However, validation for this was needed to test the crop performances under the SOSIA advice. During phase 2, a total of 10 farmers were part of a trial of different versions of the SOSIA tool. During and after finalization of the trials, each of the involved farmers mentioned the positive benefit of SOSIA to their farm management (Annex 7, Annex 14 & Annex 15). In all the trials, the SOSIA advice has shown an added benefit as farmers noticed: (i) a sustained, or optimized crop performance, and (ii) a reduced irrigation period. The former was not quantitatively checked but as the farmers had only some rows under the SOSIA advice, it was easy to verify and check differences in crop performance on the field. The latter was quantified by the farmers as they kept records of irrigation application durations for both the drip lines under the SOSIA advice as well as the rows that were not advised by the SOSIA advice (Annex 18). Aside from surveying the trial farmers, the WTP was further determined by analysing the reactions to the tool and its price during the launch event in Zambia. During a round of raise-your-hands, more than 30 attendees (out of 50) showed interest in adopting the SOSIA advice after a thorough explanation on the tool, its benefits and it price was shared. However, it will remain to be seen how many of them will purchase an advice over the coming weeks.

Learnings during this project generally support the assumption of a high, and growing willingness to pay (WTP) among the farmers served by the intermediary. From the survey results, it was learned that farmers with a drip system are already quite progressive and risk taking. Most farmers grow cash crops such as strawberries, chili peppers and other vegetables. It was found that these farmers are willing to pay for the service, even more so given the results they obtained during the trials in phase 2. At the end of phase 2, it was thought that the height of the fee would depend on two main factors: i) the improvement of the yield, and ii) the reduction in pumping time and thus a reduction in fuel or electricity use. During phase 2, these two criteria were analysed by the local HGT teams to come up with a price setting for the respective country. For Zambia, a price of 7.50 euros per crop per season is adopted whereas Rwanda will charge 18.60 EUR per crop per season. The differences in pricing originate from the fact that the financial savings in Rwanda are significantly higher because of the higher cost of pumping compared to Zambia. In addition, having two price strategies allows to study the effect of pricing on adoption of the SOSIA advice. This will be evaluated by HGT and FutureWater in the end of June, 2023.

5.3.2 Challenges faced by intermediary

During Phase 1, it was learned that the current challenge for the intermediary is twofold:

1) Currently, it is tedious to calculate the Crop Water Requirements (CWR) for clients, since the input weather data are inaccurate, outdated and not location-specific. Therefore, the intermediary cannot give accurate advice to farmers and has to estimate and guess;
2) In the design process of irrigation systems, too much time is being spent by irrigation engineers to calculate CWR which at the end is sub-optimal and can potentially lead to an inadequate irrigation design. By using the SOSIA tool, the design of irrigation systems also becomes more precise (localized) and in a shorter period of time.

The above challenges, identified during Phase 1, serve as key intermediary “pains” to be addressed by the SOSIA tool. In phase 2, the following challenges were observed that arose from the use of the SOSIA v2.0 tool:

1) As the weekly hindcast updates are not automated, the current methodology to generate an advice, be it historical or hindcast, requires too many input variables to be inserted manually. Therefore, some sort of database would be preferred that stores the fixed farmer input data.
2) In providing the advice to the farmers, some farmers are better in using the advice than others. One specific farmer in Zambia has indicated during the survey that upon receiving the advice, he did not know what to do and how to use it without explanation by the extension officer.

Whereas SOSIA is a tool under development, the challenges of the intermediary identified at the end of phase 1 were tackled during phase 2 as the trials showed to be successful. In addition, the challenges from using SOSIA identified during phase 2, have been tackled for as much as possible. With respect to the database, as mentioned in section 3.2, a database is now included in the tool that respects data privacy of the farmers. Hence each HGT office holds its own SOSIA-tool with its own database. In terms of the challenge with effectively informing farmers on the use of SOSIA, a dedicated user-training will be provided as part of the SOSIA package. Due to the GEE limitations, the expansion of the database could not be automated, creating more work for FutureWater in keeping this up-to-date. This might result into a higher maintenance fee for the intermediary. In the future, as the user base grows, it is likely that a paid service for the database operations with GEE will be considered. This commercial trial will be evaluated within 3 months.

5.3.3 Communication channel

The survey results obtained during phase 1 (see Annex 2 and Annex 3) indicate that digital platforms are preferred by all end users interviewed. WhatsApp is considered as the best option because farmers indicate that they will than always have it available. Some farmers interviewed prefer receiving the result via email. The intermediary will also be able to print out the results in order to service farmers that do not have the access to a smartphone, though it is expected that this will not be used a lot looking at the fast-growing access of smartphones. In general, the intermediary also explains the results in detail to the farmer to be sure the farmer will interpret the results the right way and to increase the chance that the irrigation advice will lead to the desired impact.

Based on the above, it was learned that a certain flexibility needs to be maintained for disseminating the advice. The SOSIA tool was therefore designed to provide its output information and irrigation advice in csv format, leaving the intermediary with several options to convey the information to the farmer. Although the SOSIA tool has the ability to produce quite a range of data for the farmers, a selection was made, based on the questionnaire in phase 1 and interviews, to what information to include on the PDF shared with farmers. Although the farmers during the trials only used the number of minutes on the advice, a decision was made to remain the ETref, Eta and the volume of water required m^3 on the advice to the farmers. This is believed to create initial insight to the farmers of how the irrigation advise is calculated when explained by the extension officers.

5.3.4 Willingness to pay

In general, whether it be with respect to the end-user or the intermediary, the WTP has been a tricky to validate component of this innovation as it specifically requires time to be understood which was generally limited in this rather short-term project.

On the one hand, focus was laid on the end-users who after phase 2 in both Rwanda and Zambia have shown interest in adopting the tool. For Zambia, this interest has been validated with the price setting whereas for Rwanda, the interest to adopt SOSIA was expressed by the trial farmers however an official launch for SOSIA at the 20 USD price-point has not yet been held officially. Nonetheless, throughout this innovation, the added value of the tool to the end users has been well understood. For Zambia, the lower price per advice per crop/ season relates to the rather minimal cost savings given the rather low cost of electricity. In contrast, the price setting in Rwanda is higher but so are the expected savings as most farmers rely on fuel pumps which are more expensive to operate. In addition, farmers have also proven

to understand the benefit of retaining as much water in the ground as possible in terms of the sustainability of their farms and agricultural practices in the region. Nonetheless, it remained difficult for some farmers in both Rwanda and Zambia to commit at this stage to a paying service as they want to gain more trust with this tool for other crops/ larger field sizes, and in different seasons (especially during the coming dry season). As the tool was officially launched in Zambia, some new early adopters have been identified who have shown to be interested in purchasing the tool. It is yet to be seen whether these promises will also translate in a long-term commitment to the service. Therefore, it is generally concluded that the WTP from the end-user perspective is an on-going process; looking back at the different evaluation steps within this two-phased project, it was observed that the WTP has been increasing as we moved forward with the innovation.

On the other hand, there is the Willingness-to-pay from the intermediary perspective. Given the license agreement (Annex 9) drafted after the introduction of SOSIA in Rwanda at the end of phase 1, the intermediary have shown interest in adopting SOSIA within their current advisory services. However, once external funding comes to an end, the true cost of SOSIA will determine whether the price setting charged in Zambia, Rwanda and other off-takers is sufficient to maintain the tool without sacrificing on its quality. For this, FutureWater will keep track of time spent on maintaining the current version (3.0) of the tool for Rwanda and Zambia over the coming months. This generally implies monthly database updates, assistance with generating field-specific rainfall compensation records, etc. As SOSIA will be further developed in a follow-up project in Ghana (SOSIA+), the quantification of maintenance requirements and related costs will happen over the coming months. It is envisioned to come up with a final cost for maintenance (paid through a license-fee) over the next few months. As the SOSIA development was granted additional funding in a new project, the risk of discontinuation is minimised as both the developer and the intermediary have proven interest for furthering SOSIA with this follow-up project.

5.4 Viability

Other potential business cases have been explored during this project, such as selling the virtual weather station data as a separate product, as it is expected that such data could be of interest to other organizations, within or outside the agricultural sector. However, this requires further investigation and is generally not deemed to be the focus of this tool at this stage as the surveys indicated that the associated farmers are willing to pay for these services themselves.

Whereas initially the option to sell-off data to external parties who are on the value chain was considered, it has become clear that both FW and HGT do not feel comfortable, at this stage of the innovation, to focus on such a third-party inclusion to make the product more affordable for the end-user. Even though the potential benefit to the end-user of such mechanisms is well understood, the current intermediary would not feel comfortable collecting data for commercial purposes of their off takers.

Hence, it is believed that, based on the initial surveys, the good feedback on the different SOSIA tool versions (SOSIA 1.0, 2.0 and 3.0) and given that most associated farmers are identified as risk-takers, the general interest in purchasing the advice in a B2C format is viable without relying on any alternative revenue model. This was further confirmed during phase 2 as each of the trial farmers responded positively to the cost SOSIA per crop per season. At the launch event, under the presence of 50 potential end-users this price setting was shared after which more than half of the attendees showed interest in purchasing the SOSIA advice.

However, one way to make the service more affordable to farmers is to include it in a wider range of products and services. HGT, as intermediary, is in a position to explore this option because of its existing inputs and services strategy. Two sales strategies have been identified that allow for SOSIA to be used in an economically viable and sustainable way. The advice will either be sold individually per crop per season, or in case of new customers it would be sold as part of their new irrigation kit as a hidden cost at first. 3

For FutureWater, the business case is two-fold as well as the following revenue models are considered:

1. B2B: FutureWater (Innovator) tailors SOSIA to a new context, intermediary, etc. on a project basis and a license fee is applied to cover for operational and maintenance costs.
2. B2C: FutureWater (Innovator) gains on the business between intermediary and end-user through license fee and commission based on SOSIA turnover.

This is ascertained via the license agreement established and put in place during phase 1 of this project.

A last strategy, that is context-dependent, is the act in which governments and/or NGOs, aiming to improve food security, water efficiency, or in general want to support small-scale farmers, could also decide to subsidize the SOSIA tool for specific target groups. Organizations such as, for example, the UN World Food Programme (WFP), USAID or SNV could decide to pay 50% of the irrigation advice so that a small-scale farmer is only required to contribute 50% him/herself. Such mechanisms will at no point be avoided by the intermediary, as it is believed that through such collaborations the tool might reach a larger impact. This option has not been further explored specifically during phase 2 as the focus was on finalizing the tool first before reaching out to new parties with a tool that is not finished. However, at the launch event in Zambia, USAID was present. They showed great interest in this tool and are very active in Zambia. A follow-up with them is foreseen. NGO´s and government organizations can also be interested for getting their own user rights for the tool. In this case FutureWater and HGT can give an offer in terms of a user license after which (extension) staff of the interested party can use the tool by itself and generate the advises for its end-users. This strategy also fits well in the B2B strategy agreed on by both FutureWater and Holland Greentech.

During phase 1 it was foreseen that FutureWater would spend about 20 working days per year on maintenance, to keep the tool up and running. this included time for periodic service updates, general maintenance, troubleshooting and support. These activities would be equivalent to about EUR 10,000, which do not include further developments or maintenance of the tool. As the SOSIA tool will be further developed and shaped in a follow-up project, the maintenance requirement is yet to be fully understood. Also, during phase 1, it was not yet realized that maintenance requirements heavily depend on the needs. During the coming months therefore, as the tool has now been launched in Zambia and Rwanda officially, FutureWater will keep track of the required time for maintaining the tool in both countries in to better understand the maintenance requirements. A tool with less maintenance yet remaining sufficiently functional for the end-users, indicating it would come at a lower cost, is as interesting as a tool that is updated weekly but comes at a cost that is no longer interesting for the end-users to consider. This contradiction is the main learning in terms of identifying the maintenance requirements and cost.

5.5 Impact

As shown in Figure 15, Impact is one of the LQ categories that was only addressed to a limited extent in Phase 1. At the time, several concise and preliminary learnings were listed:

- Due to the short duration of Phase 1 and the focus on development and feasibility assessment, no fully-fledged impact assessment could be achieved. However, first steps were taken in obtaining insights into the expected impact of the SOSIA tool. It was expected that the service directly impacts productivity, income, and sustainability of land and water use, and would have indirect impacts on resilience and improved food security. These expectations were based on the indicative results using the existing logbook obtained from one of the associated HGT farmers (Annex 8), as well as the positive results of the surveys among intermediary staff as well as end users. The beneficial evaluation from both groups provides an initial indication that user requirements are addressed well, which should stimulate uptake of the SOSIA tools and thus enhance impact in practice.
- Inclusivity is considered highly important by the innovation developer. In the learning process during Phase 1, it was realized that the choice for the current intermediary and the primary focus on drip-irrigation technology only may limit the extent to which an inclusive, diverse group

of users can be reached by the service. For this reason, upscaling activities in Phase 2 would explicitly aim to reach other types of irrigation end-user groups. Overall, SOSIA entails a digital innovation to support precision agriculture, which is typically popular with the youth. ‘

During the mid-term surveys in Rwanda, it became obvious that 100% of the trial farmers in Rwanda and Zambia saw a reduction in irrigation with SOSIA while crop performance of demo and control plots were indifferent. For Rwanda, the water and fuel savings were between 10 and 30%, whereas in Zambia savings up to 50% were observed. All of the farmers indicated that the SOSIA advise was easy to implement, except for one farmer who reported some miscommunication regarding how-to use the advice at the beginning of the trials because the advice was sent to him without much explanation. In addition, the SOSIA advice tends to motivate farmers to be precise with the irrigation scheduling. In addition, the SOSIA advice made the farmers feel more committed to their farming practices. In general, 100% of the farmers that adopted SOSIA saved water: (i) more water remained in open surface or ground water resources, (ii) more water remained available for downstream situated farmers, and (iii) production remained high indicating water productivity increased. Hence, from the economic feasibility, and as described under project activities for WP2, WP3 and WP4, the SOSIA tool for each of the 10 trial farmers have led to optimized yields for less water, hence an improved water productivity of up to 50%. These findings are obtained for both Zambia and Rwanda during the past two cropping seasons.

In addition to the direct benefits of SOSIA, phase 2 pilots focused on involving young and female farmers. Mme Cristine and her son, Mme Wood, Mme Phiri were all involved in the trial of SOSIA in Zambia, each of them being independent and real businesswomen. Mme Christine of Chimoko Seedlings (Figure 9) owns a farm where both seedlings for other farmers are produced, compost is sold as well as crops are cultivated for the open market. Mme Phiri leads with other women of her village a cooperative and her husband assists other farmers in adopting to drip irrigation. Together, they run an agroshop affiliated with HGT. Mme Wood visits her farmland five times a day to check in on the young irrigation and farm managers working on the fields. Each of these have been using the SOSIA advice during the past months and have indicated to be satisfied with the impact SOSIA has had on their farm and management practices. It was noted that the younger farm operators interviewed over the course of this project, showed interest in using the tool and/ or discussing the source code; which directly provides evidence as to why digitalization can positively affect youth involvement in agriculture. They are specifically surprised by the amount of water they previously supplied to the land, not knowing they could improve significantly. Mme Wood grew Impwa (African Eggplant) and unlike all the other farmers applied the SOSIA advice from day 1 to all of her field as she fully believed in its potential.

One thing to note is that so far, the SOSIA tool has not been used for a full dry season crop as the start of phase 2 first focussed on finalizing SOSIA v2.0 and rain seasons commenced during completion of this version and lasted till now. Hence, the tool has not yet been tested in a dry season during which rainfall events are not present. The developers believe that SOSIA will perform well in a full dry season since the datasets that are most important to estimate the CWR are much more accurate compared with the rainfall-datasets. Farmers mention that this tool specifically will be interesting to use in the dry season when crops fully rely on irrigation. Therefore, benefits are expected to be most outspoken in the dry season. Nonetheless, it has been observed by each of the farmers that even in a wet season SOSIA is handy as it provides them with an irrigation advice for the intermittent drought periods which are occurring more frequently under climate change.

5.6 Suitability

At the end of phase 1, it was found that HGT has the potential to contribute effectively to the impact goals, this has been further proven over the course of the second phase. The organization has a strong local presence and an elaborate, already established farmer network inside and outside of Rwanda. Moreover, its services are diverse (also including e.g. soil tests, irrigation equipment), meaning that an integrated and tailored product can be delivered to maximize impact for the specific farmer group. By

familiarizing extension officers with the SOSIA tool, they are able to obtain a better understanding and provide effective guidance to farmers.

Several beneficiaries have been preliminarily identified during this project, such as the Rwanda Agriculture Board (RAB), the Food and Agriculture Organization of the United Nations (FAO), and multiple NGOs targeting smallholder farmers. The inventory of potential stakeholders was planned to be verified and expanded on in Phase 2. However, the importance for developing a solid tool afore spreading the news of an unfinished tool to other potential stakeholders, has limited the extent to which this has been undertaken. Specifically, regarding the exploitation of the tool, little progress was made in function of the prioritized tool development. Nonetheless, at the launch event in Lusaka, Zambia on February 4, 2023 USAID attended the presentation and demo. This will be followed-up on to see how they could benefit from SOSIA and/ or to determine how they could assist us in reaching more potential users and intermediaries.

The strong collaboration between the innovation developer and the intermediary has greatly benefited the local contextualization of the service. FW already has extensive experience in working in Rwanda and Zambia for different clients in the agriculture and water sectors. Moreover, throughout Africa, the network of both FutureWater and Holland Greentech will lead to more opportunities for SOSIA. For example, the new SOSIA+ project in Ghana which has already commenced.

On the other hand, having gone through this extensive innovation process also highlighted some pitfalls and gaps within the current set-up of the SOSIA services. A limitation is the lack of permanent physical presence of the innovator in Africa, however this is not considered a major bottleneck because of the good relationship with the intermediary. In addition, a more critical bottleneck could be the need for sustaining effective communication as here there is a potential gap between the feedback/ wishes from the field (farmers and HGT) and the development team of FutureWater. Regular meetings are foreseen to enhance the exchange of ideas and feedback as much as possible both between the intermediary and the end-users as well as between the developer and the intermediary (credited through the license fee). In addition to this, there is quite an extensive translation gap between the technical processes embedded in the tool (the script) and the extension officers working daily with the SOSIA tool. During the launch event in Zambia, a training on technical back end of the tool was provided to ensure the extension officers trust and rely on the output of SOSIA but moreover can detect if SOSIA would be corrupted and/ or malfunctioning.

5.7 Process

We regard this competition as a very welcome and helpful opportunity to develop a high-impact service in close collaboration with intermediary HGT. The flexibility of the competition in terms of themes, geographical scope, and input datasets has allowed us to design the project activities in a way that is directly beneficial to the development of our particular service. At the same time, the short time frame (3 months) in which project phase 1 took place, followed by 6 months of phase 2 limited the scope of activities that are practically feasible.

This limitation related to the fact that during phase 1, SOSIA v1.0 needed to be developed in a very short period of time, paying attention to a wide range of aspects (e.g. technical, economic, organizational), but also to the fact that there are three clear parties in the setup of the competition: the innovator, the intermediary, and the end user. To sufficiently address e.g. the compliance of the innovation with the needs of intermediary and end user and the expected impact along the entire chain, frequent and elaborate interaction was required in which all three parties played a certain role. It was found that three months was a very short project duration to make all of this take place in a satisfactory manner.

One would think that the follow-up phase 2 granted the time to walk through all of the necessary steps which were at the end of phase 1 deemed as only possible in a project with a longer time span. Even here, the same limitations observed during phase 1 were faced. This is again partly attributed to a

mismatch between the phasing of the second phase which commenced in August (holiday period for most involved colleagues). Consequently, the improved version of the tool only was ready by the end of October 2022 (SOSIA v2.0) which subsequently had to be tested in a mostly wet season. Mid-term reviews were based on field-surveys taken around November 2022, the moment at which rain gauges were installed to validate the precipitation hindcast product. With Christmas and New-Year celebrations in between, the last surveys in early February 2023 happened simultaneously with the release of the final SOSIA 3.0 version. Hence, one could note that an official duration of 6 months in phase 2, compared to 3 months in phase 1, is still somewhat limited within the context of this price draw innovation project. This has specifically limited the scope to effectively reach out to new beneficiaries and intermediaries as a completed tool was always prioritized afore it being introduced in a new geographical and institutional context. Also, in terms of available time, it was underestimated how much time would need be spent on the technical improvements of the tool which made it close to impossible to tailor the SOSIA tool over the past 6 months to a new intermediary with potentially different needs and expectations. Hence, this also impacted the willingness to pay component so critical and vital to the success of SOSIA. The time required for establishing a trust-relationship with the farmers for this new tool spans a greater period than what is available in the current project duration. To gain insight in the Willingness to Pay for irrigation advice a longer trial period is deemed necessary, as farmers indicate they want to specifically test SOSIA 2 in a dry season which has not occurred within the current project duration.

Nonetheless, with the second phase, SOSIA was further developed and made more technically sound and user friendly from the perspective of the end-user as well as the intermediary. Also, extensive fieldwork was undertaken which was key in order to capture the impact and make an improved business case. In addition, all of the trials proved to be effective, the SOSIA advice reduced water application while sustaining optimal harvest. We noticed that farmers are better engaged in their farming practices. Our last version, SOSIA 3.0 is a strong tool based on all the lessons learned in phase 2, mainly in terms of user friendliness. The tool is ready for commercial application and commercial testing by the intermediary to keep learning how the tool can be applied most optimally.

5.8 The unexpected

One unexpected learning relates to how the theory of change has been adopted at the end of phase 1, due to the unexpected realization that the way the SOSIA tool is introduced to the farmer, i.e. through the intermediary; and because the versatile applications the tool offers to the intermediary (i.e. both irrigation duration advice, and irrigation infrastructure design), shows that one tool has different end-users within this two-tiered business model. This is an unexpected learning as it was not the initial focus of this innovation study to make such a distinct division between both user groups.

6 Conclusions and Reflection on Theory of Change

As thoroughly explained in the previous section, various learnings have been made throughout this innovation project. Whereas some have been fully completed, other learnings such as the desirability, viability, impact and suitability components are on-going processes that at no point within this project duration could be fully captured. Hence, whereas within each of these components various learnings have been collected, it should be specifically noted that they might change as SOSIA is further developed, upscaled and exploited. Therefore, the concluding remarks presented below should be interpreted with account of this continuous process.

The SOSIA tool was evaluated thoroughly in-field in both Rwanda and Zambia over the past few months. As presented above, each of the learning categories have had an impact on the theory of change initially established. Whereas at the end of Phase 1 it was anticipated that the ToC might require significant changes, as Phase 2 progressed, ultimately the version presented six months ago has not been altered too significantly by the revisions we have had while writing up the learnings of Phase 2.

Generally, it is argued that the development of the tool and the various in-field surveys with both the end-user farmers as well as the intermediary have shown that SOSIA is a welcome development, not only because of its functionality, but also because current farmer practices are well below optimal farm management. As originally hypothesized in the preliminary theory of change, presented in the first proposal, impact was expected to be achieved at two levels. On the one side the farmer was expected to be positively impacted, whereas on the other hand the intermediary would gain an improved business case and thus market position. During Phase 1 of this project, it was noticed that the differentiated impact actually implies that there are, in a sense, two beneficiaries and thus two market cases as part of this tool: (1) a product that is used by the intermediary to provide its customer base with local irrigation duration advice, and (2) a product that uses some of the output of the tool to optimize infrastructure design of potential new clients of HGT. Both expected impacts directly address the challenges faced by the irrigation engineers upon introduction of the SOSIA tool, as discussed under the Desirability LQ (section 5.3). As both products indirectly benefit the farmers (end-users), the developed product sits within a two-tiered business case, in which the relation between innovator and intermediary is independent from the relation between the intermediary and the farmers (end-user). Therefore, the outcome and impact for each user group is distinct. Whereas at the end of phase 1 it was thought that this distinction was crucial for further developing SOSIA, during phase 2 most of focus was lain on the former market case as the ability for SOSIA to assist in design is seen as an additional feature to be still fully explored as it has not been part of any trial during phase 2. Therefore, it is argued that the TOC should not be amended as it is still believed that SOSIA allows both market cases to be explored, and both will benefit the end-user farmer group, nonetheless during this project only the irrigation tool has been validated and the design component is yet to be implemented and evaluated practically.

FW solely aims to work with intermediaries such as HGT, as it does not have the ambition, nor the local network to work with farmers directly. However, as each of the potential intermediaries will provide advice to farmers, the impact made on the second level can still be ascribed to the tool. Hence, the two-tiered business case yield impacts for both the intermediary as well as the farmer. This realization has been included in the updated theory of change during Phase 1, and remained unchanged in the revised final version.

Aside from a two-tiered business strategy, also some of the initial assumptions were adapted based on new insights gained throughout this first and second phase. These assumptions are now better understood and were pivotal for quantifying the exact impact during Phase 2 and were specifically targeted for in the semi-structured interviews held when the pilots came to an end (Annex 14, Annex 15). In addition, the impact has been subdivided into short-term and long-term impact goals. As shown in Figure 17, it is expected that some of the impact goals will not be fully quantified over the course of this project, therefore the Theory of Change has been adjusted to account for this. A distinction between short- and long-term impact has been provided. Whereas the former has been quantified over the course of phase 2, the latter is currently based mostly on (updated) assumptions as it is not possible to study such effects within a project with a duration of less than a year. Nonetheless, as both FW and HGT have already signed a mutual agreement that will take this tool further upon finalization of this project, and

because a follow-up SOSIA+ project has been granted and commenced in Ghana, it is ascertained that this impact will be thoroughly followed up as part of the mutual agreement and commitment expressed by both the innovator as well as the intermediary. Continuous evaluation of impact and scope for improvement is instrumental for the SOSIA tool to realize the long-term impact it envisions.

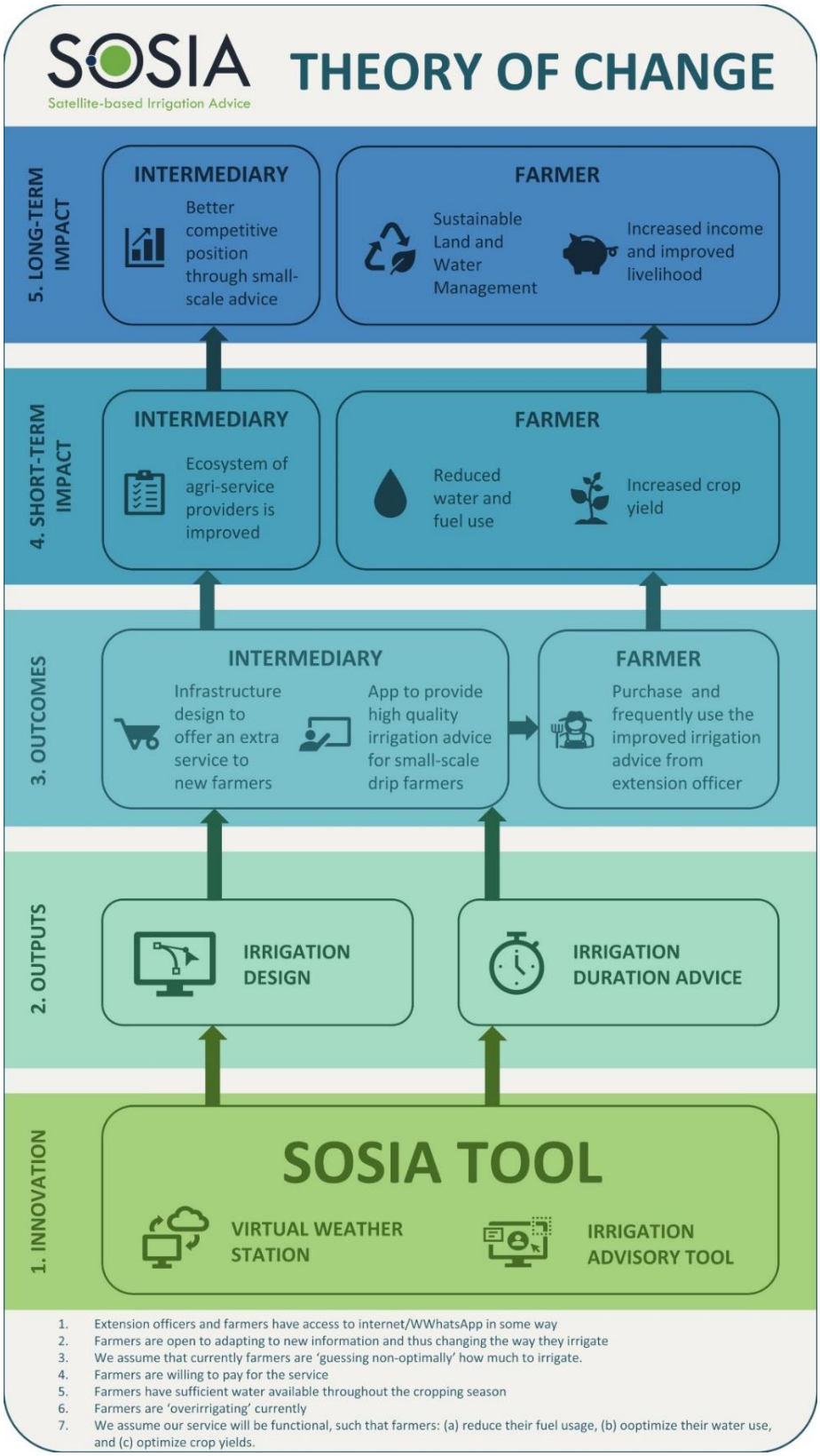


Figure 17. Theory of Change after phase 1

Annex 1- User profiles

SOSIA
Satellite-based Irrigation Advice

Persona 3 – **End user**

Mrs. Aliane

Age: **48** Occupation: **Farmer** Location: **Kigali, Rwanda**

User Story

I'm a farmer that has a passion for healthy vegetables and my farm is a 2.5-hour drive from my home in Kigali. When I retire, I hope to resettle at my farm and enjoy the view of the beatiful hillls and my crops every day. I invest a lot of my savings into developing the farm and I also purchased drip irrigation from HGT. For a long time, I had no idea on how long to ask my farm worker to irrigate and I was not sure if he was doing the right thing, especially in my absence! My crop suffered because of that.

