Scaling Precision Agriculture in West Africa Smallholder Irrigation and Water Management Systems

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Abstract
The advent of precision agriculture (PA) is changing global agricultural productivity; through underlining principles that ensure inputs required for the management of soil, water and crop agronomy are supplied precisely across the field landscape resulting in optimum yield. Smallholder irrigated crop production across West Africa accounts for significantly more areas in Burkina Faso, Ghana, Mali, Nigeria and Senegal than the conventional large irrigation schemes. Scaling the practice of PA specifically in large scale commercial and smallholder irrigation systems faces different challenges thus requiring different approaches. Distinction is made between large scale and smallholder irrigation with farm holdings between 0.1 to 1.0ha., with farmers' technical and financial capabilities being major critical factors limiting the scaling of irrigation technology in West Africa (WA). Scaling PA in WA smallholding system using basic tools like TDR moisture meter, wetting front detector, Chameleon sensor and simple soil test kits are required to guide irrigation scheduling in smallholder irrigation system; enabling efficient water use and improved crop yield. The use of these tools is still very low across WA with only few farmers in Ghana trained in the use of wetting front detector and Chameleon sensor. There is need to scale down and digitalize soil information from regional project like AfSIS and make it available to smallholder farmers to improve on fertilizer usage. Scaling these tools for efficient deployment of PA in irrigation systems at smallholder scale will involve awareness, capacity building, and a business model that make such tools affordable for small holder farmers.

Keywords: Precision agriculture, West Africa, Irrigation, Smallholder, AfSIS

Introduction

The need to ensure that inputs in crop production system are efficiently allocated, utilized and deliver maximum benefit necessitated the concept of precision agriculture (PA); which refers to an integrated crop management system that attempts to match the kind and amount of inputs with actual needs of crop for small area within a field (Davis et al., 1998). Variability in soil properties specifically within agricultural field are well known. Farmers had attempted divers form of site-specific crop management although the idea of using electronic information technology to automate that process is relatively recent (James and Bruce, 2019). According to Whelan and MacBratney (2000), PA is an attempt to match resource application and agronomic practices with soil and crop requirements as they vary in space and time within a field. According to Ncube et al., (2018) a recent addition to the principles of PA is precision irrigation, which focuses on 'differential irrigation' treatment of field variation as opposed to the 'uniform irrigation' treatment that underlies traditional irrigation management. Precision irrigation saves water and reduces costs by applying the optimum amount of irrigation to individual plants or small areas within a field, while the traditional practice takes a 'whole field' approach (Smith and Baillie 2009) in which specific amount of water is given to the entire field irrespective of soil moisture variation at the time of irrigation. The major benefit of PA is in substantial savings of agricultural inputs, as these are applied as needed in the cropping systems (Takacs-Gyorgy et al., 2013; Ncube et al., 2018), offering benefits for yields, profits and the environment (Silva et al., 2007; James and Bruce, 2019). The PA including precision irrigation comes with investment in machinery particularly when deployed at the conventional commercial or at the scale beyond the smallholders. Although, studies have shown that farmers may consider this cost too expensive (Reichardt and Jürgens, 2009) nevertheless, PA can save up to 60% in agro-chemical and 30% in mineral fertilizers (Ncube et al., 2018). Another major advantage of PA is what Isioye (2013) observed as the cyclic nature of the processes inputs and yield measurement resulting in variable rate application. The operation of PA depends on the use of control systems of crop, soil and positioning sensors, machine controls responsible for variable rate application, computer-based systems. Conventional PA requires integration of three elements: (1) positioning capabilities (currently, global positioning system or GPS) to know where equipment is located; (2) real-time mechanisms for controlling nutrient, pesticide, seed, water or other production inputs; and (3) databases or sensors that provide information needed to develop input response to site-specific conditions (Evandro et al., 2007; Abdusalam, 2019). This paper examines the level of PA practices in the smallholder irrigation systems in West Africa and suggest the levels at which PA could be deployed.

