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Procedia Computer Science 177 (2020) 86–93

Procedia Computer Science

www.elsevier.com/locate/procedia

The 11th International Conference on Emerging Ubiquitous Systems and Pervasive Networks (EUSPN 2020)
November 2-5, 2020, Madeira, Portugal

IoT-based Irrigation Management for Smallholder Farmers in Rural Sub-Saharan Africa

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Abstract

Ensuring food security has become a challenge in Sub-Saharan Africa (SSA) due to combined effects of climate change, high population growth, and relying on rainfed farming. Governments are establishing shared irrigation infrastructure for smallholder farmers as part of the solutions for food security. However, the irrigated farms often failed to achieve the expected crop yield. This is partly due to lack of water management system in the irrigation infrastructure. In this work, IoT-based irrigation management system is proposed after investigating problems of irrigated farmlands in three SSA countries, Ethiopia, Kenya, and South Africa as case studies. Resource-efficient IoT architecture is developed that monitors soil, microclimate and water parameters and performs appropriate irrigation management. Indigenous farming and expert knowledge, regional weather information, crop and soil specific characteristics are also provided to the system for informed-decision making and efficient operation of the irrigation management system. In SSA, broadband connectivity and cloud services are either unavailable or expensive. To tackle these limitations, data processing, network management, irrigation decisions and communication to the farmers are carried out locally, without the involvement of any back-end servers. Furthermore, the use of green energy sources and resource-aware intelligent data analysis algorithm is studied. It is expected that an intelligent data analysis will help to discover new knowledge that support further development of agricultural expertise. The proposed IoT-based irrigation management system is expected to contribute towards long term and sustainable high crop yield with minimum resource consumption and impact to the biodiversity around the case farmlands.

Keywords: Internet of things; smart irrigation; smallholder farmers; intelligent data analysis; low-cost sensors

1. Introduction

In Sub-Saharan Africa (SSA), agriculture contributes in average 32% of the total GDP and employs more than half of the total labor force [1]. However, it is characterized by low productivity and lack of modern farming technologies, causing the yield of major crops to remain below the global average and affecting the food security in the region. SSA's capacity to ensure food security is challenged by the combined impacts of natural resources degradation, population growth, exposure to climate risks and

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1877-0509
10.1016/j.procs.2020.10.015

vulnerability of the agricultural systems to different climate change scenarios. Farming in SSA are largely rainfed, making it more sensitive to climate variability. For example, temperature is projected to rise faster than the rest of the world, which could exceed 2°C by mid-21st century and 4°C by the end of 21st century [2]. This change will further decrease the crop yields by shortening the length of growing season, amplifying water stress and increasing incidence of diseases, pests and weeds outbreaks. These challenges can only be solved through the widespread adoption of sustainable, climate resilient, productive, and increasingly efficient farming practices. IoT has been proposed for improving performance and sustainability in various sectors [3] [4]. The implementation of IoT-based systems to improve agricultural water resources usage can have considerable contributions to sustainability as well as operational and cost efficiency. The use of IoT in the agricultural sector has been proposed for several purposes, such as in irrigation management [5] [6], precision farming [7], predicting droughts [8], microclimate monitoring [9] [10], and crop disease risk evaluation [11]. However, few of them target specific challenges of the agricultural sector in SSA.

Understanding the conundrum of agriculture and food insecurity, governments in SSA region are moving towards irrigated farming. Currently, most of the introduced irrigation mechanisms lack efficient water management and use outdated mechanical systems that result in the wastage of water resources. In addition, the sharing of water resource and infrastructure among several smallholder farmers sometimes causes conflict due to unfair management. In this paper, an autonomous irrigation management system using IoT technology is proposed in order to solve the issues with minimal cost by introducing an architecture for low-cost IoT-based irrigation management system. Efficient irrigation management brings huge benefits by keeping irrigation-based farming at an optimal level contributing to better crop yield and efficiently managed water supplies lasting beyond dry seasons. The design of the architecture takes into consideration the infrastructural and resource limitations in the SSA region. In addition, sustainability of the irrigation management system is taken into account by integrating locally relevant and indigenous knowledge in the decision process, and promoting the use of green energy sources in the irrigation management system. Unlike most of the existing smart irrigation management systems that are targeted for the developing world [12], [5], [13], [14], the proposed system does not require broadband connectivity and cloud services. The major contributions of this work are: i) Evaluation of the benefits of applying IoT based irrigation management in three representative irrigated farms in SSA region; and ii) Resource-efficient IoT architecture for low-cost irrigation management.