With The SOSIA irrigation advice that was given to me by an HGT extension worker, my headache disappeared! I can now easily instruct my farm worker on how long to switch on the pump every day and have a crop that deserved to be admired.

Goals

- Develop a small but profitable farm
- Data-based information that helps to manage the farm

Frustrations

- Unsure what to instruct in terms if irrigation scheduling
- Hard to know if irrigation is done well and crops receive the right amount of water

Watch video interviews

"With the SOSIA advice, It is very clear on how long to irrigate based on accurate information. This helps me to manage my farm better and improve my yields."

Figure 18. User profile of end user Mrs Aliane, farmer

SOSIA
Satellite-based Irrigation Advice

Persona 2 – **End user**

Watch video interviews

Mr. Pacique

Age: **28** Occupation: **Farmer** Location: **Gatsibo, Rwanda**

"Every day I have to guess how much water my crop needs and how long to irrigate. The SOSIA advice helps me to make my farm more perfect."

User Story

I'm a farmer that grows vegetables because I feel it can make good money when everything is done perfectl, starting from the soil all the way to the market. This is however not easy, and my costs of production are high. Inputs such as fertilizer, seeds and fuel are getting more and more expensive and making my margin small. Although, I have invested in a drip irrigation system and a pump, I keep guessing on how long I should pump to get the best crop. My ways to determine my irrigation are limited.

The SOSIA irrigation advice simply tells me how many minutes to irrigate every day to meet the requirements of the crop so at least that is a concern less!

Goals

- Achieve highest yield potential
- Optimize (costly) use of resources
- Optimize agri- business case

Frustrations

- Invested in drip but it is still guess work
- High input costs, low margins

Figure 19. User profile of end user Mr. Pacique, farmer

SOSIA
Satellite-based Irrigation Advice

Persona 1 – **Intermediary**

Gilbert Tuyisenge

Age: **30** Occupation: **Irrigation engineer @ Holland Greentech** Location: **Kigali, Rwanda**

User Story

As an irrigation expert of Holland Greentech, I advise farmers almost every day about what irrigation technologies will work best for them, I make tailor-made designs, prepare quotations, install the drip irrigation systems and provide training in operation and maintenance. What drives me, is the happy feedback of farmers when visiting them for after sales service and see that the irrigation system – and other HGT inputs and services support in improving their livelihoods.

The SOSIA tool offers me the chance to have an even greater impact on our clients. I can use the tool myself on my smartphone in the field, or on my laptop at our office to give the client an easy to understand advise on their irrigation scheduling. Additionally, it helps me to improve on my designing because it makes it very easy to check if the design that I make will accommodate the peak water requirements on the exact farm location of the client.

Goals

- Improve service satisfactory of clients
- Improve localized and precise insight in crop water requirements
- Improve drip irrigation designing

Frustrations

- Too difficult to help farmers in how to schedule their irrigation
- No localized and precise information accessible concerning the irrigatoin water requirements

Watch video interviews

"My drive is to help farmers, on a beneficial way, a way that really benefits them well, the SOSIA tool supports me on that mission!"

Figure 20. User profile of intermediary Gilbert Tuyisenge, irrigation engineer at HGT

Annex 2 - Survey Questions WP1 Field Trip 1: March 22-25 2022

WP 1

Identification stakeholders and user segments for the SOSIA tool.

Date of interview:_____/_____/2022
Location:_____

- Name farmer
- Gender: male / female
- Age
- Phone number
- Location farmer
- Size farm
  - Coordinates
  - Total size farm
  - Size of fields where farmer is growing crops
  - Size of fields that use irrigation
- Crops
  - Crop type/variety
  - Intercropping
  - Planting date
  - Plant spacing
- Soil:
  - Soil type:
  - Any soil test done?
- Description of farm
  - How many casual workers?
  - Description of water source
    - River / dam / borehole / furrow / stream
    - Water availability (include seasonal differences if they exist:
  - Description of current irrigation system
    - Water source used
    - Dam liner/water tank size
    - Pump info
    - Height tank (if they use a tank) / dam liner (in meter)
    - Distance tank to fields
    - Include photos of several system (components)
    - Type of drip line (need to be HGT sourced)
      - Brand

- Emitter spacing
- Emitter flow rate

Interview question form for farmers - WP1-Sosia

1. When was the first time you operated the system (month - year) ?
2. Does the system supply enough water for your crop?
   - ☐ yes: How can you see that the crop has enough water?
   - ☐ If answered no: How can you see that the crop has not enough water?

Explanation:_____
_____

3. Do you measure how long you irrigate one field (in e.g. minutes or hours)?
   - ☐ IF yes, how do you measure this?
   - ☐ If no, can you explain why not?

Explanation:_____
_____

4. Do you keep records of your irrigation schedule? (when and how long you irrigate)
   - ☐ Yes
   - ☐ No

5. Do you think it is useful to measure the time how long you irrigate?
   - ☐ yes, why is this useful?
   - ☐ no, why is this not useful?

Explanation:_____
_____

6. If you measure the irrigation, how do you record this (timing/litres/m^3)?

Explanation:_____
_____

7. Would you like HGT to give you more elaborate advice on how long to irrigate, based on weather data, your location, crop type etc?
   - ☐ If yes, explain
   - ☐ If no, can you explain why not?

Explanation:_____
_____

8. What information would you like to receive in the advice (thick multiple boxes)
   - ☐ evaporation crop (mm/day)
   - ☐ minutes of irrigation per day needed
   - ☐ daily amount of water of water required
   - ☐ weekly amount of water required
   - ☐ other_____
   - ☐ other_____

9. How often would you like to receive such information (Frequency)?
   - ☐ Once in the beginning of the crop season as a crop schedule?
   - ☐ Daily/ weekly updates on irrigation advice?

- ☐ Once in the beginning of the crop season + on special moments due to e.g. weather

10. How would you prefer to receive this information?
    - ☐ As a PDF on your WhatsApp/phone,
    - ☐ As a PDF on your email
    - ☐ Verbal explanation by a HGT staff member?
    - ☐ Printed out schedule (hardcopy)

11. Are you also interested to receive the above information expressed per plant or per ha?
    - ☐ Only for my own field size
    - ☐ Also the amount of water per plant
    - ☐ Also the amount of water per ha

Explanation:_____
_____

12. Do you have a smartphone?
    - ☐ yes
    - ☐ no
13. Would you be willing to pay for this service?
    - ☐ Yes
    - ☐ no
14. If answered question 13 with yes: How much would you be willing to pay for a detailed irrigation advice which is based specific for your farm conditions? (This advice would be a complete advice for one whole crop-cycle)

    - ☐ 5.000 RWF
    - ☐ 10.000 RWF
    - ☐ 15.000 RWF
    - ☐ 25.000 RWF
    - ☐ Other:_____

15. Do you check for information on the weather to manage your farm?
    - ☐ Yes Describe what data you access.
        - ☐ Weather parameters: Rainfall / temperature / reference ET
        - ☐ Historical data: Last days / Last month / Last year
        - ☐ Forecast for next days
    - ☐ _____

Annex 3 - Survey Results WP1, Phase 1, Field Trip 1: Summary

WP 1- Input & Output analysis SOSIA

Identification stakeholders

The user group of the SOSIA-tool will be farmers with irrigated fields of an area between 0,5 and 10 ha. The farmers that were selected for the analysis concerning the required input and output characteristics of the tool had field sizes in this range. Annex 4 includes the questions that were asked to the farmers in order to create insight in the input- and output requirements to suit the local context best and in line with the needs of the end-user. Annex

Drip irrigated fields in Rwanda.

Some key- characteristics of the target group:

- Field(s) under irrigation <10 ha
- Small- medium scale commercial orientated growers
- Drive towards precision agriculture
- Open to apply new technologies in order to improve their farm operations
- Values (information) services to improve farming operations
- Benefits from more efficient water use (e.g. limited water available/pumping costs)

Identified user needs

During the initial surveys the following needs were identified:
The farmers indicate that irrigation advise is required to:

- Improve system operation (irrigation efficiency & water management)
- Make it easier to determine how long to irrigate depending on the changing weather
- Receive information about new irrigation practices
- Improve plant performance and yield
- Insight in the possible reduction of irrigation time and the subsequent water use
- Reduce operating costs in terms of energy use for pumping

Types of information (output)

The following types of information were found to be useful for the target group:

Information (Output)	% of target group

Evaporation crop (mm/day)	63%
Minutes of irrigation per day needed	100%
Daily amount of water required (Pump volume)	50%
Weekly amount of water required	25%

The above indicates that the output of the SOSIA tool should include the minutes of irrigation per day that is required and the evaporation crop. The total daily volume is also found useful for 50% of the end users and can also be included. The weekly amount of water is not a must to include in the output.

Frequency and form of information sharing

The survey also included in which frequency the farmers would like to receive the irrigation advise and how.

Frequency of receiving irrigation advise	% responded positive
Only once in the beginning of the crop season as crop schedule?	13%
Daily/ weekly updates on irrigation advice?	13%
Once in the beginning of the crop season + on special moments due to e.g. weather	100%

From the results of the survey, the farmers would find it most useful to receive a complete advise in the beginning of the crop with several updates throughout the crop to e.g. changing weather factors.

Preferred ways of information sharing	% responded positive
As a PDF on your What's app/phone,	100%
As a PDF on your email	38%
Verbal explanation by a HGT staff member?	13%
Printed out schedule(hardcopy)	13%

Sharing the results via phone is the preferred option of the interviewees. A PDF via email is also preferred by 38% of the farmers. Therefore, A PDF that is easy to read on phones deserve a priority in the development of the tool. Additionally a more elaborate PDF with additional information is an advantage for the HGT personnel to create more detailed insights in the advice. This can also be shared to clients that would like additional information.

Are you also interested to receive the above information expressed per pant or per ha?	% responded positive
Only for my own field size	0%
Own field size & amount of water per plant	100%
Also the amount of water per ha	13%

The farmers prefer to receive information for their own field size and also the required water for one specific plant. Though, it seems that the interviewees interpreted rather the 'amount of water per plant' to be crop specific information and not per se as the amount of water needed for one individual plant. The amount of water per ha was not to be found interesting to most of the farmers.

Willingness to pay

From the farmers included in the questionnaire, 63% indicates to be willing to pay for an irrigation advise service. The amount would mainly depend on the quality and completeness of the advice. Farmers found it difficult to determine the amount they would be willing to pay as they could not see how the advice would look like exactly. Therefore, the amount that farmers are willing to pay should be part of the farmer enquiry after a first prototype of the SOSIA tool is made.

Crops

Since the advice should be crop specific, insight in which crops to include is key to meet the needs of the end- user. Crops that were identified as important in the survey are:

- Lettuce
- (French) beans
- Habanero peppers
- Brassicas (cabbage, cauliflower, broccoli)
- Onions
- Tomato
- Strawberries
- Okra
- Potatoes
- Maize

From experience of HGT, looking at their customer clientele the following crops should also be included:

- Cucumber
- African eggplant
- Aubergine
- Sweet pepper
- Watermelon
- Melon
- Carrot

The interviewed farmers also indicate they grow avocado and flowers. To add more crops like fruit crops and flowers can be an added value but does not fall in line with the initial scope of the SOSIA tool.

List with input requirements

- Name Client/Farm
- Contact number
- Location farm (coordinates) include an easy way to select place e.g. google maps kind of environment)
- Name field
- Field size (m^2)
- Intercropping?
    - Yes
    - No

- Crop
- Plant population field
- Bed width (m)
- Footpath in between beds?
    - Yes
    - No
- Planting/transplanting date
- (Expected) Date of first harvest
- (Expected) Date of last harvest
- Soil type (light – medium – heavy) (sandy – loamy – clay)
- Water source:
    - Borehole
    - Open well
    - Dam
    - Marshland
    - River
    - Lake
    - Stream
- Irrigation type
    - Irrigation type: T-tape drip irrigation, emitter spacing 20cm. emitter flow rate 1lph.
        - Number of laterals on field
        - Lateral length (m)
    - Other
- Notes

List with output requirements: Output for information PDF shared to client:

- For whole crop cycle:
    - Evaporation crop (mm/day) - this could be done as weekly averages but indicated as ET_C per day
    - Required minutes of irrigation (minutes/day)
- Updates ET_c and required daily minutes of irrigation based on special situations such as weather

Information for on the PDF output but not directly related to the quantitative irrigation advise

- Name Client/Farm
- Contact number
- Location farm (coordinates) include an easy way to select place e.g. google maps kind of environment)
- Name field
- Field size (m^2)
- Intercropping?
    - Yes
    - No
- Crop
- Plant population field
- Bed width (m)
- Footpath in between beds?
    - Yes
    - No
- Planting/transplanting date
- (Expected) Date of first harvest

- (Expected) Date of last harvest
- Soil type (light – medium – heavy) (sandy – loamy – clay)
- Water source:
    - Borehole
    - Open well
    - Dam
    - Marshland
    - River
    - Lake
    - Stream
- Irrigation type
    - Irrigation type: T-tape drip irrigation, emitter spacing 20cm. emitter flow rate 1lph.
        - Number of laterals on field
        - Lateral length (m)

    - Other
- Notes

Not quantitative irrigation advise:

- Information specified to soil type
    - Info about water holding capacity
    - Suggestion of irrigation interval range
    - Short explanation how to interpret the quantitative results to other intervals than every day
- Information about season when crop is planted
    - For example: Season is characterised by abcd, dry spells but also rain showers: subsequently: these are tips concerning irrigation in this season: abcd
- Other tips and tricks
    - Tips on operating a drip irrigation system
    - Maintenance irrigation system
- Cultivation tips not directly related to irrigation? (general or crop specific)
    - E.g. crop rotation, Soil health advise

Additional output suggestions for HGT staff

These are suggestions to add to the advice of the farmer on a separate PDF for HGT or clients that have special additional interest/ more knowledge than average) .

- ET_0 values (mm/day)
- Kc factors used
- Total Etc (total crop water requirements in mm that you would need in whole growing season)
- Total irrigation demand season (mm) and m^3
- Weather data from virtual weather stations

Annex 4 - WP1 Survey Logbook of recorded answers and pictures from the field

	Farmer 1	Farmer 2
Date of Interview	04/06/2022	04/05/2022
Name farmer	Pacifique NIYONASENZE	Ndahiro Jean
Gender: male/female	Male	Male
Age	32	44
Phone number	0788849556	0788487909
Location farmer	Kigali-Rusororo	Bugesera-Juru-Mugorore-Tabarari
Size farm		
Coordinates	1°59'06.39"S 30°12'08.89"E	
Total size farm	42 ha	4 ha
Size of fields where farmer is growing crops	25 ha	2 ha
Size of fields that use irrigation	6 ha	1 ha
Crops		
Crop type/variety	Lettuce, French beans, Bracas	Habanero, Onions, Tomato, Beans
Intercropping	Rotation	Rotation
Planting date	Year round	Year round
Plant spacing	lettuce: 30*20, French beans: 20*10, Bracus: 30*30	
Soil		
Soil type	Clay loam	Laom
Any soil test done?	Yes	Yes
Description of farm		5, are increased according to peak season
How many casual workers?	42	
Description of water source:		
River/dam/borehole/furrow/stream	Marshland	Lake
Water availability (include seasonal differences if they exist)	Available	Available
Description of current irrigation system		

Water source used	Marshland	Lake
Dam liner/water tank size	Dam liner: 250 m3; Water tank size: 4 tanks*10m3	
Pump info		
Height tank (if they use a tank)/(dam liner (in meter)	160m from Pumping suction	
Distance tank to fields		450 m
Include photos of several system (components)		
Type of drip line (need to be HGT sourced)		
Brand	T-Tape	T-Tape
Emitter spacing	20 cm	20 cm
Emitter flow rate	1 L/hr	1 L/hr
When was the first time you operated the system (month-year)	June,2019	July, 2020
Does the system supply enough water for your crops?		
Yes: How can you see that the crop has enough water? If answered no: How can you see that the crop has not enough water?	Yes	Yes
Explanation:	Hand feeling method from soil after/before irrigation	They check soil status clogged drippers and areas that doesn't have enough water
Do you measure how long you irrigate one field (in e.g. minutes or hours) ?		
If yes how do you measure this? If no, can you explain why not?	Yes, in minutes	Yes
Explanation:	They irrigate 20 minutes. Opening and closing time is measured by using a watch.	By using watch, see starting time and closing time
Do you keep records of your irrigation schedule? (when and how long you irrigate)		
Yes	Yes	No

Once in the beginning of the crop season asa cropschedule? Daily/ weekly updates on irrigation advice? Once in the beginning of the crop season +on special moments due to e.g weather	yes	yes
Haw would you prefer to receive this information ? As a PDF on your Whats app/phone, As a PDF on your email Verbal explanation by a HGT staff member? Printed out schedule(hardcopy)	yes	yes
Are you also interested to receive the above information expressed per pant or per ha? Only for my own field size Also the amount of water per plant Also the amount of water per ha	yes	yes
Explanation:	Different plant with different water requirements and one behaved differently to others	plants/crops water requirements are different
Do you have a smart phone? Yes No	yes	yes
Would you be willing to pay for this service? Yes No	yes	
If answered question 13 with yes :haw much would you willing to pay for a detailed irrigation advice which is specific for your farm conditions?(This advice would be a complete advice for one whole crop-cycle). 5.000RWF		

No		
Do think it is useful to measure the time how long you irrigate?		
Yes, why is this useful?	Yes	No
No, why is this not useful?		
Explanation:	To supply right amount of required water and for efficiency use of fuel/pump	It is not enough alone, there is not standard time. It depends on many factors: soil, crop stage, weather
If you measure the irrigation, how do you record this? (timing/liters/m3)		
Explanation:	They record m3 used	No records
Would you like HGT to give you more elaborate advice on how long to irrigate, based on weather data, your location, crop type, etc?		
If yes, explain	Yes	Yes
If no, can you explain why not?		
Explanation:	To be more efficiency and to predict/plan according to the weather	Need advice to improve the system operation and apply enough water to plants
What information would you like to receive in the advice (thick multiple boxes)		
Evaporation crop (mm/day)	Yes	
Minutes of irrigation per day needed	Yes	Yes
Daily amount of water required	Yes	
Weekly amount of water required		
Other		
other		
Haw often would you like to receive such information(frequency)?		

10.000RWF 15.000RWF 25.000RWF		
Other:....	To know first how useful it is and their accuracy	Need a proof that he will benefit from it,added value to what he was currently doing(Test it before)
Do you check for information on the weather to manage your farm?		
Yes Describe what data you access	yes	
weather parameters:rainfall/temperature/reference ET Historical data:Last days/Last month/Last year		yes
Forecast for next days	yes	yes
Pictures of different components		

	  	
Date of Interview	**Farmer 3** 25/3/2022	**Farmer 4** 31/03/2022
Name farmer	Muganga Jean Sauveur	UWAYITU NYAMPETA Apolline

Gender: male/female	Male	Female
Age	33	77
Phone number	0788545966	0788300409
Location farmer	Rulindo-Mbogo-Bukoro-Kibaya-Bahimba	Bugesera-Gashora
Size farm		
Coordinates	1°44'40"S & 29°56'47.6"	Latitude: 2°14'41.75'S & Longitude: 30°15'.02E
Total size farm	1 ha	10 ha
Size of fields where farmer is growing crops	1 ha	10 ha
Size of fields that use irrigation	1 ha	10 ha
Crops		
Crop type/variety	Strawberries/3 varieties	French beans and Okra
Intercropping	_	Rotation
Planting date	25/09/2021	18/01/2022 for french beans, 02/01/2022 for Okra
Plant spacing	50*25cm	4 rows per bed (French beans: 15*20cm and Okra: 40*50 cm)
Soil		
Soil type	Sand loam	One part is clay other part is sand loam (sand loam and clay loam)
Any soil test done?	Yes	Yes, 2019
Description of farm	45 workers/day	50 workers/day
How many casual workers?		
Description of water source:		
River/dam/borehole/furrow/stream	River	Lake
Water availability (include seasonal differences if they exist)	Available	Available always
Description of current irrigation system		
Water source used	River	Lake

Dam liner/water tank size	_	Dam liner: 5m3; Water tank size: 250m3*2=500m3
Pump info	THD: 27m, 60m3/hr	THD: 100m, Qmax: 38m3
Height tank (if they use a tank)/(dam liner (in meter)	No available	Height: 2m, Dam liner: 400m far, 15m near, 33,5m Height
Distance tank to fields	_	Near: 15m, Far: 60m
Include photos of several system (components)		
Type of drip line (need to be HGT sourced)		
Brand	T-Tape	T-Tape
Emitter spacing	20 cm	20cm firt, other 10cm used for french beans
Emitter flow rate	1 L/hr	1 L/hr
When was the first time you operated the system (month-year)	September, 2021	January,2020
Does the system supply enough water for your crops?		
Yes: How can you see that the crop has enough water?	Yes	Yes
If answered no: How can you see that the crop has not enough water?		
Explanation:	After irrigation I checked and I found some place/plant without water especially on the edges	Test with hand or hoe by touching and squeeze the soil
Do you measure how long you irrigate one field (in e.g. minutes or hours) ?		
If yes how do you measure this?	Yes	Yes
If no, can you explain why not?		
Explanation:	We operate the system 1h30'/3 times per week and we use reccomendation given by irrigation technician from HGT	They irrigate each block for/between 30-40min

Do you keep records of your irrigation schedule? (when and how long you irrigate)		
Yes	Yes	Yes
No		
Do think it is useful to measure the time how long you irrigate?		
Yes, why is this useful?	Yes	Yes
No, why is this not useful?		
		It helps to keep field record or if anyone whom may search for information on water
Explanation:	To be more accurate/ for irrigation efficiency	usage can see it
If you measure the irrigation, how do you record this? (timing/liters/m3)		
		Date, block, storting time and ending time
Explanation:	Irrigation times are kept in logo book (timing)	of irrigation water quantity, signature
Would you like HGT to give you more elaborate advice on how long to irrigate, based on weather data, your location, crop type, etc?		
If yes, explain	Yes	Yes Because weather is changing especially during dry season where more water is needed. It is complicated to manage and know what quantity they should apply
If no, can you explain why not?		
	For irrigation efficiency and water	
Explanation:	managements	
What information would you like to receive in the advice (thick multiple boxes)		
Evaporation crop (mm/day)	Yes	
Minutes of irrigation per day needed	Yes	Yes
Daily amount of water required		

No		no(should be HGTobligation)
If answered question 13 with yes :haw much would you willing to pay for a detailed irrigation advice which is specific for your farm conditions?(This advice would be a complete advice for one whole crop-cycle). 5.000RWF 10.000RWF 15.000RWF 25.000RWF		
Other:….	Will be based on its benefit to the farm	
Do you check for information on the weather to manage your farm? Yes Describe what data you access	yes	
weather parameters:rainfall/temperature/reference ET Historical data:Last days/Last month/Last year		
Forecast for next days	yes(are not helpful ,more elaboration is needed)	yes(But those data are not reriable ,they are not precised thus they are not helpful for the farm management
Pictures of different components		

Weekly amount of water required		
Other		Minutes of irrigation + Frequency (How many times_day)
other		
Haw often would you like to receive such information(frequency)?		
Once in the beginning of the crop season asa cropschedule?		
Daily/ weekly updates on irrigation advice?		
Once in the beginning of the crop season +on special moments due to e.g weather	yes	yes
Haw would you prefer to receive this information ?		
As a PDF on your Whats app/phone,	yes	yes
As a PDF on your email		yes
Verbal explanation by a HGT staff member?		
Printed out schedule(hardcopy)		
Are you also interested to receive the above information expressed per pant or per ha?		
Only for my own field size		
Also the amount of water per plant	yes	yes
Also the amount of water per ha		
Explanation:	Because water reqiurements varies depending on crops.Different crop has different water requirements	Because they deal with plants'water requirements not other factors
Do you have a smart phone?		
Yes	yes	yes
No		
Would you be willing to pay for this service?		
Yes	yes	

	Farmer 5	Farmer 6
Date of Interview	04/01/2022	04/04/2022
Name farmer	William MACHARIA	Innocent TEGERA
Gender: male/female	Male	Male
Age	45	29
Phone number	0789510438	
Location farmer	Bugesera	Rwamagana-Munyiginya
Size farm		
Coordinates	2°08'27.53"S &30°02'51.07"E	1°53'13.25" S& 30°22'56.56" E
Total size farm	20 ha	30 ha
Size of fields where farmer is growing crops	20 ha	12 ha
Size of fields that use irrigation	20 ha	12 ha
Crops		
Crop type/variety	French beans, Potatoes, Cabbages, Onions	Flowers, Avocado
Intercropping		
Planting date	Year round	Avocado, 3/2021, Flowers: 6/2021
Plant spacing	Based crops. French beans: 30*10, cabbage: 60*40, Potato: 75*40, Onions: 20*10	Flowers: 60*60cm, Avocado: 5*5m
Soil		
Soil type	Sandy loam	Clay loam
Any soil test done?	Yes	Yes
Description of farm	100	16
How many casual workers?		
Description of water source:		
River/dam/borehole/furrow/stream	Dam	Lake
Water availability (include seasonal differences if they exist)	Available	250m3

Description of current irrigation system		
Water source used		
Dam liner/water tank size	Dam liner, Carlton UK, THD: 55m, Qmax: 38000 lpm; Honda THD: 27m, Qmax: 555 lpm.	
Pump info	Koshin THD: 75m, Qmax: 1050 lpm	THD:80 M, 38M3/HR FLOW RATE(Diesel)
Height tank (if they use a tank)/(dam liner (in meter)	450 m3	THD 27m, 60m3/hr(Koshin)
Distance tank to fields	100m	
Include photos of several system (components)		
Type of drip line (need to be HGT sourced)		
Brand	T-Tape	T-Tape
Emitter spacing	20cm	20cm
Emitter flow rate	1 L/hr	1 L/hr
When was the first time you operated the system (month-year)	January,2018	
Does the system supply enough water for your crops?		
Yes: How can you see that the crop has enough water?	Yes	Yes
If answered no: How can you see that the crop has not enough water?		
Explanation:	We have tools to measure crops water needs/driplines deliver suffient water to the crop	Check soil status & crop appearance
Do you measure how long you irrigate one field (in e.g. minutes or hours) ?		
If yes how do you measure this?	Yes	Yes
If no, can you explain why not?		

Explanation:	Depends on cropstage and the irrigation regime is calculated based soil type, number of times per day to compensate water lost. We also check the day to day weather pattern.	Using a watch, they irrigate 1h30'
Do you keep records of your irrigation schedule? (when and how long you irrigate)		
Yes	Yes	Yes
No		
Do think it is useful to measure the time how long you irrigate?		
Yes, why is this useful?	Yes	Yes
No, why is this not useful?		
Explanation:	This helps us not to overirrigate or underirrigate	To know the quantity of water supplied/used depend on crop stage, weather, it can vary. It is important to measure
If you measure the irrigation, how do you record this? (timing/liters/m3)		
Explanation:	We use timing	They record liters used, block, date
Would you like HGT to give you more elaborate advice on how long to irrigate, based on weather data, your location, crop type, etc?		
If yes, explain	Yes To share experiences and information on new irrigation methods	Yes It will help to improve yield and plant performance
If no, can you explain why not?		
Explanation:		
What information would you like to receive in the advice (thick multiple boxes)		

Evaporation crop (mm/day)	Yes	Yes
Minutes of irrigation per day needed	Yes	Yes
Daily amount of water required	Yes	Yes
Weekly amount of water required	Yes	
Other	Unclogging driplines	Evapotranspiration
other	Method/chemical to use to unclog	
Haw often would you like to receive such information(frequency)?		
Once in the beginning of the crop season asa cropschedule?	yes	
Daily/ weekly updates on irrigation advice?	yes	
Once in the beginning of the crop season +on special moments due to e.g weather	yes	yes
Haw would you prefer to receive this information ?		
As a PDF on your Whats app/phone,	yes	yes
As a PDF on your email		yes
Verbal explanation by a HGT staff member?	yes	
Printed out schedule(hardcopy)	yes	
Are you also interested to receive the above information expressed per pant or per ha?		
Only for my own field size		
Also the amount of water per plant	yes	yes
Also the amount of water per ha	yes	
Explanation:	This can help because different crops have different water requirement	Different crops,1 ha can have more than one crop.
Do you have a smart phone?		
Yes	yes	yes
No		
Would you be willing to pay for this service?		