Materials and Methods

This work present, firstly a review of literatures on PA practices in irrigation and water management among the smallholder farmers in West Africa. A distinction is made between conventional PA practices typically deployed in large farms with machine control equipment as against field equipment and tools used in smallholder systems to guide specific field operations. Secondly, the interactions with smallholder farmers in Burkina Faso, Ghana, Mali and Nigeria, in relation to their approach to irrigation and water management and how much of PA principles and practices have been integrated.

Precision irrigation agricultural practices

The deployment of precision irrigation in public large and commercial irrigation schemes were considered. The following were considered in relation to application of variable rate technolgoies and its components:

- Irrigation methods and extent of precision irrigation practice
- Equipment types deployed
- Knowledge and capacity to efficiently use the systems
- Constraints and limitation to the scaling of the precision irrigation agricultural practices and how those constraint could be overcome

The study identified technology access related issues to improve the the deployment of precision irrigaiton practices in the West Africa farming systems.

PA related technologies in smallholder irrigation systems

The observations and evaluation present were conducted using field survey, stakeholders' meetings, innovation platforms and personal interviews. These were part of different agricultural water management and irrigation extension programmes at different times. The experiences of the farmers in smallholder systems confirms the imperativeness of deployment of precision agricultural practices to enhance productivity of the farming systems. The following were the key issues focused on in the various meeting and evaluation of smallholder irrigation works.

- Size of farm holdings
- Irrigation practices (types and methods)
- Irrigation equipment
- Constraints to increased irrigation practices
- Knowledge and capacity

The investigations included efforts of the farmers to ensure high productivity in water application (irrigation schedule practices) and nutrient application methods. The contribution of these strategies to the principles and practices of precision irrigation were identified.

Results and Discussion

PA in West Africa

The conventional PA is gradually gaining recongnition across the Africa agricultural landscapes. According to James and Bruce (2010), various components of a conventional PA system may be available, the practice is not yet feasible and indeed negligible within the smallholder systems. The components required to ensure variable rate application are not yet available to farmers at the smallholder scale either in the general agricultural practices or for irrigation in the countries of West Africa (Abdusalam 2019).

Agricultural water management and irrigation system across West Africa

Irrigation practices across west African countries falls under 3 major categories: formal public irrigation schemes, commercial large scale schemes and informal smallholder private irrigation or farmer led irrigation practices. These structures were observed in Ghana, Nigeria, Mali, Burkina Faso as well as in other sub-Saharan countries (Namara and Sally, 2014).

Public large irrigation schemes

The large schemes in Nigeria, Ghana, Mali and Burkina Faso are managed by a specific agency of Government (Table 1). The main approach has been to share the large schemes as small holdings among farmers who produced in the crops of their choices. With the exception of Mali, which has equipped over 40% of her irrigation potential, the actual area under irrigaiton in most other West African countries is about 12% (Namara and Sally, 2014).

Table 1: Irrigation potential in selected West African countries

Country	Irrigation Development Agency	Estimated Potential irrigated area (1,000ha)	% of potential area equipped for irrigation
Burkina Faso	Ministry of Agriculture and Irrigation Development Burkina Faso (Ministère de l'Agriculture et des Aménagements Hydrauliques)	165	15.2
Ghana	Ghana Irrigation Development Agency	1900	1.6
Mali	Office Du Niger	566	41.7
Nigeria	River Basin Development Authorieties	2331	12.6

Source: (Namara and Sally, 2014)

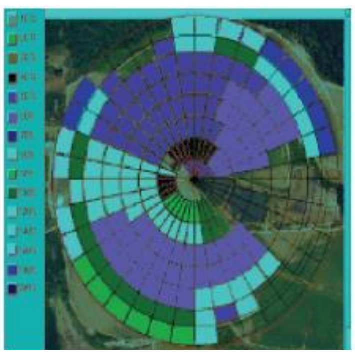
In the public large schemes, irrigation water management are difficult to be synchronized among the water users therefore, most of the schemes uses the fixed interval irrigation scheduling, wherein, water is supplied at specific intervals of 5 or 7 days and the farmers have to irrigate irrespective of their specific field. Achieving irrigation scheduling or precision water application based on specific field need is difficult in this scheme. Also, there are no incentives for water saving practices since many of these schemes across West Africa runs as public enterprises where farmers hardly pay what is commensurate to the volume of water use (Yanbo et al., 2019). This has been observed in Ghana, Mali and Burkina Faso (World Bank 2007).

