SOSIA
Satellite-based Irrigation Advice

Holland Greentech

FutureWater

Report Phase 1

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

REPORT 237

CLIENT **Netherlands Space Office**

AUTHORS **FutureWater**
Holland Greentech

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Authors
Brecht D'Haeyer – Project Leader/Hydrologist (b.dhaeyer@futurewater.nl)
Jonna van Opstal – Water Productivity Expert (j.vanopstal@futurewater.nl)
Lisa Verschuren – Hydrologist (l.verschuren@futurewater.nl)
Gijs Simons – Managing Director/Senior Hydrologist (g.simons@futurewater.nl)
Martijn de Klerk – Business Developer/Financial Manager (m.deklerk@futurewater.nl)
Bram de Vries – Irrigation Expert (bram@hollandgreentech.com)

Date
27 June 2022

Holland Greentech
FutureWater

ADDRESS
FutureWater B.V.
Costerweg 1V
6702 AA Wageningen
The Netherlands

TELEPHONE +31 317 460 050
WEBSITE www.futurewater.eu

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1 Feasibility Study

1.1 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 of a project which has evaluated the feasibility of SOSIA, a small-scale open source-based irrigation advisory service. This report describes activities, results and main learning points of the feasibility study and explains how SOSIA is expected to contribute 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. The tool consists of two main packages, the first focuses on Virtual Weather Stations (VWS) whereas the second focuses on the Irrigation Advisory Tool (IAT) which relies on the former and gives 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]. In Rwanda, agriculture is one of the key sectors of economic importance and contributes to 33% of the GDP. It provides employment for more than 70 percent of the national labour force. Although some Rwandese 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 aims 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, FutureWater (FW), in close consultation 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. It is foreseen that, ultimately, SOSIA will 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.

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

Chapter 1.1 of this report summarizes the main findings of Phase 1 of the project. Section 1.2 describes the individual consortium partners, as well as their synergies and role division. Section 1.3 presents the project organization and structure. Subsequently, Section 1.4 describes the project results regarding technological and economic feasibility, as well insights gained into the expected local impact of the SOSIA tools. Section 1.5 discusses the main learning questions answered during this innovation project, which were defined at the start of the feasibility stage. Ultimately, Section 1.6 shows how the originally foreseen Theory of Change (ToC) has ultimately been affected by the activities implemented in Phase 1.

1.2 Consortium Partners

1.2.1 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. 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.

1.2.2 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 11 country offices. HGT's core expertise relates to scaling and growing impact at thousands of farmers, based on the business case of the individual farmer. HGT delivered complete irrigation kits to hundreds of farmers in 2021 and expects to continue to grow strongly in their teams, customer base and service packages in 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.

1.2.3 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, 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 an effective irrigation advice (IAT), 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 as well as the HGT staff based in-country. 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 will, upon completion of project Phase 2, be shared with the sector through the media channels of both partners.

Towards Phase 2 and beyond, 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 the irrigation tool, it can be applied directly by the HGT team to existing customers and/or to design irrigation systems for new customers. As a result, a successful prototype can be scaled up relatively easily beyond Phase 2, both inside and outside Rwanda (Ghana, Uganda, Zambia, etc.).

1.3 Project Activities

In this section the work performed in each Work Package (WP) to develop the SOSIA tool is presented. For each work package, its main goals are described, followed by a detailed overview of activities to address these goals. WP5 concerned overall project management and is not separately described below.

1.3.1 WP 1: Establish technical demands

The main objective of WP1 was to identify stakeholders and users of SOSIA and their needs. During the first week of the project, a visit was made to Rwanda to meet with local intermediary HGT Rwanda. The intermediary consists of irrigation engineers, who provide irrigation advisory services (along with other services) to farmers in Rwanda (Figure 2). 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- medium scale commercial 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.

This visit aimed at establishing an initial idea of the customer persona (see Annex 1) to identify the customer base of HGT, who are the envisaged end users of the SOSIA tools. Furthermore, a survey was conducted to identify the end-users needs (Annex 2, Annex 3 and Annex 4). After online meetings with several extension officers from the intermediary and the HGT irrigation consultants, a survey was developed to address the following topics:

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

HGT selected several existing irrigation clients (10) to participate in the survey. Ultimately, 8 farmers were interviewed by the intermediary. The resulting data from the farmer survey and several meetings

with HGT staff resulted in a good initial insight of the needs of both Intermediary and the end-users. Together with the intermediary, key user requirements were determined for both the intermediary and the end-user (farmer) to further develop the SOSIA tools based on these survey results and meetings.

1.3.2 WP 2: Development of the Virtual Weather Station-methodology

The objective of WP2 was to establish the Virtual Weather Stations (VWS) using OS datasets, most of which are satellite-derived. The goal of the VWS approach was two-fold, 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, and
2) to provide the state-of-the-art regional weather input data to be used in the irrigation advisory tool that is developed within Work Package 3.

For developing the VWS approach, first a platform for the application had to be selected. Considering the pros and cons of various tools and packages available, Google Earth Engine[1] (GEE) was selected as the main platform. A main advantage is that GEE, being a cloud computing solution, does not require to have data stored and processed locally. This is especially expected to be advantageous during scale-up of the innovation (see Chapter 2). After selection of the platform, various datasets were analyzed to determine their individual and combined applicability for integration into an ensemble of VWS data, based on the scope of the service and user needs. In line with goal 1 of the VWS approach, the VWS data are not only incorporated in the IAT but also is available as a separate tool.