The structure of the paper is as follows. In Section 2, challenges in existing irrigated farms in SSA are discussed. The proposed IoT architecture is presented in Section 3. The components and technologies of the architecture are explained in Section 4. The need for intelligent data analysis is discussed in Section 5. Finally, in Section 6 the conclusions of the work are presented.

2. Issues in irrigated smallholder farms in SSA

There are several challenges associated with irrigation in SSA region. Most irrigated farms in SSA use flooding techniques without monitoring of the relevant dynamic parameters. Either there is no weather station at all in the farm or their spatial distribution is very low. In most irrigation scheme, the schedule often fails to capture the dynamic changes of the influencing parameters as they are determined through infrequent laboratory tests and pre-defined empirical models. In SSA, irrigation infrastructure is shared among several smallholder farms and various crops are grown at the same time. Despite crop specific water needs, the same water scheduling and amount is applied in the farms. In addition, there is inadequate awareness of water resource saving strategies, and maintenance of irrigation facilities. Representative irrigation schemes in Ethiopia, Kenya and South Africa and their issues are discussed below.

2.1. Koga, Ethiopia: flooding irrigation

Most farmers in Ethiopia produce only one crop per year due to lack of irrigation infrastructure and large temporal and spatial variation in rainfall. To address this issue and take advantage of the vast cultivable land, the government is investing in irrigation infrastructure. One such investment is Koga irrigation scheme, which is located in south of Lake Tana, in the Upper Blue Nile Basin. It is built to irrigate 7000 ha in order to serve around 3000 farmers [15]. The major crops produced in Koga irrigation scheme are wheat, barely, maize, bean, cabbage, potato, tomato, onion, shallot and pepper. The Koga irrigation infrastructure includes a 19.7km long concrete lined main canal, 52km of hydraulic performance standards lined secondary canals, 156km of unlined tertiary canals, 905km of unlined quaternary canals, and 11-night storages. Other infrastructure of the irrigation system includes road crossings, silt traps, division boxes with gates and turnarounds.

Koga irrigation scheme uses flooding based irrigation technique without any water usage monitoring and decision system in its infrastructure. Due to poor water management, Koga irrigates currently around 6200 ha instead of the targeted 7000 ha. The farms near to canal often overwater their plots whereas the farthest one suffers shortage of water. Both over- and under-watering affect the yield negatively. A study at one site in Koga demonstrated that the water consumption of wheat and potato was reduced on average by 36% after installing simple wetting front detectors [16]. There are often conflicts among farmers because some farmers are overwatering or using others' irrigation turn. The conflict is exacerbated especially in the dry season when the river water discharge decreases considerably. Another cause for water shortage is the performance of the night storage below their full capacity. This is due to the inflow of sediment to the reservoir [17]. The introduction of IoT system for the management of Koga irrigation scheme can help to avoid water wastage and covering the intended 7000 ha with improved yield. Furthermore, the IoT based irrigation management system is expected to result in an equitable and demand-based water resource allocation to the farming.

2.2. Dedan Kimathi University of Technology (DeKUT) Kenya farm: drip irrigation

DeKUT farm was initially established as a plantation farm but has evolved over time to provide high quality facilities, resources and opportunities for research in crops and animals. It has 650 acres of farm of which 400 acres are under crop and vegetable production while the remaining portion is reserved for biodiversity refuge points. The crops and vegetables in the farm are coffee (294 acres), maize (45 acres), bananas, beans, arrowroots and an assortment of vegetables (36 acres). Coffee and 14 acres of vegetables are under irrigation. The coffee portion is irrigated through overhead while vegetables are under drip irrigation. A petrol-powered pump is used for delivering water to watering hosepipes in the drip irrigation. The farm also has three medium sized greenhouses of which two of them are drip irrigated. Water for irrigation is harvested from a nearby river Muringato. The Farm has a simple rain gauge and keeps a daily rainfall record with an average rainfall of 26 mm during rainy season.

