Report on lessons learnt from the deployment of the SAROS prototype in Kenya and Tanzania. – Kennedy Nganga, 2017.

Introduction

The SAROS – Smart Agricultural Resources Optimization System, is a decision support and farm automation system meant to increase the efficiency of resource usage in agriculture. It specifically targets to optimize the efficiency of scarce inputs such as water and expensive inputs such as fertilizer, through using ICT technologies to control the application of these inputs. It also seeks to encourage sustainable land management practices so as to conserve the fertility of the soil and ensure optimum productivity into the future. The SAROS accomplishes this using a combination of hardware and software to interface with the farmer and his farm. The hardware is installed at the farm and attached to systems such as the drip irrigation system among others. It uses a variety of sensors to measure environmental and weather parameters and based on these measurements certain tasks such as irrigation are initiated when necessary. This allows the SAROS to be objective in its application of resources such as water allowing finer control in their consumption. The parameters sensed by the SAROS include air temperature, relative humidity, soil moisture and soil temperature, all of which are sent over the internet to a cloud-based Internet-of-Things platform. Here the data is remotely monitored to ensure the smooth operation of the system as well as being subjected to detailed analysis to generate alerts and other important information to support farm management. This information is then passed over to the farmer using an intuitive mobile-based platform. The SAROS therefore not only saves on inputs, it also saves the farmers time by automating routine functions, while at the same time building capacity by empowering farmers with the information they need to sustainably manage their farms. The SAROS is designed to help farmers adapt to climate change and sustainably increase yields by bridging the knowledge divide and enhancing smallholder decision making using information. The purpose of this paper is to discuss the experiences resulting from the field deployment of the SAROS hardware in both Kenya and Tanzania. It begins with a discussion of the system setup, methodology of operation, and includes lessons learnt from the trials and recommendations for system improvement.

The need for optimization and decision support

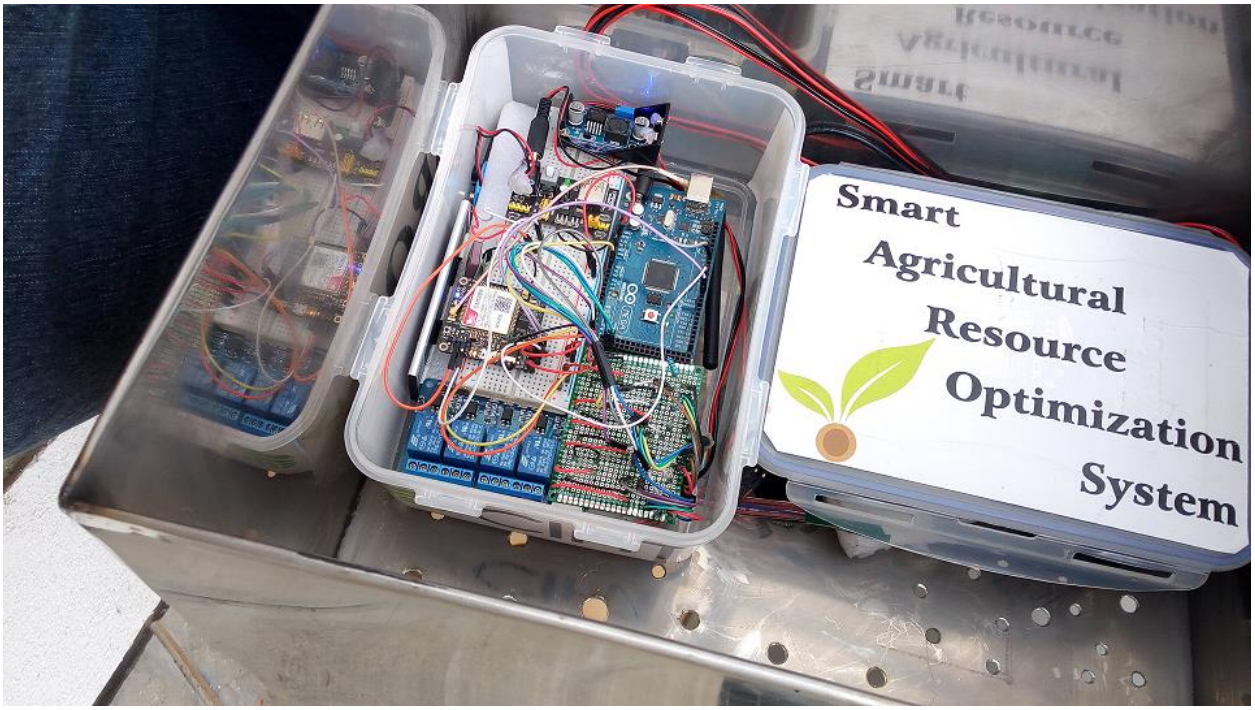
Small scale agriculture has been shown to suffer from several technical inefficiencies (Seyoum, 1998). This is due to several causes ranging from lack of technical knowledge by smallholder farmers, to lack of equipment to improve practices. These technical inefficiencies affect different facets of agricultural production. In particular they have an impact on the quantities of inputs such as water that are utilized in production (Speelman, 2008). It has been estimated that small-scale irrigation schemes can have up to 49% inefficiencies attributable to technical limitations (Speelman, 2008). This is of significance given the importance such resources have in contributing to livelihoods and development in farming communities. It is also a pertinent issue given the pressure exerted on such resources by growing populations and climate change. The pressure on resources and the potential for increasing productivity make a strong case for enhancing technical efficiencies in smallholder agriculture. Smallholder farmers are also starting to realize the need for and demand better decision support tools to help them adapt to climate change and other challenges. Studies have shown that the productivity of rice systems for instance can be raised by increasing the technical efficiency of smallholder farmers (Idiong, 2007). The proliferation of mobile handsets and ICT technologies across the developing world presents an opportunity to disrupt the current knowledge paradigm by delivering to farmers' real-time, strategic, actionable information to guide their decision making.