1.3.3 WP 3: Development of the Irrigation Advisory Tool

Making use of VWS data, the subsequent development activities regarding the SOSIA Irrigation Advisory Tool (IAT) were part of WP3. Ultimately, two main components are foreseen to be part of the IAT:

1. 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;
2. A Near-Future Crop Schedule, which uses Global Forecast System (GFS) data to compute ET_{ref} (through Penmann-Monteith equation) to calculate daily water volumes and irrigation duration for the next 5 days.

The first version of the IAT focuses on the Historic Crop Schedule. The IAT (version 1.0) was, similar to the VWS component, developed on the Google Earth Engine platform. In the GEE-based SOSIA portal, the user (irrigation engineer of HGT Rwanda) can generate crop schedules for each of the connected farmers for each of their specific crop types.

The IAT gives information on the water deficiency of specific crop types, the irrigation volumes needed per day and the irrigation duration per day. This information leads to a daily crop schedule for the season of the specific crop, based on historic evaporation data, derived from the embedded VWS application. The season is specified by the crop, which has specific durations for the early-, mid- and late planting stages (FAO56). The crops used in Phase 1 are Habanero Peppers, French Beans, Onions, and Lettuce. These crops were suggested by the intermediate, as most HGT clients plant these crops and they are foreseen to be part of the Phase 2 piloting. The underlying calculations of the IAT were operationalized under the WP3 activities. Below, a description is provided of the key computations that are performed in the back-end of the IAT, which were developed, coded and tested as part of WP3.

ET_{ref} was obtained from the FAO-WaPOR dataset, which is consistent with the VWS approach. The crop-specific Crop Factor (K_c) was derived from the FAO56 handbook for different plant stages. Based on K_c

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

and ET_{ref}, the daily 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 to feed into the IAT. 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 can be determined in two ways, which is dependent on whether a footpath between the beds is present. If these are absent, the area of the field is derived directly from what the irrigation engineer enters for the area (in m^2). When there is a footpath, the area of the field is calculated from the width of the bed, the number of driplines per bed and the total length of the dripline.

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

Furthermore, the irrigation duration is 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 needed to irrigate per day are calculated, which constitute a key location-specific output of the IAT.

1.3.4 WP 4: Project evaluation and Communication

The objective of WP4 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 innovations and the use and development of the tool for the irrigation engineers and end-users were evaluated.

A total of two visits were made, as discussed under WP1, an initial visit to identify the needs of both the intermediary as well as the end-users. This visit took place from March 22 – 25, 2022 during which various drip irrigation farmers as well as irrigation staff of HGT were consulted. The last 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.

After completion of the Irrigation Advice Tool (IAT, v1.0), the tool was evaluated by the intermediary. Secondly, an existing logbook of 1 farmer was checked for consistency with the IAT. Other irrigation and harvesting records that can be used to validate the tool, will be gathered this planting season and will be evaluated in the beginning of Phase 2. There are in total three fields where pilots have been launched.

Next to the validation, a workshop on how to use the tool was held with the irrigation engineers. Furthermore, the intermediary visited farmers to showcase the preliminary tool, to check how it impacted their initial understanding on ‘willingness-to-pay’ as further outlined in Section 1.4.3. After preliminary validation and testing of the tool by the intermediates and end-users, a few changes were applied, and the IAT (version 1.1) was relaunched.
The evaluation of the learning questions, as was continuously accounted for over the course of this first phase, has resulted in the first learnings regarding technical (mostly) and economic feasibility (1.4.2 and

1.4.3, respectively). As the tool has not yet been implemented, nor actively used by the end users, the economical as well as impact analysis are yet to be quantified.

1.4 Results

During the project, the Virtual Weather Station and Irrigation Advisory Tool components were developed based on input from both the intermediary and the end users. The results of Phase 1 are discussed below according three guiding principles that wee at the base of the project organization: impact, technological feasibility, and economic feasibility.

1.4.1 Impact

To assess the impact of SOSIA advisory tool, 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 1.3.1). These were initially constructed using the insights of the first field visit and were later improved based on the second field visit, 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 were held. As has become clear during this study, both users are expected to be impacted differently, since their initial needs are quite distinct.

For evaluation, the SOSIA tool was shared with the HGT Irrigation Team in Rwanda. As briefly touched upon above, the actual impact the tool has on crop yield is yet to be evaluated, afore it can be claimed. A short training was given and afterwards everyone was able to use it easily. The first version of the IAT 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 confirm this 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 the IAT that was evaluated is complete for the whole crop cycle, farmers can clearly see in the irrigation scheduling that the amount of water increases when the crop matures up until harvesting time. Currently, farmers rely on day-to day-estimates on how long to irrigate. They do 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 decides to irrigate either 30 minutes, 1 hour, 1,5 hours or 2 hours. This leads to sub-optimal growing conditions because the crop water requirements are not always met or over-irrigated. When farmers implement the SOSIA irrigation advise, their yields will be optimized and the right amount of (irrigation) water will be used, 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.