Yes	yes	
No		no
If answered question 13 with yes :haw much would you willing to pay for a detailed irrigation advice which is specific for your farm conditions?(This advice would be a complete advice for one whole crop-cycle).		
5.000RWF	Yes	
10.000RWF		
15.000RWF		
25.000RWF		
Other:....		
Do you check for information on the weather to manage your farm?		
Yes Describe what data you access		no
weather parameters:rainfall/temperature/reference ET	yes	
Historical data:Last days/Last month/Last year	yes	
Forecast for next days	yes	
Pictures of different components		

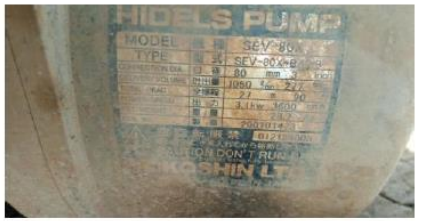
	   	 
	Farmer 7	**Farmer 8**
Date of Interview	04/04/2022	04/04/2022

Name farmer	Annonciate KAREMERA	NGABONZIZA Emmanuel
Gender: male/female	Female	Male
Age	59	30
Phone number	0788308987	0788242840
Location farmer	Gasabo-Ndera-Cyaruzinge-Karubibi	Gatsibo-Kabarore-Simbwa-Kibondo
Size farm		
Coordinates	1°56'57.09"S &30°11'00.00''	1°32'03.60"S &30°19'00.41''E
Total size farm	15 ha	6 ha
Size of fields where farmer is growing crops	9 ha	6 ha
Size of fields that use irrigation	1,5 ha	5 ha
Crops		
Crop type/variety	Flowers (Tuberose, Amimi visnag, crocosmia, Erynqum and Moby dick)	French beans, Chilli, Maize baby corn
Intercropping		Rotate
Planting date		Year round
Plant spacing	30*10	French beans: 20*15, Chilli: 60*60, Maize: 60*60
Soil		
Soil type	Sand-clay loam	Sand loam
Any soil test done?	No	Yes
Description of farm	150	45
How many casual workers?		
Description of water source:		
River/dam/borehole/furrow/stream	River	River
Water availability (include seasonal differences if they exist)	Available	250m3
Description of current irrigation system		10*12m
Water source used	Pump direct from river	
Dam liner/water tank size		

Pump info	Petrol (Robin) THD 27M, Flow: 60m3/hr	Koshin:27m head,60m3/hr. Disiel: 70m head,38m3/hr
Height tank (if they use a tank)/(dam liner (in meter)		
Distance tank to fields	100m for 2m near water source	
Include photos of several system (components)		
Type of drip line (need to be HGT sourced)		
Brand	T-Tape	T-Tape
Emitter spacing	20cm	20cm
Emitter flow rate	1 L/hr	1 L/hr
When was the first time you operated the system (month-year)		January, 2021
Does the system supply enough water for your crops?		
Yes: How can you see that the crop has enough water?		Yes
If answered no: How can you see that the crop has not enough water?	No	
Explanation:	Pump efficiency is low/doesn't have full capacity to pump enough water as bigger pipes was used.	Every 3 months they calibrate by checking drippers flow rate, dig and check by hand after each irrigation.
Do you measure how long you irrigate one field (in e.g. minutes or hours) ?		
If yes how do you measure this?	Yes	Yes
If no, can you explain why not?		
Explanation:	They irrigate 1 hr per each block, using watch before they open the system have to know what time is it after also they chech if 1 hr operation is finished, they close.	starting -ending time records, 2 hr for every block is used as irrigation time with phone they check irrigation hours
Do you keep records of your irrigation schedule? (when and how long you irrigate)		
Yes		Yes

No	No	
Do think it is useful to measure the time how long you irrigate?		
Yes, why is this useful?	Yes	Yes
No, why is this not useful?		
		It helps to measure water applied for crops and to manage related costs such as fuel
Explanation:	For economy reasons, less fuel	costs
If you measure the irrigation, how do you record this? (timing/liters/m3)		
Explanation:	They does not keep record	Timing and m3 used and dates
Would you like HGT to give you more elaborate advice on how long to irrigate, based on weather data, your location, crop type, etc?		
If yes, explain	Yes	Yes
		Can help him to know to exact and good
	To know if they should increase or reduce	time to irrigate or not to irrigate water
If no, can you explain why not?	irrigation time or amount of water usage	management and cost reduction
Explanation:		
What information would you like to receive in the advice (thick multiple boxes)		
Evaporation crop (mm/day)		Yes
Minutes of irrigation per day needed	Yes	Yes
Daily amount of water required		Yes
Weekly amount of water required		Yes
Other		Weather info
other		
Haw often would you like to receive such information(frequency)?		

Once in the beginning of the crop season asa cropschedule?		
Daily/ weekly updates on irrigation advice?		
Once in the beginning of the crop season +on special moments due to e.g weather	yes	yes
Haw would you prefer to receive this information ?		
As a PDF on your Whats app/phone,	yes	yes
As a PDF on your email		yes
Verbal explanation by a HGT staff member?		
Printed out schedule(hardcopy)		
Are you also interested to receive the above information expressed per pant or per ha?		
Only for my own field size		
Also the amount of water per plant	yes	yes
Also the amount of water per ha		
Explanation:	Plant based water requirements,different plant different water requirements	Plant water requirements differ per plant/crop.
Do you have a smart phone?		
Yes	yes	yes
No		
Would you be willing to pay for this service?		
Yes	yes	yes
No		
If answered question 13 with yes :haw much would you willing to pay for a detailed irrigation advice which is specific for your farm conditions?(This advice would be a complete advice for one whole crop-cycle).		
5.000RWF		
10.000RWF		

15.000RWF 25.000RWF Other:....		
Do you check for information on the weather to manage your farm?		
Yes Describe what data you access		yes
weather parameters:rainfall/temperature/reference ET	yes	yes
Historical data:Last days/Last month/Last year		
Forecast for next days	yes	yes
Pictures of different components	  	 






EY20D



Annex 5 - Learning Questions BopInc Sheet

Note: This annex is a copy from the excel worksheet provided by BopInc. Upon discussion with BopInc, it was agreed that the excel sheet could be replaced by any format. The consortium has registered their most important learning questions, assumptions, and learnings in the below document which replaces the excel document.

Overview of learning questions

Overall, activities under the Phase 1 knowledge component have led to valuable insights related to the development of digital services in the context of sustainable agriculture and water management. Knowledge development has been guided by a set of pre-defined Learning Questions (LQs):

Below sections provide a synthesis of key insights that were obtained during Phase 1. These go beyond learning points that are only relevant to the specific SOSIA service, and relevant learnings are discussed in the broader context of geodata initiatives which aim to support food security and sustainable use of land and water resources in agricultural systems.

Feasibility

1a. What are the technical bottlenecks in embedding an OS geodata-based irrigation advice in the intermediary's existing information services? Is there sufficient local calibration data available as input for the information service, to ensure sufficient generate reliable output?

1b. To what extent does the use of open geodata (positive and negative) influence the value of the service?

Desirability

2a. What are the current challenges farmers & intermediaries face and what is the expected economic benefit of the service? What is the expected willingness to pay of end users and intermediaries?

2b. What communication channel is most effective for giving irrigation advice to the farmers?

Viability

3a. What are alternative revenue models to make the service more affordable for smallholder farmers? (e.g. investigating how the generated data/insights can be sold to other stakeholders within the value chain)?

3b. What are the anticipated maintenance costs of the solution, or different possible variants of the solution (depending on farmer interaction, type of information, frequency, etc.)?

Impact

4a. To what extent does our digital service directly or indirectly contribute to better productivity, resilience, and income of smallholder farmers, as well as improved food security and sustainable land and water use in Africa?

4b. How to improve inclusivity of our service, taking into account gender & youth?

Suitability

5a. To what extent does the current intermediary HGT contribute effectively to the impact goals? What are other potential stakeholders (local governments, water management bodies etc.) that can be beneficiaries of the solution?

5b. What are the gaps in our team to support the intermediaries locally to contextualize the offering?

Process

6a. What is the influence of the flexibility and duration of this competition on the implementation of the activities required to realize our innovation?

The Unexpected

7a. Is there any unexpected learning at the end or during the pilot process.?

Feasibility

1a. What are the technical bottlenecks in embedding an OS geodata-based irrigation advice in the intermediary's existing information services? Is there sufficient local calibration data available as input for the information service, to ensure sufficient generate reliable output?

Assumption:

A technical challenge in using open geodata, particularly when integrating multiple datasets, is the need for downloading, processing, uploading and managing large amounts of data. These activities do not only require considerable resources, but also pose technical risks of failures along the complex chain of activities. During Phase 1 development and testing activities, it was learned that the use of a cloud computing platform (in this case Google Earth Engine - GEE) is an effective way to minimize these risks. Data can be accessed and processed in the cloud, and no major storage space or high-speed computing infrastructure is needed.

In addition, it was found during Phase 1 that an important technical challenge relates to the need for having a tool that fits a collaborative, agile framework for developing a geodata-based service in close consultation with the end user. It was learned that the use of GEE, especially given the ease with which configuration and functionality can be modified, is very suitable for supporting agile development processes and assessments of fit-for-purposeness for future other users. Changes to the source code of the application directly reflect in a visual change to the graphical user interface, which can immediately be evaluated by the user.

A generic learning point relates to the availability of local calibration data, which is a typical challenge for developing advisory services based on OS geodata. Satellite-derived data in general have the greatest added value in contexts with limited ground data. In Phase 1, we learned that this issue can be mitigated, at least partly, by making use of OS data products from renowned international organizations, which have been scientifically published and undergone extensive validation and quality control mechanisms. These include for example WaPOR data, which have been developed and tested particularly in the African context. Further insight into the issue of calibration is foreseen in Phase 2, where a Work Package on quality assessment is included (see Ch. 2) which includes comparison of VWS data with field data, existing weather stations, and irrigation logs.

1b. To what extent does the use of open geodata (positive and negative) influence the value of the service?

Assumption:

Another important technical learning relates to the limitations to the level of spatial detail that can be achieved with some OS products, which are developed on a global or continental scale and thus are not delivered with spatial resolutions in the same order of magnitude as field sizes. The main learning from the intermediary and end user feedback is that the added value of these services should be seen in the perspective of the current situation, where essential data are lacking. The level of improvement from the OS geodata-based services is considered significant, despite the aforementioned limitations. Furthermore, the use of (open) geodata also allows for developing a service that provides information that is consistent in both space and time. This allows for comparing current conditions to historical conditions, thus enabling detection of trends and anomalies, as well as facilitating comparison between fields, farmers, and crops.

OS geodata are produced by renowned knowledge institutes that are generally transparent about the processing steps that are involved. There is, however, also a certain risk of continuity as some of the products are generated within projects that may end at some point. This risk is mitigated by our service in several ways:

- Our service is designed to be flexible, allowing new or better products to be added as input data to the tool in the future. Dissemination of OS geodata is a major trend, and more and improved relevant products are expected to come available over the next years.
- We make use of 5-6 different OS geodata sources to compute the virtual weather station data, where multiple datasets are consulted to compute individual meteorological parameters. By diversifying the inputs, the impact of future gaps in the ensemble of input data is minimized.
- The strength of FW as a company is its focus on the interface between research and consultancy. The company has strong ties with the scientific community and is therefore aware of new and upcoming data products that can be used to improve the service.

The above is considered a learning point that is relevant to all operational services for the agricultural sector which are based on OS geodata

Desirability

2a. What are the current challenges farmers & intermediaries face and what is the expected economic benefit of the service? What is the expected willingness to pay of end users and intermediaries?

Assumption: Is only the lack of information the challenge for the farmers related to irrigation? or lack of efficient and timely water supply is also a bigger part of the problem?

Challenges faced by farmers

The Rwandese farmers served by HGT face several challenges in their daily farm operations. Although the target farmers invested in efficient irrigation methods, a gap of knowledge exists in how much water to apply and thus how long to irrigate. Currently the duration of irrigation is done by guess work, looking at the weather (no measurements, no data, no weather stations). The economic benefit for a farmer, to supply the right amount of water at the right time to the crop is that the crop will perform better which results in higher crop yield per m^2, less pest pressure (a vigorous crop is more resistant), improved soil life (optimal soil moisture content benefits soil life), water saving and more importantly: economic saving due to decreased fuel use, since the far majority of farmers are using petrol pumps and fuel prices are currently increasing rapidly. Based on the survey results presented in Annex 3, the latter is considered by the farmers as the most important gain of optimal irrigation advice.

Comparing the first results of the SOSIA tool with irrigation records retrieved from 2 farmers in Rwanda indicate that they currently irrigate for longer periods of time than necessary when looking at the Crop Water Requirements derived from the SOSIA tool (Annex 8). This indicates that, by implementing the SOSIA advice, less water would be used, and fuel would likely be saved. However, validation is needed to test the crop performances when the SOSIA advice is being implemented. Two farmers are selected for this pilot evaluation and this data can be used in Phase 2 for answering this learning question more elaborately.

Learnings during Phase 1 support the assumption of a high willingness to pay (WTP) among the farmers served by the intermediary. From the survey results, it was learned that farmers with a drip system are already quite progressive and risk taking. Most farmers grow cash crops such as strawberries, and vegetables. It was found that these farmers are willing to pay for the service, provided that its effectiveness is proven in the planned Phase 2 evaluations. The height of the fee would depend on two main factors: i) the improvement of the yield, and ii) the reduction in pumping time and thus a reduction in fuel use.

Challenges faced by intermediary

During Phase 1, it was learned that the current challenge for the intermediary is twofold:

1) Currently, it is tedious to calculate the Crop Water Requirements (CWR) for clients, since the input weather data are inaccurate, outdated and not location-specific. Therefore, the intermediary cannot give accurate advice to farmers and has to estimate and guess;
2) In the design process of irrigation systems, too much time is being spent by irrigation engineers to calculate CWR which at the end is sub-optimal and can potentially lead to an inadequate irrigation design. By using the SOSIA tool, the design of irrigation systems also becomes more precise (localized) and in a shorter period of time.

The above challenges, identified during Phase 1, serve as key intermediary "pains" to be addressed by the SOSIA service.

2b. What communication channel is most effective for giving irrigation advice to the farmers?

Assumption: The farmers we work with are willing to invest in the required technology needed as communication channel. The intermediary is interested in offering tailored communication depending on the farmers 'abilities, however it would be ideal if the service can be provided through 1 main communication channel.

The survey results indicate that digital platforms are preferred by all end users interviewed. WhatsApp is considered as the best option because farmers indicate that they will than always have it available. Some farmers interviewed prefer receiving the result via email. The intermediary will also be able to print out the results in order to service farmers that do not have the access to a smartphone, though it is expected that this will not be used a lot looking at the fast-growing access of smartphones in Rwanda. In general, the intermediary also explains the results in detail to the farmer to be sure the farmer will interpret the results the right way and to increase the chance that the irrigation advice will lead to the desired impact.

Based on the above, it was learned that a certain flexibility needs to be maintained for disseminating the advice. The SOSIA service was therefore designed to provide its output information and irrigation advice in PDF format, leaving the intermediary with several options to convey the information to the farmer.

Viability

3a. What are alternative revenue models to make the service more affordable for smallholder farmers? (e.g. investigating how the generated data/insights can be sold to other stakeholders within the value chain)?

Assumption: how marketable is open-source software?

Whereas initially the option to sell-off data to external parties who are on the value chain was considered, it has become clear that both FW and HGT do not feel comfortable, at this stage of the innovation, to focus on such a third-party inclusion to make the product more affordable for the end-user. Whereas the potential benefit to the end-user of such mechanisms is well understood, the current intermediary would not feel comfortable collecting data for commercial purposes of their off takers. Aside from this, other potential business cases have been explored during this first phase, such as selling the virtual weather station data as a separate product, as it is expected that such data could be of interest to other organizations, within or outside the agricultural sector. However, this requires further investigation and is generally not deemed to be the focus of this tool at this stage as the surveys indicated that the associated farmers are willing to pay for these services themselves. Hence, it is believed, based on the initial surveys, the good feedback on the first tool version (SOSIA 1.0) and given that most associated farmers are identified as risk-takers, that the general interest in purchasing the advise in a B2C format is viable without relying on any alternative revenue model.

However, one way to make the service more affordable to farmers is to include it in a wider range of products and services. HGT as intermediary is in a position to explore this option because of its existing inputs and services strategy. Specifically, this exploration will be part of phase 2 where the different business strategies will be assessed.

A last strategy, that is context-dependent, is the act in which governments and/ or NGO's, aiming to improve food security, water efficiency, or in general want to support small scale farmers, could also decide to subsidize the SOSIA tool for specific target groups. For example, The WFP, USAID or SNV could decide to pay 50% of the irrigation advice so that a small-scale farmer only is required to contribute 50% him/herself. Such mechanisms will at no point be avoided by the intermediary as it is believed that through such collaborations, the tool might yield a larger impact.

3b. What are the anticipated maintenance costs of the solution, or different possible variants of the solution (depending on farmer interaction, type of information, frequency, etc.)?

Assumption: The maintenance cost is only considered to be constant for the first year

Regarding the maintenance costs of the tool, the following costs that will contribute to the total were identified.

1. Operational costs to keep the tool running
2. Bug fixes
3. Fixed costs + commission per farmer

Furthermore, it is anticipated that the contract between the innovator and the intermediary will include a clausula on tool upgrades which will come at an additional cost to be confirmed between two parties. These updates will be done/ checked for at least twice a year, whenever:

1. new OS satellite data, new crops, net irrigation lay-outs require to be added to the model code,
2. upscaling of the service is progressing
3. Innovation & evaluation exercise by Future Water, together with intermediary indicates that the tool could be further innovated.

Lastly, there are also expected maintenance and operational costs of service by the intermediary, which encompass: a yearly license fee, or to be integrated (phase 2 evaluation) with other services as 1 larger service (Pest management, land prep advice, etc.) which will be further assessed during phase 2.

Impact

4a. To what extent does our digital service directly or indirectly contribute to better productivity, resilience, and income of smallholder farmers, as well as improved food security and sustainable land and water use in Africa?

Assumption: assuming we can measure each of these criteria within the timeframe of phase 1 and/ or phase 2. Support is needed on how to best evaluate project impacts without doing an in-field pilot.

Impact is one of the LQ categories that have only been addressed to a limited extent in Phase 1. Still, several concise and preliminary learnings can be listed:

Due to the short duration of Phase 1 and the focus on development and feasibility assessment, no fully-fledged impact assessment could be achieved. However, first steps were taken in obtaining insights into the expected impact of the SOSIA service. It is expected that the service directly impacts productivity, income, and sustainability of land and water use, and will have indirect impacts on resilience and improved food security.

4b. How to improve inclusivity of our service, taking into account gender & youth?

Assumption: Inclusivity is important, however it is noted that the current intermediary, and the primary focus on drip-irrigation technology only might limit the extent to which an inclusive representative group can be reached within the project.

Inclusivity is considered highly important by the innovation developer. In the learning process during Phase 1, it was realized that the choice for the current intermediary and the primary focus on drip-

irrigation technology only may limit the extent to which an inclusive, diverse group of users can be reached by the service. For this reason, upscaling activities in Phase 2 will explicitly aim to reach other types of irrigation and user groups. Overall, SOSIA entails a digital innovation to support precision agriculture, which is typically popular with the youth. Phase 2 pilots will focus on involving young and female farmers.

Suitability

5a. To what extent does the current intermediary HGT contribute effectively to the impact goals? What are other potential stakeholders (local governments, water management bodies etc.) that can be beneficiaries of the solution?

Assumption: local governments are willing to use this commercial tool.

From Phase 1, it has been found that HGT has the potential to contribute effectively to the impact goals. The organization has a strong local presence and an elaborate, already established farmer network inside and outside of Rwanda. Moreover, its services are diverse (also including e.g. soil tests, irrigation equipment), meaning that an integrated and tailored product can be delivered to maximize impact for the specific farmer group. By familiarizing extension officers with the SOSIA tool, they are able to obtain a better understanding and provide effective guidance to farmers.

Several beneficiaries have been preliminarily identified during Phase 1, such as the Rwanda Agriculture Board (RAB), the Food and Agriculture Organization of the United Nations (FAO), and multiple NGOs targeting smallholder farmers. The inventory of potential stakeholders will be verified and expanded in further in Phase 2.

5b. What are the gaps in our team to support the intermediaries locally to contextualize the offering?

Assumption: N/A

The strong collaboration between the innovation developer and the intermediary has greatly benefited the local contextualization of the service. FW already has extensive experience in working in Rwanda for different clients in the agriculture and water sectors. A limitation is the lack of permanent physical presence of the innovator in Rwanda, however this is not considered a major bottleneck at the current development stage.

Process

6a. What is the influence of the flexibility and duration of this competition on the implementation of the activities required to realize our innovation?

Assumption: N/A

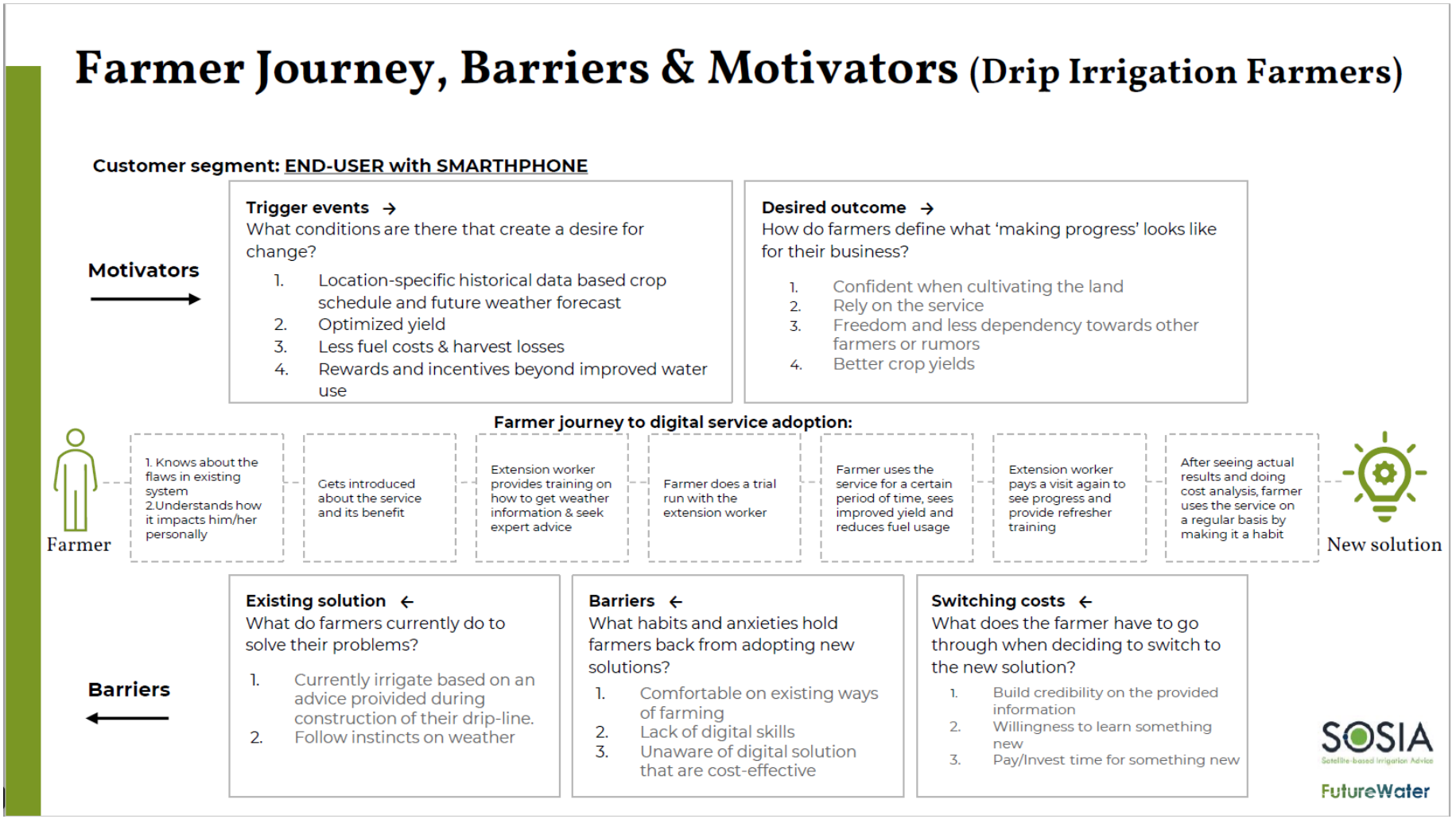
We regard this competition as a very welcome and helpful opportunity to develop a high-impact service In close collaboration with intermediary HGT. The flexibility of the competition in terms of themes, geographical scope, and input datasets has allowed us to design the project activities in a way that is directly beneficial to the development of our particular service. At the same time, the short time frame (3 months) in which project phase 1 takes place, limits the scope of activities that are practically feasible. This limitation relates to the fact that a tool / service needs to be developed in a very short period of time, paying attention to a wide range of aspects (e.g. technical, economic, organizational), but also to the fact that there are three clear parties in the setup of the competition: the innovator, the intermediary, and the end user. To sufficiently address e.g. the compliance of the innovation with the needs of intermediary and end user and the expected impact along the entire chain, frequent and elaborate interaction is required in which all three parties play a certain role. It was found that three months is a very short project duration to make all of this take place in a satisfactory manner.

The Unexpected

7a. Is there any unexpected learning at the end or during the pilot process.?

One unexpected learning relates to how the theory of change has been adopted at the end of phase 1, due to the unexpected realization that the way the SOSIA tool is introduced to the farmer, i.e. through the intermediary; and because the versatile applications the tool offers to the intermediary (i.e. both irrigation duration advice, and irrigation infrastructure design), shows that 1 tool has different end-users within this two-tiered business model. This is an unexpected learning as it was not the initial focus of this innovation study to make such a distinct division between both user groups.

Annex 6 - Farmer Journey



Annex 7 - Survey WP3-4 Evaluation of SOSIA version 1.0 (June 6 -14 2022)

Objectives

- Feedback from farmers on how the results are presented
    - What do they see as strong points?
    - What improvement points exist?
    - What main advantages do farmers see? (collect more details than in initial survey)
- Feedback from HGT team on usage of the tool
- Feedback from HGT team on interface specifically for HGT (google earth engine)
- Willingness to pay assessment based on examples of results with farmers
- Willingness to pay assessment estimation of HGT team based on their experiences and knowledge of farmers
- Commercial ways to sell the advice with HGT team. E.g. part of a package of products/services / offer as separate service etc.
- Ease of implementation irrigation advise assessment.
- Recommendations for further developments SOSIA tool.
- Input from field / local experiences to reporting
    - Include impressions from HGT team and farmers
    - Include pictures for reporting showing the advice being discussed in the field etc.
    - Some small movies for presentation / marketing tool etc?
- Constructing of customer persona Farmer
- Constructing of customer persona HGT Extension officer

Approach:

Interview questions are prepared that can gather information to fulfill the objectives. However, in the current phase semi-structured interviews / open conversations will be effective to get most insights on the first version of the tool and the results it produces. The interview questions prepared will therefore function as a guideline in the semi structured interviews with either farmers and/ or the HGT extension staff.

Concerning the HGT staff, a co-creation method will be applied to have an open discussion with the extension staff to discuss the tool, usability, improvement points, strong points, the business case of the tool and ways how to make the tool commercially viable in the broader HGT business strategy.

Interview questions for farmers WP3-4-SOSIA

Introduction for farmers that were interviewed before:

A prototype of a tool was developed which will give you information on crop water requirements and how long to irrigate. The goal is to achieve the most optimal yield and water use.

We would like to share some results and examples of this irrigation advice and explain how the application works. We love to hear your opinion about it so it can be adjusted to make it as useful as possible for you.

Introduction for farmers that are interviewed for the first time:

HGT is working together with a Dutch company, Future Water to develop a tool that will provide advise to farmers that use irrigation to optimize their irrigation operations and give insight in how much water to use, based on your crop, and the weather-season situation. As HGT we will use this tool to improve our service towards our clients. We love to show you the first results and hear your

feedback. What you think are useful elements of the advice and what we could further develop to make it even better.

SOSIA TOOL
What are your first impressions of the information included in the advice?

Is the result easy to understand and implement for you?

What is still missing in the advice?

What do you think of the lay-out of the advice? Score 1-5, 1 is poor, 5 excellent)

Explain in words what you like about the lay-out and what can be improved.

IMPACT
When you compare the outcome of the advise and your current irrigation scheme, what are differences you see?

Do you think, when looking at the scheme, you will use more or less water compared with how you currently irrigate?

What do you think will be the effect of your yield when implementing the irrigation advise?

COMMERCIAL
How much would you be willing to pay for the shown irrigation advise? (of a whole growing season)

Why would you be willing to pay for the irrigation advise?

What most important advantages will the irrigation advice have for you?

If you like the advice, how many times per year would you purchase one (for the price indicated at question 9)?

Would you also like this advice when purchasing other products from HGT?

- ☐ No
- ☐ Yes, when I buy irrigation products
- ☐ Yes, when I buy seeds
- ☐ Yes, when I purchase soil testing
- ☐ Yes, when I buy_____
- ☐ Yes, for all of the above

Interview questions for HGT staff
Will have an open character, questions are for structure purposes.
Will be done with multiple people at the same time, staff can discuss each other views and responses on the questions facilitated by Bram. This will enable co-creation on the topics.
Will not be worked out per interview but summary of different HGT staff interviewed will be provided in report form.
Will be conducted by Bram

SOSIA Tool
What are your first impressions of the information included in the advice to farmers?

Is the result easy to understand and explain for you? (explain why yes or why no)

Do you think farmers will be able to implement the advise (explain why yes or why no)

What is still missing in the advice to farmers?

What can be improved for the advice to farmers?

What do you think of the lay-out of the advice? Score 1-5, 1 is poor, 5 excellent)

Explain in words what you like about the lay-out and what can be improved.

What is the most important shortfall of this irrigation advice?

COMMERCIAL
How much would a farmer be willing to pay for the irrigation advise? (of a whole growing season, on average).

Do you think farmers will perceive the advice as an additional cost? Or would they think the costs will outweigh the advantages (in terms of e.g. water use, pumping costs, better harvests) explain?

How many times per year would you estimate a farmer would purchase the irrigation advice? (for the price indicated at question 8)?

Would farmers like this advice when purchasing other products from HGT?

- ☐ No
- ☐ Yes, when buying irrigation products
- ☐ Yes, when buying seeds
- ☐ Yes, when purchasing soil testing
- ☐ Yes, when buying_____
- ☐ Yes, for all of the above

IMPACT
When you compare the outcome of the advise and current irrigation practices of farmers using drip irrigation, what are differences you see/expect?

Do you think, when looking at the scheme, farmers will use more or less water compared with how they currently irrigate?

What most important advantages will the irrigation advice have for the farmer?

IF HGT can give this irrigation advice to farmers, what do you think is the biggest advantage for HGT?

What do you think will be the effect of your yield when implementing the irrigation advise?

Which groups of farmers will be mainly attracted to the irrigation advise (can choose multiple)?

