Digital Technologies for Tailored Agronomic Practices for Small-Scale Farmers

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Abstract. The rapid widespread of digital technologies over the past decades has been changing the way to deliver agricultural extension services to farmers in rural areas in Africa. This shift is driven by the development of digital agricultural advisory initiatives. They provide knowledge and practices improvement to farmers in order to increase their production and, thus their income. However, although they are promising, these initiatives often have a limited impact on agricultural practices or farm-gate prices for three main reasons: (1) the advice is too general and doesn't match local farming processes, (2) the change of scale, due to in-person dependent agricultural extension efforts that are expensive and fraught with accountability problems, and (3) finally its cost. In this context, it becomes interesting to investigate how to transform the widespread adoption of mobile technology to real agricultural development opportunities. This paper presents a tool-supported approach that overcomes these difficulties. In our approach, agronomic extension services are science-based, locally customized and individualised at plot level. Advice is delivered at the appropriate time during the agricultural season by an automated crop management plan designed by local extension service support. The advice is then specific, and the extension officers can reach out to many more farmers than solely through field visits. Finally, as the implementation service is cloud-based, costs are reduced.

Keywords: AgTech · Agronomic extension services · digital tools · Smart agriculture · Smallholder farmers

R. A. Saeed et al. (Eds.): AFRICOMM 2022, LNICST 499, pp. 149–159, 2023.
https://doi.org/10.1007/978-3-031-34896-9_10

1 Introduction

1.1 The Context

Sub-Saharan Africa faces a dramatic dilemma, its current population of 1.1 billion tends to achieve 2.1 billion by 2050 and food production rises in a slower rate and is below the world average. Eastern and Western Africa respectively had 884 and 674 kg/ha in 1960 and the World's yield average was 1353 kg kg/ha. In 2019 the world's average achieved 4113 kg kg/ha, but both areas in Africa reached just 2027 and 1269 kg kg/ha. This explains why 17.6% of Africa's population suffered from undernourishment in 2014 and in 2019 it reached 19.1%. Despite they represent more than 60% of the sub-Saharan population and 23% of their countries' GDP, smallholder farmers are those that mostly suffer from food insecurity. It is essential to reduce poverty and meet the growing food demand faced with climate change.

1.2 An Underperforming Agricultural Sector

Some of the reasons why the agricultural sector is underperforming in Subsaharan Africa - and most of these constraints are shared by a vast majority of rural poor in Gabon - are low quality inputs (seeds, fertilizers, ...), lack of access to agronomic knowledge and best practices, illiteracy, fragmented markets, age of farmers, the rural exodus of young people, and the impacts of climate change [2]. As a result, Gabon imports almost 90% of the food consumed in the country. Another aspect of the problem is that 80% of local production in Gabon is done by smallholder farmers in rural areas, who also bear the burden of domestic chores and are responsible for feeding their families. Without assistance, their average food production can achieve one ton per hectare, but mostly of them only get few hundred kilograms. One of the biggest challenges they face is the lack of individualized agronomic monitoring and guidance, due to the limited amount of agricultural experts, where the ratio between an extension officer and farmer is approximately 1:1000, a common case in many Sub-Saharan African countries.