For a next step, farmers indicated that they would like to test the advice to monitor crop performance and tool-related potential fuel savings. As this only can be measured and validated by means of an in-field pilot; due to the mismatch of project duration with the growing seasons, these pilots have, although commenced, not yet been finalised. Pilot farmers were selected during the second field visit, and are 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. This hints at potential water spillage on field level. However, given the coarse level of detail provided in the logbook, field pilots are still considered to be the best method to evaluate the performance of the SOSIA tools which is planned for evaluation in phase 2.

The Business Case/Financial Impact from a Farmer's Perspective

In a preliminary comparison of the logbooks, the SOSIA service led to a decrease in water use for irrigation of about 50% for Rwandan French bean farmer Sunripe. This decrease in water use leads to an equal decrease in pumping requirement and thus fuel use and costs. In Rwanda, fuel costs about EUR 1.40 per liter and the average quantity of fuel used on a reference field in Nigeria[1] was found to be 360 liters per season per ha. When we assume the Rwandese farmers also use 360 liters per season per ha, the fuel costs for a farmer with a field of 0.5 ha will be EUR 250 per season. Using the SOSIA tool, the cost for pumping could be reduced by 50%, equivalent to EUR 125 per season. With the cost for the service, to be paid for by the farmer, just being a fraction of this (see 1.4.3) this would be well-worth the investment. Apart from this reduction in fuel 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.

After evaluation of the on-field impact of the SOSIA tools has been completed, the farmers will be more convinced of using this tool in their daily farm management, given the interest they have shown so far. If the field-data shows that the irrigation advice optimizes yield while reducing fuel usage, they expect that they will have a further interest in obtaining a location specific irrigation advice, which further strengthens the willingness to pay component.

Without the SOSIA-tool, the intermediary, like HGT is currently 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. The SOSIA tools offer them a valuable additional service to their existing offerings and equips their extension officers with an easy-to-use tool to provide complete irrigation advise 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 tools will make it possible for extension officers to guide the farmers in their irrigation practices both in a qualitative and quantitative way. Extension officers of HGT will use the SOSIA tools to provide high quality irrigation advise to their clients, something that before relied on an intense process which meant that irrigation specific advice was only provided once during construction of the drip line infrastructure.

The outcome of the semi-structured surveys conducted during this visit (Annex 7) has 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 (version 1.1).

1.4.2 Technological Feasibility

One of the goals of this project was to develop the SOSIA tool. The SOSIA tool, consist of two tools: the Virtual Weather Station and the Irrigation Advisory Tool. The VWS is a tool which shows multiple weather parameters for a specific location, both historically, real time and near-future. The second tool that is created is the IAT, which translates weather parameters into crop specific irrigation advice in volumes, but also in minutes.
From the first survey (Annex 2, Annex 3), an overview was established of the available input and required output needs of the SOSIA tools to be developed. The results of the first survey included that all the

[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

farmers do wish to base their irrigation scheduling on **accurate information** and that this can be a very useful product for the intermediary to include in their existing package (Annex 2, Annex 3). Farmers are mainly interested in the **daily minutes** they need to irrigate their fields. The total daily amount of water needed per field was also considered as useful. All farmers interviewed prefer to receive the results as a PDF via WhatsApp. Furthermore, a hybrid between a complete irrigation advice of the whole cropping cycle and updates when (weather) situations change is preferred.

Looking at the intermediate, 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 for the intermediary.

With the needs of both users in mind, the first version of the SOSIA tools were developed. For this end, Google Earth Engine was selected (https://earthengine.google.com/). The platform was selected because it has capabilities for both analyzing 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.

The SOSIA Tools require the most recent data to be used for most effective operational decision-making for the farmers. Google Earth Engine (GEE) makes use of cloud computing and has recent data available for a number of datasets. This was another advantage to select this platform over other available platforms. There is no need for downloading and processing large datasets, which comes with a need for major storage space, high-speed computing infrastructure etc. This has been overcome by using GEE as the platform for data access and cloud computing, as well as for data dissemination. Furthermore, it is possible to open GEE applications on your mobile phone (through the internet).

Datasets Virtual Weather Stations

The SOSIA tools rely on multiple datasets and show both historic and near future (5 days ahead) timeseries for different parameters. For the VWS, these parameters are Reference ET (ETref), Air Temperature, Precipitation, Wind Speed, Relative Humidity and Solar Radiation. For the Irrigation Advice Tool (IAT) (version 1) only Reference ET is considered.

One of the advantages of Google Earth Engine, is the availability of cloud-datasets through the platform. A list of available data that was potentially interesting for the development of the SOSIA tools was made (Table 1). For each dataset the most recent image and the available data variables were noted. Datasets that have more recent images available were selected over other datasets due to its applicability for an operational tool, where farmers need recent and forecasted information. Ultimately, most of the considered datasets were selected, except the ones that are not refreshed frequently and/ or that are not suitable for the resolution of the envisioned tool. The datasets that were used for the SOSIA Tools are shown in boldface. There is 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. As can be seen in table 1, the data is not available on a very small scale, but it will improve the current situation where farmers rely on national climate data. In addition, each of these datasets have licenses that can be used for commercial purposes of this sort.

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	Resolu-tion	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	✓					
CFS 3 Hourly	11-4-2022 (16 day forecast)	Forecasting	27 km	✓		✓	✓	✓	✓

* 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

With the platform and datasets selected, the SOSIA tools were developed. Both the VWS tool and IAT (Figure 3) are available in a dashboard format that is accessible through the internet on your laptop and/or smartphone. The 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. Secondly, there are additional options added that are not necessary for calculations but are inserted for database purposes. With that data the irrigation engineer can find the specific farmer quickly and can store data that is, for example, needed for irrigation design. When data is entered, 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.