- ☐ Women
- ☐ Youth (<35 years)
- ☐ Men
- ☐ Elderly (>35 years

<u>Survey Results Summarized</u> Date: 10th June 2022

First observations (Semi Structured interviews with HGT Rwanda Staff)

- Gilbert: the tool result is easy to understand, we would have to test if it safes fuel. A pilot would be needed to compare the results. Maybe the water increases/cost increase but also yield might increase even more.
- Every farm with irrigation can have interest in the advice of the tool
- For HGT it would be very good if the advice is also useful for greenhouses.
- The tool is needed for our technicians to advice accurately. Farmers often ask questions about how much water to give and how long to open the irrigation system.
- To interest the farmers we have to explain what factors are taken into account, so they get a good picture that this is based on more / better information than other existing methods they use currently.
- Farmers will not have much faith in the advise when only given once at the beginning of the crop since they understand weather can change. The updates on forecasted weather (phase 2) would resolve that.
- Rain: how rain influences the irrigation scheduling what the farmer should do/what will change when it rains need to be included.
- We can consider to include one crop which is an average of different vegetable crops to be used when the crop of the farmer is not (yet) in the overview?
- Systems with gravity tend to have different pressure depending on how many fields are irrigated at the same time and the elevation of the fields. Ideally, a farmer would measure the flow from a few emitters.

Suggestions, Improvements

<u>Operational (user experience of tool)</u>

- Function for quick/easy data export (or download) from tool/platform
  - Template in Excel
  - 1 table with user input/ 1 table with results
  - GEE based SOSIA tool works well on devices of local staff
- *Function to save the input / results in the tool (so it is easy for HGT staff to re-run the advice when necessary to share again with client/ send updates, all the results are in one platform(?)*
- Format table:
  - Daily output data is considered perfect
  - Add colours (like in your template)
  - Rounding of numbers after the decimal (max 1 decimal)
- They like the current look a lot.

<u>Technical (calculations and data)</u>

- Add precipitation data
  - GPM is most recent dataset with 1 day delay but 11km resolution
  - CHIRPS has 5km resolution
  - *How to include rain in the irrigation advise? (that the number of minutes will reduce based on rainfall?) maybe a formula for effective rainfall and taking a certain water holding capacity of the soil into account? for example, when effective irrigation =12 mm and the crop needs 3 mm per day, the tool could calculate: water in soil reservoir =12mm >CWR of 3mm. So next day 0 minutes of irrigation – new soil reservoir=9 mm etc. ? → Phase 2*
  - *A way for HGT agronomist to decide themselves to run the analysis again when there is e.g. a lot of rain to provide an update to the advise / a more short term advise*
  - *Historical Precipitation is considered less relevant, forecasting is better for operational purposes.*
- Is it not yet possible to make an application for greenhouses?
- Results for irrigation time is reasonable compared to logbook data.
- Add default field crop
  - We can also replace crop-specific values with general ones (following FAO-56): small vegetables, solanum family, cucumber family, roots and tubers, legumes, perennial vegetables, fibre crops, oil crops, cereals. Etc.…
  - Add these as csv file asset to be read more easily by script (@Lisa)

- *Adjust the timing / scheduling based on the first –and last harvest data.*
- *At the moment: not all input is used in the calculations. Can you indicate which parameters are used in the tool? Especially when it comes to area and meters of drip line*
- *As discussed, we need to take the footpath into account provided there is a gap in the canopy cover as often is the case. So, when a farmer has 1 ha of land, in our calculations we might e.g. the bed width into account for our CWR calculations. It will be useful to also see this area in the output page. We could call this: Total bed area (I would not know a better alternative?) this will be important for the hgt staff.*
- *Is there a way to include soil maps / info of soils in the tool, possibly link it to soil reservoir indication?*
    - *Yes, using hydrosoils (FW product) >> phase 2*
- *Virtual weather station: also include tables next to the current graphs.*

Annex 8 - Napkin Calculation Logbook: French Beans Sunripe Farm, Rwanda

Farm	Sunripe
Crop	French beans
Area	0.5 ha
Pump Discharge	38000 L/hr

Output SOSIA Irrigation Advisory Tool					Irrigation logbook Sunripe					
Date	ETc in mm/day	ETref in mm/day	Irrigation needs in m3/day	Irrigation time in min/day	Date	Total irrigation time (min)	amount of water used	Days	m3/day	irrigation time (min/d)
2022-02-15	2.07	4.14	12.22	9	17/02/2022	300	190,000	2	95	150
2022-02-16	2.1	4.2	12.4	9	18/02/2022	240	152,000	1	152	240
2022-02-17	2.03	4.05	11.98	9	21/02/2022	300	190,000	3	63	100
2022-02-18	1.94	3.88	11.45	9	22/02/2022	240	152,000	1	152	240
2022-02-19	1.85	3.7	10.92	8	01/03/2022	300	190,000	7	27	43
2022-02-20	1.65	3.29	9.74	7	07/03/2022	240	152,000	6	25	40
2022-02-21	1.97	3.94	11.63	9	08/03/2022	300	190,000	1	190	300
2022-02-22	2.06	4.11	12.16	9	11/03/2022	300	190,000	3	63	100
2022-02-23	1.92	3.83	11.33	8	12/03/2022	240	152,000	1	152	240
2022-02-24	1.66	3.31	9.8	7	19/03/2022	300	190,000	7	27	43
2022-02-25	2.04	4.07	12.04	9	20/03/2022	240	152,000	1	152	240
2022-02-26	2.11	4.21	12.46	9	24/03/2022	300	190,000	4	48	75
2022-02-27	1.92	3.84	11.33	8	25/03/2022	240	152,000	1	152	240
2022-02-28	2.15	4.29	12.69	9	29/03/2022	300	190,000	4	48	75
2022-03-01	2.02	4.03	11.92	9	30/03/2022	240	152,000	1	152	240
2022-03-02	2.16	4.32	12.75	10	04/04/2022	300	190,000	5	38	60
2022-03-03	1.83	3.65	10.8	8	05/04/2022	240	152,000	1	152	240
2022-03-04	1.97	3.94	11.63	9	08/04/2022	300	190,000	3	63	100
2022-03-05	1.96	3.92	11.57	9	09/04/2022	240	152,000	1	152	240
2022-03-06	1.84	3.67	10.86	8	15/04/2022	300	190,000	6	32	50
2022-03-07	2.12	4.24	12.52	9	16/04/2022	240	152,000	1	152	240
2022-03-08	2.07	4.13	12.22	9	22/04/2022	300	190,000	6	32	50
2022-03-09	2.07	4.13	12.22	9	24/04/2022	240	152,000	2	76	120

2022-03-10	1.99	3.97	11.75	9	26/04/2022	300	190,000	2	95	150
2022-03-11	2.21	4.41	13.05	10	27/04/2022	240	152,000	1	152	240
2022-03-12	2.11	4.22	12.46	9	04/05/2022	300	190,000	7	27	43
2022-03-13	2.1	4.2	12.4	9	05/05/2022	240	152,000	1	152	240
2022-03-14	2.1	4.19	12.4	9	11/05/2022	300	190,000	6	32	50
2022-03-15	2.16	4.32	12.75	10	12/05/2022	240	152,000	1	152	240
2022-03-16	2.23	4.46	13.16	10	**Total**				**2805**	
2022-03-17	2.03	4.06	11.98	9						
2022-03-18	2.02	4.04	11.92	9						
2022-03-19	1.84	3.67	10.86	8						
2022-03-20	1.95	3.9	11.51	9						
2022-03-21	1.87	3.73	11.04	8						
2022-03-22	1.89	3.78	11.16	8						
2022-03-23	1.89	3.78	11.16	8						
2022-03-24	1.78	3.55	10.51	8						
2022-03-25	1.91	3.81	11.28	8						
2022-03-26	1.78	3.56	10.51	8						
2022-03-27	1.81	3.61	10.69	8						
2022-03-28	1.59	3.17	9.39	7						
2022-03-29	2.06	4.12	12.16	9						
2022-03-30	1.85	3.7	10.92	8						
2022-03-31	1.9	3.8	11.22	8						
2022-04-01	1.64	3.27	9.68	7						
2022-04-02	1.88	3.75	11.1	8						
2022-04-03	1.91	3.82	11.28	8						
2022-04-04	1.67	3.33	9.86	7						
2022-04-05	1.86	3.72	10.98	8						
2022-04-06	1.87	3.74	11.04	8						
2022-04-07	3.75	3.57	22.14	17						
2022-04-08	3.73	3.55	22.02	16						
2022-04-09	3.92	3.73	23.14	17						
2022-04-10	4.01	3.82	23.67	18						
2022-04-11	4.03	3.84	23.79	18						

2022-04-12	3.71	3.53	21.9	16
2022-04-13	3.85	3.67	22.73	17
2022-04-14	3.58	3.41	21.13	16
2022-04-15	3.72	3.54	21.96	16
2022-04-16	3.7	3.52	21.84	16
2022-04-17	3.64	3.47	21.49	16
2022-04-18	3.61	3.44	21.31	16
2022-04-19	3.71	3.53	21.9	16
2022-04-20	3.53	3.36	20.84	16
2022-04-21	3.44	3.28	20.31	15
2022-04-22	3.59	3.42	21.19	16
2022-04-23	3.77	3.59	22.26	17
2022-04-24	3.64	3.47	21.49	16
2022-04-25	3.56	3.39	21.02	16
2022-04-26	3.22	3.07	19.01	14
2022-04-27	3.48	3.31	20.54	15
2022-04-28	3.61	3.44	21.31	16
2022-04-29	3.73	3.55	22.02	16
2022-04-30	3.32	3.16	19.6	15
2022-05-01	3.31	3.15	19.54	15
2022-05-02	3.43	3.27	20.25	15
2022-05-03	3.55	3.38	20.96	16
2022-05-04	3.74	3.56	22.08	16
2022-05-05	3.38	3.22	19.95	15
2022-05-06	3.43	3.27	20.25	15
2022-05-07	2.99	3.32	17.65	13
2022-05-08	3.02	3.35	17.83	13
2022-05-09	2.95	3.28	17.41	13
2022-05-10	2.88	3.2	17	13
2022-05-11	2.77	3.08	16.35	12
2022-05-12	2.86	3.18	16.88	13
2022-05-13	3.02	3.35	17.83	13
2022-05-14	3.01	3.34	17.77	13
2022-05-15	3.08	3.42	18.18	14
2022-05-16	3	3.33	17.71	13
Total			**1403**	

Annex 9 - License Agreement FutureWater and Holland Greentech

SOSIA LICENSE AGREEMENT

This SOSIA License Agreement ('Agreement') is entered into as of 1 June 2022 between:

1. The private company with limited liability FutureWater, with its registered office at Costerweg 1V, 6702 AA Wageningen, the Netherlands, registered in the trade register of the Dutch Chamber of Commerce under number 09129725, legally represented by its statutory director, Mr Martijn de Klerk, hereinafter referred to as 'FutureWater', party on the one side

and

2. The private company with limited liability Holland Greentech International, with its registered office at Duinhorst 52, 2204BT Noordwijk, the Netherlands, registered in the trade register of the Dutch Chamber of Commerce under number 75862654, legally represented by its statutory director, Mr Norbert van der Straaten, including its world-wide subsidiaries, hereinafter referred to as 'Intermediary', party on the other side

jointly referred to as 'Parties'

whereas

- Parties jointly developed the SOSIA Satellite-based Irrigation Advisory Tool ('Tool') as part of the NSO Prijsvraag 'Bevorderen gebruik open-access geodata ten behoeve van voedselzekerheid en duurzaam land- en watergebruik in Afrika en het Midden-Oosten' ('Project')
- Intermediary wishes to make use of the Tool for its extension services to farmers and other organizations ('Services')
- both Parties wish to make arrangements regarding any future income generated by FutureWater or Intermediary with regard to the Tool, for which this Agreement is entered, and agree as follows:

Article 1: Usage rights of the Tool

1.1 In countries where the Tool is being used by Intermediary, Intermediary has the sole usage rights for the Tool. FutureWater is not allowed to distribute the Tool to any other organization, unless agreed upon by Intermediary.

1.2 In countries where the Tool is not (yet) being used by Intermediary, FutureWater is allowed to distribute the usage rights of the Tool to any other organization willing to pay for it. Before entering into an agreement with the interested organization, Intermediary has the first right to match the proposed payment by the organization willing to make use of the Tool. If the payment is matched, Intermediary will have the sole right to make use of the Tool (article 1.1). If the payment is not matched, FutureWater may distribute the Tool to the interested organization, subject to article 2.3 and 2.4.

Article 2: Business-to-consumer sales of Services making use of the Tool

2.1 Intermediary is allowed to sell services to consumers (mainly farmers) that make use of the Tool by paying a fixed usage fee to FutureWater. This fee differs per country and will be determined in mutual agreement between both Parties each time the Tool will be used by Intermediary in a new country.

2.2 Intermediary shall pay FutureWater an amount equal to 15% of the gross amount invoiced on sales, leases or other transfers of the Tool, excluding VAT ('Net Sales').

2.3 Intermediary can request FutureWater to maintain, update and/or further develop (features of) the Tool, upon payment of additional fees that will be determined in mutual agreement between both Parties.

2.4 Intermediary is not allowed to have the Tool maintained, updated and/or further developed by any other organization.

FutureWater Holland Greentech 1

Article 3: Business-to-business sales of Services making use of the Tool

3.1 Both Parties will jointly offer Services making use of the Tool to other organizations.
3.2 Selling price of these Services will be determined in mutual agreement between both Parties.
3.3 In countries where the Intermediary has a physical office, the revenue from sales to other businesses will be divided as follows:
- 60% of the Net Sale to FutureWater
- 40% of the Net Sale to Intermediary

3.4 In countries where the Intermediary does not have a physical office, the revenue from sales to other businesses will be divided as follows:
- 85% of the Net Sale to FutureWater
- 15% of the Net Sale to Intermediary

Article 4: Sale of the complete Tool including its intellectual property rights

4.1 In case the complete Tool and its intellectual property rights are sold to any organization, in any country, the revenue will be divided as follows:
- 60% of the Net Sale to FutureWater
- 40% of the Net Sale to Intermediary

Article 5: Term and termination

5.1 The term of this Agreement shall commence on 1 June 2022 and shall continue to be in full force until terminated by both Parties in mutual agreement.

Thus agreed

FutureWater

Location: Wageningen, The Netherlands

Date: 23-06-2022

Name: Martijn de Klerk

Function: General manager

Intermediary

Location: Leeuwarden, The Netherlands

Date: 23-06-2022

Name: Bram de Vries

Function: Consultant & Shareholder

Annex 10 - Letter of Intent Phase 2

KK 10 Ave 7 Kigali, Rwanda
Info@hollandgreentech.com
+250 781 449 656

21st of June, 2022

Letter of endorsement

For the purposes of the NSO award (prijsvraag) 'Bevorderen gebruik open-access geodata ten behoeve van voedselzekerheid en duurzaam land- en watergebruik in Afrika en het Midden-Oosten', a first phase of the development of an irrigation advisory tool has been executed by Future Water in development with our own organization.

With this letter, we (Holland Greentech) would like to express the desirability to further enhance and upscale the SOSIA tool. Since we are in close contact with Future Water and have provided a lot of feedback from our clients and our extension staff, we trust that after phase two, the tool will become an even more effective and validated tool that we can use to improve our service package to our clients. Our wish is that the tool can also become available in other countries besides Rwanda. We are active in 11 countries in Sub-Sahara Africa where insight in crop water requirements and irrigation scheduling can make a difference.

Through this letter, we express our support for the continuation of the development of the tool in a second phase in which we will also provide the necessary support in the improvements, testing and validation of the SOSIA-tool.

Date of signing: 23 June 2022/ Kigali - Rwanda

Location: Kigali, Rwanda

Jacques Tuyishime
Managing director Holland Greentech Rwanda
Jacques@hollandgreentech.com
+250 781 449 656

Annex 11 - Letter of Support: Sunripe Farms Rwanda

SUNRIPE
FARMS · RWANDA

22st of June, 2022

Support Letter

For the purposes of the NSO award (prijsvraag) 'Bevorderen gebruik open-access geodata ten behoeve van voedselzekerheid en duurzaam land- en watergebruik in Afrika en het Midden-Oosten', a prototype of an irrigation advisory tool is made by Future Water in collaboration with Holland Greentech.

Through this letter, support is provided from Sunripe farms Rwanda who is a current client of Holland Greentech. The client has seen the first version of the SOSIA tool and would like to express that he is supporting the further development of the tool since the first version seemed very promising. The client is willing to support the development in the proposes phase 2, to e.g. test the tool in the field and provide feedback to Holland Greentech and Future Water.

The undersigned has indicated that this irrigation advisory tool is expected to be of great benefit and assist in adopting climate smart agricultural practices. The undersigned acknowledges that, based on the results of SOSIA-phase 1, this tool will be beneficial in determining the optimal irrigation scheduling.

Signed 22-06-2022

TIN: 106133278
SUNRIPE FARM LTD
+250 788 277 423
+250 785 473 075
Web: sunripefarmsrwanda.com

William Macharia
Sunripe Farms Rwanda.
Rwanda

Annex 12- Energy cost calculations

Example scenario	*scenario direct pumping from borehole*	
field size	5000	m2
borehole	60	meter
subm. Pump	1.1	KW
	1.5	HP
	3.4	m3/hr at 60m
	3400	litre/hr
litre/KWH	3,090.91	litre/KWH
Costs electricity	1	kwacha/KWH
costs kwacha/litre	0.000323529	kwacha/litre
required litres growing season	3,587,250.00	litres
costs	1160.580882	kwacha
Normal irrigation 30% more than sosia		
	1,076,175.00	litres saved
	1076.175	m3 saved
	348.1742647	kwacha saved

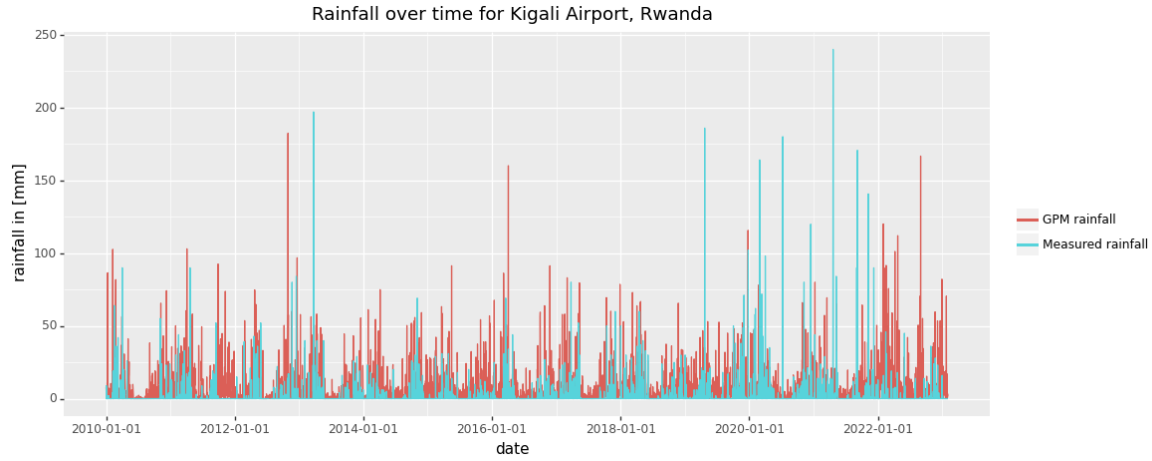
Example scenario	*scenario first pumping from borehole in reservoir, then booster pump to drip system*	
field size	5000	m2
borehole	60	meter
subm. Pump	1.1	KW
	1.5	HP
	3.4	m3/hr at 60m
	3400	litre/hr
litre/KWH	3090.909	litre/KWH
Costs electricity	1	kwacha/KWH
costs kwacha/litre	0.000324	kwacha/litre
required litres growing season	3587250	litres
costs	1160.581	kwacha
Booster pump	0.75	kw
	6.8	m3/hr
	6800	lph
required pumping hours	527.5368	hours
required kwh	395.6526	KW

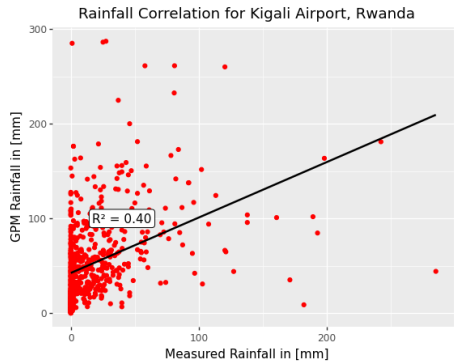
costs	395.6526	kwacha
total costs	1556.233	kwacha
estimated saving 30%	466.87	kwacha

Annex 13 – Quality Assessment Rainfall Hindcast

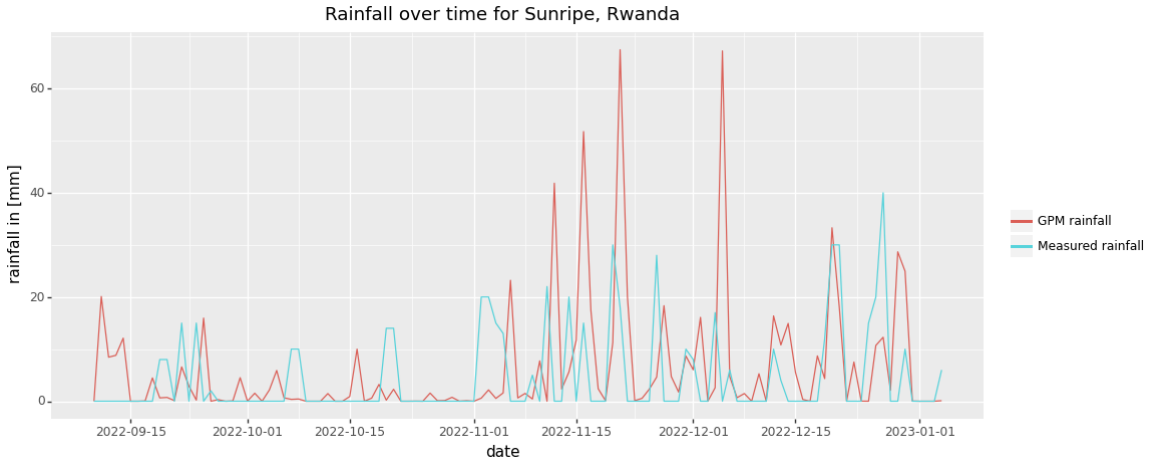
Location	*Country*	*Correlation GPM and Measured rainfall (R^2)*	*Difference in [mm] on a weekly basis*
Kigali Airport	Rwanda	0.40	35.7 mm
Sunripe	Rwanda	0.52	11.8 mm
Kayonga	Rwanda	0.62	33.2 mm
Diawema enterprise	Zambia	0.58	104.3 mm
Wood	Zambia	0.73	177.7 mm
Holland Greentech	Zambia	-0.25	208.2 mm

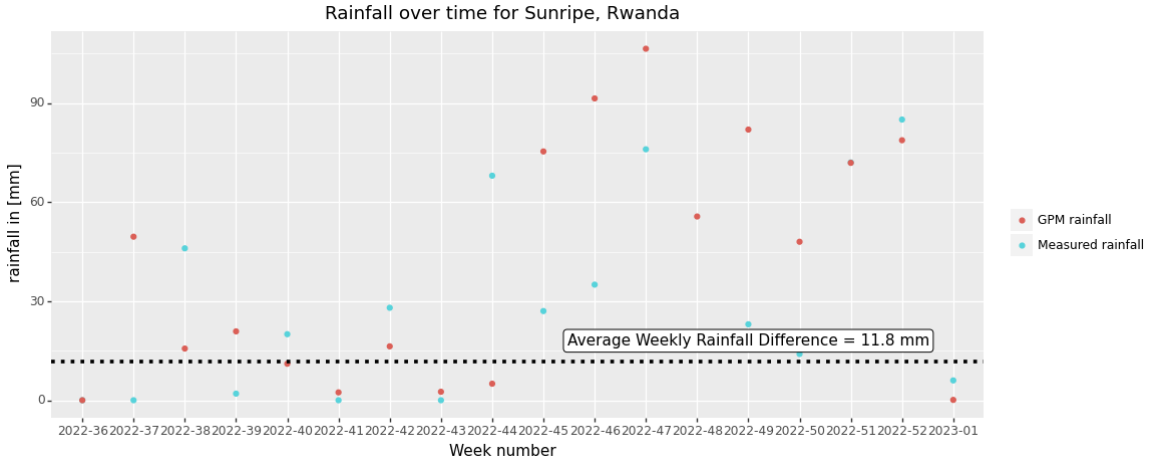
Kigali Airport figures

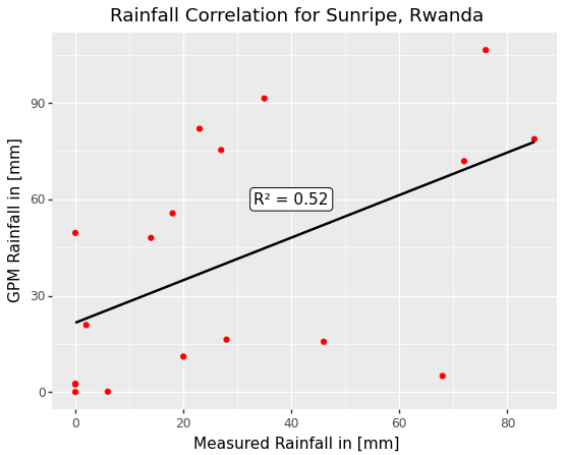




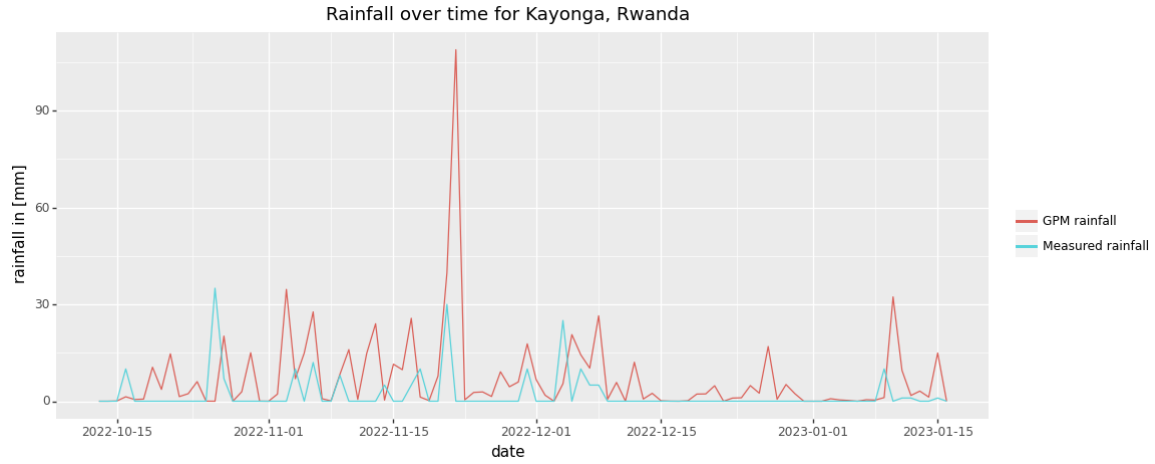
Sunripe

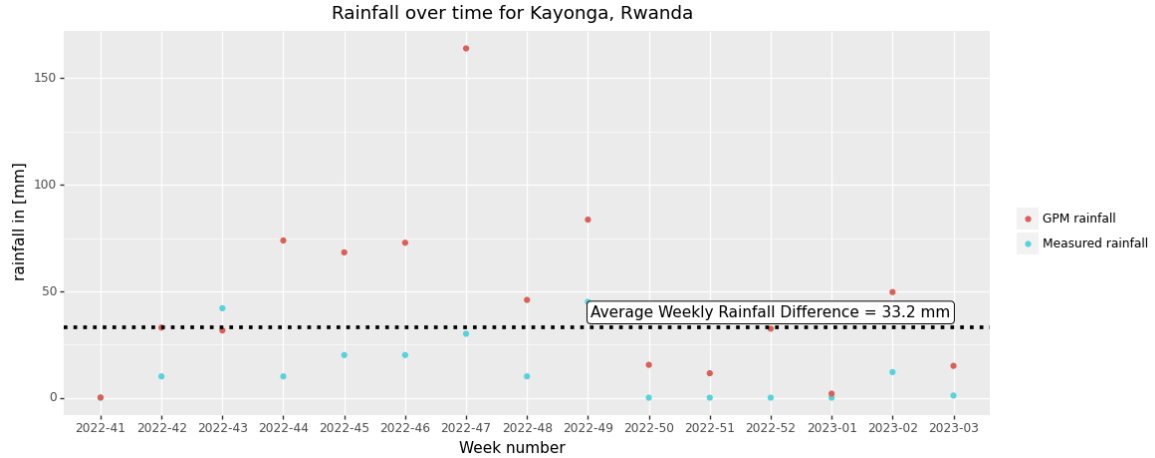

Rainfall over time for Sunripe, Rwanda
rainfall in [mm]
0
20
40
60
2022-09-15
2022-10-01
2022-10-15
2022-11-01
2022-11-15
2022-12-01
2022-12-15
2023-01-01
date
GPM rainfall
Measured rainfall

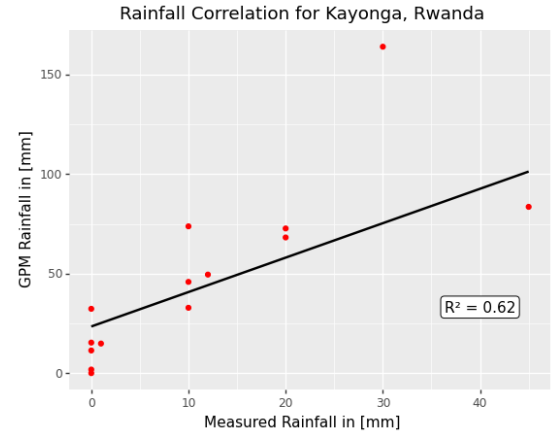

Rainfall over time for Sunripe, Rwanda
rainfall in [mm]
0
30
60
90
Average Weekly Rainfall Difference = 11.8 mm
2022-36
2022-37
2022-38
2022-39
2022-40
2022-41
2022-42
2022-43
2022-44
2022-45
2022-46
2022-47
2022-48
2022-49
2022-50
2022-51
2022-52
2023-01
Week number
GPM rainfall
Measured rainfall