1.3 Improving Agricultural Extension Services to Boost the Local Production

As widely reported, improved extension service and proper use of agricultural information in developing countries can enable farmers to adopt and/or adapt to new and improved practices that enhance yields and incomes [13]. This can be achieved by adapting the pedagogical model, using information and communications technology (ICT) to reach farmers directly with more tailored and timely information, incentivizing trainers based on learning outcomes, and leveraging social networks for last-mile information delivery. In fact, extant literature shows that access to accurate agronomic information can lead to change and engender progress in the agricultural sector by empowering farmers with the ability to make informed decisions pertaining to value-adding agricultural production [7–10,12]. In support of this point, several experimental studies [1,3,6] show that mobile -based extension information improves farmers' knowledge and self-reported adoption or planned adoption of recommended agricultural inputs and practices [4,14–16]. This clearly implies that if one want to see substantial development in the agricultural sector [5], we have to ensure farmers' access to timely, reliable, and field specific relevant agricultural information. As such, prosperity in the sector significantly depends on smallholder farmers' ability to not just access and acquire reliable agricultural information but also to use them accordingly at the right time and at the right location [11]. Lessons learned from our field with African farmers suggest that the knowledge provided to the farmer needs to be individualized down to the level of his particular plot of land for best accuracy and relevance to the local context. It also needs to be generated through dynamic crop management planning and delivered via digital tools for scalability, and to get around the lack of available experienced agronomists locally. This paper presents a tool-supported approach that overcomes these difficulties. In our approach, agronomic extension services delivered to farmers are science-based, locally customized and individualised at the plot level. Advice is delivered at the appropriate time during the agricultural season by an automated crop management plan designed by local extension service support. This solves both the relevance of the advice, which is then specific, and the problem of changing scale, since the extension officers can reach out to many more farmers than solely through field visits. Finally, as the implementation service is cloud based, costs are inevitably reduced. The paper is organised as follows. Section 2 presents the big picture our method for elaborating plot level tailored advice. Section 3 introduces the case study used to illustrated ideas presented in the paper. Section 4 illustrates the application the proposed methodology on the case study. Section 5 concludes and introduces some future works.

2 Proposed Method

2.1 General Architecture of the Proposed Method

The assessment presented in this paper is based on research conducted in various smallholder landscapes, visiting hundreds of smallholders, cooperatives and agribusinesses in sub-Saharan Africa; and we have managed to articulate the work around four dimensions of work, namely:

1. **Step 1**: Understanding the local context and collecting data (soil profiles, observations, actual yields, farmers, traditional practices in place, crops, etc.), including the delimitation of plots. The types of agricultural activities are one of the main factors responsible for variations in the information needs of rural smallholders. It is necessary to identify this precisely in order to design or adapt the tools properly.

2. **Step 2**: Categorization of farmers' information needs according to context (situation-specific, internally or externally driven), frequency (recurrent or new need), predictability (anticipated or unexpected need), importance (degree of urgency) and complexity (easily solved or difficult) in order to be able to design a tailored agronomic extension service easily adaptable on particular context or location.
3. **Step 3**: Integration of captured needs in the Platform, and their coupling with a mobile phone communication service for scalability, and
   - to get around the lack of available experienced agronomists locally and
   - to reach out to many more farmers than solely through field visits, especially in situations where the extension officer-to-farmer ratio is high (approximately 1:1000), a common case in many Sub-Saharan African countries.
4. **Step 4**: Automatic dissemination of agronomic advice through the automatization of technical itineraries to monitor farmers' activity and send reminders of interventions to be carried out via simple text messaging (sms) in real-time.

Figure 1 illustrated the general framework of the implementation of the proposed method.

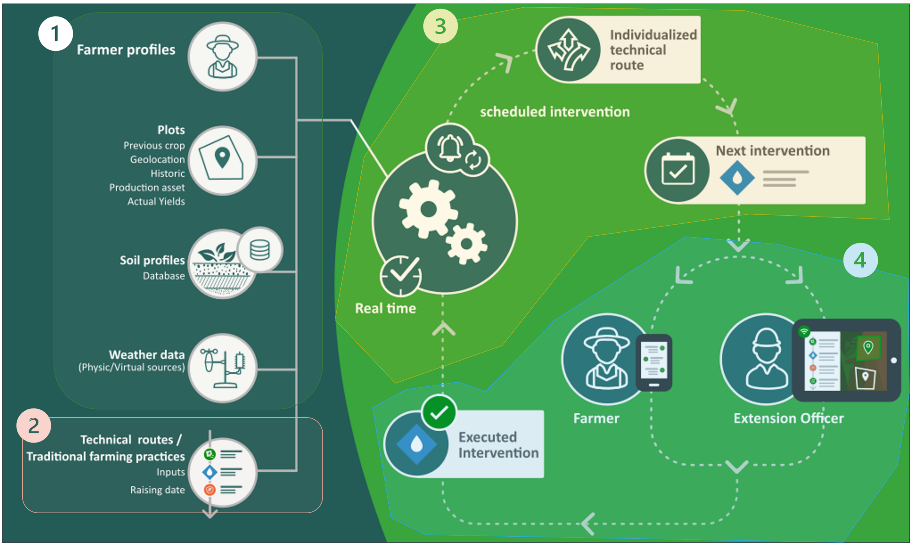

Fig. 1. The big picture of the framework of the digitalization of the proposed method