In the period from 6-15 June an initial evaluation was conducted by FW and HGT to discuss the first version of the tools and its results with the two user groups (farmers and the HGT irrigation team). Several farmers were visited in the East of Rwanda and surrounding Kigali to conduct research concerning the impact, usability, and commercial viability of the tool. Information was collected on how the results of the tool can be presented in a simple yet complete way with information that the farmer requires, without the risk of the farmer to 'drown' in excessive tables and graphs. The 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. This was taken into consideration for the further development of the SOSIA tool.

HGT Rwanda also organized a demo with the irrigation engineers. The input of the farmers and irrigation engineers led to the improved version of the IAT (version 1.1). Furthermore, as explained in the impact chapter, preliminary analysis shows that the irrigation data of the IAT gives lower values than the data of the farmer, hinting at overirrigation by the farmer.

A validation with local weather data has not yet been completed, due to the lack of a good local dataset. Although this would benefit the accuracy of the output data, given the scale of detail at which the tool operates, calibration with local data is not expected to yield significantly different estimates.

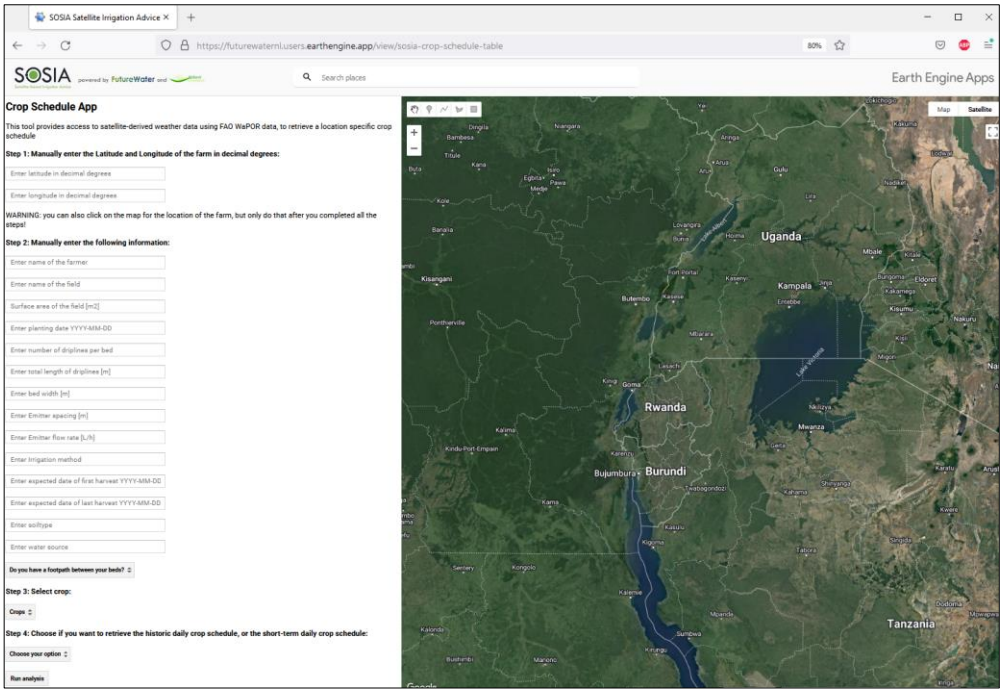


Figure 3. Screenshot of the SOSIA Irrigation Advisory Tool

1.4.3 Economical Feasibility

Value proposition

For farmers who are (potential) precision irrigation users, who want to improve their water efficiency and productivity, our service informs them when and how long to irrigate. This enables them better provide water application to their plants, optimising their productivity. It is unique because it is a new offering in Rwanda 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 included in a set of existing services offered by HGT, to be further determined in phase 2.
4. Lack of information is the main challenge for farmers related to irrigation.
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, 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.

Competitor analysis

Irrigation advisory services have been on the market for some time, but differ greatly in application level (spatial scale) and spatial detail. Figure 4 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 4.

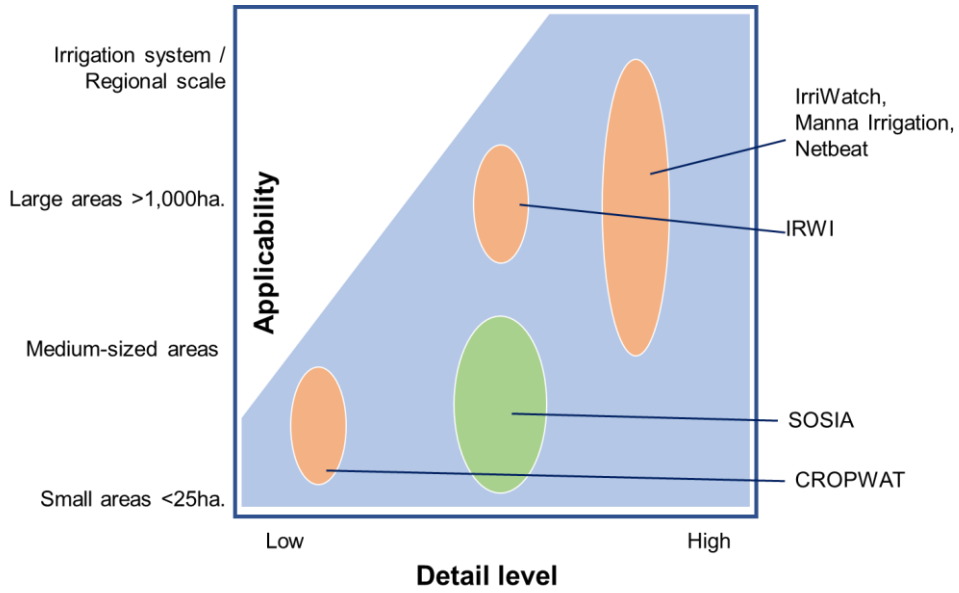


Figure 4. Overview of irrigation advice products sorted by applicability (y-axis) and detail level (x-axis)