Methodology and beneficiaries

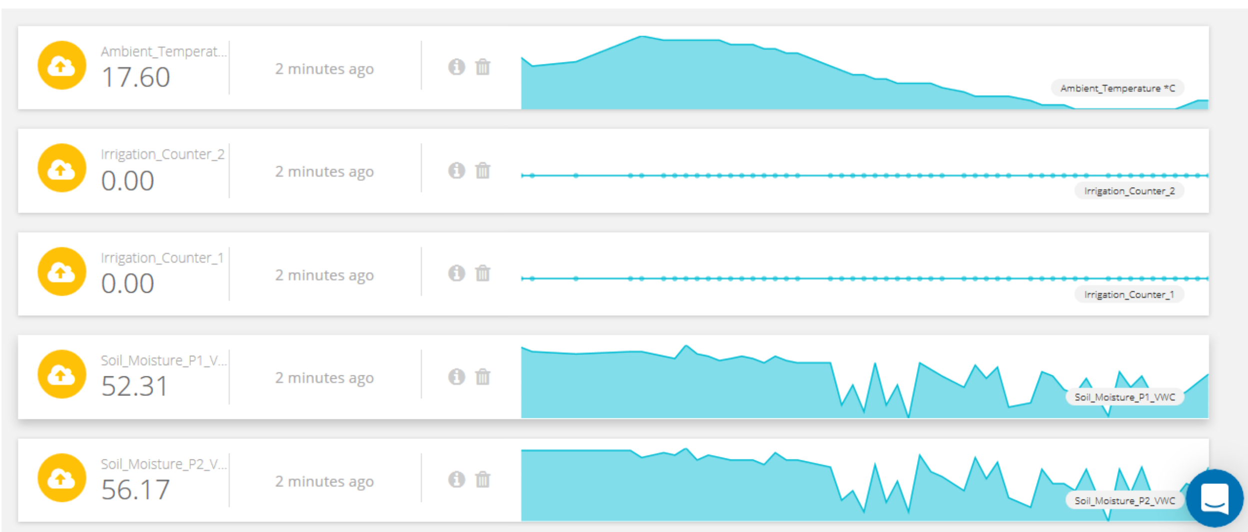
The system is built around a field-deployable kit that monitors the weather, soil moisture and other environmental parameters to determine when irrigation should be done and how much water needs to be released. The kit has sensors that measure a variety of environmental conditions and relay the data to an onboard micro-controller. The micro-controller evaluates this data to determine if it is necessary to irrigate given the crops agronomic details. In this way the kit is able to regulate the amount of water used in crop production to a very high degree of efficiency, since it is programmed with the technical information necessary to make optimal decisions. The kit can be configured to automatically open irrigation systems when it detects the crop needs watering, thus allowing the automation of routine tasks. This not only allows higher levels of efficiency to be achieved, but it also has the dual advantage of freeing the farmer from the monotonous task of watering plants repeatedly. This means the farmer's time is freed allowing them to engage in other activities. The fact that manual irrigation in Sub-Saharan Africa is usually left to women means that the SAROS system has a gender dimension in that it frees up the time women use on the farm allowing them to engage in other livelihood activities. It also means plants get water whenever they need it with no delays or under/over irrigation due to human error. The field kit logs the amount of water dispersed during each irrigation cycle and periodically uploads data to a cloud server. By connecting to a back-end system where the data is uploaded, the kit sends back data that can be used to inform land management decisions. This data is analyzed to produce information that is then posted to a knowledge platform that farmers can connect to through their mobile phones. In this way farmers are able to sustainably increase their returns from agriculture by basing their land management decisions on technical data rather than custom or intuition. This combination of the field kit, the back end software, and the knowledge platform to provide information to farmers is what we call the SAROS.