Rainfall Correlation for Sunripe, Rwanda
GPM Rainfall in [mm]
0
30
60
90
R² = 0.52
0
20
40
60
80
Measured Rainfall in [mm]

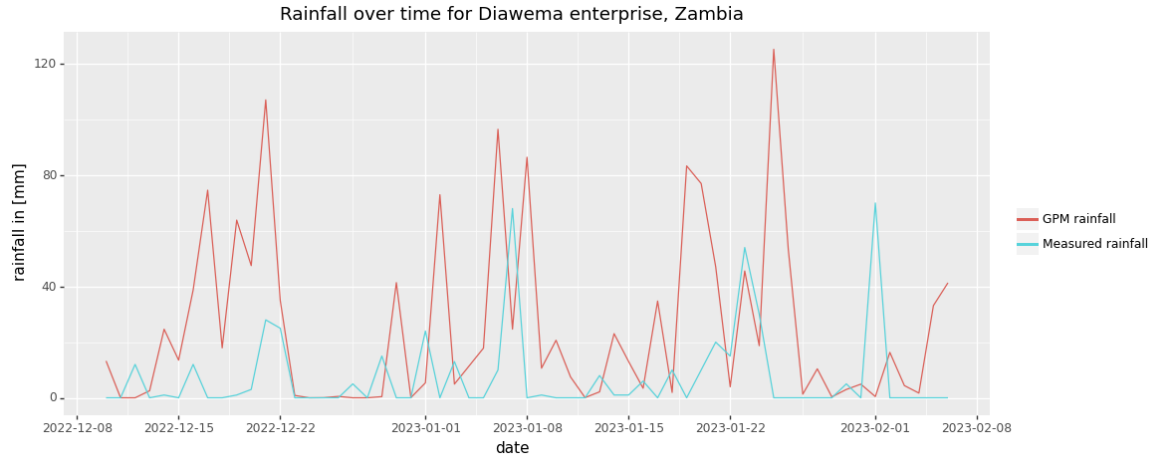
Kayonga

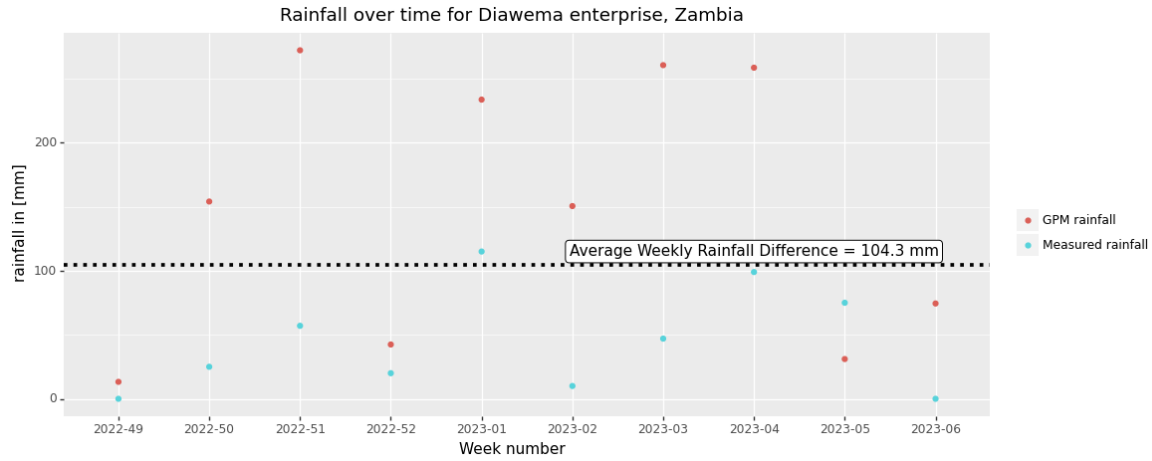

Rainfall over time for Kayonga, Rwanda
rainfall in [mm]
90
60
30
0
2022-10-15
2022-11-01
2022-11-15
2022-12-01
2022-12-15
2023-01-01
2023-01-15
date
GPM rainfall
Measured rainfall

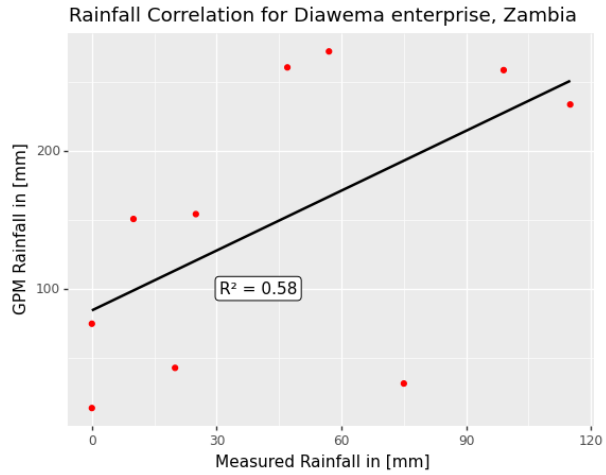

Rainfall over time for Kayonga, Rwanda
rainfall in [mm]
150
100
50
0
Average Weekly Rainfall Difference = 33.2 mm
2022-41
2022-42
2022-43
2022-44
2022-45
2022-46
2022-47
2022-48
2022-49
2022-50
2022-51
2022-52
2023-01
2023-02
2023-03
Week number
GPM rainfall
Measured rainfall


Rainfall Correlation for Kayonga, Rwanda
GPM Rainfall in [mm]
150
100
50
0
R² = 0.62
0
10
20
30
40
Measured Rainfall in [mm]

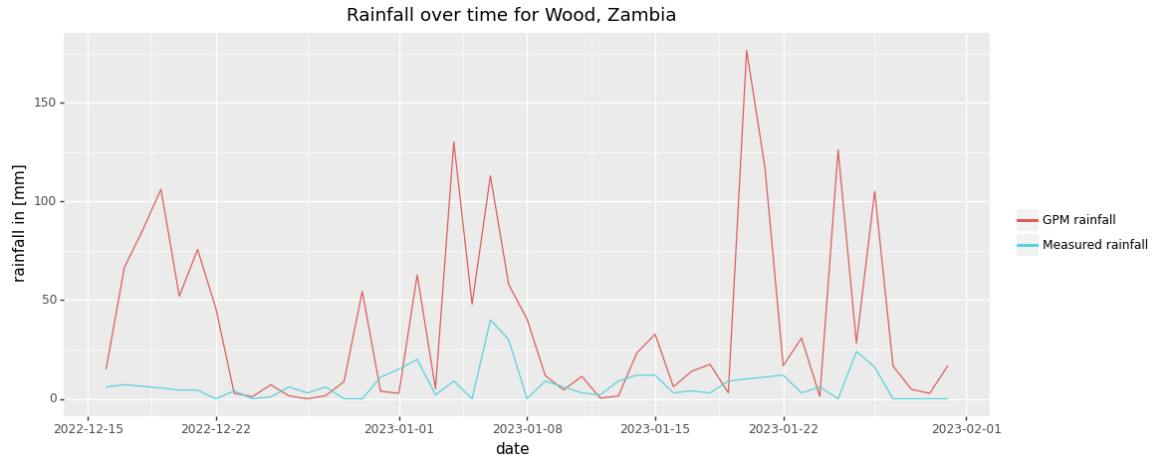
Diawema enterprise

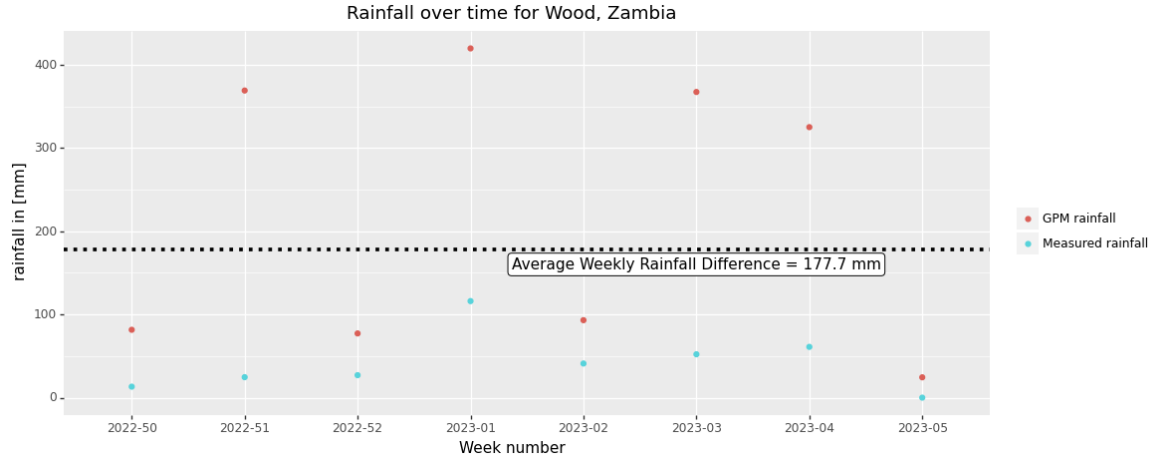


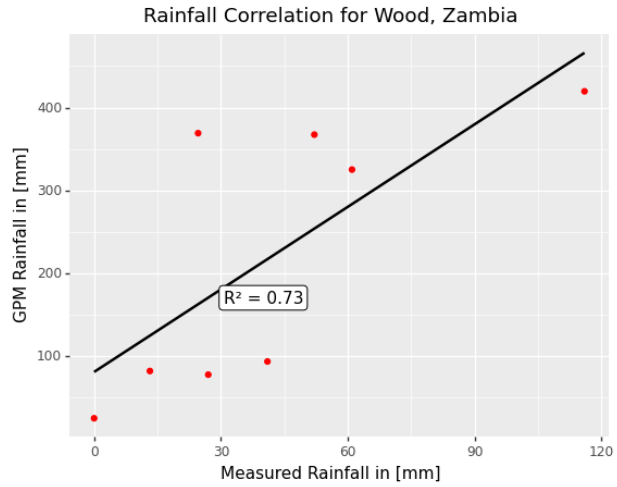




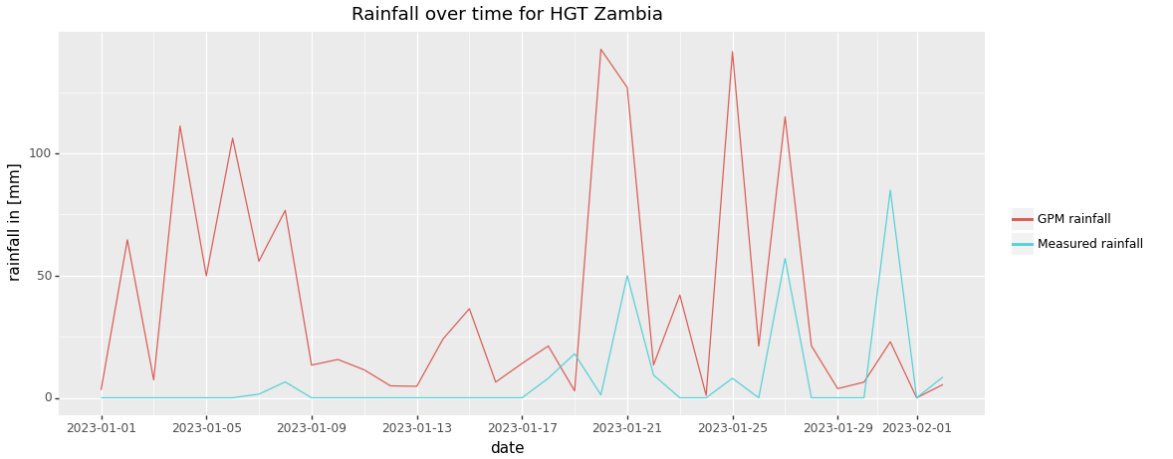
Wood

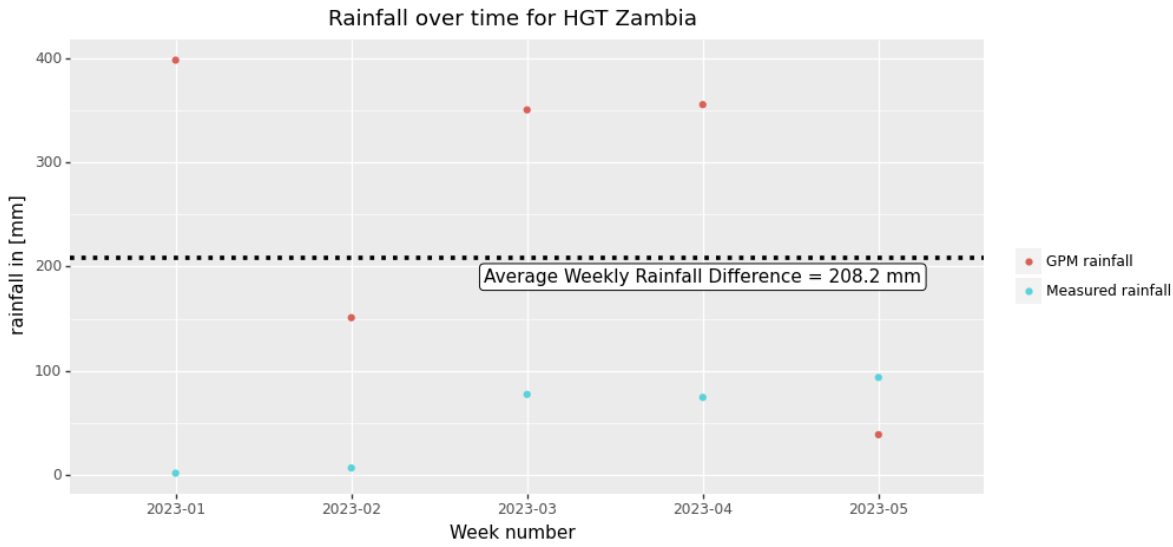

Rainfall over time for Wood, Zambia
rainfall in [mm]
150
100
50
0
2022-12-15
2022-12-22
2023-01-01
2023-01-08
2023-01-15
2023-01-22
2023-02-01
date
GPM rainfall
Measured rainfall

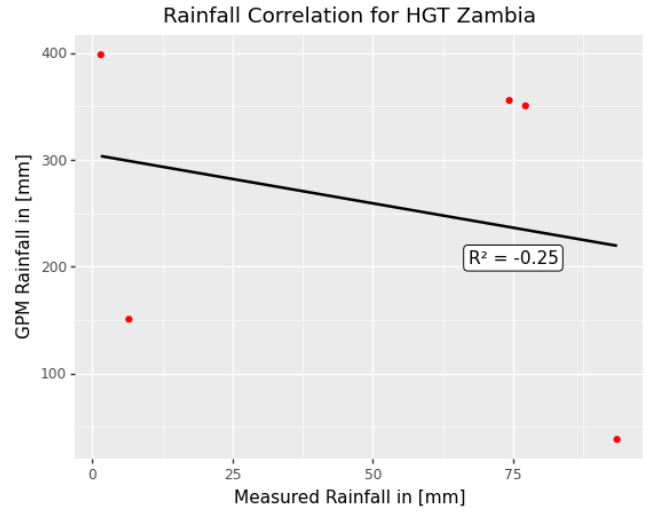

Rainfall over time for Wood, Zambia
rainfall in [mm]
400
300
200
100
0
Average Weekly Rainfall Difference = 177.7 mm
2022-50
2022-51
2022-52
2023-01
2023-02
2023-03
2023-04
2023-05
Week number
GPM rainfall
Measured rainfall


Rainfall Correlation for Wood, Zambia
GPM Rainfall in [mm]
400
300
200
100
R² = 0.73
0
30
60
90
120
Measured Rainfall in [mm]

Holland Greentech







Annex 14 – Surveys Phase 2, mid-term
Rwanda (06 Nov-23 – 10-Nov-23)

Farmer interview sosia phase 2 mid-term evaluation trials

Date of interview:08/11/2022 Location: Pride farms, Rwanda

- Name farmer: Pride farms, interview with Patrick irrigation manager and Eva (Farm manager)
- Gender: male / female:
- Phone number:
- Location farmer:
- Size farm
  - Coordinates: -1.9859 , 30.2030
  - Total size farm: 32 ha
  - Size of fields where farmer is growing crops: 2
  - Size of fields that use irrigation: 2
- Crops
  - Crop type/variety: Lettuce
  - Intercropping: no
  - Planting date: 2022-09-09
  - Plant spacing : 30cm x 30cm
- Soil:
  - Soil type: medium
  - Any soil test done? no
- Description of farm
  - How many casual workers: 10
  - Description of water source
    - Stream/swamp
    - Water availability (include seasonal differences if they exist):no shortage
  - Description of current irrigation system
    - Water source used: reservoir
    - Dam liner/water tank size: not known
    - Pump info: solar pump
    - Height tank (if they use a tank) / dam liner (in meter): height difference 10 meter.
    - Distance tank to fields: 50 meters
    - Type of drip line (need to be HGT sourced):
      - Brand: Rivulis T-tape
      - Emitter spacing: 20 cm
      - Emitter flow rate: 1lph
  - Date when trial started: 09-09-2022
  - Expected end date trial (when crop is harvested): 01-11-2022

Interview question form for farmers Sosia-2

The interview questions below form the basis of a semi-structured interview. Some of the interview questions are the start of an interactive conversation with the interviewee. It is for the interviewer to ask supplementary questions to get the most realistic and complete insight.

Baseline questions suggestions

The goal of this part of the questionnaire is to hear from the farmers themselves to understand the weight of the problem that you are trying to solve.

How did you irrigate before getting the SOSIA advice?

We check soil moisture by hand, and we check the weather. If it's a hot day we would irrigate more. We did not use any calculations or data. We irrigate approximately 30 minutes-45 minutes per for lettuce.

What do you think is the challenge you face during the irrigation?

Pressure variance due to height differences in the fields. Some fields have much higher pressure. Also not knowing the uniformity in one line.
Soil type: how long to irrigate/what to change per soil type.

Experience SOSIA advice

Establish first that we are doing the research and trying to improve the product for your benefit. The farmers can help to improve the product by giving critical feedback.

How did you use the SOSIA irrigation advice?

We received the irrigation advise from Holland Greentech in pdf. We followed this day by day. Next to that we received the gain gauge from Holland Greentech and when it rains, we communicated to the Gilbert (extension officer) to ask for guidance on how to adjust the irrigation scheme.

How useful was the irrigation advice?

Very useful it helps with the irrigation scheduling, to know how long to irrigate and how much water to use. Overall it was a good experience.

How is the irrigation advise different from your normal way of irrigation?

We noticed that the irrigation advise was shorter than our traditional method. We also keep records of all fields. For example the advice would should 23 minutes but we would irrigate 30 minutes in our normal way

How do you think the SOSIA-irrigation advice is better for your crop? tell us in what way it helped you with the challenges that you mentioned earlier.

We did not detect any stress on the crop. We were thinking in the beginning that maybe the crops would be small because of less water. But when we harvested the lettuce, the lettuce was just the same as the rows where we used our normal irrigation method.

What was the impact on water usage after using the advice? how significant was that?

- ☐ More water compared with my normal way of irrigation
- X Less water compared with my normal way of irrigation

If you are also considering fuel savings, ask if the farmers saw savings in fuel consumption for the irrigation?
We are using solar pump, so no fuel was used. But it is important to safe water.

What did you like the most about the irrigation advice?
It was easy to use, a good guidance in irrigation timing.

What did you not like about the irrigation advice?
It was not clear how much water in m3 I would use. It was included but I did not understand.

It is possible that you could not follow the advice all the time for different reasons. What were such moments where you could not follow the irrigation advice, and why?
We always could follow the advice. Only when we did not want to irrigate the whole field, we could not only irrigate the SOSIA bed due to the limitation of the valves.

If you missed single/ multiple SOSIA advice, how did you compensate in case you skipped a day?
-did not happen

Communication, Information Delivery and Design

How did you use the PDF/ Image to follow the Irrigation Advice?
Every day I read the minutes, went to the field and opened the valves to the sosia bed for the given number of minutes. (with the exception that when the whole block was not irrigated, the sosia advise was not possible to do. This didn't happen much though (see records)

How is it for you to read through the irrigation advice in the file (PDF)
It was very easy.

What did you like about the information presented in the PDF?
It was easy, not challenging to do.

What did you not like about the information presented in the PDF?
It was not clear to me what the volume per day was in the schedule. Only now I understand it (after explanation of team)

How was it for you to keep records of your irrigation (filling out the irrigation record forms provided)?
This was not challenging because we are used to keep a lot of records including the irrigation timing per block.

Do you think it is useful to measure the time how long you irrigate?

X yes, why is this useful?
☐ no, why is this not useful?

Explanation: It is important so you can evaluate the performances of the crop.

After this SOSIA experience, would you keep holding irrigation records?

X yes, why?
☐ no, why ?

Explanation: It is a practice we are already used to.

How often would you like to receive updates concerning irrigation timing? (based on new/updated weather info?

☐ Every day
☐ Every week
☐ When significant changes occur in the advice based on weather
☐ Never
☐ Other
- We did not ask this question -

To know the influence of rain on your irrigation schedule, measuring with a meter is most accurate. Would you be able to measure and record the rainfall at a daily /weekly basis?
Explanation:
In this trial we measured daily rainfall. This was possible. We needed some help to adjust the irrigation schedule from Holland Greentech. It is not difficult to measure and keep the rain records.

Would you be able to account for rainfall yourself, using a field meter? For example, subtracting rainfall on a daily basis from the crop water requirements as indicated by the SOSIA advice.

X Yes
☐ No

Explain:
Measuring the rain is not a problem but to convert this to how many minutes to reduce is a challenge.

Commercial viability

What should be added in the Sosia advice for you to use it for the other crops in the future? Would you like to use it for other crops?

X yes, why?
☐ no, why ?

Explanation:
We are happy with the results of the trial and would like to use it for our next lettuce crop. For the other type of crops, we don't know yet how it will work. So we first have to do trials for the other crops to know of effective it is before we can fully implement.

Do you expect that the SOSIA advice will save you money? (in terms of e.g. less pumping / better yield?)

☐ yes, why?
X no, why ?

Explanation:
No, because we use solar pump to pump water.

If answered yes at question 12: Estimate the amount (RWF) you estimate you would safe Amount: RWF

Explanation: no price setting known at the time

How much would you be willing to pay for the service? **RWF per crop per season -**

Impact

Did the SOSIA project impact your livelihood? X Yes ☐ No
How (not)?

What are your main learnings/benefits from the project? Explain.
We could see that the crop was performing just as good with less water. We can thus improve in our water usage.

What are some recommendations you would have for the SOSIA tool?
Clarity in the table name of the advice. Especially when it comes to the daily amount of water.

Photos taken on 08/11/2022

Pictures taken from the sosia irrigated lettuce

Control bed

Lettuce irrigated according to Sosia advise.

Farmer interview sosia phase 2 mid-term evaluation trials

Date of interview: **09/11/2022** Location: **Rwanda**

- Name farmer: **Sunripe**_____
- Gender: male / female:
  _____
- Age:
  _____
  ____
- Phone number:
  _____
- Location farmer:
  _____
- Size farm
  - Coordinates:
    _____
  - Total size farm:
    _____
  - Size of fields where farmer is growing crops:
    _____
  - Size of fields that use irrigation:
    _____
- Crops
  - Crop type/variety:
    _____
  - Intercropping:_____
    _____
  - Planting date:
    _____
  - Plant spacing :
    _____
- Soil:
  - Soil type:
    _____
  - Any soil test done?
    _____
- Description of farm
  - How many casual workers?_____
  - Description of water source
    - River / dam / borehole / furrow / stream
    - Water availability (include seasonal differences if they exist):_____
  - Description of current irrigation system
    - Water source used:
      _____

- Dam liner/water tank size:
  _____
- Pump info:
  _____
- Height tank (if they use a tank) / dam liner (in meter):
  _____
- Distance tank to fields:
  _____
- Include photos of several system (components)
- Type of drip line (need to be HGT sourced):_____
  - Brand:
    _____
    __
  - Emitter spacing:
    _____
  - Emitter flow rate:
    _____

- Date when trial started:_____
- Expected end date trial (when crop is harvested):
  _____

Interview question form for farmers Sosia-2

The interview questions below form the basis of a semi-structured interview. Some of the interview questions are the start of an interactive conversation with the interviewee. It is for the interviewer to ask supplementary questions to get the most realistic and complete insight.

Baseline questions suggestions

The goal of this part of the questionnaire is to hear from the farmers themselves to understand the weight of the problem that you are trying to solve.

How did you irrigate before getting the SOSIA advice?
I determined a number of minutes to irrigate based on crop stage. For example 45 minutes. Then I irrigate that week for 45 minutes every day.

What do you think is the challenge you face during the irrigation?
I am not sure about the pressure requirements and the max run length of one drip line. What my emitter flow is in the field.

Experience SOSIA advice

Establish first that we are doing the research and trying to improve the product for your benefit. The farmers can help to improve the product by giving critical feedback.

How did you use the SOSIA irrigation advice?

I *have the advice on my phone and read how many minutes to irrigate. I than switch on the valve to the whole field but keep the two valve connecters that are controlling the water to the SOSIA trial plot closed. when the system became under pressure, I switched the valves of the sosia plot so immediately the drippers start to drip on this bed. I than checked the time and added the number of minutes so I knew when to close the valves again. When that time has reached, I would switch off the valves and recorded the time in the record sheet.*

How useful was the irrigation advice?
The advice helped to save water while the crop was performing the same as the fields that I irrigated longer.

How is the irrigation advise different from your normal way of irrigation?
Less time, water and time compared with our usual way on a daily basis. Average with sosia time 25 minutes while with current practices around 40 minutes daily.

How do you think the SOSIA-irrigation advice is better for your crop? tell us in what way it helped you with the challenges that you mentioned earlier. <<
The crop seemed to perform just as good as the control plot even when less water was used.

What was the impact on water usage after using the advice? how significant was that?

- ☐ More water compared with my normal way of irrigation
- X Less water compared with my normal way of irrigation

If you are also considering fuel savings, ask if the farmers saw savings in fuel consumption for the irrigation?
For this plot, which is directly connected to the pump, energy savings would be expected since less minutes of pumping.

What did you like the most about the irrigation advice?
The information is very clear per day

What did you not like about the irrigation advice?
It was not clear to me that before following the advise, the field should be brought to field capacity. As a result, the germination of the bed was 3 days slower than the control field. I think because the soil was drier. However, the crop picked up afterwards and soon no difference was observed anymore.

It is possible that you could not follow the advice all the time for different reasons. What were such moments where you could not follow the irrigation advice, and why?
When it was raining, I did not always follow the advise. In those cases I used a tension meter and after discussing with Holland Greentech to not irrigate or reduce.

If you missed single/ multiple SOSIA advice, how did you compensate in case you skipped a day?
This only happened with rain. The pump is very reliable we use, and we did not have any power cuts.

<u>Communication, Information Delivery and Design</u>

How did you use the PDF/ Image to follow the Irrigation Advice?
I used the pdf on my smartphone.

How is it for you to read through the irrigation advice in the file (PDF)
It was very clear what the columns meant in the advice. I only used the minute column. (that indicates the minutes of irrigation advised.

What did you like about the information presented in the PDF?
It is a complete column with a list of dates and information per day which is easy.

What did you not like about the information presented in the PDF?
It was not clear that the field needed to be on field capacity before following the advice.

How was it for you to keep records of your irrigation (filling out the irrigation record forms provided)?
A separate form was provided for the trial. This was not very different from our own records, so it was easy to fill in. for the control plot we used our own form.

Do you think it is useful to measure the time how long you irrigate?

X yes, why is this useful?
□ no, why is this not useful?

Explanation: We can analyse how much water we use.

After this SOSIA experience, would you keep holding irrigation records?

X yes, why?
□ no, why ?

Explanation± we already included irrigation record keeping in our standard way. We do this for every field.

How often would you like to receive updates concerning irrigation timing? (based on new/updated weather info?

□ Every day
□ Every week
□ When significant changes occur in the advice based on weather
□ Never
X other: *every week would be sufficient but sometimes a shorter update could be needed because of things I see in the field such as drought stress or very hot weather. It would help if I can request in those situations for an update.*

To know the influence of rain on your irrigation schedule, measuring with a meter is most accurate. Would you be able to measure and record the rainfall at a daily /weekly basis?
Explanation: Yes, we have a rain gauge.

Would you be able to account for rainfall yourself, using a field meter? For example, subtracting rainfall on a daily basis from the crop water requirements as indicated by the SOSIA advice.

X Yes

□ No

Explain: It would not be much more complicated than what we did in this trial.

Commercial viability

What should be added in the Sosia advice for you to use it for the other crops in the future? Would you like to use it for other crops?

□ yes, why?
□ no, why ?

Explanation: It is good that rain is included. That is the challenging thing now. For the other crops we would first want to test the tool before we would dare to use it on the whole fields. This would be a gradual approach.

Do you expect that the SOSIA advice will save you money? (in terms of e.g. less pumping / better yield?)

X yes, why?
□ no, why ?

Explanation: We would have to pump less because the pump is directly connected to the drip irrigation system. This would save for the trial field electricity. But we have also fields where fuel pumps are being used. If we would use the advise there, more money would be saved because fuel is very expensive.

If answered yes at question 12: Estimate the amount (RWF) you estimate you would safe
Amount:_____ RWF

Explanation: During the interview, we discussed a method to estimate the financial saving by measuring the difference in time the pump is used and estimate how much electricity would be saved. Holland Greentech and Future water will assist in this calculation.

Impact

Did the SOSIA project impact your livelihood? ☐ Yes x No

How (not)? This is a commercial farm, and the employees will not directly benefit from the cost saving etc of the employees working on the farm.

When looking at a broader perspective, less water will be taken from the marshlands, so more water stays available for households in the catchment.

What are your main learnings/benefits from the project? Explain.