In addition to the technical aspects, economic factors play a decisive role in the creation of the market landscape shown in Figure 4. 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 low market price, thanks to the focus on the use of OS data. The service is unique in that it is primarily aimed at small to medium-sized food producers, who do not have the financial means to use existing products cost-effectively.

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

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

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 costs (for pumping groundwater), assuming they are currently over-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 to one, that is, as the price draw indicated at the beginning, and because of the early stage of the product development, only **1 intermediary** has been identified: HGT Rwanda. When focusing on the second tier of this business model, i.e. the farmer level, the obtainable market size after phase 1 is around **40 farmers**. These are the farmers who make use of drip irrigation and receive the services offered by HGT Rwanda.

Accessible market

HGT has a broad network outside of Rwanda 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 **10** intermediary, as HGT has a physical presence in 10 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 in Rwanda and other African countries, 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 continent, the available market is limited to this continent with the current SOSIA tool, assuming calibration data for each of these countries is available. Hence, 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[1]. 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[2] 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] 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.
[2] 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.

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 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.

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 use for pumping is a significant part of their costs of production, and any means to lower 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 use. To obtain this proof an extensive quality assessment and evaluation of the tool is planned in phase 2, which is one of the key outputs expected from the field pilots (see section 2.2.4).

In the survey, farmers were asked to estimate the amount they would be willing to pay at this moment. The indicated amounts ranged 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 (appr. 5 ha where every 2 weeks a new crop is planted on a 0.5 ha block). This would also translate to EUR 5 per field. These estimates are considered viable by the intermediary, and have been aligned with the proposed subscription cost of using the tool.

As different business options will be explored during phase 2, including offering a complete kit or package deal with e.g. soil test, irrigation equipment and the SOSIA irrigation advise by the intermediary, further refining of the cost components is expected in the first part of phase 2. In addition, 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.

Intermediary license agreement

To make arrangements regarding any future income generated by FW or the intermediary, HGT, with regard to the SOSIA tools, a licence agreement was made. In this way it has been agreed that HGT has the sole usage rights for the tool in any country where it is using it. 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, HGT has the first right to match the proposed payment by the organization willing to make use of the tool.

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 is sold to any organization, the division is also 60-40% between FW and HGT. With this agreement the financial aspects related to services sales are now well-arranged. Furthermore, 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.

1.5 Knowledge Component

1.5.1 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.

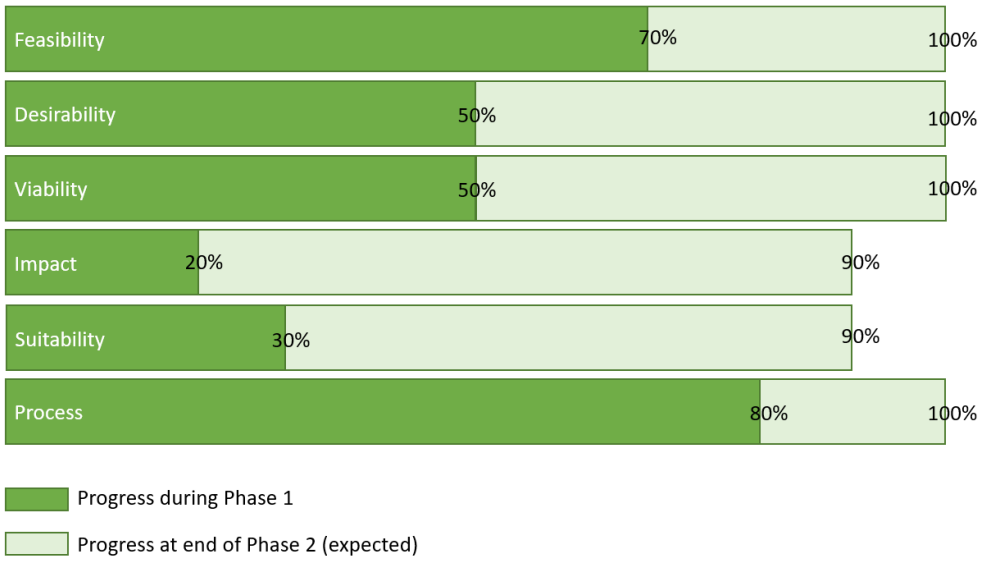


Figure 5. Estimated progress towards answering the Learning Questions during Phase 1 and Phase 2 of the competition. LQs under the category "The Unexpected" are excluded, since these by definition cannot be planned or foreseen

Due to the phased structure of the competition, not all answers can be fully answered at this stage. 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 will involve further optimization of the service by more extensive demonstration to the end user, during which further knowledge will be developed. However, all LQs have already led to interesting and useful new insights at the end of Phase 1. Figure 5 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 will be 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.