There have been frequent clogging up of water emitters leading to their dysfunction with additional maintenance cost (water filters required and regular flushing of pipe system). The irrigation schedule and water amount is the same regardless of individual plant's needs, which affects the yield and causes loss of water. High skilled agricultural expert decides the schedule of irrigation for the farm. To reduce the cost of manual labor, actuator for opening/closing the emitters is needed. These issues can be addressed through the integration of IoT systems that consists various sensors, actuators and irrigation scheduling system. The IoT system takes into account the specific needs of each crop at its different growing stage, the surrounding weather conditions, real-time soil parameters and soil properties in order to make scheduling decisions.

2.3. Thabina smallholder irrigation scheme, South Africa: flooding irrigation

Thabina irrigation scheme is one of the many smallholder irrigation schemes in South Africa. It is situated close to Tzaneen in Limpopo Province. It has a total area of 200 ha and about 160 plot holders, with an average land holding of 1.3 hectares. The irrigation scheme is fed by the Thabina River. A diversion weir leads the water into the main canal, which has a capacity of about 700 m3/hr (or 194 l/s) and this water goes into Thabina storage dam in the river. The conveyance system consists of open canals that are lined with concrete. The main canal carries a continuous flow of water, 24 hours per day. The first 12 sub-canals take water from 8:00 a.m. to 06:00 p.m. During the rest of the day, the water flows into a night storage dam, which supplies the remaining 6 sub-canals on the following day. Each sub-canals feeds up to twenty farmers. Outlet pipes operate with switch plugs for ensuring on/off water flow mechanism. Due to the on/off-system, a sub-canal supplies 7, 14, 21, 28 or 35 l/s, which is never perfectly proportional to the overwhelmingly large area served [18]. A cluster of three to five sub-canals with varying size and number of people makes a ward. Ward leaders formalize informal arrangements and resolves disputes among the smallholders that may occur. Thabina irrigation scheme supports a few large-scale commercial and several subsistence farmers [19]. In summer between the month of October and February, Thabina scheme grows predominantly maize, groundnuts and butternuts. In winter season between May to August, the scheme grows various vegetables such as tomatoes, spinach, cabbages and many more.

A number of specific issues hold back the success of Thabina irrigation scheme. For instance, water from the Thabina River is pumped straight to the main canal to satisfy the communal irrigation water requirements without appropriate scheduling mechanisms. There is a need to have proper irrigation scheduling mechanisms to save water imminent losses. In a ward system of governance, all pumps are collectively owned, i.e. they belong to the scheme. This requires a strong dispute resolution mechanism when it comes to repair and maintenance of the pumps [20]. Irrigator communities and their volunteer leadership structures, usually in the form of elected schemes committees, find it difficult to enforce rules [18]. The average water availability is far below the requirements for cropping the full area, especially during the dry winter seasons. This calls for the need for real-time and efficient water management strategies. The capacity of the main system is big enough, but losses at field level are very high, which cause low overall efficiencies. Silts and other obstructions developing in the main canal because actual water flows in the main canal to be much less than the design capacity. Therefore, there is a need to develop IoT based irrigation management system that will address most of the Thabina Irrigation Scheme challenges.

3. Architecture of smart irrigation management system

A smart irrigation management system is responsible for predicting the water needs of the crops based on collected data and actuating the water flow according to the predicted needs without the involvement of human operators. It monitors various soil, water body, plants, and microclimate parameters using distributed sensors. The specific irrigation method (e.g., flooding, spray, drip and nebulizer) has impact on the decision of how to monitor effectively the water body as well as the actuation method. Weather is among the most important factors for estimating water requirements of crops. Unlike the developed world, rural areas of SSA lack networks of weather stations, which are crucial for acquiring key variables for irrigation decisions. For example, reference evapotranspiration, one of the necessary parameters for calculating the water requirements of crops, is affected by weather parameters. To compensate the lack of weather station networks, deployment of microclimate sensors around the farmland