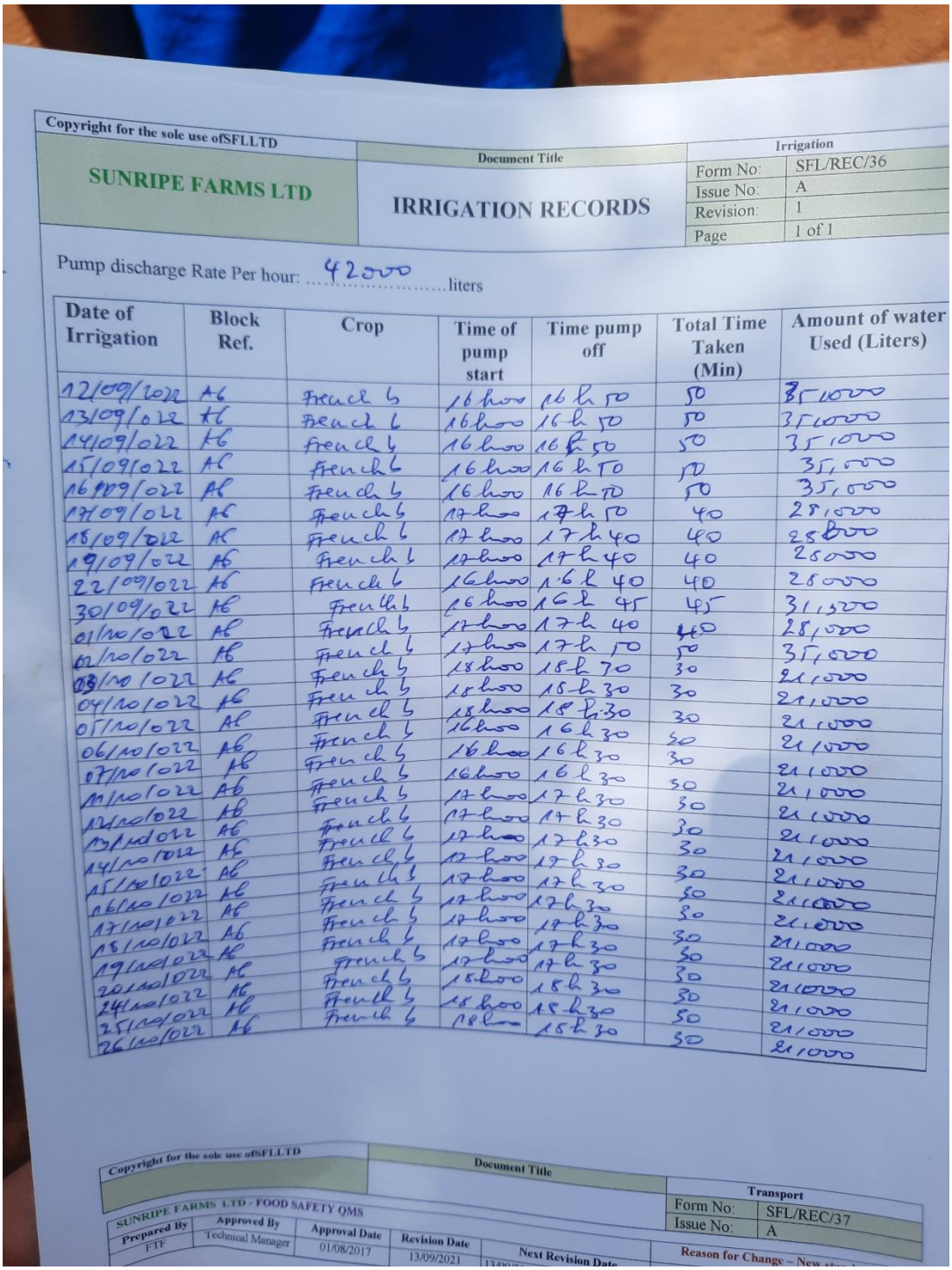
Based on the performance of the sosia trial, it seems that we use too much water with our current practices.

What are some recommendations you would have for the SOSIA tool?

Include clearer information about field capacity in the beginning of the crop. Include easy information about what to do when it rains.

1. Pictures taken at sunripe

Newly constructed water reservoir Sunripe 09/11/2022



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SUNRIPE FARMS LTD	Document Title: IRRIGATION RECORDS	Irrigation
		Form No: SFL/REC/36
		Issue No: A
		Revision: 1
		Page 1 of 1

Pump discharge Rate Per hour: 42000 liters

Date of Irrigation	Block Ref.	Crop	Time of pump start	Time pump off	Total Time Taken (Min)	Amount of water Used (Liters)
12/09/2022	A6	French b	16 hrs	16 h 50	50	35,0000
13/09/022	A6	French b	16 hrs	16 h 50	50	35,0000
14/09/022	A6	French b	16 hrs	16 h 50	50	35,0000
15/09/022	A6	French b	16 hrs	16 h 50	50	35,000
16/09/022	A6	French b	16 hrs	16 h 50	50	35,000
17/09/022	A6	French b	17 hrs	17 h 50	40	28,0000
18/09/022	A6	French b	17 hrs	17 h 40	40	28,000
19/09/022	A6	French b	17 hrs	17 h 40	40	28000
22/09/022	A6	French b	16 hrs	16 h 40	40	28000
30/09/022	A6	French b	16 hrs	16 h 45	45	31,500
01/10/022	A6	French b	17 hrs	17 h 40	40	28,000
02/10/022	A6	French b	17 hrs	17 h 50	50	35,0000
03/10/022	A6	French b	18 hrs	18 h 70	30	21,000
04/10/022	A6	French b	18 hrs	18 h 30	30	21,000
05/10/022	A6	French b	18 hrs	18 h 30	30	21,000
06/10/022	A6	French b	16 hrs	16 h 30	30	21,000
07/10/022	A6	French b	16 hrs	16 h 30	30	21,000
11/10/022	A6	French b	16 hrs	16 h 30	30	21,000
12/10/022	A6	French b	17 hrs	17 h 30	30	21,000
13/10/022	A6	French b	17 hrs	17 h 30	30	21,000
14/10/022	A6	French b	17 hrs	17 h 30	30	21,000
15/10/022	A6	French b	17 hrs	17 h 30	30	21,000
16/10/022	A6	French b	17 hrs	17 h 30	30	21,000
17/10/022	A6	French b	17 hrs	17 h 30	30	21,000
18/10/022	A6	French b	17 hrs	17 h 30	30	21,000
19/10/022	A6	French b	17 hrs	17 h 30	30	21,000
20/10/022	A6	French b	18 hrs	18 h 30	30	21,000
24/10/022	A6	French b	18 hrs	18 h 30	30	21,000
25/10/022	A6	French b	18 hrs	18 h 30	30	21,000
26/10/022	A6	French b	18 hrs	18 h 30	30	21,000

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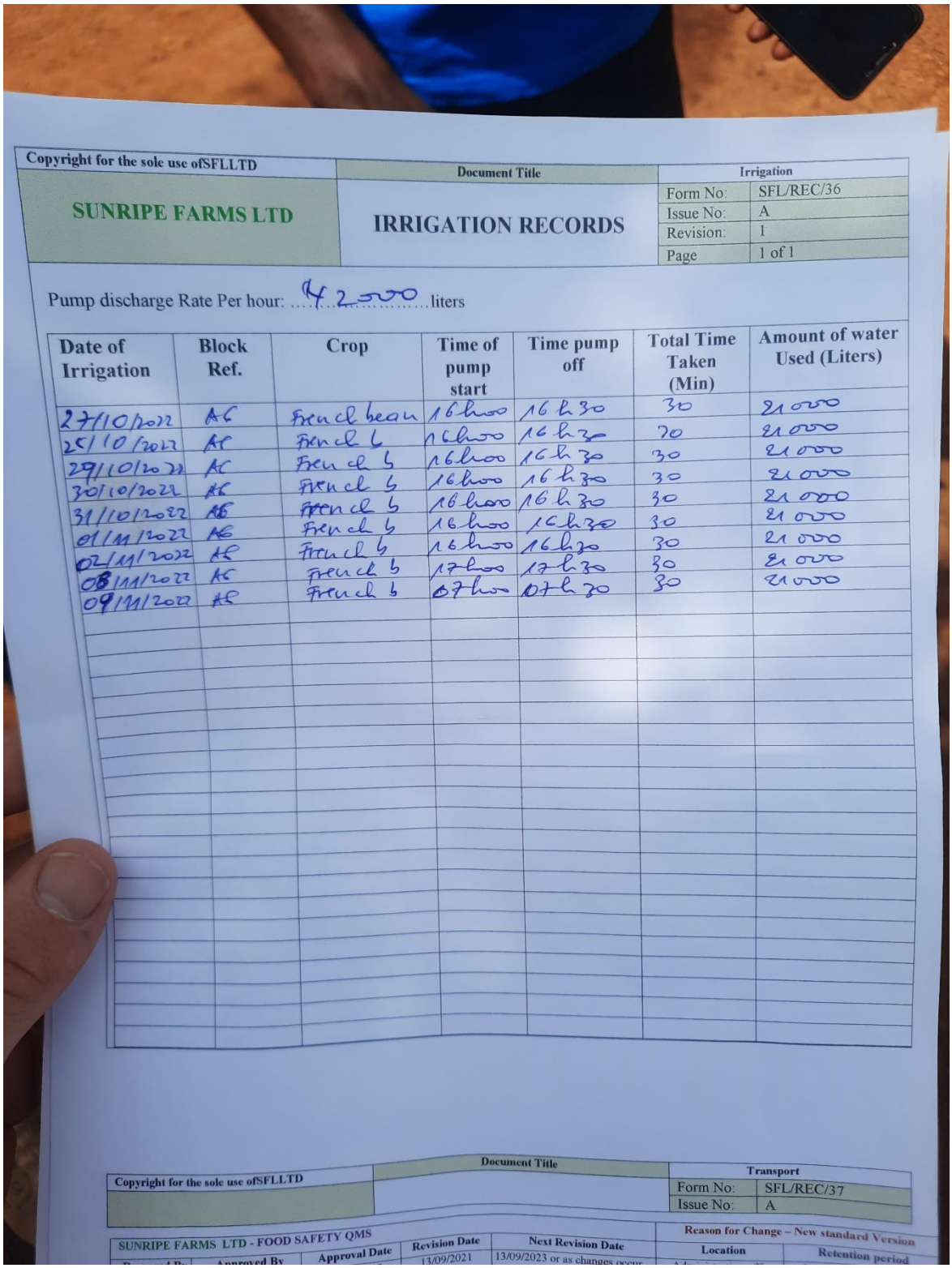
SUNRIPE FARMS LTD - FOOD SAFETY QMS	Document Title	Transport
		Form No: SFL/REC/37
		Issue No: A

Prepared By	Approved By	Approval Date	Revision Date	Next Revision Date	Reason for Change – New
FTF	Technical Manager	01/08/2017	13/09/2021		

Record of normal irrigation method – control field



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SUNRIPE FARMS LTD

Document Title: IRRIGATION RECORDS

Irrigation

Form No:	SFL/REC/36
Issue No:	A
Revision:	1
Page	1 of 1

Pump discharge Rate Per hour: 42000 liters

Date of Irrigation	Block Ref.	Crop	Time of pump start	Time pump off	Total Time Taken (Min)	Amount of water Used (Liters)
27/10/2022	AC	French bean	16h00	16h30	30	21000
25/10/2022	AC	French b	16h00	16h30	30	21000
29/10/2022	AC	French b	16h00	16h30	30	21000
30/10/2022	AC	French b	16h00	16h30	30	21000
31/10/2022	AC	French b	16h00	16h30	30	21000
01/11/2022	AC	French b	16h00	16h30	30	21000
02/11/2022	AC	French b	16h00	16h30	30	21000
08/11/2022	AC	French b	17h00	17h30	30	21000
09/11/2022	AC	French b	07h00	07h30	30	21000

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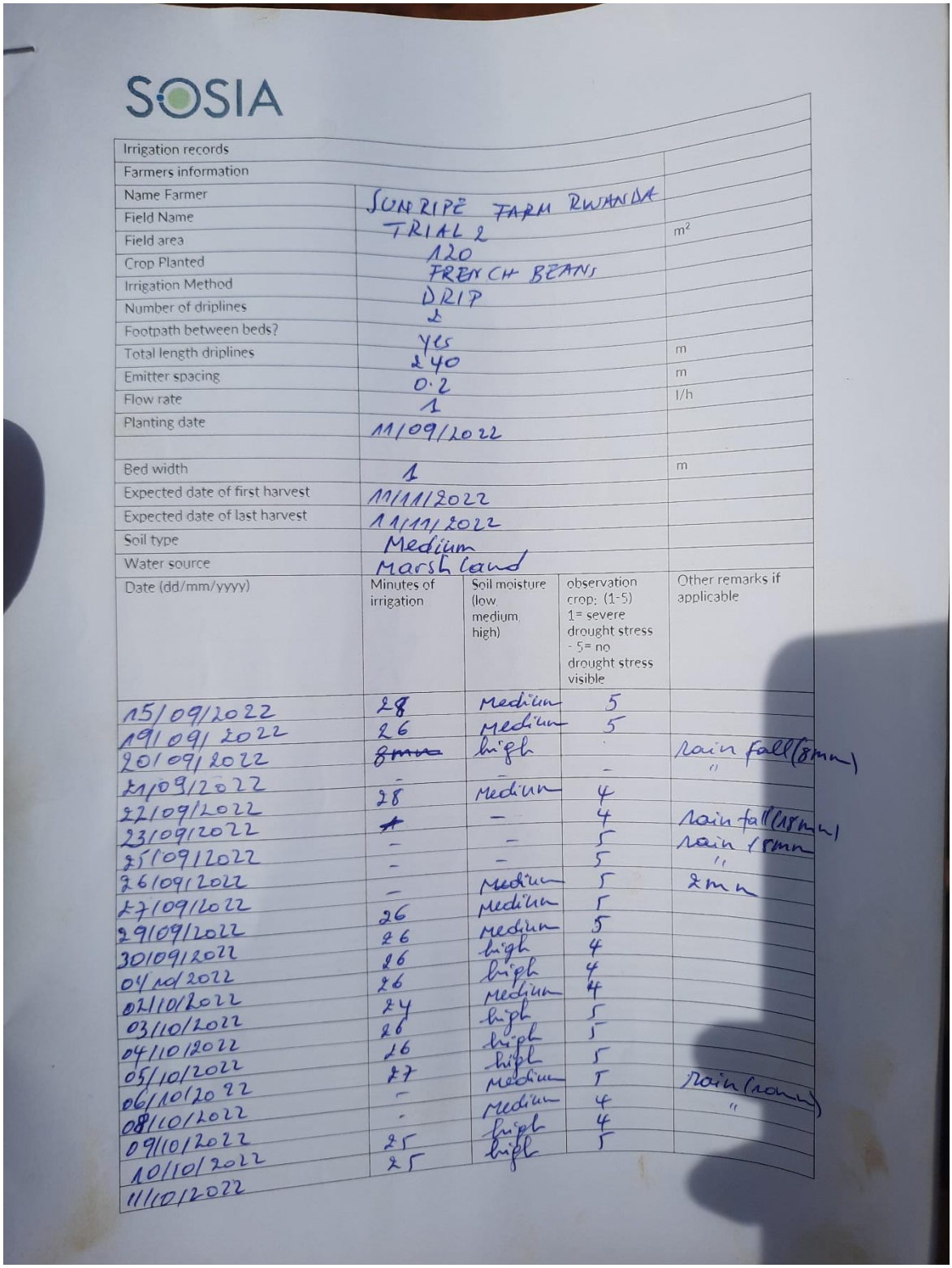
Document Title

Transport

Form No:	SFL/REC/37
Issue No:	A

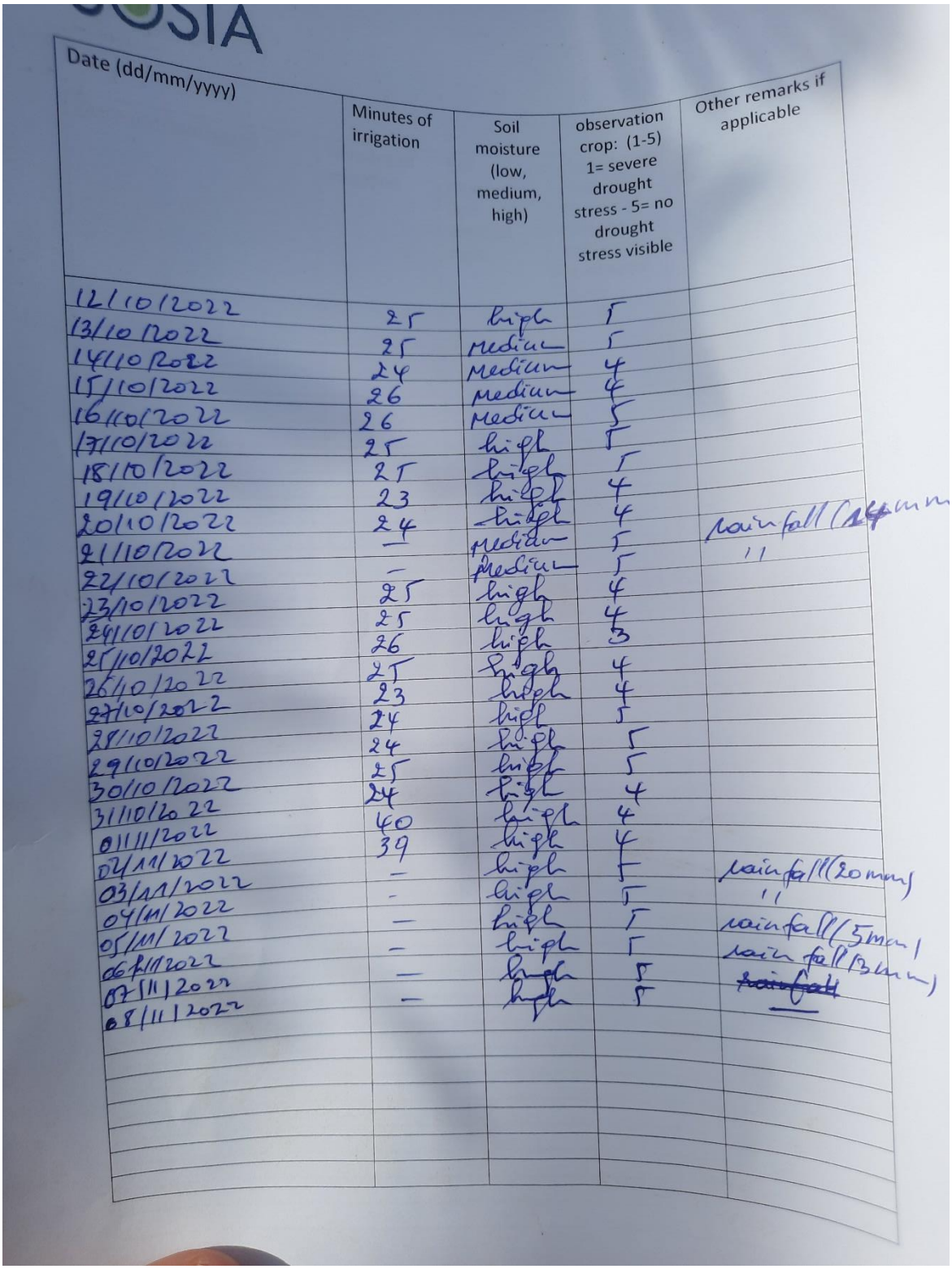
SUNRIPE FARMS LTD - FOOD SAFETY QMS				Reason for Change – New standard Version	
Approved By	Approval Date	Revision Date	Next Revision Date	Location	Retention period
		13/09/2021	13/09/2023 or as changes occur		



SOSIA

Irrigation records				
Farmers information				
Name Farmer	SUNRIPE FARM RWANDA			
Field Name	TRIAL 2			m²
Field area	120			
Crop Planted	FRENCH BEANS			
Irrigation Method	DRIP			
Number of driplines	5			
Footpath between beds?	YES			
Total length driplines	240			m
Emitter spacing	0.2			m
Flow rate	1			l/h
Planting date	11/09/2022			
Bed width	1			m
Expected date of first harvest	11/11/2022			
Expected date of last harvest	11/11/2022			
Soil type	Medium			
Water source	Marshland			
Date (dd/mm/yyyy)	Minutes of irrigation	Soil moisture (low, medium, high)	observation crop: (1-5) 1= severe drought stress - 5= no drought stress visible	Other remarks if applicable
15/09/2022	28	Medium	5	
19/09/2022	26	Medium	5	
20/09/2022	~~8mm~~	high	-	Rain fall(8mm)
21/09/2022	-	-	-	"
22/09/2022	28	Medium	4	
23/09/2022	-	-	4	Rain fall(18mm)
25/09/2022	-	-	5	Rain (8mm
26/09/2022	-	Medium	5	"
27/09/2022	26	Medium	5	2mm
29/09/2022	26	Medium	5	
30/09/2022	26	high	4	
04/10/2022	26	high	4	
02/10/2022	24	Medium	4	
03/10/2022	26	high	5	
04/10/2022	26	high	5	
05/10/2022	27	high	5	
06/10/2022	-	Medium	5	Rain (20mm)
08/10/2022	-	Medium	4	"
09/10/2022	25	high	4	
10/10/2022	25	high	5	
11/10/2022				

Irrigation records of Sosia trial plot.

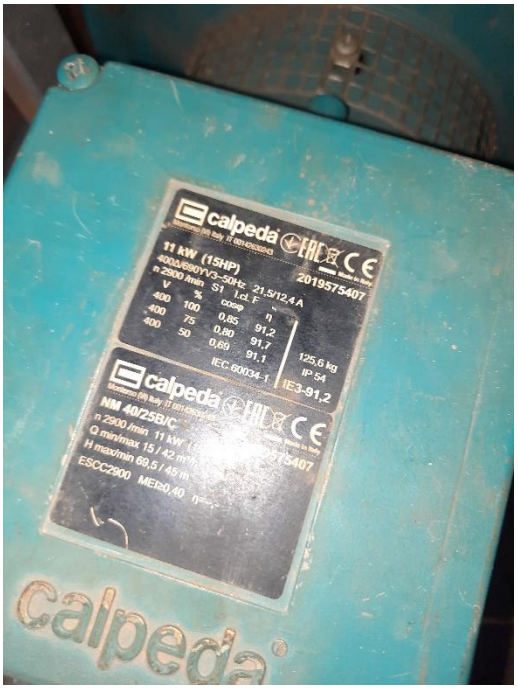


Date (dd/mm/yyyy)	Minutes of irrigation	Soil moisture (low, medium, high)	observation crop: (1-5) 1= severe drought stress - 5= no drought stress visible	Other remarks if applicable
12/10/2022	25	high	5	
13/10/2022	25	Medium	5	
14/10/2022	24	Medium	4	
15/10/2022	26	Medium	4	
16/10/2022	26	Medium	5	
17/10/2022	25	high	5	
18/10/2022	25	high	5	
19/10/2022	23	high	4	
20/10/2022	24	high	4	rainfall (14 mm
21/10/2022	—	Medium	5	11
22/10/2022	—	Medium	5	
23/10/2022	25	high	4	
24/10/2022	25	high	4	
25/10/2022	26	high	3	
26/10/2022	25	high	4	
27/10/2022	23	high	4	
28/10/2022	24	high	5	
29/10/2022	24	high	5	
30/10/2022	25	high	5	
31/10/2022	24	high	4	
01/11/2022	40	high	4	
02/11/2022	39	high	4	
03/11/2022	—	high	5	rainfall (20 mm)
04/11/2022	-	high	5	11
05/11/2022	—	high	5	rainfall (5mm)
06/11/2022	—	high	5	rain fall (3 mm)
07/11/2022	—	high	5	~~rainfall~~
08/11/2022	—	high	5	—

Team visit of trial field 09/11/2022.

Holland Greentech Extension officer inspecting SOSIA trial bed at Sunripe farm 09/11/2022.

Newly made beds at Sunripe farms 09/11/2022



Pump characteristics of electric pump directly connected to drip irrigated fields at Sunripe farms

Farmer interview sosia phase 2 mid-term evaluation trials

Date of interview: **10/11/2022** Location: **East Rwanda**

- Name farmer± **Bill Kayonga- farm managers: Francis Emmanuel**
- Gender: male / :
  _____
- Age:
  _____
  ____
- Phone number:
  _____
- Location farmer:
  _____
- Size farm
  - Coordinates:
    _____
  - Total size farm:
    _____
  - Size of fields where farmer is growing crops:
    _____
  - Size of fields that use irrigation:
    _____
- Crops
  - Crop type/variety: Bird-eye chillies
  - Intercropping:_____
    _____
  - Planting date:
    _____
  - Plant spacing :
    _____
- Soil:
  - Soil type:
    _____
  - Any soil test done?
    _____
- Description of farm
  - How many casual workers?_____
  - Description of water source
    - River / dam / borehole / furrow / stream
    - Water availability (include seasonal differences if they exist):_____
  - Description of current irrigation system
    - Water source used:
      _____
    - Dam liner/water tank size:
      _____

- Pump info: _____
- Height tank (if they use a tank) / dam liner (in meter): _____
- Distance tank to fields: _____
- Include photos of several system (components)
- Type of drip line (need to be HGT sourced):_____
  - Brand: _____
  - Emitter spacing: _____
  - Emitter flow rate: _____

- Date when trial started:_____
- Expected end date trial (when crop is harvested): _____

Interview question form for farmers Sosia-2

The interview questions below form the basis of a semi-structured interview. Some of the interview questions are the start of an interactive conversation with the interviewee. It is for the interviewer to ask supplementary questions to get the most realistic and complete insight.

Baseline questions suggestions

The goal of this part of the questionnaire is to hear from the farmers themselves to understand the weight of the problem that you are trying to solve.

How did you irrigate before getting the SOSIA advice?

We have just started using the drip lines. Before we had them, we used the watering hose and some sprinklers. We are learning how to use the drip lines.

What do you think is the challenge you face during the irrigation?

The drip lines are a new technology to us. We still have to get experience in for example how long to irrigate and how to plant the seedlings next to the drip lines.

Experience SOSIA advice

Establish first that we are doing the research and trying to improve the product for your benefit. The farmers can help to improve the product by giving critical feedback.

How did you use the SOSIA irrigation advice?

I had the advice printed and every day I read how many minutes to irrigate. I used the phone to keep track of the time. After irrigating I would record the findings on the printed (record keeping)

form. When it would have rained, I call Gilbert (Holland Greentech) to inform him how much it had rained., Gilbert would than advise how to adjust the irrigation schedule. It often rained but for example 5 mm on a day.

How useful was the irrigation advice?
It was useful to me because I didn't know how long to irrigate with this (drip) technology.

How is the irrigation advise different from your normal way of irrigation?
The normal (control) field was irrigated normally 1 hour per day unless there was rainfall. When there was rainfall it was shorter. We did not keep records of the exact timing.

How do you think the SOSIA-irrigation advice is better for your crop? tell us in what way it helped you with the challenges that you mentioned earlier.
The crop looks good under the SOSIA irrigation schedule. I would not be able to say yet if it is better or the same as the normal crop. We have been using the SOSIA advise for about 1 month now so have not yet had the flowering and fruiting.

What was the impact on water usage after using the advice? how significant was that?

- ☐ More water compared with my normal way of irrigation
- X Less water compared with my normal way of irrigation

If you are also considering fuel savings, ask if the farmers saw savings in fuel consumption for the irrigation?
We are using a diesel pump to pump from the reservoir into the drip lines. This cost a lot of money. It is a challenge to buy enough fuel for the pump. With the irrigation advise I have to pump much less!

What did you like the most about the irrigation advice?
The column with the minutes to irrigate per day is easy to follow.

What did you not like about the irrigation advice?
Can´t think of anything.

It is possible that you could not follow the advice all the time for different reasons. What were such moments where you could not follow the irrigation advice, and why?
Only when it was raining, but Holland Greentech guided me how to adjust the irrigation minutes.

If you missed single/ multiple SOSIA advice, how did you compensate in case you skipped a day?
N/A

<u>Communication, Information Delivery and Design</u>

How did you use the PDF/ Image to follow the Irrigation Advice?
Printed a version and used that every day to check how long to irrigate.

How is it for you to read through the irrigation advice in the file (PDF)
For me, I only used the printed version. This paper was easy to understand for me.

What did you like about the information presented in the PDF?
It was just fine.

What did you not like about the information presented in the PDF?
I did not use all the information. Just the column with the minutes.

How was it for you to keep records of your irrigation (filling out the irrigation record forms provided)?
It was not a challenge for me since the form was provided to me.

Do you think it is useful to measure the time how long you irrigate?

X yes, why is this useful?
☐ no, why is this not useful?

Explanation:_____
_____

After this SOSIA experience, would you keep holding irrigation records?

X yes, why?
☐ no, why ?

Explanation: I would do it when I would also have the SOSIA advise to check and be able to learn and show Holland Greentech how long we irrigated so they can advise.

How often would you like to receive updates concerning irrigation timing? (based on new/updated weather info?

☐ Every day
☐ Every week
☐ When significant changes occur in the advice based on weather
☐ Never
X Other: *As long as it is good for the crop. I don't have this preference*.

To know the influence of rain on your irrigation schedule, measuring with a meter is most accurate. Would you be able to measure and record the rainfall at a daily /weekly basis?
Explanation: For this trial we have been measuring the rain on a daily basis. This did not give me any challenges.

Would you be able to account for rainfall yourself, using a field meter? For example, subtracting rainfall on a daily basis from the crop water requirements as indicated by the SOSIA advice.

X Yes
☐ No

<u>Commercial viability</u>

What should be added in the Sosia advice for you to use it for the other crops in the future? Would you like to use it for other crops?

X yes, why?
□ no, why ?

Explanation: We would like to try it also for the other crops. We just planted onion and we would like to follow the SOSIA advise for this crop.

Do you expect that the SOSIA advice will save you money? (in terms of e.g. less pumping / better yield?)

X yes, why?
□ no, why ?

Explanation: We are starting to lean the drip irrigation now. So if we keep the record, we can use this to lean and to show to Holland Greentech what we did. This can help to improve next time. So far it seems that the advice shows a shorter irrigation time than what we would guess based on the weather.

If answered yes at question 12: Estimate the amount (RWF) you estimate you would safe
Amount:_____?_____ RWF
Explanation: we do not keep track of the exact fuel costs per field. I think we can save 15% fuel approximately.