This SAROS is primarily targeted at small holder farmers who typically have limited technical knowledge on agronomy and land management practices. The also lack access to current and useful information that can be applied to refine their processes. The solution is meant to bridge this knowledge divide thus allowing the farmers to increase their technical efficiencies. By basing resource use decisions on actual data and knowledge, the SAROS removes much of the guesswork involved in small-scale irrigation. The land management data processed at the back-end of the system allows farmers to query and receive information about different aspects of their farm from the convenience of their mobile handsets via the knowledge platform. The platform will also be accessible to policy makers allowing fact-based decision making across the hierarchy from field level to landscape level.

SAROS system components



An image of the SAROS field device housed in a protective metal casing.



An image of the Internet of Things cloud service where the SAROS data is uploaded.

Field deployment

The SAROS was deployed in the Upper Tana watershed in central region of Kenya in mid 2016, and thereafter deployed in the Babati district of Tanzania in early 2017. The sites where the SAROS was deployed were identical in terms of the demographic and prevalent economic activities. Both places were rural, inhabited by small-scale farmers, and the main economic activity was agriculture. Moreover the two sites had almost similar climatic conditions and produced nearly similar crops. The challenges and opportunities presented by the two sites were similar, and will therefore be considered together in the context of this report. Given the extensive functionality of the SAROS it was decided to test out a specific set of the overall functionality as a proxy for the performance of the whole system. In both sites the automation of agriculture and uploading of data to the cloud was tested. The following are the lessons learnt from the field trial.

Efficiency factor

The SAROS showed that it could reduce the amount of water used by as much as 50 %. A 125 liter reservoir of water could be used for twice as long to irrigate a small plot of vegetables when controlled by the SAROS system as opposed to manual irrigation.

Cost factor

The cost of the SAROS can be divided into two components. First is the cost of the field kit itself which is responsible for data collection and triggering automated functionality. This cost includes the cost of the field kit, the solar panel and battery, as well as the mounting box used to protect the sensitive electronics from the elements. The total cost of this first component of the SAROS averaged about US dollars $200. However this cost is volume dependent and likely to go down by as much as 50% when the volume produced is sufficient to enjoy economies of scale. The second cost is that of associated infrastructure that goes together with the SAROS field kit. This includes the drip irrigation system among other components that can be connected to the SAROS field kit for automation. This component of the SAROS is more variable as it depends on the acreage of landholding as well as the types of infrastructure being connected. In most instances, a drip irrigation system that is compatible with the SAROS system will cost a typical smallholder farmer around US dollars $200. This includes the cost of the reservoir, valves, filters, main lines and the drip irrigation laterals. The above cost would apply for a farmer owning approximately an acre of land, and would vary as the size of land increases or decreases. Overall the investment is more sensible when a larger piece of land is being outfitted with the technology since the SAROS can work with different farm sizes. The larger piece of land ensures a faster return on investment since it utilizes the potential of the system more fully.

Effort factor

The SAROS cuts down considerably on the effort and time spent executing routine agricultural tasks. Irrigation is one of those repetitive activities whose automation can reduce the drudgery associated with smallholder farming. During the trials, the SAROS was able to save approximately 15 minutes time per irrigation plot, which for most households with 2 plots resulted in up to half an hour saved per irrigation session. These savings add up to a significant amount of time as it is common practice for most households to irrigate their plots twice daily. It has been estimated that the SAROS saves as much as 7 hours per week in labor time, freeing the time up for other livelihood or social activities.

Gender Factor

The time and effort savings above apply mostly to women who are traditionally responsible for the small scale irrigation observed at the study sites. Therefore the SAROS had an impact on the time spent by women in monotonous tasks associated with agriculture. This resulted in their being able to spend time on other aspects of their agriculture, such as poultry rearing as the time previously spent on irrigation was available for other use.