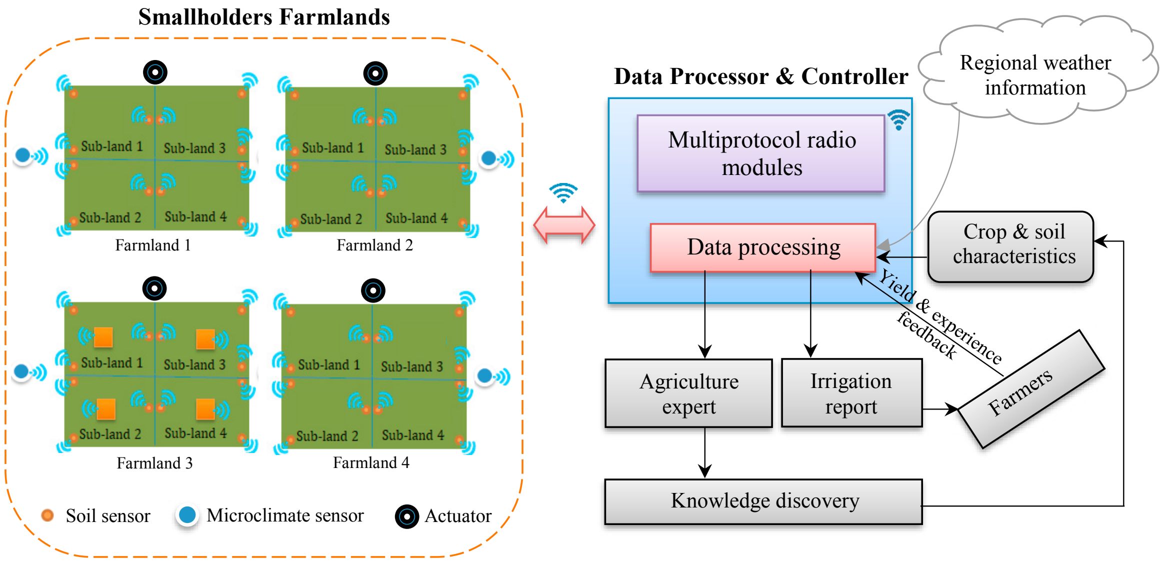

Figure 1 System-level architecture of irrigation management system

is considered in the proposed architecture of the irrigation system. In addition, the crops specific water requirement (amount and watering frequency) at different stages of their growth has to be taken into account by the irrigation management system. The inclusion of regional weather information as input to the data processing component besides the data from the microclimate sensors enable reliable near-future forecast of climate parameters that help to estimate the water needs of the crops with better accuracy. The irrigation management system performs intelligent data analysis and decides on the most appropriate actuation based on the analysis results. To accomplish these tasks the system needs various hardware components, such as sensors, actuators, low-power IoT nodes, low-power wireless communication modules, and computing device. The system-level architecture of the proposed irrigation management system is illustrated in Figure 1. Unlike the common IoT architecture, the collected data processing and decision-making are done locally instead of in remote cloud. This approach addresses the unavailability of broadband connectivity or the associated costs of remote computing infrastructure and connectivity. The supplementary inputs (regional weather information, information on crop and soil characteristics from agricultural expert, and farmers' indigenous knowledge) are key for improving the accuracy of the actuation decisions. The inclusion of expert knowledge on the specific crop and soil characteristics in the data processing is important to optimize the irrigation schedule without impacting the crop yield and/or depletion of soil nutrient. The incorporation of the feedback and indigenous knowledge from the farmers is necessary to further improve resource usage and acceptance of the system by the local community. The discovered knowledge along with the irrigation report helps the agricultural expert to better understand the characteristics of crop and soil under irrigation scheme.

4. Components and technologies of the architecture

4.1. Sensors and actuators

Sensors are among the key components that assist an IoT-based irrigation management systems to capture the dynamics in soil properties and microclimate conditions. They also provide information about the level of water in the storage, and health of the water infrastructure. As can be seen in Table 1, we categorized the required sensors into three. The commonly monitored soil parameters are temperature, moisture, pH and nutrients [21], [22]. Fast depletion of soil nutrients may happen because of overwatering. The type of soil material and density affects water infiltration in the soil and its retention capability. The moisture content of the soil is an indicator of the water retention performance of the soil. For optimal growth, each crop requires specific soil moisture content at different stages of their growth. The real-time soil moisture content and the knowledge of the crop specific moisture need at its various stage are among the required data for reliable irrigation decisions. The level of soil pH indicates the availability of nutrients and most plants favor pH between 5.5 and 6.5. Knowledge on the irrigation water's pH, temperature and conductivity is necessary as these parameters reveals the quality of the water [23]. The irrigation water quality has impact on the soil, such as soil salinity, water infiltration rate, and toxicity [24]. Salts in the water or soil reduce water availability to the crop. The salinity of water can be detected through conductivity measures. In addition, monitoring the water level, flow, and silt in the irrigation infrastructure is necessary in order to achieve efficient water usage.

