Realtime digital soil fertility data for fact-based fertilizer selection by smallholder farmers

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Introduction

Africa is facing an escalating soil fertility crisis and without immediate interventions the continent continues to lose over US$4 billion per year worth of nutrients (Africa Status Report, 2016). To halt and revert the trend of continuous depletion of the farmers' most precious resource, the current practice of farming needs to be revisited. Increasing productivity whilst decreasing soil fertility decline demand for balanced fertilization. At present, farmers are refrained from on-site information and base their fertilizer selection on intuition or on tacit knowledge and advice from local agrodealers, without knowing the actual nutrient status of their soils. This results in a mismatch between applied nutrients and required nutrients for productive soils. More so, applying non-limiting nutrients result in economic losses and environmental degradation.

This problem can be overcome when farmers could base their fertilizer selection on real-time information of the nutrient status of their soils. However, worldwide only about 5% of the farmers have access to reliable soil testing information. Conventional soil test laboratories can't give real time information; soil samples need to be taken, sent to the laboratory and be analyzed there. A slow, expensive method, with results that are often difficult to interpret by farmers.

Recent technological innovations in IT, sensor technology and machine learning have opened the possibility to use Near InfraRed (NIR) sensors for on-the-spot, real-time and affordable soil tests within 10 minutes using a Bluetooth connection between the NIR sensor and a software application for data interpretation on a smartphone. Hence, within 10 minutes the farmer receives a fertilizer recommendation for his specific crop selection. This innovation was first released in Kenya in 2017 and has rapidly expanded to 15 countries, and growing. In this paper, the innovation, experiences and new developments since the introduction of the innovation are presented.

The SoilCares Scanner Applications

SoilCares, part of AgroCares, has developed two products for soil testing using sensor technology; a comprehensive laboratory using Mid Infra Red (MIR) and X Ray Fractionation (XRF) for full analysis of macronutrients, microelements and soil texture, and the handheld Soil Scanner with a NIR sensor for fast and affordable in field diagnosis of soil fertility status. This paper focusses on the SoilCares Scanner and its applications for different value chains.

The soil Scanner measures the spectral image of the soil with a NIR sensor. The spectral image is sent to the application on the smartphone via Bluetooth. Subsequently, the smartphone application connects to AgroCares' global calibration database to convert the spectral image into the required soil data and recommendations for the selected crops. Several regression models produce the numerical predictions that are returned to the application as soil status. Indeed, the real intelligence

of the innovation lies in the database and its algorithms. By creating and training machine learning regression models it is possible to predict the fertility status of a soil sample from a NIR spectrum.

The regression models are uniquely built for each spectral image using 200 spectral neighbors from AgroCares's global calibration database. This Global Calibration Database contains over 14000 soil samples from more than 20 countries. All these samples were treated identically; after sample pretreatment half of the sample was analysed in AgroCares' conventional laboratory (Golden Standard Lab, GSL) and half of it was analysed in its sensor laboratory.

In the GSL all samples are analysed for 93 parameters. These parameters include chemical elements, but also a range of other parameters like texture, EC and pH. About every month the prediction models are updated and only when a certain parameter passes the quality criteria per country, it is released for that specific country. AgroCares has a global database. This means that all data, from all over the world, are stored in one database and that the prediction models use all data, but the release is based on a country by country quality compliance.

The value for the farmer is in the output created by the applications for the different stakeholders in the value chain. AgroCares has put an application strategy in place resulting in applications for different stakeholders, market segments and objectives. Depending on the position of the user (input suppliers, advisors, retail or smallholder famer), specific information on crop, fertilizer use or soil preparation are provided to the user as a recommendation or as monitoring data.

Business model
AgroCares applies a business-to-business approach by supporting a network of suppliers and service providers who offer soil testing services to their networks of farmers. The individual service providers buy the Scanner for 3000 Euro ex works from The Netherlands and a license for a specific application with unlimited use of the database. The price for the license differs for different application, but is 1800 euro per year for the SoilCares Africa Advisor, the most well-known application of SoilCares at this moment. The Advisor Application provides soil test results with crop specific fertilizer recommendations for a user-defined target yield.

Introducing the Scanner to Africa
AgroCares introduced the soil Scanner and the advisor application first in Kenya in early 2017. Within one year 30 organizations acquired in total 78 scanners. Service providers consisted of cooperatives, agrodealers, NGOs, input suppliers and independent consultants. Critical to the success was the organizational strength and business sense of the service provider. Although the potential for the sensors is about 30 soil samples per day (on one battery), soil testing agents rarely reached over 500 samples per year (less than 1 per day). Only after continuous support in marketing and capacity building, service providers are becoming more acquainted with the technology and business proposition.

Farmers paid on average KSh 1000,- for a soil test report including a fertilizer recommendation for macronutrients, lime and compost. User surveys performed by SoilCares Foundation in 2017 and 2018 revealed that about 75% of the farmers changed their farming practices after receiving the soil test report and about half of the farmers reported increased yields. More than 80% of the farmers reported recurrent requests for soil testing. At the same time yield impact studies showed yield increments of on average 25% compared to yields following existing recommendations.

At the same time, the adoption rate of the innovation was closely linked to the development of the value chain and the involvement of all its stakeholders. Soil testing in isolation of complimentary services like seed, crop protecting, storage and processing was less successful than soil tests performed in an integrated value chain.

Today, AgroCares offers the service to over 22 countries worldwide of which Africa (7) and Asia (2) are leading and fast-growing regions. Also, AgroCares continuously expands its calibration database both in geographical terms as in product terms. New releases will allow to use the NIR Scanner for feed analysis and leaf analysis next to soil analysis.

Outlook
The recent developments in IT, machine learning and sensor technology have enabled farmers to make fact-based decision on fertilizer selection and application methods. The innovation shows that fact-based decisions lead to more rational farm management and better return of investments on fertilizers for farmers.

The next step is to integrate soil test information in platforms for data analysis, e.g. by financial institutions or governmental bodies. Financial institutions use soil test information as part of farmer assessment reviews and governmental bodies use soil test information in their land evaluation programmes and fertilizer policies. Integrating different sources of information gives a holistic view on the agricultural sector and will allow for solutions that can be tight into the system. The AgroCares innovation unlocks the potential of integrating farmers most valuable asset, their land, into financial products and services for value chain optimization.