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. Annex 5 presents a word-copy of the BopInc Learning Excel sheet with tracked answers for each of the learning questions.

1.5.2 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 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.

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.

1.5.3 Desirability

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 2, the latter is considered by the farmers as the most important gain of optimal irrigation advice.

Comparing the first results of the SOSIA tools with irrigation records retrieved from a farmer in Rwanda indicates that the farmer currently irrigates more than necessary. The advised daily irrigation volumes of the SOSIA-tool consequently are factor 2 lower than currently 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 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 (see section 1.4.3).

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.

Communication channel

The survey results (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 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 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.

1.5.4 Viability

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 (section 1.4.3). Hence, it is believed that, 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, the general interest in purchasing the advice in a B2C format is viable without relying on any alternative revenue model.

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.

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 the Irrigation Advisory Tool to be used in an economically viable and sustainable way. These strategies will be further explored as part of phase 2 (more information in section 2.1.4).

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 yield a larger impact.

To keep the tool up and running, FutureWater offers periodic service updates, general maintenance, troubleshooting and support. These activities roughly require an input of 20 working days, which would be equivalent to about EUR 10,000. This does not include further developments of the tool for which the proposal for phase 2 is aimed (see section 2.1.4).

1.5.5 Impact

As shown in Figure 5, 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 tool (see Section 1.4.1). 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. These expectations are 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 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.

1.5.6 Suitability

As shown in Figure 5, Suitability 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:

- 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.
- 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.

1.5.7 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 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.

1.5.8 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 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.

1.6 Conclusions and Reflection on Theory of Change

As thoroughly explained in the previous section, various learnings have been made, yet none have reached a final phase yet. Therefore, the concluding remarks presented below should be interpreted with account of this continuous process.

The SOSIA tool is yet to be evaluated thoroughly in-field before the expected impact can be claimed. However, several learnings have been obtained during Phase 1 of this competition, mostly related to feasibility, desirability, and the general process. As presented above, each of these have an impact on the theory of change initially established. Whereas only minor changes could be amended now, it is expected that over the course of Phase 2 progressive insights could lead to further modifications. At this stage, the development of the tool and the various in-field surveys with both the end user farmers as well as the intermediary has 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 1.5.3). 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.

FW will mostly 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.

Aside from a two-tiered business strategy, also some of the initial assumptions were adapted based on new insights gained throughout this first phase. These assumptions are now better understood and are pivotal for quantifying the exact impact during phase 2, when the pilots have come to an end.

In addition, also the impact has now been subdivided further into short-term and long-term impact goals. As shown in Figure 6 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 is expected to be 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, it is ascertained that this impact will be thoroughly followed up as part of the agreement. Continuous evaluation of impact and scope for improvement is instrumental for the SOSIA tool to realize the long-term impact it envisions.