Microclimate conditions are among the key factors for irrigation decisions. The commonly monitored microclimate parameters are air temperature, air humidity, luminosity, wind speed and direction, precipitation/rainfall, and atmospheric pressure [9]. Temperature and humidity has effect on the evapotranspiration of the water in the soil. High solar radiation combined with elevated temperature causes water loss from the soil. Detecting the level of precipitation and rainfall is necessary for deciding irrigation schedule that avoid overwatering. With the use of the data from the microclimate sensors along with the regional weather prediction, a more reliable short-term weather forecast can be achieved.

Actuators control the flow of water from the water infrastructure (e.g., pump, valve, sprinklers, and water gates) to the farm. Various types of actuators are available and the appropriate ones depend on the type of irrigation scheme. Irrigation systems are usually classified as flood, spray, drip and nebulizer techniques. The irrigation management system controls the operation of the actuators, such as when they should open the water flow, how long to keep them open, and the amount of water flow. Apart from the sensors listed in Table 1, we also envisage that biodiversity aware agricultural practices are important to consider in this case. This implies that sensors for detecting and reducing unnecessary use of chemical fertilizers need to be used in order to avoid negative impacts on the biodiversity in and around the farming lands [25].

Table 1 commonly monitored parameters

Category	Parameters	Measurement method	Example sensors on the market
Soil	Temperature	Generation & propagation of EM field	SM300, VH400
	Moisture	Conductivity between electrodes	YL69, FC-28, S-XNQ-04
	Nutrients	Metal oxide based gas sensors	1185 SunRom
	pH	High impedance voltage source	SEN-10972
Water	Conductivity	2-electrode resistance	CN0349
	pH	Adjustable potentiometer	SEN0169
	Temperature	Bus protocol with pull-up resistor	DS18B20
	Level	Ultrasonic	HC-SR04
	Flow	Hall effect turbine	Gems FT110 G3/8 – 0.5 – 5 l/min
Microclimate	Wind speed	DC motor RPM to voltage	SEN0170
	Luminosity	Light sensitive resistive measurement	BH1750, SN-500
	Atmospheric pressure	Piezo-resistive measurement	GY-BMP280-3.3
	Rainfall	Potentiometer	FC-37, YL-83
	Air temperature	Thermistor	DHT11, LM35, DHT22
	Relative humidity	Capacitive	DHT11, DHT22

4.2. Connectivity technologies

A number of low-power wireless connectivity technologies have been developed in the last ten years for IoT systems [26], [27]. These technologies differ in their communication range, complexity of the underlying protocols, network capacity and the adopted spectrum band. The communication between IoT nodes and gateway requires low-power wireless technologies in order to achieve long network lifetime with very limited energy source. For IoT nodes and actuators that are deployed in farms, long-range connectivity technologies are preferred over short-range ones since repeater nodes are not required to cover large areas. Among long-range technologies, LoRaWAN [28], [29], Sigfox [30], and NB-IoT [31], [32] are most commonly employed due to the availability of well-established development platforms. NB-IoT requires cellular infrastructure and involves subscription fees, which may be costly for the smallholder farmers in the long run. Similarly, Sigfox technology also has a subscription fee that varies depending on the amount of exchanged data. Unlike NB-IoT and Sigfox, LoRaWAN is fully open standard, does not require subscription fees, its devices are less costly with a potential for a large user community. Its features including security of LoRaWAN has been studied extensively [33] [34]. Thus, LoRaWAN is chosen as the connectivity technology for the proposed irrigation management system.

In IoT applications, the connectivity among gateway, remote cloud and user usually involve a broadband communication network. However, in most rural SSA countries, broadband connectivity is either very costly or non-existent. In addition, cloud services entail additional running cost to the irrigation management system. To address these issues, the proposed IoT architecture avoids the need for broadband networks and cloud services using local processing and storage at the gateway. GPRS/GSM communication is considered for the reporting to the farmer and access to the regional weather information. Affordable broadband technologies such as the TVWS, being tested in South Africa and globally, can provide both backhaul and last mile wireless connectivity for agricultural IoT based systems placed remotely at different locations [35] [36].