2.2 Proposed Model Stages

From the framework presented in Fig. 1, the implementation of our method results in the architecture presented in Fig. 2. In this figure, the farmer receives recommendations from the Platform via simple text messages. Literate farmers can register all actions they perform by sending text messages (through formatted commands). This allows the Platform to get up to date field information, which is then made available to the Extension Officers and authorities via actions' timelines and dashboards. As the platform receives farmers' feedbacks, it combines them with already provided information on what has been done till now to calculate appropriate actions that can be applied next. The use of mobile phones in a two-way communication between farmers and the Platform allows real-time monitoring and easy collection of field data. This approach gives an added value to the Extension Officer whose role is not only to control the compliance of farmer's actions anymore, but also to act in a proactive way by giving explanations and precise recommendations all along the crops cycle.

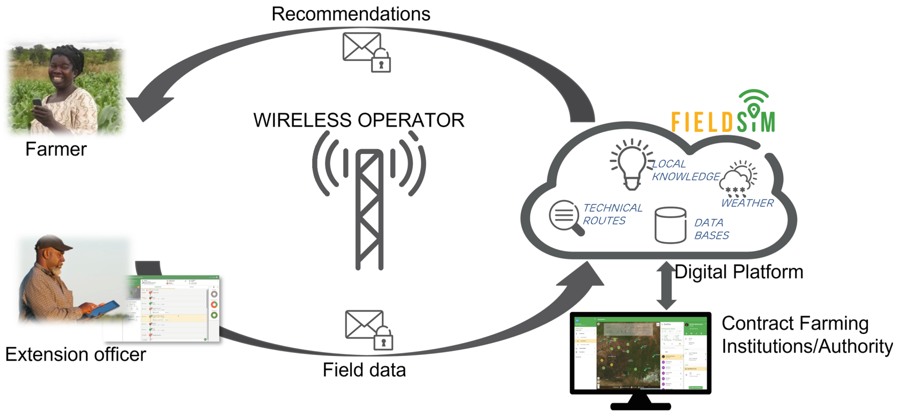

Fig. 2. Architecture of the proposed method

3 The Case Study

The objective is to bring small-scale coffee/cacao producers into a concrete process of increasing their agricultural production at all in a sustainable and environmentally friendly way, by making the best use of subsidized nutritional inputs. Gabonese government hopes to have a knock-on effect on the food chains through a parallel development of the coffee/cacao to guaranteeing the country's food autonomy with a controlled impact on the environment. In particular, the project will allow small farmers who today have difficulty ensuring their food autonomy, to make a leap forward on innovative and sustainable cultivation practices, by benefiting from digital technologies, climate-smart practices and