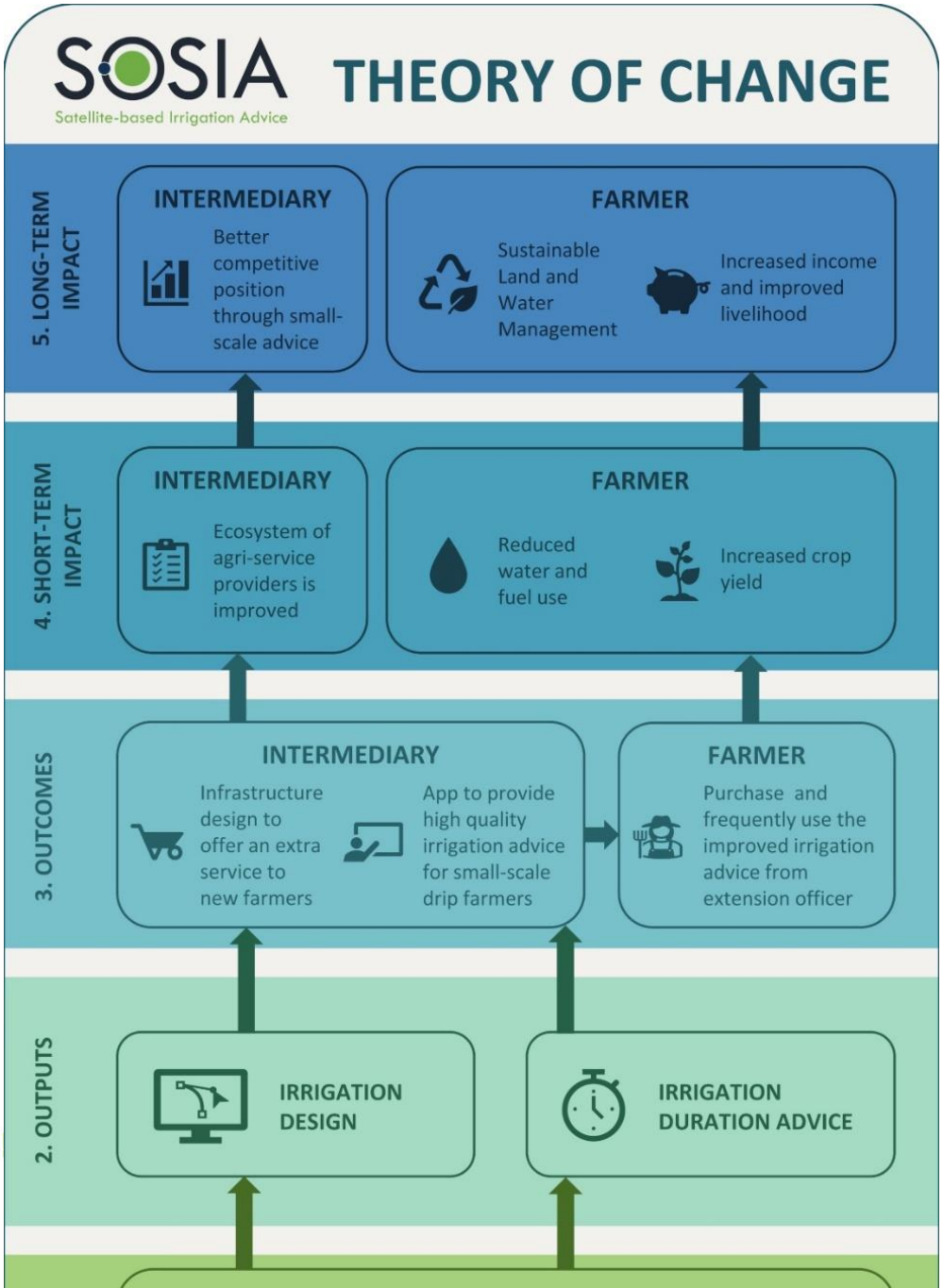

SOSIA
Satellite-based Irrigation Advice
THEORY OF CHANGE
5. LONG-TERM IMPACT
INTERMEDIARY
Better competitive position through small-scale advice
FARMER
Sustainable Land and Water Management
Increased income and improved livelihood
4. SHORT-TERM IMPACT
INTERMEDIARY
Ecosystem of agri-service providers is improved
FARMER
Reduced water and fuel use
Increased crop yield
3. OUTCOMES
INTERMEDIARY
Infrastructure design to offer an extra service to new farmers
App to provide high quality irrigation advice for small-scale drip farmers
FARMER
Purchase and frequently use the improved irrigation advice from extension officer
2. OUTPUTS
IRRIGATION DESIGN
IRRIGATION DURATION ADVICE

Figure 6. 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 7. 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 8. User profile of end user Mr. Pacique, farmer

SOSIA
Satellite-based Irrigation Advice

Persona 1 – **Intermediary**

Watch video interviews

Gilbert Tuyisenge

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

> ***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!***

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

Figure 9. 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/liters/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 whats app/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 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 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
- Water melon
- 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 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		yes
Historical data:Last days/Last month/Last year		
Forecast for next days	yes	yes
Pictures of different components		

	Farmer 3	Farmer 4
Date of Interview	25/3/2022	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? If answered no: How can you see that the crop has not enough water?	Yes	Yes
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? If no, can you explain why not?	Yes	Yes
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		

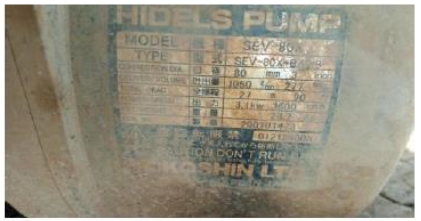
	   	 
	Farmer 7	**Farmer 8**
Date of Interview	04/04/2022	04/04/2022

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, As a PDF on your email Verbal explanation by a HGT staff member? Printed out schedule(hardcopy)	yes	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:	Plant based water requirements,different plant different water requirements	Plant water requirements differ per plant/crop.
Do you have a smart phone? Yes No	yes	yes
Would you be willing to pay for this service? Yes No	yes	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 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 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 are 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 partie. 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