4.3. IoT nodes

As depicted in Figure 1, IoT nodes (consisting of sensors, radio module, processing unit, power source and management) have to be deployed in the farmlands and water body/infrastructure. There exist a variety of low-cost development boards, such as Arduino (e.g., UNO, Pro Mini, nano, MEGA), Intel Galielo and Gen-x that can be employed for the proposed irrigation management system. It is also possible to assemble customized boards from off-the-shelf components that fulfill the specific requirements of the system. The main considerations when selecting/designing IoT nodes are cost, required supply voltage, memory, processing speed, type of I/O interfaces (e.g., analog, digital, SPI, and I2C), number of I/O ports that allow interconnecting two or more sensors besides the radio module and supported programming development environment. The more the number of I/O pins, the better as such boards are able to host more sensors, leading to cost savings. For example, it is cost-effective, if all the soil monitoring sensors (soil moisture, temperature, pH) and LoRaWAN radio module can be interconnected in a single IoT node.

4.4. Data processor and controller

Unlike other IoT systems with separate back-end resources (e.g. network servers, and cloud services) for data processing and network management, in the proposed irrigation management system data processing, actuation decisions and other network related configurations/management are performed locally at a dedicated device near to the network. In the context of conventional IoT architecture, the dedicated device replaces the gateway with more computing and decision responsibilities instead of merely protocol translation and forwarding the data collected by the IoT nodes to the edge/cloud. We name this dedicated device Data Processor and Controller. The data processor and controller is responsible for: i) sensors data and knowledge (indigenous and expert) collection; ii), network configuration and management including over the air activations of IoT nodes and security configuration; iii) performing data analysis and knowledge discovery; iv) actuation decisions and sending commands to the actuators; and v) communicating irrigation report to farmers through 2G/3G texts. It supports two radio protocols, LoRaWAN and 2G/3G GPRS. The data from the IoT nodes are collected through LoRaWAN while the reporting to the farmers and collection of regional weather data from weather servers are carried out through 2G/3G GPRS. Crop and soil characteristics are added to the database of the data processor and controller through wired connection. The discovered knowledge is also extracted periodically through wired connection. The main components of the data processor and controller along with interactions among them are shown in Figure 2.

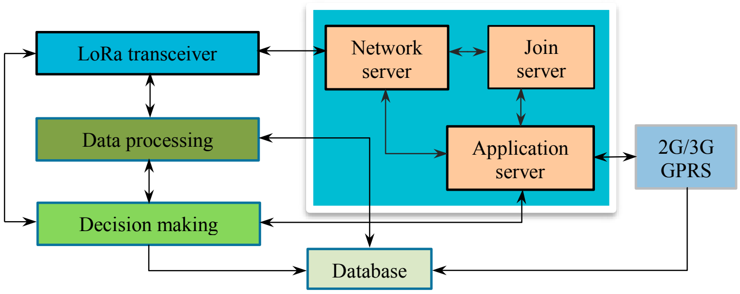

Figure 2 Main components of data processor and controller

4.5. Green energy source

Energy efficiency of the overall network is important because of the limited availability of power grids in rural SSA regions. The architecture needs to include energy harvesting technologies (e.g., solar and kinetic) not only for longer network lifetime but also for the sustainability of the irrigation system. The recent past has witnessed an improved battery life, however the need for periodical maintenance and wastes of large-scale deployments remains a limitation [37]. As a result, green energy sources, which are capable of harvesting energy from the environment (e.g., mechanical vibration, temperature gradients, natural/artificial light, and pipes with air/water fluid), must be explored for self-powering IoT nodes of the irrigation management system.