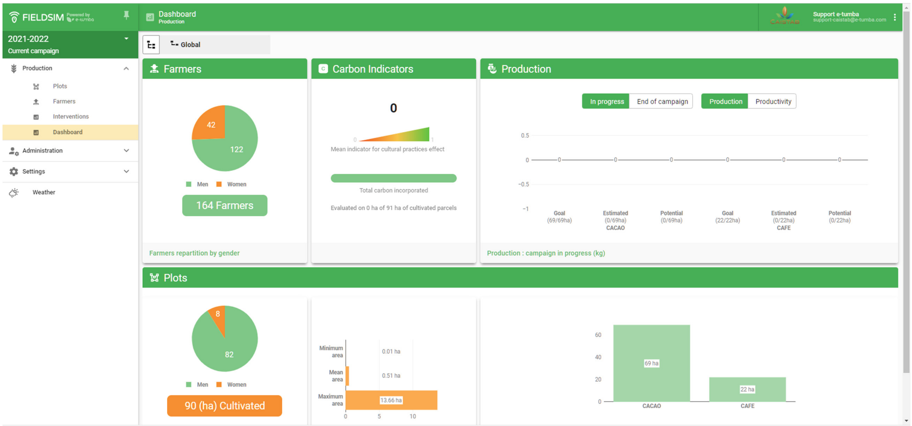

Fig. 3. Sample Dashboard view

distribution of information adapted to the managers of the sector up to the personalized agricultural advice to small producers. To achieve this objective, we start by collecting reliable and up to date field data in the Region of Ngounie (South of Gabon). These data have then been analysed, categorized and integrated into our Platform FieldSim (see Figs. 3 and 4). The results of this first study is presented in the next section.

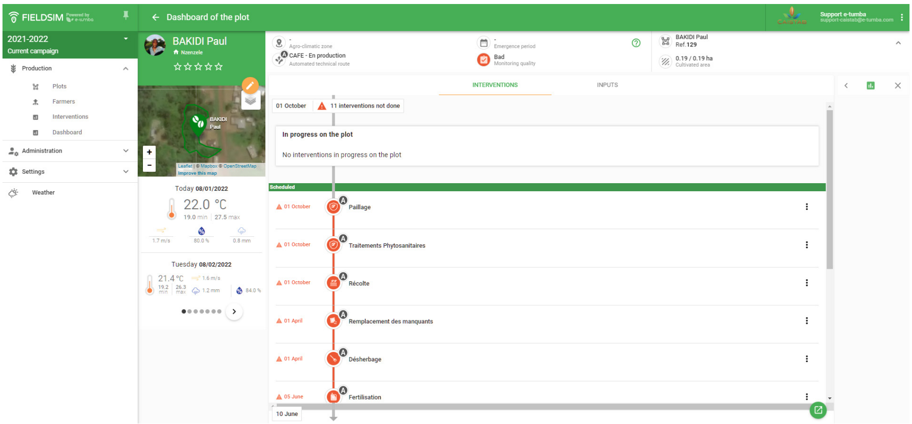

Fig. 4. Sample interventions's Timeline

4 The Application on the Case Study

With the data collected in FieldSim we can propose a visualisation of this data to provide a wide view of the context, helping the decision making process. Business

Inteligence tools are a way to provide quick and easy visualisations, with filters and agregations. We used *PowerBI*® from *Microsoft*® to get the graphs and maps. We grouped farmers and their plots per crop and we notice that there's an inverse relationship between farmers and surfaces, in Ngounié there are less cocoa farmers, but their surface are larger than coffee farmers Fig. 5. Since we collected the plots' borders and calculated the area, we can plot their locations and see their geographical distribution (see Fig. 6).

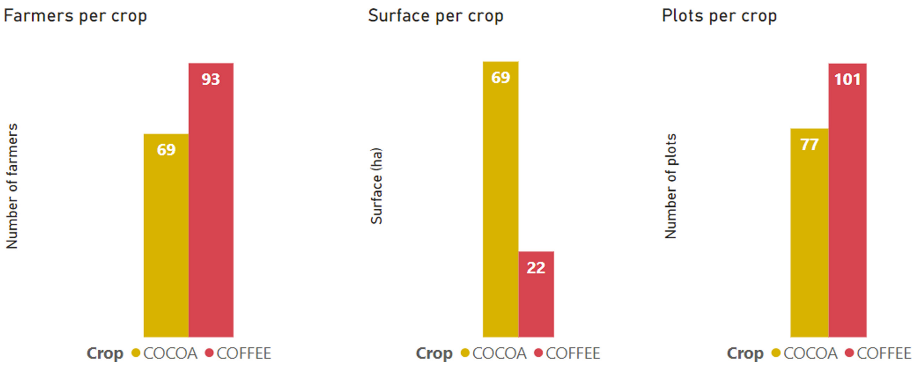

Fig. 5. Relationship between farmers and surfaces

In Fig. 7, the farmers that have more than one plot, we see how many of them are just cocoa and coffee farmers. From the 15 farmers that have more than 1 plot, there are 3 farmers that have both crops.