Farmer expectations

The trials exposed the importance of explaining to the farmer how the system works, laying out the benefits, and discussing the limitations, in order to manage expectations. This is particularly important during the initial laying out and testing of the field components of the system and associated infrastructure. During this period of the initial set-up and testing, it is important to keep farmers involved of the progress of installation and testing. This avoids their getting disappointed by the system before it is even up and running. Managing expectations is also necessary to ensure the farmers know what tasks are being automated and which they still have to take care of themselves.

Technical challenges

The trials demonstrated that the setup of the SAROS system faces unique technical challenges at each new site. This is a factor of the length of wire required to run from the solar panel to the battery, from the SAROS field device to the solenoids, among others. The topography of the land also determines how easy it is to set up associated infrastructure such as the drip irrigation system. All in all it emerged that each site needs specific consideration during system setup so as to overcome the unique challenges at the location.

Data collected

The SAROS proved capable of consistently collecting data and transmitting it across the network to online databases. The parameters measured during the trials were primarily those concerned with the weather and soil properties related to irrigation. However the SAROS retained enough idle capacity to allow the future integration of more sensors and collection of a richer dataset.

In terms of data collected, the SAROS collected and uploaded data to the cloud very ten minutes as part of its programming. This was meant to offer more data points than necessary which created a buffer against the instances when the connection was dropped and data couldn't be uploaded. In such scenarios the SAROS was programmed to restart its communication module and prepare to upload data when the next upload slot was open. By this method it was ensured that data was uploaded at least twice an hour allowing the consistent collection of data points hourly.

The data was uploaded to a cloud based IoT service from where it could be visualized and synthesized into usable information. The visualization enabled identification of interesting trends and patterns while the synthesizing to a more intuitive form enabled extraction of information that could then be fed to the farmer knowledge platform.

Screenshot of the data stream showing soil moisture trend inside a screen-house.

Screenshot of the data stream showing soil moisture trend outside a screen-house.

Conclusions and recommendations

The SAROS proved its capability to be deployed for purposes of resource efficiency and data gathering for decision support. It operated in the field setting as expected despite initial set-up challenges. These initial challenges could be reduced with the refinement of the technology from prototype stage to market-version stage. Not only would this result in miniaturization of the field kit, it would also lead to the development of supporting infrastructure such as drip-irrigation kits that are cheaper and therefore more suited to smallholder farmers. Another bottleneck during setup is the involving and technical nature of the work, again attributable to the complexity of the current technology. By packaging the technology in a simpler and more intuitive manner, it will make installation a non-technical task allowing the SAROS to better appeal to farmers. Another barrier to access would be the cost of the system, currently ranging at around US $400. The trials demonstrated that the way to reduce this cost was if the SAROS and associated infrastructure were being created in large volumes thereby allowing economies of scale.

The above leads to the conclusion that the SAROS technology is viable and has demonstrated applicability in smallholder systems. Though still on going in its pilot stage, it has already demonstrated clear advantages in terms of both data collection for decision support as well as in increasing the efficiency of irrigation on smallholder systems. However, the technology still has space to improve and refine in both its hardware and software; through movement from prototype-version to market-version that is easier for the farmers to use. To facilitate this, it is recommended to move in the direction of commercialization, as a possible means of developing a market-version of the technology. It is recommended that this be a user-led process through close collaboration of developers with the farmers intended to use the final product. Their inputs, suggestions and insights should shape the development of the market-version of the technology.

Online resources

The SAROS data dashboard can be accessed via the following web link:

https://app.ubidots.com/ubi/public/getdashboard/page/znPhRJzk4o3krLWpLKR6PCa7lKY

References

Seyoum, E. T., Battese, G. E., & Fleming, E. M. (1998). Technical efficiency and productivity of maize producers in eastern Ethiopia: a study of farmers within and outside the Sasakawa-Global 2000 project. *Agricultural economics*, *19*(3), 341-348.

Speelman, S., D'Haese, M., Buysse, J., & D'Haese, L. (2008). A measure for the efficiency of water use and its determinants, a case study of small-scale irrigation schemes in North-West Province, South Africa. *Agricultural systems*, *98*(1), 31-39.

Idiong, I. C. (2007). Estimation of farm level technical efficiency in smallscale swamp rice production in cross river state of Nigeria: a stochastic frontier approach. *World Journal of Agricultural Sciences*, *3*(5), 653-658.