Commercial irrigation farms

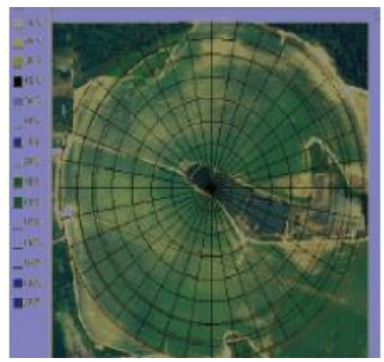
Commercial private irrigation farms are becoming a major part of irrigation development efforts in West Africa. These have been observed in Burkina Faso, Ghana, Mali and Nigeria where rice, wheat and sugar cane cultivation are taking the centre stage. A number of these large commercial farms use sprinkler and centre pivot systems; these irrigation methods of have good potential for the integration of PA infrastructure in their systems. The advantages in the use of PA with these equipment have been identified by Best and Duke (2001). The integration of variable rate technology which could be possible with the centre pivot irrigation system (Figure 1), is not feasible with the basic equipment and irrigation methods common (basin, furrow, hose sprinkling) in the smallholder private irrigation systems (James and Bruce, 2010).

Smallholder irrigation practices

Outside the large public irrigation schemes across West Africa, there have a been a long-standing practice of crop production off season in the inland valleys, flood plains and within landscapes with shallow groundwater. These are farm holdings between 0.2 – 1ha (Namara and Sally, 2014). Often, irrigation scheduling and efficient water appication methods are not quickly adoptable in the smallholder farmings system. This is because, the reason for the extra cost of equipment to better manage water use are not 'convincing' enough to farmers.



a) Map of application of water based on crop requirements in the different parts of the area under irrigation.



b) Example of aerial view and subdivision of irrigation areas based on the variable rate application system installed.

Figure 1: Center pivot variable rated irrigation system (Source: Best and Duke 2001)

Plausible precision irrigation practices in smallholder irrigation systems

Inclusion of conventional PA principles, equipment and practices in smallholder irrigation practices are very remote. Smallholder irrigation farmers are often concerned about supplying water to meet the crop needs, and this is done without measurement or control. Precision irrigation may not be easily integrated in the smallholder irrigation except some practices that can ensure precise and efficient water application are adopted. Few practices that are adaptable to smallholder system with potential to improve productivity of irrigation include:

- Irrigation scheduling - contrary to what obtains in the public irrigation schemes, improving irrigation scheduling will allow water to be applied when crops need it.
- Efficient irrigation methods - to improve on PI in smallholder system, the immediate approach may include deploying more efficient irrigation methods, such as sprinkler and drip irrigation systems, leading to increase precise application of irrigation water.
- Soil moisture depletion management - smallholder irrigators often depend on their personal judgement, experience and observation of soil and plant stresses to determine when to irrigate; the deployment of small field level moisture monitoring tools such as Time Domain Reflectometry (TDR) Probes, Chameleon Sensor (Stirzaker, 2005) and Wetting front detector (Stirzaker, 2003) will go a long way in monitoring moisture depletion and ensuring precise water application (Ncube et al., 2018). This tool has great potential to help smallholder farmers in the guide against over irrigation and ensuring application of appropriate depth of irrigation water.

Soil nutrient monitoring, application and PA practices

The novel work of the Africa Soil Information System (AfSIS) project provided spatial predictions of soil macro and micro-nutrient contents across sub-Saharan Africa at 250m spatial resolution and 0–30 cm depth interval (Hengi et al., 2017); has great potential to assist in making reliable and precise nutrient levels available for major macro and micro nutrients available to guide application within the smallholder fields. The information if made available at the farm scale level to farmers for site specific nutrient application to crops and field will be a step higher in the deployment of PA in Africa.

Conclusion

There is need to scale down and digitalize soil information from regional projects like AfSIS and others and make them available to smallholder farmers. Scaling these tools for efficient deployment of PA in irrigation systems at smallholder scale will create awareness, capacity building, and a business model that make such tools affordable for small holder farmers.

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