In the context of the irrigation management system in rural SSA, energy harvesting from light, wind, and water sources are preferred options. The energy from sun/artificial light is inexhaustible, renewable, clean and ubiquitous. Using photovoltaic techniques, up to a power density of 15 mW/cm^2 can be harvested and accumulated in battery storage and management system of the proposed architecture to power mainly data processing and controller subsystem efficiently and effectively [38]. As the wind flows through the actuators such as pumps and sprinklers, wind energy can be converted into mechanical energy, then into electromagnetic and finally into electrical energy. Accumulated energy can self-power actuators and sensors at the farmlands. The electromagnetic wind generators are reliable and have small mechanical damping effect at low wind velocities. As the water flows through the irrigation tunnels, kinetic energy is produced due to the water pressure fluctuation. This kind of harvester converts hydraulic kinetic energy into electrical energy by mechanic and electromagnetic conversions [39]. Wasted mechanical energy that exists in the environment of irrigation systems including the mechanical rotation of water pumps, wind blowing and an overflowing water waves can be efficiently captured to generate useful electric power for self-powered IoT wireless sensor devices. To obtain sufficient power to implement self-powered or maintenance-free devices, multiple types of energy harvested by hybrid technologies have become the recent trend [40].

5. Data analysis

Efficient irrigation management system achieves less water consumption while contributing to increased crop yield. Determining optimal irrigation point is challenging due to the complex interdependencies among several static (e.g., farmland elevation and slope) and dynamic (e.g., soil fertility, microclimate conditions, and fertilization) parameters. To reach at a reliable and sustainable irrigation decision, holistic analysis of the involved soil, microclimate and water parameters along with the specific characteristics of the soil and crop, and farmers' indigenous knowledge and feedbacks is necessary. By applying intelligent data analysis on collected data, values of several parameters (e.g., soil moisture, air temperature, and relative humidity) can be predicted and the water needs of the crops can be determined more precisely. The use of such type of intelligent analysis optimizes the use of water and helps to improve the crop yield because it avoids both over- and under-watering of the farmland.

Researchers proposed various types of data analysis algorithms for irrigation management systems, such as Majority Vote Algorithm (MVA), Adaptive Neuro Fuzzy Inference Systems (ANFIS), and fuzzy logic. The features of some of the proposed algorithms are presented in Table 2. As can be seen from Table 2, none of the algorithms consider the water related parameters in their analysis. Parameters of water quality, supply, and infrastructure health are important for informed decision making that enable autonomous operation of the irrigation system. The machine learning based algorithms have the capabilities to capture complex interdependencies among the parameters, which may lead to knowledge discovery. This is beneficial to establish key indicators that inform agricultural researchers and experts about the performance of irrigated farms. Some of the example indicators are the average water sensitivity of the crop, the reliability of the water resource and its infrastructure, and crop health score.

In the context of the proposed irrigation management architecture, resource efficient algorithms are preferred as the data processing is performed locally instead of resource rich cloud computing environment. It is known fact that the results of any intelligent data analysis depends on the considered parameters, the size of the data, the employed data optimization technique and the suitability of the employed algorithms for the problem. To ensure the veracity of the analysis results, in-depth study of the algorithms suitability and the involved parameters as well as close cooperation with agricultural experts are mandatory.

Table 2 Features of some of the applied data analysis algorithms for irrigation management

Algorithm type	Experimental period	No. of Input Parameters	Included Parameters			Output/ Predicted parameter
			Soil	Climate	Water	
Fuzzy logic [41]	2 weeks	3	X	X	-	Motor status
Neuro-Fuzzy [42]	14 weeks	4	X	X	-	Soil moisture
ANFIS [43]	24 weeks	11	X	X	-	Irrigation pattern in minutes
MVA [44]	NA	1	X	-	-	Motor on/off

6. Conclusions

Resource-efficient IoT architecture that monitors soil, microclimate and water parameters and performs autonomous actuations was developed for smart irrigation management in SSA. Indigenous farming and expert knowledge, regional weather information, crop and soil specific characteristics are also taken into account for informed-decision making by the irrigation management system. In the architecture, data processing, network management and irrigation decisions and communication to the farmers are performed locally without the involvement of back-end servers, thus avoiding the need for long-haul broadband connectivity and cloud services. The use of green energy harvesting system reduces the running costs of the management system, making it more applicable in rural SSA areas where power grids are unavailable. The paper proposes an intelligent data analysis of the collected data, to help discover case specific knowledge that can ultimately lead to improved irrigation management. Therefore, the proposed IoT architecture has the potential to contribute towards improving traditional agricultural practices and ensure food security in SSA. In our future work, the developed architecture will be implemented and tested in the three case study irrigation schemes in Ethiopia, Kenya and South Africa with intelligent data analysis based on machine learning.

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