How much would you be willing to pay for the service?
I don't know.

Impact

Did the SOSIA project impact your livelihood? ☐ Yes x No
How (not)? This was still a trial so not much impact besides more knowledge. If we can apply the advice on all the crops, we would save a lot of fuel and money maybe.

What are your main learnings/benefits from the project? Explain.
That it is possible to irrigate with not much water

What are some recommendations you would have for the SOSIA tool?
In this season it was also raining. So I don't know how much the rain contributed to the growth.

Rain meter made of water bottle for SOSIA calibration/evaluation.

Screen filter assembly for drip irrigation system

Mixed cropping of macadamia and vegetables

Trial beds SOSIA 10-11-2022

Farmer interview sosia phase 2 mid-term evaluation trials

Date of interview: **10/11/2022** Location: **East Rwanda**

- Name farmer **Nyirimihogo**
- Gender: male
- Age:
  _____
  ____
- Phone number:
  _____
- Location farmer:
  _____
- Size farm
  - Coordinates:
    _____
  - Total size farm:
    _____
  - Size of fields where farmer is growing crops:
    _____
  - Size of fields that use irrigation:
    _____
- Crops
  - Crop type/variety: **tomato**
  - Intercropping:_____
    _____
  - Planting date:
    _____
  - Plant spacing :
    _____
- Soil:
  - Soil type:
    _____
  - Any soil test done?
    _____
- Description of farm
  - How many casual workers?_____
  - Description of water source
    - River / dam / borehole / furrow / stream
    - Water availability (include seasonal differences if they exist):_____
  - Description of current irrigation system
    - Water source used:
      _____
    - Dam liner/water tank size:
      _____

- Pump info:
  _____
- Height tank (if they use a tank) / dam liner (in meter):
  _____
- Distance tank to fields:
  _____
- Include photos of several system (components)
- Type of drip line (need to be HGT sourced):_____
  - Brand:
    _____
    __
  - Emitter spacing:
    _____
  - Emitter flow rate:
    _____

- Date when trial started:_____
- Expected end date trial (when crop is harvested):
  _____

Interview question form for farmers Sosia-2

The interview questions below form the basis of a semi-structured interview. Some of the interview questions are the start of an interactive conversation with the interviewee. It is for the interviewer to ask supplementary questions to get the most realistic and complete insight.

Baseline questions suggestions

The goal of this part of the questionnaire is to hear from the farmers themselves to understand the weight of the problem that you are trying to solve.

How did you irrigate before getting the SOSIA advice?
One hour per day is our normal way. We only reduce when it rains.

What do you think is the challenge you face during the irrigation?
NA

Experience SOSIA advice
Establish first that we are doing the research and trying to improve the product for your benefit. The farmers can help to improve the product by giving critical feedback.

How did you use the SOSIA irrigation advice?
The crop was 1 month old when we started using the advice. So the first 1 month, we used our normal irrigation timing. Afterwards, we have been following the advice given by Gilbert (Holland Greentech)

How useful was the irrigation advice?
The daily irrigation time was useful and easy.

How is the irrigation advise different from your normal way of irrigation?
Normally we irrigate 1 hour, the SOSIA guideline is much easier to follow

How do you think the SOSIA-irrigation advice is better for your crop? tell us in what way it helped you with the challenges that you mentioned earlier.
In this crop we had many problems (both sosia bed as control field). We had a bacterial wilt and problems because of heavy rain showers. The crop therefore did not perform well. This was not due to irrigation.

What was the impact on water usage after using the advice? how significant was that?

- ☐ More water compared with my normal way of irrigation
- X Less water compared with my normal way of irrigation

If you are also considering fuel savings, ask if the farmers saw savings in fuel consumption for the irrigation?
We use solar, so no fuel saving.

What did you like the most about the irrigation advice?
Saving irrigation time.

What did you not like about the irrigation advice?
The advice was good.

It is possible that you could not follow the advice all the time for different reasons. What were such moments where you could not follow the irrigation advice, and why?
Sometimes there is not enough sun here and the solar pump is not pumping enough water to irrigate enough.

If you missed single/ multiple SOSIA advice, how did you compensate in case you skipped a day?
During the trial we always had enough water to follow the advise.

Communication, Information Delivery and Design

How did you use the PDF/ Image to follow the Irrigation Advice?
I had a printed version that I used every day.

How is it for you to read through the irrigation advice in the file (PDF)
It is very easy to read after explanations of Holland Greentech.

What did you like about the information presented in the PDF?
It gave information for the whole season.

What did you not like about the information presented in the PDF?

Nothing

How was it for you to keep records of your irrigation (filling out the irrigation record forms provided)?
It was not hard., managed to fill in everything.

Do you think it is useful to measure the time how long you irrigate?

X yes, why is this useful?
□ no, why is this not useful?

Explanation: So I could explain to HGT how long I irrigated and they could tell me what to do.

After this SOSIA experience, would you keep holding irrigation records?

X yes, why?
□ no, why ?

Explanation: I like to have the information of the crop, fertilizers, chemicals, varieties, planting dates so I can assess the performance and talk to agronomists to be able to advise me.

How often would you like to receive updates concerning irrigation timing? (based on new/updated weather info?

□ Every day
□ Every week
□ When significant changes occur in the advice based on weather
□ Never
X *Other Any moment, as long as it is useful for me.*

To know the influence of rain on your irrigation schedule, measuring with a meter is most accurate. Would you be able to measure and record the rainfall at a daily /weekly basis?
Explanation: It is not a problem to measure rainfall for me, a rain meter was given to me.

Would you be able to account for rainfall yourself, using a field meter? For example, subtracting rainfall on a daily basis from the crop water requirements as indicated by the SOSIA advice.

X Yes
□ No

Explain: We can measure and record the rain on a daily basis. But we would not know how to change the irrigation scheduling based on the measurement. Holland Greentech is helping with this now.

<u>Commercial viability</u>

What should be added in the Sosia advice for you to use it for the other crops in the future? Would you like to use it for other crops?

X yes, why?
□ no, why ?

Explanation: Holland Greentech agronomist advise us with every step what to do. When to plant what, crop rotation, variety, fertilizer and irrigation.

Do you expect that the SOSIA advice will save you money? (in terms of e.g. less pumping / better yield?)

☐ yes, why?

X no, why ?

Explanation we are using a solar pump so water is free. Only sometimes there is not enough water for all the field so in that case the tool might prevent some drought stress.

Impact

Did the SOSIA project impact your livelihood? ☐ Yes x No

How (not)? This was a small trial but maybe it can help to achieve a better crop and I can make more money from the field.

What are your main learnings/benefits from the project? Explain.

It is a very clear guidance. I am more motivated to follow this advice. With my normal way, I am not very precise because I don't know what is good. Maybe I want to irrigate for 1 hour, but I only close the valve after 1 hour and 20 minutes for example. With the SOSIA it gives me the exact number of minutes so I want to also follow this precisely.

What are some recommendations you would have for the SOSIA tool?

I don't know.

The already harvested beds of the sosia trial

Collapsing crop due to heavy rains and pests induced by the rains.

Weeded fields, ready for planting

Valve assembly for 2 irrigation zones plus civil works

Annex 15 – Surveys Phase 2, end-term
Zambia (31-Jan-23 – 04-Feb-23)

Mrs. CHRISTINE – CHIMOKO SEEDLINGS – 31/01/2023

Interview question form for farmers Sosia-2

The interview questions below form the basis of a semi-structured interview. Some of the interview questions are the start of an interactive conversation with the interviewee. It is for the interviewer to ask supplementary questions to get the most realistic and complete insight.

Baseline questions suggestions

The goal of this part of the questionnaire is to hear from the farmers themselves to understand the weight of the problem that you are trying to solve.

How did you irrigate before getting the SOSIA advice?
Guessing the irrigation time, up to three hours a day

What do you think is the challenge you face during the irrigation?
That you don't know exactly how much to irrigate. Also, it takes a lot of time and water and electricity cost a lot of money. Sometimes there are days without power.

Explain more about the challenges and try to quantify them (for example, how much additional water, and fuel they burn, and how big is the problem for them)

Experience SOSIA advice

Establish first that we are doing the research and trying to improve the product for your benefit. The farmers can help to improve the product by giving critical feedback.

How did you use the SOSIA irrigation advice?
Mme. Christine used the seasonal advice. She received the pdf with the daily irrigation minutes for the whole season.

How useful was the irrigation advice?
Mme. Christine found the advice to be very useful. She was able to plant an additional field of crops, because she could calculate beforehand how long and how much to irrigate, so she knew she had enough time and water. Furthermore, she saved a lot of money because she used less water and electricity. Also she was excited about the time she saved; max. 1 hour instead of up to 3 hours.

How is the irrigation advise different from your normal way of irrigation?
It takes less time and the normal way is more guesswork.

How do you think the SOSIA-irrigation advice is better for your crop? tell us in what way it helped you with the challenges that you mentioned earlier.
The crops performed the same as without the SOSIA advice, while saving money and time and being able to plant more.

What was the impact on water usage after using the advice? how significant was that?

- ○ More water compared with my normal way of irrigation
- ● Less water compared with my normal way of irrigation

If you are also considering fuel savings, ask if the farmers saw savings in fuel consumption for the irrigation?

Also less fuel was used

What did you like the most about the irrigation advice?

Mostly the time saved.

What did you not like about the irrigation advice?

Nothing was mentioned but it was asked

It is possible that you could not follow the advice all the time for different reasons. What were such moments where you could not follow the irrigation advice, and why?

Advice was always followed instead when it rained

If you missed single/ multiple SOSIA advice, how did you compensate in case you skipped a day?

NA

Communication, Information Delivery and Design

How did you use the PDF/ Image to follow the Irrigation Advice?

With the daily seasonal irrigation minutes that was sent before planting

How is it for you to read through the irrigation advice in the file (PDF)

It was clear

What did you like about the information presented in the PDF?

Simple to use.

What did you not like about the information presented in the PDF?

Nothing, but in the next season she'll let us know if she has critique.

How was it for you to keep records of your irrigation (filling out the irrigation record forms provided)?

NA

Do you think it is useful to measure the time how long you irrigate?

- ○ yes, why is this useful?
- ○ no, why is this not useful?

Explanation:_____
_____

After this SOSIA experience, would you keep holding irrigation records?

○ yes, why?
○ no, why ?

Explanation:_____
_____

How often would you like to receive updates concerning irrigation timing? (based on new/updated weather info?

○ Every day
○ Every week
● *When significant changes occur in the advice based on weather*
○ Never
○ Other_____

To know the influence of rain on your irrigation schedule, measuring with a meter is most accurate. Would you be able to measure and record the rainfall at a daily /weekly basis?
Explanation: yes

Would you be able to account for rainfall yourself, using a field meter? For example, subtracting rainfall on a daily basis from the crop water requirements as indicated by the SOSIA advice.

● **Yes**
□ No

Commercial viability

What should be added in the Sosia advice for you to use it for the other crops in the future? Would you like to use it for other crops?

● yes, why?
○ no, why ?

Explanation: because it worked for the lettuce, so would be nice to also use it for the other crops (sweet pepper, watermelon, cabbage)

Do you expect that the SOSIA advice will save you money? (in terms of e.g. less pumping / better yield?)

● yes, why?
○ no, why ?

Explanation: less pumping and more yield (able to plant another field)

If answered yes at question 12: Estimate the amount (RWF) you estimate you would save
Amount: ? RWF

Explanation: save half of the water, but used it for another field

Would you recommend the SOSIA advice to other farmers, friends, colleagues? With 1 indicating "not at all" and 10 "Yes, I will definitely recommend"

□ 1
□ 2
□ 3
□ 4

- □ 5
- □ 6
- □ 7
- □ 8
- □ 9
- □ *10*

She didn't give an exact number but she would definitely recommend the tool to other people. "you do not keep nice things to yourself."

Based on first estimate, the advice will cost 150 kwacha per crop per season per farmer. Do you think this cost is a good value?

- □ Not at all
- □ Neutral
- □ Somewhat
- ● Very much so

How much would you be willing to pay for the service? _____ RWF per crop per season

She didn't think 150 kwacha was that much, so definitely more

<u>Impact</u>

Did the SOSIA project impact your livelihood? ● **Yes** ○ **No**

How (not)? ***Water, time, fuel, money***

What are your main learnings/benefits from the project? Explain.

Not that much irrigation is needed

What are some recommendations you would have for the SOSIA tool?

She didn't have any

Farm visit to Mrs Christine and her son at Chimoko Seedlings Farm (31/01/2023).

Current cabbage crop under irrigation of SOSIA at Chimoko Seedlings Farm (31/01/2023).

Mrs Wood – 01/02/2023

Interview question form for farmers Sosia-2

The interview questions below form the basis of a semi-structured interview. Some of the interview questions are the start of an interactive conversation with the interviewee. It is for the interviewer to ask supplementary questions to get the most realistic and complete insight.

Baseline questions suggestions

The goal of this part of the questionnaire is to hear from the farmers themselves to understand the weight of the problem that you are trying to solve.

How did you irrigate before getting the SOSIA advice?
Guessing the irrigation time, up to 3.5 hours a day.

What do you think is the challenge you face during the irrigation?
Not knowing how much to irrigate.

Explain more about the challenges and try to quantify them (for example, how much additional water, and fuel they burn, and how big is the problem for them)
Challenges mostly about not knowing how much to irrigate. Water availability is not a problem; boreholes are never dry. (they are dry in chalala, so there are places in Zambia where water availability is a problem).

Experience SOSIA advice

Establish first that we are doing the research and trying to improve the product for your benefit. The farmers can help to improve the product by giving critical feedback.

How did you use the SOSIA irrigation advice?
Mrs Wood used the seasonal advice. She received the pdf with the daily irrigation minutes for the whole season. Furthermore, they used the sosia advice for the whole field of eggplants.

How useful was the irrigation advice?
They found the advice useful as they saved water and time, and the crop did not show signs of drought.

How is the irrigation advice different from your normal way of irrigation?
It takes less time, and the normal way is more guesswork. They feel like they saved water; they irrigated 40 min in the morning and 40 min in the evening. Sometimes they increased it to 50 is they felt it was hot (because "you farm with your eyes")

How do you think the SOSIA-irrigation advice is better for your crop? tell us in what way it helped you with the challenges that you mentioned earlier.
Water savings and motivates knowing how long to irrigate.

What was the impact on water usage after using the advice? how significant was that?

- More water compared with my normal way of irrigation
- *Less water compared with my normal way of irrigation*

If you are also considering fuel savings, ask if the farmers saw savings in fuel consumption for the irrigation?
They use electricity so electricity was saved.

What did you like the most about the irrigation advice?
Mostly the water saved, and time saved

What did you not like about the irrigation advice?
NA.

It is possible that you could not follow the advice all the time for different reasons. What were such moments where you could not follow the irrigation advice, and why?
Advice was always followed instead when it rained or when they felt it was hot and they irrigated for a little longer.

If you missed single/ multiple SOSIA advice, how did you compensate in case you skipped a day?
NA

Communication, Information Delivery and Design

How did you use the PDF/ Image to follow the Irrigation Advice?
With the daily seasonal irrigation minutes that was sent before planting

How is it for you to read through the irrigation advice in the file (PDF)
It was clear and easy to use.

What did you like about the information presented in the PDF?
Simple to use

What did you not like about the information presented in the PDF?
NA

How was it for you to keep records of your irrigation (filling out the irrigation record forms provided)?
Easy

Do you think it is useful to measure the time how long you irrigate?

- ○ yes, why is this useful?
- ○ no, why is this not useful?

Explanation: -

After this SOSIA experience, would you keep holding irrigation records?

- x yes, why?
- ○ no, why ?

Explanation: yes, as keeping irrigation records was easy with the rain gauge. Furthermore, they kept records and filled them out in the morning; so the rainfall recorded is the rainfall of the day before.

How often would you like to receive updates concerning irrigation timing? (based on new/updated weather info?

- ○ Every day
- ○ Every week
- ● When significant changes occur in the advice based on weather
- ○ Never
- ○ Other_____

To know the influence of rain on your irrigation schedule, measuring with a meter is most accurate. Would you be able to measure and record the rainfall at a daily /weekly basis?
Explanation: yes

Would you be able to account for rainfall yourself, using a field meter? For example, subtracting rainfall on a daily basis from the crop water requirements as indicated by the SOSIA advice.

- X **Yes**
- □ No

Explain:

Commercial viability

What should be added in the Sosia advice for you to use it for the other crops in the future? Would you like to use it for other crops?

- ● yes, why?
- ○ no, why ?

Explanation: it worked for the eggplants so she would also like to use it for cabbage, cucumber, green beans

Do you expect that the SOSIA advice will save you money? (in terms of e.g. less pumping / better yield?)

- ● yes, why?
- ○ no, why ?

Explanation: less pumping and more time available for other fields

Would you recommend the SOSIA advice to other farmers, friends, colleagues? With 1 indicating "not at all" and 10 "Yes, I will definitely recommend"

- □ 1
- □ 2
- □ 3
- □ 4
- □ 5
- □ 6
- □ 7
- □ 8
- □ 9
- □ 10

She would recommend it to other farmers

Based on first estimate, the advice will cost 150 kwacha per crop per season per farmer. Do you think this cost is a good value?

- ☐ Not at all
- ☐ Neutral
- ☐ Somewhat
- *Very much so*

How much would you be willing to pay for the service? _____ RWF per crop per season
150 kwacha is a good price

Impact

Did the SOSIA project impact your livelihood? ● **Yes** ○ **No**
How (not)? Water, time, fuel, money → especially water

What are your main learnings/benefits from the project? Explain.
Not much irrigation is needed compared to what Mrs wood irrigated before

What are some recommendations you would have for the SOSIA tool?
She didn't have any

Young farmers (prisoners) at work on the Impwa (African Eggplant) field of Mrs Wood. The crop was currently irrigated according the SOSIA advice (01/02/2023).

Mrs Wood discussing her field trials of Impwa with the developer (centre). Mary (left) is the main irrigation officer at HGT Zambia who distributes and communicates with the farmers using SOSIA.

Tutorial on the cucumber field of Mrs Wood on how to best prepare your beds for a new growing season (01/02/2023).

Mr and Mrs Phiri – 02/02/2023

Interview question form for farmers Sosia-2

The interview questions below form the basis of a semi-structured interview. Some of the interview questions are the start of an interactive conversation with the interviewee. It is for the interviewer to ask supplementary questions to get the most realistic and complete insight.

Baseline questions suggestions

The goal of this part of the questionnaire is to hear from the farmers themselves to understand the weight of the problem that you are trying to solve.

How did you irrigate before getting the SOSIA advice?
Guessing the irrigation time, up to an hour, 1.5 hours a day

What do you think is the challenge you face during the irrigation?
Water is critical! Now they don't know how much to irrigate exactly and water and electricity costs money.

Explain more about the challenges and try to quantify them (for example, how much additional water, and fuel they burn, and how big is the problem for them)
In the neighbourhood of the Phiri's, close to Kafue, there are not a lot of water shortages. Sometimes the electricity doesn't work, but they also have a solar pump. Problems they face are mostly that they don't know how to irrigate exactly and would like to save water costs. Furthermore, the weather conditions are sometimes very harsh (temperature high, rainfall extreme).

Experience SOSIA advice

Establish first that we are doing the research and trying to improve the product for your benefit. The farmers can help to improve the product by giving critical feedback.

How did you use the SOSIA irrigation advice?
Mr and Mrs Phiri used the seasonal advice. They received the pdf with the daily irrigation minutes for the whole season.

How useful was the irrigation advice?
They found the advice useful, though the pdf with the irrigation minutes was unclear and Mr. Phiri didn't receive proper instructions. After he received the instructions, he understood it and used the irrigation advice every day.

How is the irrigation advise different from your normal way of irrigation?
It takes less time, and the normal way is more guesswork. They feel like they saved water.

How do you think the SOSIA-irrigation advice is better for your crop? tell us in what way it helped you with the challenges that you mentioned earlier.
Water is critical, so they feel like they can save money by using the application

What was the impact on water usage after using the advice? how significant was that?

- More water compared with my normal way of irrigation
- Less water compared with my normal way of irrigation

If you are also considering fuel savings, ask if the farmers saw savings in fuel consumption for the irrigation?
They have a solar pump and electricity, but electricity was probably saved.

What did you like the most about the irrigation advice?
Mostly the water saved and the electricity costs.

What did you not like about the irrigation advice?
Due to harsh weather conditions, their crop failed so they are not completely convinced yet.

It is possible that you could not follow the advice all the time for different reasons. What were such moments where you could not follow the irrigation advice, and why?
Advice was always followed instead when it rained

If you missed single/ multiple SOSIA advice, how did you compensate in case you skipped a day?
NA

Communication, Information Delivery and Design

How did you use the PDF/ Image to follow the Irrigation Advice?
With the daily seasonal irrigation minutes that was sent before planting

How is it for you to read through the irrigation advice in the file (PDF)
It was clear after explanation of the holland Greentech irrigation engineer. The help however came a little bit late.

What did you like about the information presented in the PDF?
Simple to use when understood

What did you not like about the information presented in the PDF?
Unable to understand without explanation. Also the second update sent was confusing.

How was it for you to keep records of your irrigation (filling out the irrigation record forms provided)?
Easy to upkeep

Do you think it is useful to measure the time how long you irrigate?
- ○ yes, why is this useful?
- ○ no, why is this not useful?

Explanation: -

After this SOSIA experience, would you keep holding irrigation records?
- ○ yes, why?
- ○ no, why ?

Explanation: yes, because its easy

How often would you like to receive updates concerning irrigation timing? (based on new/updated weather info?

- ○ Every day
- ○ Every week
- ● When significant changes occur in the advice based on weather
- ○ Never
- ○ Other

Explanation: Not too often, as it is quite confusing to have too much different schedules at the same time. Also the preferred way of receiving information is through WhatsApp, as most farmers have this

To know the influence of rain on your irrigation schedule, measuring with a meter is most accurate. Would you be able to measure and record the rainfall at a daily /weekly basis?
Explanation: yes

Would you be able to account for rainfall yourself, using a field meter? For example, subtracting rainfall on a daily basis from the crop water requirements as indicated by the SOSIA advice.

- □ Yes
- □ No

Explain: We haven't asked but when we explained it, they seemed to be able to

Commercial viability

What should be added in the Sosia advice for you to use it for the other crops in the future? Would you like to use it for other crops?

- ● yes, why?
- ○ no, why ?

Explanation: because it saved water. It must be said that the crop failed due to extreme weather conditions (too hot for onions) and they need to test is more to get more feeling. Other crops: chili, cabbage.

Do you expect that the SOSIA advice will save you money? (in terms of e.g. less pumping / better yield?)

- ● yes, why?
- ○ no, why ?

Explanation: less pumping, so electricity bill is lower

Would you recommend the SOSIA advice to other farmers, friends, colleagues? With 1 indicating "not at all" and 10 "Yes, I will definitely recommend"

- □ 1
- □ 2
- □ 3
- □ 4
- □ 5
- □ 6
- □ 7
- □ 8

- □ 9
- □ 10

they didn't give an exact number but they would recommend the tool to other people if they see more what the benefits are (using it for another field)

Based on first estimate, the advice will cost 150 kwacha per crop per season per farmer. Do you think this cost is a good value?

- □ Not at all
- □ Neutral
- □ Somewhat
- yes

150 kwacha is a good price. Mr Phiri would like it better if a lump sum could be paid to use it for a whole year for unlimited crops.

Impact

Did the SOSIA project impact your livelihood? ● **Yes** ○ **No**

How (not)? Water, time, electricity, money

What are your main learnings/benefits from the project? Explain.

That not that much irrigation is needed for the crops

What are some recommendations you would have for the SOSIA tool?

Delivery of advisory service; trial; WhatsApp message minutes. WhatsApp is preferred channel. Weekly is ideal. WhatsApp is the best; most people have it. Every morning? No. Also lumped sum instead of price per crop per growing season.

Currently, Mrs. and Mr. Phiri grow various Habanero peppers with the SOSIA advice (02/01/2023).

Discussion on the SOSIA trial with Mrs and Mr Phiri who used the advice on their onion crop (02/01/2023).

Annex 16 – Surveys Extension Officers – 06-Nov-23

Questions for Extension officers

Desirability

Questions regarding their challenges of helping farmers with irrigation advice

Before irrigation design in general, we only used climate data, and requesting this data in our country is not easy. You have to write a letter to MoE and they forward to Meteo Rwanda, takes about 5 months. They need quick information for their clientele. Also the data they can provide is limited. But also, they do not have all the data required for their work. Also there are regions for which data is missing. 1990 – 2000 there is no data available. They want to make a sustainable design. Since SOSIA is here, more efficient and faster method of providing advice as well as designing fields.

W.r.t. the farmer, when the farmers don't have the realistic data, there is too much guessing. There is no thrust in the current information available.

How does this tool help you to be better at your job? How significantly the tool is helping you?

SOSIA will be very beneficial. Those data will be in the surrounding areas, and it will affect the region of these farms. We are sure that the information provided to the farmer is good for the farmer, they are more confident in this data even without validation.

What should be improved to make the tool better for them?

- Database
- Faster

Usability

Understand how easy it is for them to use the tool and what challenges they face from technical and user experience perspectives.

Serafin: I was just looking at the list of input. Type of soil would be nice as an input, using a georeferenced dataset. SoilGrids 250m could be added as an output?
Bram elaborates that soil type is not part of the calculation. But it might be good for the understanding of the extension officer.
Serafin: Add information bullets with definitions.

How would you incorporate the hindcast in the irrigation advice?
Serafin : Farmer is only interested in how much to irrigate and how long. And how much it will cost? Maybe add a cost of pumping in the advice, to further convince them of the economic benefits.
Bram: calculate the historical growing season and determine seasonal pumping costs based on SOSIA. Not to be part of the tool.

On hindcasting, Serafin: Give advice after 2 days. After one week they could lose high production. After 2/3 days, they can't lose much produce. So ideally even more than once a week an update.
Bram: Will require a lot of time, how can you facilitate this.
Serafin: How long can we wait with updating the farmers.
Bram: Relates the question to the buffering capacity of the soil. Stage of crop has big impact.

Gilbert: The frequency should be based on when the plant shows indications of water stress. Lets first start with one week, and we can make it more frequent if we see indications of drought.

Serafin: Gilbert gave previous recommendations to farmers.

Gilbert: How do we account for mulching, if you apply it, you gain better efficiency. SOSIA assumes an efficiency of 90% in the system.

Bram: in the tool we use one efficiency 90%.

Brecht: Do farmers maintain their infrastructure?

Serafin: Gilbert yes. Its s a big investment. They keep it nice.

Serafin and gilbert talk about the importance of this trial in the dry season. From January up to February it will be somewhat hot and it will give us a better indication of the usefulness of the SOSIA Tool.

Would you like to see the historical ETref in the hindcasted table output? Are there other recommendations?

Gilbert: if possible, include the shortage in minutes in a table for a daily advice. Also likes if it is fully updated.

Would you like to keep the graphs in the output or what output is most relevant for you?

Serafin finds the combination of both better.
Gilbert: for scientists it is maybe needed but not for my day-to-day use.
Serafin: Option in app to select for table or graphs output.

Are there any columns missing or abundant in both the historical and hindcasted output?

Guiding questions:

- Try to have the extension worker use the tool in front of you without any help from your team.
- Interview them about where they usually get stuck and why?
- Which components of the app are most useful ?

  - ☐ Historic Advice
  - ☐ Historical Advice – Rainfall
  - ☐ Projected Advice
  - ☐ Projected Advice – Rainfall
  - ☐ A combination of Historic and Updates based on projected?

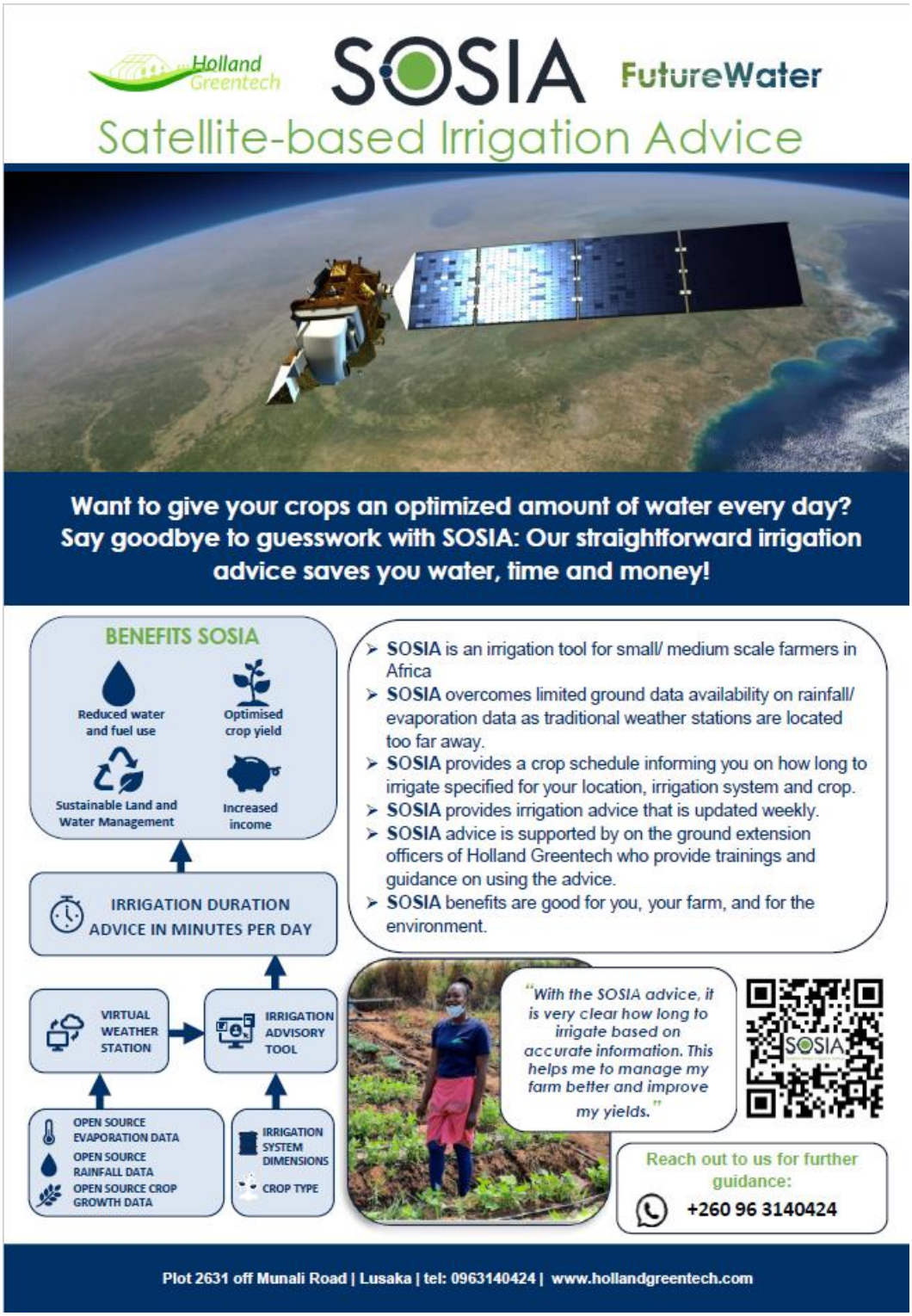
Rate the impact on your production and income for each service component (check the box):

Impact	None	Minor	Moderate	Significant	Major
Historical Advice					
Historical Advice – Rainfall					
Forecast Advice					
Forecast Advice - Rainfall					
Training on the use of SOSIA					

Extension officer- Farmer journey – On the field

- Understand how they interact with the farmers to give advice. What are the touch points between both and what kind of information is being shared on each touch point and with what channels (WhatsApp, meeting, etc?
- Check what touchpoints are crucial and how can you help to improve those
- Understand what are the components of the full advice (SOSIA advice could be one of the component).