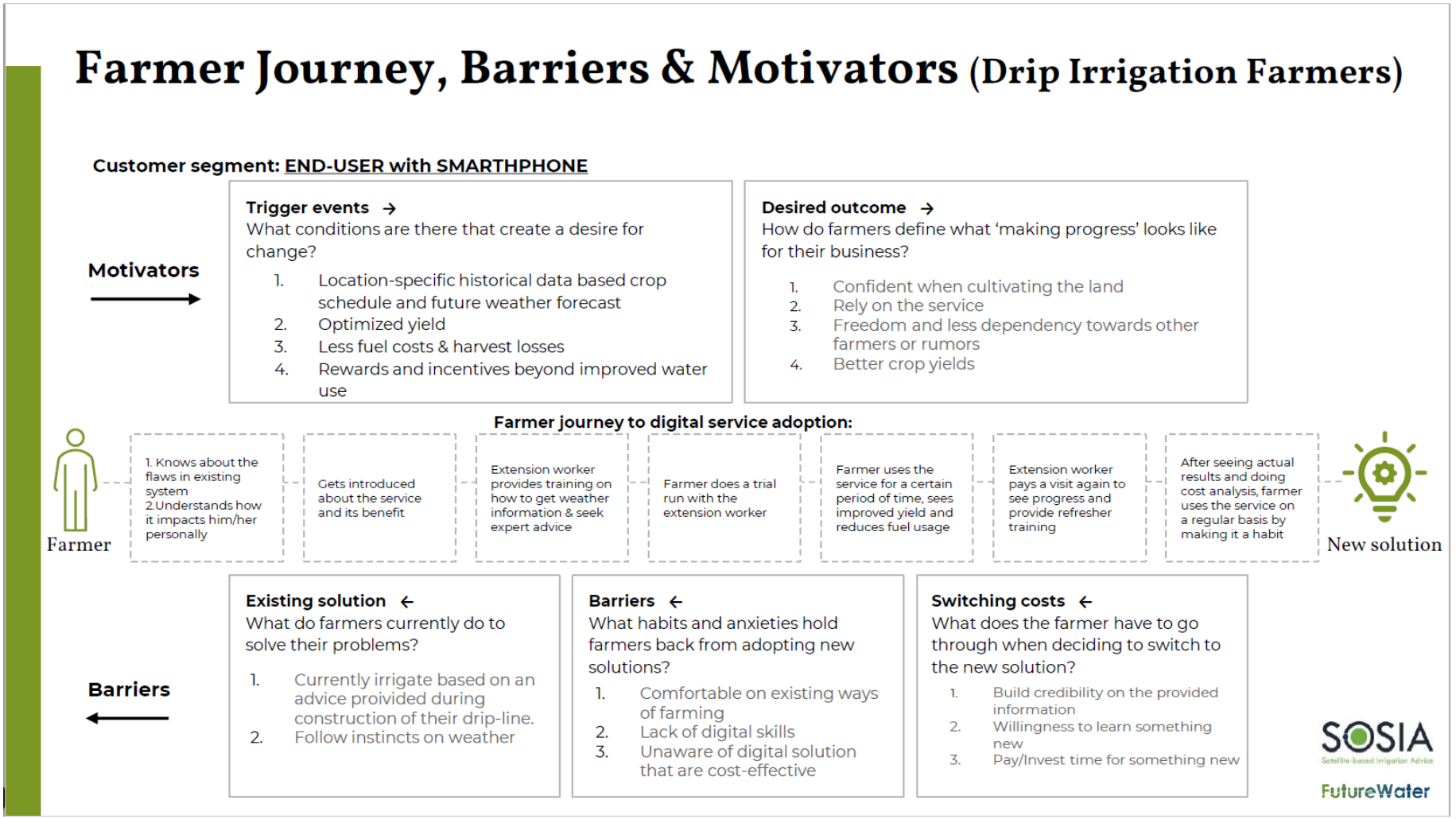
We regard this competition as a very welcome and helpful opportunity to develop a high-impact service In close collaboration with intermediary HGT. The flexibility of the competition in terms of themes, geographical scope, and input datasets has allowed us to design the project activities in a way that 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 advise 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 advise 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 ad a guideline in the semi structured interviews with either farmers and 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 advise and what we could further develop to make it even better.

SOSIA TOOL

16. What are your first impressions of the information included in the advice?
17. Is the result easy to understand and implement for you?
18. What is still missing in the advice?
19. What do you think of the lay-out of the advise? Score 1-5, 1 is poor, 5 excellent)
20. Explain in words what you like about the lay-out and what can be improved.

IMPACT

21. When you compare the outcome of the advise and your current irrigation scheme, what are differences you see?
22. Do you think, when looking at the scheme, you will use more or less water compared with how you currently irrigate?
23. What do you think will be the effect of your yield when implementing the irrigation advise?

COMMERCIAL

24. How much would you be willing to pay for the shown irrigation advise? (of a whole growing season)
25. Why would you be willing to pay for the irrigation advise?
26. What most important advantages will the irrigation advice have for you?
27. If you like the advice, how many times per year would you purchase one (for the price indicated at question 9)?
28. 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

1. What are your first impressions of the information included in the advice to farmers?
2. Is the result easy to understand and explain for you? (explain why yes or why no)
3. Do you think farmers will be able to implement the advise (explain why yes or why no)
4. What is still missing in the advise to farmers?
5. What can be improved for the advise to farmers?
6. What do you think of the lay-out of the advise? Score 1-5, 1 is poor, 5 excellent)
7. Explain in words what you like about the lay-out and what can be improved.
8. What is the most important shortfall of this irrigation advice?

COMMERCIAL

9. How much would a farmer be willing to pay for the irrigation advise? (of a whole growing season, on average).
10. 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?
11. How many times per year would you estimate a farmer would purchase the irrigation advice? (for the price indicated at question 8)?
12. Would farmers like this advice when purchasing other products from HGT?
    - ☐ No
    - ☐ Yes, when buyin irrigation products
    - ☐ Yes, when buying seeds
    - ☐ Yes when purchasing soil testing
    - ☐ Yes when buying_____
    - ☐ Yes, for all of the above

IMPACT

13. When you compare the outcome of the advise and current irrigation practices of farmers using drip irrigation, what are differences you see/expect?
14. Do you think, when looking at the scheme, farmers will use more or less water compared with how they currently irrigate?
15. What most important advantages will the irrigation advice have for the farmer?
16. IF HGT can give this irrigation advice to farmers, what do you think is the biggest advantage for HGT?
17. What do you think will be the effect of your yield when implementing the irrigation advise?
18. 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 Stuctured 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

Operational (user experience of tool)

- Function for quick/easy data export (or download) from tool/platform
  - Template in Excel
  - 1 table with user input/ 1 table with results
  - GEEbased 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 colors (like in your template)
  - Rounding of numbers after the decimal (max 1 decimal)
- They like the current look a lot.

Technical (calculations and data)

- 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 lesss 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 usefull 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