We also asked their ability to read to see if it would be a difficult part of the SMS system implementation. True are those who answered that can they read, blank are those that it wasn't assigned and False that they can not read (Fig. 8). We also show by their age, 0 (zero) represents [0,20[; 20 - [20,40[; 40 - [40, 60[; 60 - [60, 80[; 80 is above 80. That way we can better develop strategies to target farmers. Most of farmers from Ngounié know how to read and they are between 40 to 60 years old.

We also digitalized the most important agricultural practices (see Fig. 9) that farmers apply in their orchards, this way the responsible from a zone can track farmers practices and send advice according to the practice in the right time for it. Eight cropping management plans were designed for cocoa and coffee, seedling, implantation (year 0), before production (year 1–3), production (year 4-later). To each practice there are SMSs that were previously written, if needed they can be written in a local language and sent to farmers assigned to this language. In Gabon, people are alphabetized in French and local languagesdon't have a formal

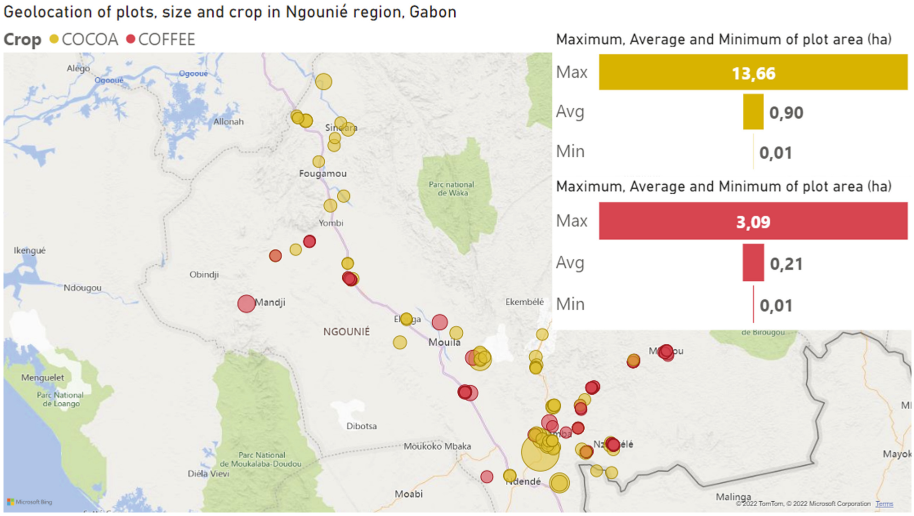

Fig. 6. Geographical farmers distribution according to the plots and surface

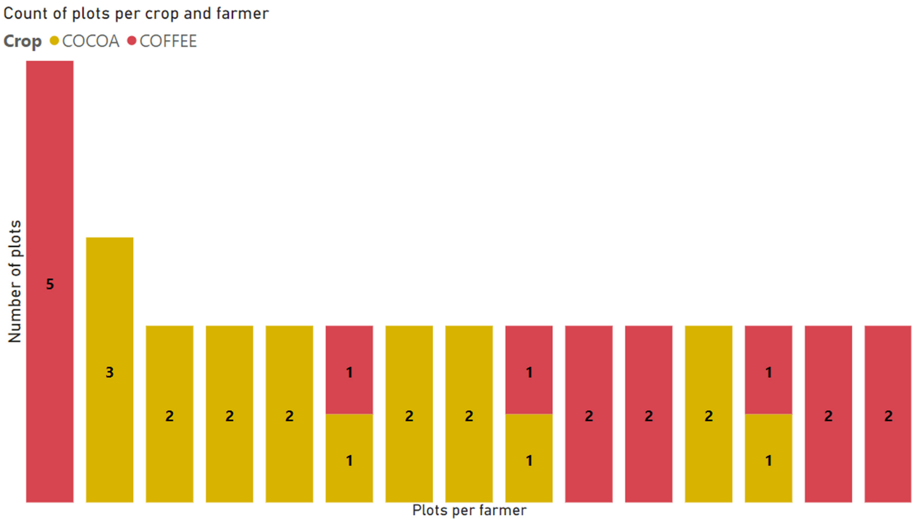

Fig. 7. Average number of plots cacao/coffee per farmers

writing and are not taught in schools, which disfavours the implementation of SMS in local languages in Gabon, in other African countries it is possible.