Annex 17 - Flyer Launch Event



Annex 18 – Logbook Farmers Template + Digitized Logbooks of Trial Farmers.

SOSIA

Satellite-based Irrigation Advice

Irrigation records				
Farmers information				
Name Farmer				
Field Name				
Field area				m^2
Crop Planted				
Irrigation Method				
Number of driplines				
Footpath between beds?				
Total length driplines				m
Emitter spacing				m
Flow rate				l/h
Planting date				
Bed width				m
Expected date of first harvest				
Expected date of last harvest				
Soil type				
Water source				
Date (dd/mm/yyyy)	Minutes of irrigation	Soil moisture (low, medium, high)	observation crop: (1-5) 1= severe drought stress - 5= no drought stress visible	Other remarks if applicable

SOSIA
Satellite-based Irrigation Advice

Date (dd/mm/yyyy)	Minutes of irrigation	Soil moisture (low, medium, high)	observation crop: (1-5) 1= severe drought stress - 5= no drought stress visible	Other remarks if applicable

SOSIA
Satellite-based Irrigation Advice

Date (dd/mm/yyyy)	Minutes of irrigation	Soil moisture (low, medium, high)	observation crop: (1-5) 1= severe drought stress - 5= no drought stress visible	Other remarks if applicable

SOSIA
Satellite-based Irrigation Advice

Date (dd/mm/yyyy)	Minutes of irrigation	Soil moisture (low, medium, high)	observation crop: (1-5) 1= severe drought stress - 5= no drought stress visible	Other remarks if applicable

SOSIA
Satellite-based Irrigation Advice

Instructions on filling out irrigation records

- Date: Every time you irrigate, fill out the date in the following form: dd/mm/yyyy for example: 30 august 2022. 30/08/2022. Filling out the year in only the first entry is fine. We will know which year it in the records after.

- Minutes of irrigation: In this column, you indicate the exact number of minutes between the start of irrigation until closing the valve or switching off the pump. For this trial you have to follow the number of minutes from the SOSIA advice.

- Soil moisture: In this column you fill in the soil moisture level after the irrigation turn. You estimate the soil level by 1) visible observation 2) feel with your hand on 10 cm depth. Indicate if the soil moisture is low, medium or high

  Low: visible: soil looks dry from the top soil and when digging 10 cm with your hand, soil feels dry till a little bit wet.
  Medium: Soil has a wet strip along the drip line of 7-15 cm wide. When digging 10 cm the soil feels cool and moist. When squeezing in the soil, no water/mud is being squeezed in between your fingers but one feels the moisture in between the soil particles
  High: visible: soil is completely wet along the drip line and wets the bed to a width of approx. 15-20 cms on both sides. When digging 10 cm deep, the soil is at field capacity and when squeezing soil in the palm of your hand, water and mud starts to drip in between your fingers.

- Observation crop: Sometimes one can observe drought stress when observing the plant. Particularly the leaves can give a good indication. The turgor of the plant is low when the plant does not have access to sufficient water, this can cause stems to start bending downwards and leaves to start curling.

  Score 1: the plant looks very stressed – stems are bend a lot and look weak. When touching the stem, one observes that it has lost most of its strength. Leaves are very curled and the tip of the leaves is facing towards the ground. Other possible observations: a lot of flower abortions, leaves are smaller than usual, flowers are many but tiny. Colour of leaves is pale
  Score 2: The plant is stressed like with the description of score 1, only the stems still have quite a bit of strength. Colour of leaves is pale
  Score 3: the plant's stem look moderately strong but the leaves are curled and point downwards, the plant looks stunted. Colour of leaves is in between pale and green.
  Score 4: The stems of the plant have a good vigour and only some of the leaves are slightly curled but are in a more horizontal direction, the points of the leaves are not all in the direction of the ground but point in different directions. The crop is performing well and looks healthy. Colour is green.
  Score 5: no indications of drought stress. Leaves and stems look healthy and the colour of the leaves is ' healthy green'.

Irrigation record					
Farmer informaion	HGTZambia_Tomato_20922				
Name Farmer	HGT				
Field Name	Hgt demo				
Field area	7.2		m2		
Crop planed	mashadu (tomato trial)				
Irrigation method	drip				
Number of driplines	1				
Total length driplines	12		m		
Emiter spacing	0.2		m		
Flow rate	1		l/h		
Planing date	20/09/2022				
Bed width	0.6		m		
Expected date of firs harvest	10/12/2022				
Expected date of last harvest	06/04/2023				
Soil type	sandy loam				
Water source	tank				

Date(dd/mm/yyyy)	minutes of irrgation	soil moisture status) (low,medium,high)	observation crop:(1-5); 1=severe drought stress vs 5=no drought stress visible	other remarks if applicable	Rain (mm/day)
21/09/2022	0	low	5	20l no water manual irrigation	
22/09/2022	53	medium	5		
23/09/2022	0	low	5		
24/09/2022	0	low	5	20l no water manual irrigation	
25/09/2022	52	medium	5		
26/09/2022	52	medium	5		
27/09/2022	0	low	5		
28/09/2022	62	medium	5	20l no water manual irrigation	
29/09/2022	61	medium	5		
30/09/2022	0	low	5	30l no water manual irrigation	
01/10/2022	0	low	4	30l no water manual irrigation	
02/10/2022	0	low	4	30l no water manual irrigation	

03/10/2022	0	low	4	30l no water manual irrigation	
04/10/2022	0	low	4	30l no water manual irrigation	
05/10/2022	0	low	4	30l no water manual irrigation	
06/10/2022	0	low	4	30l no water manual irrigation	
07/10/2022	0	low	4	10l no water manual irrigation	
08/10/2022	0	low	4	10l no water manual irrigation	
09/10/2022	0	low	4	10l no water manual irrigation	
10/10/2022	0	low	4	10l no water manual irrigation	
11/10/2022	0	low	4	40l no water manual irrigation	
12/10/2022	0	low	4	30l no water manual irrigation	
13/10/2022	0	low	4	30l no water manual irrigation	
14/10/2022	0	low	4		
15/10/2022	0	low	4		
16/10/2022	61	medium	4		
17/10/2022	63	medium	4		
18/10/2022	65	medium	4		
19/10/2022	65	medium	4		
20/10/2022	55	medium	4		
21/10/2022	0	low	5	30l no water manual irrigation	
22/10/2022	55	medium	5		
23/10/2022	53	medium	5		
24/10/2022	30	medium	5	cut in H20 supply	
25/10/2022	0	low	5	20l no water manual irrigation	
26/10/2022	57	medium	5		
27/10/2022	0	low	5		
28/10/2022	0	low	5		
29/10/2022	57	medium	5		
30/10/2022	0	high	5	raining	
31/10/2022	0	high	5	raining	
01/11/2022	0	high	5	raining	
02/11/2022	0	high	5	raining	
03/11/2022	0	high	5	raining	
04/11/2022	0	high	5	raining	

05/11/2022	0	high	5	raining	
06/11/2022	0	high	5	raining	
07/11/2022	0	high	5	raining	
08/11/2022	0	high	5	raining	
09/11/2022	0	high	5	raining	
10/11/2022	0	high	5	raining	
11/11/2022	0	high	5	raining	
12/11/2022	0	high	5	raining	
13/11/2022	0	high	5	raining	
14/11/2022	0	high	5	raining	
15/11/2022	0	high	5	raining	
16/11/2022	0	high	5	raining	
17/11/2022	68	medium	5		
18/11/2022	0		5	no water	
19/11/2022	52	medium	5		
20/11/2022	0	medium	5	no water	
21/11/2022	60	high	5		
22/11/2022	52	high	5		
23/11/2022	53	high	5		
24/11/2022	0	medium	5	raining	
25/11/2022	70	medium	5		
26/11/2022	69	medium	5		
27/11/2022	69	medium	5		
28/11/2022	71	high	5		
29/11/2022	71	high	5		
30/11/2022	67	high	5		
01/12/2022	0	medium	4	raining	
02/12/2022	71	medium	4		
03/12/2022	70	medium	4		
04/12/2022	70	medium	4		
05/12/2022	70	medium	4		
06/12/2022	70	low	4		
07/12/2022	70	medium	4		

08/12/2022	0	medium	4	(1.5mm) raining	1.5
09/12/2022	0	medium	4	(6.5mm) raining	6.5
10/12/2022	67	medium	4		
11/12/2022	65	medium	4		
12/12/2022	0	medium	4		
13/12/2022	69	medium	3	the crop was attacked by leaf minor	
14/12/2022	67	medium	3		
15/12/2022	66	medium	3		
16/12/2022	0	medium	3		
17/12/2022	0	medium	3		
18/12/2022	0	high	3		
19/12/2022	0	medium	3	(8mm) raining	8
20/12/2022	0	high	3		18
21/12/2022	0	high	3	(1.2mm)raining	1.2
22/12/2022	0	high	3	(50mm)raining	50
23/12/2022	0	high	3	(9.3mm) raining	9.3
08/01/2023	0	high	3		
09/01/2023	0	high	3		
10/01/2023	0	high	3	(8mm)raining	8
11/01/2023	0	high	3		
12/01/2023	0	high	3	(57mm) raining	57
13/01/2023	0	high	3		
14/01/2023	0	high	3		
15/01/2023	0	high	3		
16/01/2023	0	high	3	(85mm)raining	85
17/01/2023	0	high	3		
18/01/2023	0	high	3	(8.5mm)raining	8.5
19/01/2023	0	high	3		
20/01/2023	0	high	3		
21/01/2023	0	high	3		
22/01/2023	0	high	3		

Nyirimihigo_Tomato_15822	SOSIA Advice (min)	Minutes of irrigation applies	Soil Moisture Status	Crop Observation	Rainfall (mm)	Other remarks
15/08/2022	29					
16/08/2022	28					
17/08/2022	29					
18/08/2022	29					
19/08/2022	30					
20/08/2022	28					
21/08/2022	29					
22/08/2022	29					
23/08/2022	29					
24/08/2022	30					
25/08/2022	28					
26/08/2022	29					
27/08/2022	29					
28/08/2022	29					
29/08/2022	28					
30/08/2022	28					
31/08/2022	27					
01/09/2022	27					
02/09/2022	27					
03/09/2022	27					
04/09/2022	28					
05/09/2022	27					
06/09/2022	27					
07/09/2022	27					
08/09/2022	27					
09/09/2022	28					
10/09/2022	26					
11/09/2022	28					
12/09/2022	27					started with the trial 13 sept.
13/09/2022	28	29 h			5	

14/09/2022	30	30	h	5			
15/09/2022	29	29	h	5			
16/09/2022	28	28	h	5			
17/09/2022	27	27	h	5			
18/09/2022	28	28	h	5			
19/09/2022	28	29	h	5			
20/09/2022	27	27	h	5			
21/09/2022	30	30	h	5			
22/09/2022	29	29	h	5			
23/09/2022	29	29	h	5			
24/09/2022	29	29	h	5			
25/09/2022	28	23	h	5			
26/09/2022	27	27	h	5			
27/09/2022	27	0	h	5		5	
28/09/2022	27	27	h	5			
29/09/2022	28	28	h	5			
30/09/2022	28	28	h	5			
01/10/2022	28	27	h	5			
02/10/2022	27	0	h	5		25	
03/10/2022	26	0	h	5			
04/10/2022	27	0	h	5		40	lots of rain, crop affected by bacterial wilt
05/10/2022	28	0	h	5	rain		Soil was moist
06/10/2022	28	0	h	5	rain		Soil was moist
07/10/2022	30	0	h	5		10	
08/10/2022	28	0	h	5	rain		Soil was moist
09/10/2022	28	0	h	5			
10/10/2022	27	27	h	5			
11/10/2022	27	27	h	5			
12/10/2022	27	27	h	5			
13/10/2022	28	28	h	5			
14/10/2022	26	26	h	5			
15/10/2022	28	28	h	5			
16/10/2022	27	27	h	5			

17/10/2022	27	0	h	5	15
18/10/2022	26	0	h	5	Soil was moist
19/10/2022	25	0	h	5	Soil was moist
20/10/2022	37	37	h	5	
21/10/2022	39	39	h	5	
22/10/2022	40	40	h	5	
23/10/2022	39	39	h	5	
24/10/2022	40	40	h	5	
25/10/2022	41	41	h	5	
26/10/2022	40	40	h	5	
27/10/2022	38	38	h	5	
28/10/2022	36	36	h	5	
29/10/2022	38	38	h	5	
30/10/2022	39	39	h	5	
31/10/2022	37	37	h	5	
01/11/2022	39	39	h	5	
02/11/2022	38	38	h	5	
03/11/2022	36	36	h	5	
04/11/2022	35	35	h	5	
05/11/2022	36	36	h	5	
06/11/2022	36	36	h	5	
07/11/2022	36	36	h	5	
08/11/2022	39	39	h		
09/11/2022	36	36	h		
10/11/2022	36	36	h		

Pridefarm_Lettuce_9922	SOSIA Advice (min)	Normal Practices (min)	Minutes of irrigation	Soil Moisture Status (L - M - H)	Crop Observation (1-5)	Rainfall	Other remarks
09/09/2022	24						
10/09/2022	23	30	23	H	5		
11/09/2022	24	30	24	H	5		
12/09/2022	24			H	5		
13/09/2022	24			H	5		
14/09/2022	26			H	55		
15/09/2022	25	30	25	H	5		
16/09/2022	24	30	24	H	5		
17/09/2022	24						
18/09/2022	24						
19/09/2022	24						
20/09/2022	23	30	23	H	5		Pressure variance
21/09/2022	26	30	26	H	5		Pressure variance
22/09/2022	25	30	25	H	5		Pressure variance
23/09/2022	25	30	25	H	5		Pressure variance
24/09/2022	25	30	25	H	5		Pressure variance
25/09/2022	24					5	
26/09/2022	24					5	
27/09/2022	23	30	23	H	5		
28/09/2022	24	30	24	H	5		
29/09/2022	24	30	24	H	5		
30/09/2022	24	30	24	H	5		
01/10/2022	24	30	24	H	5		
02/10/2022	24	30	24	M	3		
03/10/2022	23	30	23	H	5		
04/10/2022	23	30	23	H	5		
05/10/2022	24	30	24	H	5		
06/10/2022	25	30	25	H	5		
07/10/2022	25	30	25	H	5		

08/10/2022	25	30	25	H	5	
09/10/2022	24	30	24	H	5	
10/10/2022	23	30	23	H	5	
11/10/2022	23	30	23	H	5	
12/10/2022	23	30	23	H	5	
13/10/2022	24	30	24	H	5	
14/10/2022	22					
15/10/2022	24					
16/10/2022	24					
17/10/2022	23					
18/10/2022	23					
19/10/2022	21					
20/10/2022	22					
21/10/2022	23					
22/10/2022	23					Last harvest?
23/10/2022	23					
24/10/2022	23					
25/10/2022	24					
26/10/2022	23					
27/10/2022	22					
28/10/2022	22					
29/10/2022	23					
30/10/2022	28					
31/10/2022	28					
01/11/2022	28					
02/11/2022	28					
03/11/2022	26					
04/11/2022	26					
05/11/2022	26					
06/11/2022	27					
07/11/2022	27					
08/11/2022	28					
09/11/2022	27					

10/11/2022	27
11/11/2022	26
12/11/2022	28
13/11/2022	26
14/11/2022	27
15/11/2022	26
16/11/2022	25
17/11/2022	27
18/11/2022	25
19/11/2022	24
20/11/2022	25
21/11/2022	26
22/11/2022	26
23/11/2022	26
24/11/2022	
25/11/2022	
26/11/2022	
27/11/2022	
28/11/2022	
29/11/2022	
30/11/2022	
01/12/2022	
02/12/2022	
03/12/2022	
04/12/2022	
05/12/2022	

Sunripe_FrenchBean_11922	SOSIA Advice (min/day)	Minutes of irrigation	Soil Moisture Status (L - M - H)	Crop Observation (1-5)	Rainfall (mm/day)	Other remarks
10/09/2022						
11/09/2022	26					
12/09/2022	26					
13/09/2022	26					
14/09/2022	28					
15/09/2022	28	28	m	5		
16/09/2022	26					
17/09/2022	26					
18/09/2022	27					
19/09/2022	26	26	m	5		
20/09/2022	25	0	h		8	
21/09/2022	29	0			8	
22/09/2022	28	28	m	4		
23/09/2022	27			4	15	
24/09/2022	27					
25/09/2022	27			5	15	
26/09/2022	25			5		
27/09/2022	26		m	5	2	
28/09/2022	26					
29/09/2022	26	26	m	5		
30/09/2022	26	26	m	5		
01/10/2022	26	26	m	4		
02/10/2022	26	26	h	4		
03/10/2022	24	24	h	4		
04/10/2022	26	26	m	5		
05/10/2022	26	26	h	5		
06/10/2022	27	27	h	5		
07/10/2022	27					
08/10/2022	27	0	m	5	10	
09/10/2022	26	0	m	4	10	

10/10/2022	25	25	h	4		
11/10/2022	25	25	h	5		
12/10/2022	25	25	h	5		
13/10/2022	25	25	m	5		
14/10/2022	24	24	m	4		
15/10/2022	26	26	m	4		
16/10/2022	26	26	m	5		
17/10/2022	25	25	h	5		
18/10/2022	25	25	h	5		
19/10/2022	23	23	h	4		
20/10/2022	24	24	h	4		
21/10/2022	25	0	m	5	14	
22/10/2022	25	0	m	5	14	
23/10/2022	25	25	h	4		
24/10/2022	25	25	h	4		
25/10/2022	26	26	h	3		
26/10/2022	25	25	h	4		
27/10/2022	23	23	h	4		
28/10/2022	24	24	h	5		
29/10/2022	24	24	h	5		
30/10/2022	25	25	h	5		
31/10/2022	24	24	h	4		
01/11/2022	40	40	h	4		
02/11/2022	39	39	h	4		
03/11/2022	38	0	h	5	20	
04/11/2022	37	0	h	5	20	
05/11/2022	37	0	h	5	15	
06/11/2022	38	0	h	5	13	
07/11/2022	38	0	h	5		
08/11/2022	40	0	h	5		
09/11/2022	38	38	h	5		
10/11/2022	38	0	h	5	5	
11/11/2022	37					Last harvest

12/11/2022	40	0	h	5	22
13/11/2022	37				
14/11/2022	39				
15/11/2022	37	0	h	5	20
16/11/2022	36				
17/11/2022	39	0	h	5	15
18/11/2022	36				
19/11/2022	34				
20/11/2022	37				
21/11/2022	38	0	h	5	30
22/11/2022	38	0	h	5	18
23/11/2022	37				
24/11/2022	37				
25/11/2022	36				
26/11/2022	36				
27/11/2022	38	0			28
28/11/2022	38				
29/11/2022	36				
30/11/2022	35				
01/12/2022	31	0			10
02/12/2022	33	0			8
03/12/2022	34				
04/12/2022	32				
05/12/2022	34	0			17
06/12/2022	34				
07/12/2022	35	0			6
08/12/2022	33				
09/12/2022	34				
10/12/2022	34				
11/12/2022					
12/12/2022					
13/12/2022		0			10
14/12/2022		0			4

15/12/2022		
16/12/2022		
17/12/2022		
18/12/2022		
19/12/2022		
20/12/2022	0	12
21/12/2022	0	30+
22/12/2022	0	30+
23/12/2022		
24/12/2022		
25/12/2022		
26/12/2022	0	15
27/12/2022	0	20
28/12/2022	0	40
29/12/2022		
30/12/2022		
31/12/2022	0	10
01/01/2023		
02/01/2023		
03/01/2023		
04/01/2023		
05/01/2023	0	6

Bill_Chili_71022	Minutes of irrigation	Soil Moisture Status (L - M - H)	Crop Observation (1-5)	Rainfall (mm/day)	Other remarks
13/10/2022	50	H	5		To reach field capacity
14/10/2022	60	H			To reach field capacity
15/10/2022	20				
16/10/2022			5		
17/10/2022	36			10	
18/10/2022		H			
19/10/2022	31				
20/10/2022	18				
21/10/2022	17				
22/10/2022	17				
23/10/2022		H	5		
24/10/2022	34				
25/10/2022	18				
26/10/2022					
27/10/2022	33			35	
28/10/2022				7	
29/10/2022			5		
30/10/2022					
31/10/2022		H			
01/11/2022			5		
02/11/2022					
03/11/2022		H	5		
04/11/2022					
05/11/2022		H	5	10	
06/11/2022					
07/11/2022				12	
08/11/2022					
09/11/2022					
10/11/2022				8	
11/11/2022					

12/11/2022			
13/11/2022	H	5	
14/11/2022			
15/11/2022			5
16/11/2022			
17/11/2022	H	5	
18/11/2022			5
19/11/2022			10
20/11/2022			
21/11/2022	H	5	
22/11/2022			30
23/11/2022			
24/11/2022			
25/11/2022			
26/11/2022	H	5	
27/11/2022			
28/11/2022			
29/11/2022	H	5	
30/11/2022			
01/12/2022			10
02/12/2022			
03/12/2022			
04/12/2022	H	5	
05/12/2022			25
06/12/2022	H	5	
07/12/2022			10
08/12/2022			5
09/12/2022			5
10/12/2022			
11/12/2022			
12/12/2022			
13/12/2022			
14/12/2022			

15/12/2022			
16/12/2022			
17/12/2022			
18/12/2022			
19/12/2022			
20/12/2022			
21/12/2022			
22/12/2022			
23/12/2022			
24/12/2022			
25/12/2022			
26/12/2022			
27/12/2022			
28/12/2022			
29/12/2022			
30/12/2022			
31/12/2022			
01/01/2023			
02/01/2023			
03/01/2023			
04/01/2023			
05/01/2023			
06/01/2023			
07/01/2023			
08/01/2023			
09/01/2023			
10/01/2023			10
11/01/2023			
12/01/2023	H	5	1
13/01/2023			1
14/01/2023	H	5	
15/01/2023			
16/01/2023			1

17/01/2023	H	5
18/01/2023		

Wood_Impwa	Minutes of irrigation	Soil Moisture Status (L - M - H)	Crop Observation (1-5)	Rainfall (mm/day)	Other remarks
06/11/2022		H	5		Yellow leaves
07/11/2022		H	5		Yellow leaves
08/11/2022		H	5		Yellow leaves
09/11/2022		H	5		Yellow leaves
10/11/2022		H	5		
11/11/2022		H	5		
12/11/2022		H	5		
13/11/2022		M	5		
14/11/2022	80	M	5		
15/11/2022	80	M	5		
16/11/2022		M	5		
17/11/2022		M	5		Nice green leaves
18/11/2022	80	M	5		Nice green leaves
19/11/2022		M	5		Nice green leaves
20/11/2022		M	5		Nice green leaves
21/11/2022		M	5		Nice green leaves
22/11/2022		M	5		Nice green leaves
23/11/2022		H	5		
24/11/2022		H	5		
25/11/2022		H	5		
26/11/2022		M			
27/11/2022		M			
28/11/2022		M			
29/11/2022		M			
30/11/2022		M			
01/12/2022		M			
02/12/2022	100	M			
03/12/2022	100	M			Yellow leaves
04/12/2022	100	M			Yellow leaves

05/12/2022	100	M			Yellow leaves
06/12/2022	100	M			Yellow leaves
07/12/2022		M			Yellow leaves
08/12/2022		M			
09/12/2022	100	M			
10/12/2022		M			
11/12/2022		M			
12/12/2022		H	5		
13/12/2022	100				
14/12/2022	100				
15/12/2022	100				
16/12/2022		M			
17/12/2022		M		6	
18/12/2022		H		7.2	
19/12/2022		H		6.3	
20/12/2022		M		5.5	
21/12/2022		M		4.4	
22/12/2022	100	M		4.4	
23/12/2022		M			
24/12/2022		H	5	4	
25/12/2022		M	5		
26/12/2022		H	5	1	
27/12/2022		H	5	6	
28/12/2022		H	5	3	
29/12/2022		M	5	6	
30/12/2022		M	5		
31/12/2022		M	5		
01/01/2023		H	5	11	
02/01/2023			5	15	
03/01/2023			5	20	
04/01/2023		M	5	2	
05/01/2023		M	5	9	
06/01/2023		M	5		

07/01/2023	H	5	40
08/01/2023	H	5	30
09/01/2023	H	5	
10/01/2023	H	5	9
11/01/2023	H	5	6
12/01/2023	H	5	3
13/01/2023	H	5	2
14/01/2023	M	5	9
15/01/2023	M	5	12
16/01/2023	H	5	12
17/01/2023	M	5	3
18/01/2023	M	5	4
19/01/2023	M	5	3
20/01/2023	H	5	9
21/01/2023	H	5	10.1
22/01/2023	H	5	11
23/01/2023	H	5	12
24/01/2023	H	5	3
25/01/2023	H	5	6
26/01/2023		5	
27/01/2023	H	5	24
28/01/2023		5	16
29/01/2023		5	
30/01/2023		5	
31/01/2023		5	
01/02/2023	H	5	

Pyrus_Onion_22922	Minutes of irrigation	Soil Moisture Status (L - M - H)	Crop Observation (1-5)	Rainfall (mm/day)	Other remarks
04/11/2022	48	M	3		Crop stressed due to intesnive heat just after planitn seedling.
05/11/2022		H			
06/11/2022		H			
07/11/2022		H			
08/11/2022		H			Ground moist
09/11/2022					
10/11/2022		H			
11/11/2022		H			
12/11/2022		M			Ground moist
13/11/2022		H			
14/11/2022		H	3		Ground moist
15/11/2022		M	3		Ground moist
16/11/2022		M	3		Ground moist
17/11/2022		M	3		Ground moist
18/11/2022	58	M	3		Ground moist
19/11/2022	56				Very hot day
20/11/2022	52	L	3		Onion looking pale blue
21/11/2022	56	L	3		Onion looking pale blue
22/11/2022	53	M	3		
23/11/2022	52	L	3		Ground moist
24/11/2022	52	L	3		Extremely hot day
25/11/2022	52	L	3		Extremely hot day
26/11/2022	48	M	3		
27/11/2022	45	L	3		
28/11/2022	49	L	3		Extremely hot day
29/11/2022	50	L	3		Extremely hot day
30/11/2022	50	M	3		Extremely hot day
01/12/2022	54	M	3		
02/12/2022	55	L	3		
03/12/2022	56	L	3		

04/12/2022	55	L	3		
05/12/2022	49	L	3		
06/12/2022	50		3		
07/12/2022		H	3		
08/12/2022		H	3		
09/12/2022		L	3		
10/12/2022		L	3		Installed rain gauge
11/12/2022		L	3		
12/12/2022		L	3		Pump broken
13/12/2022		L	3	12	
14/12/2022		H	3		
15/12/2022		M	3	1	
16/12/2022		L	3		
17/12/2022		H	3	12	
18/12/2022		M	3		
19/12/2022		H	3		
20/12/2022		H	3	1	
21/12/2022		M	3	3	
22/12/2022		H	3	28	
23/12/2022		H	3	25	
24/12/2022		M	3		
25/12/2022		L	3		
26/12/2022		L	3		
27/12/2022		L	3		
28/12/2022		L	3	5	
29/12/2022		L	3		
30/12/2022		H	3	15	
31/12/2022		M	3		
01/01/2023		M	3		
02/01/2023		H	3	24	
03/01/2023		M	3		
04/01/2023		M	3	13	
05/01/2023		H	3		

06/01/2023	H	3	
07/01/2023	H	3	10
08/01/2023	H	3	68
09/01/2023	H	3	
10/01/2023	M	3	1
11/01/2023			
12/01/2023	M	3	
13/01/2023			
14/01/2023			8
15/01/2023			1
16/01/2023			1
17/01/2023	M	3	6
18/01/2023	H	3	
19/01/2023	H	3	10
20/01/2023	H	3	
21/01/2023	H	3	10
22/01/2023	H	3	20
23/01/2023	H		15
24/01/2023	H		54
25/01/2023	H		30
26/01/2023	H		
27/01/2023	H		
28/01/2023	M		
29/01/2023	M		
30/01/2023	M		
31/01/2023	M		5
01/02/2023	M		
02/02/2023	H		70
03/02/2023			
04/02/2023			
05/02/2023			
06/02/2023			
07/02/2023			