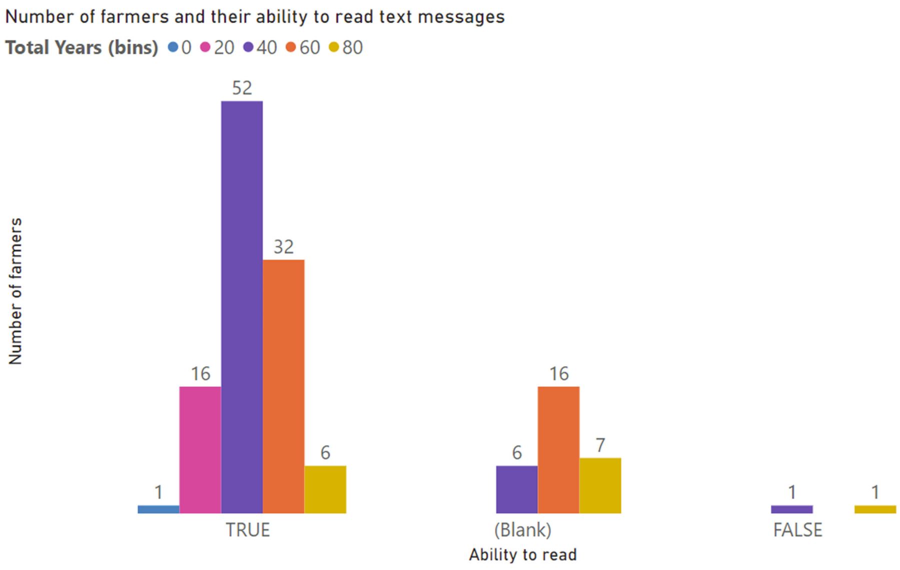

Fig. 8. Number of farmers and their ability to read text messages per age

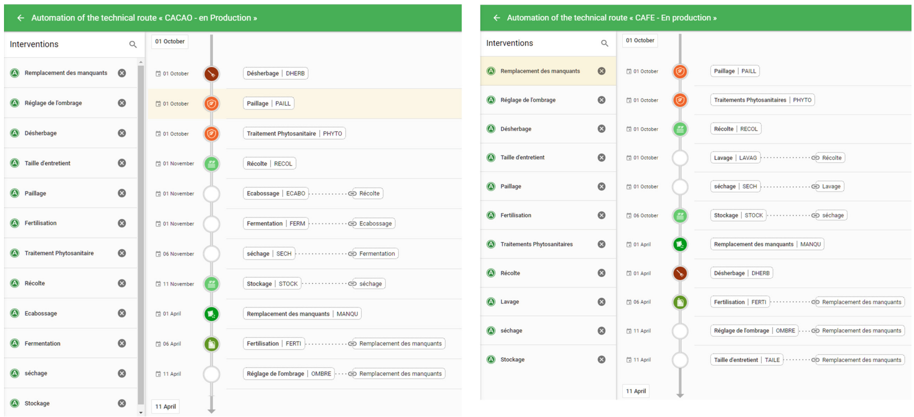

Fig. 9. Digitalization of cacao (left) and coffee (right) technical routes

5 Conclusion and Future

The use of digital tools enables to collect and visualise data to have a wide view of farmers and their context. They help to provide insights in how to drive agricultural advice and the implementation of an SMS bulk system. Farmers were grouped according to their age, ability to read, location, surface and crop it will be possible to design the SMSs to be sent according to their needs along the season. The next steps consists in collecting farmers practices, mainly their execution dates and then correlate to soils data from the ISDA soil map, crop models and the yields at the end of the season. The presentation of the first results to the country's authorities raised a great interest. The data collection, analysis and the digitalization of agronomic extension services, which was initially planned in 4 regions (Estuaire, Haut-Ogooué, Ngounié and Woleu-Ntem), will be extended to the whole country.

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