Title of pilot program:	Evaluation of methodology and performance of the Remote Extension Delivery tool (Capture) with 1,000 Farmers
Implementation Team:	Rural Farmers Hub & AGRA/NAERLS CBA Project
Project Period:	Apr-Dec, 2020
Theme:	Remote soil testing by nutrient zoning; Remote crop health advisory using precision agriculture technology
Pilot Locations:	- Niger state (Paikoro, Katcha, and Mashegu LGA) - Kaduna state (Lere, Kaura, Makarfi, Kubau, Igabi, Giwa, and Kagarko LGA)

Report on the 2020 Pilot Program in Kaduna and Niger state on Remote Extension Delivery using Capture app.

– Submitted to AGRA/NAERLS CBA Project by Rural Farmers Hub

This report is a summary produced during the course of a one-year pilot program to assess the viability, and measure the performance of **Capture** (a cloud-based software based on satellite remote sensing) in the delivery of crop and soil health insights to smallholder farmers through a network of community-based facilitators. This pilot is funded by AGRA/NAERLS CBA, therefore Rural Farmers Hub wishes to acknowledge the help and cooperation given by staff of the organisation towards the completion of this work. In particular, the outgoing Executive Director of NAERLS, Prof. M.K. Othman; and Prof Christopher Daudu for trusting us with the opportunity, and the entire pilot implementation team who provided very valuable support with the CBAs in Niger and Kaduna state respectively. The conclusions and recommendations presented here are those of Rural Farmers Hubs and do not represent the official position AGRA/NAERLS CBA and her partners.

Report Sections

8. Recommendations and conclusions

Section 1. Executive summary

What the report is about

Extension service delivery for the smallholder farmers is at a crossroads, with intersecting forces of decades of reduced budgetary provision, continuing uncertainty about the best localized strategy for climate resilience, and the desire of government organisations to examine the role of technology in the delivery of extension at scale, and affordably too. Traditional models of extension may not be appropriate to current conditions for crop production. This report examines satellite-based data-driven extension arrangements and points towards future possibilities against a background of an extension model driven by fine-grain data and science at the upstream. Insights generated by the software technology (Capture) were delivered through community-based facilitators or directly to farmers via SMS or voice call.

Who is the report targeted at?

The report aims to inform AGRA/NAERLS CBA, affiliated partners, and individuals which have responsibilities for, or interests in, tech-enabled extension provision under this pilot program in the year 2020.

What are the relevant technicalities?

The software technology solution deployed in this pilot is Capture. It uses fine-grained multispectral satellite data to measure and manage stress factors to photosynthesis during the critical growth stages, and using proprietary algorithms to produce insights that protect and maximize yield potential. Parameters measured include in-crop/in situ moisture content, nutrient uptake rate, and impact of disease on vigour; monitoring and mitigating these can protect the yield potential. Capture leverages scientific technique for remotely observing farm fields and an extensive database of GAPs and recommendations.

Background

This pilot looks at how Capture technology, a remote extension and agronomic advice delivery solution, can close the gap in the delivery of personalized agronomic advisory and extension services to smallholder farmers.

It is expected to

- satisfy the Terms of Reference ToR, of this pilot as recommended by AGRA/NAERLS CBA Project (see Aims/objectives below)

- help the participating farmers increase the yield and profitability of their farm enterprise.

The pilot has been undertaken in response to our proposal to AGRA/NAERLS CBA for:

- a systematic evaluation of the proposed e-extension tool (Capture) to determine its merit/demerits to CBAs and how it benefit smallholder farmers, and
- the development of a strategic framework for sustainable remote extension delivery.

Aims/objectives

At the end of the pilot program, we expect to see:

a. Increase adoption rate of precision farming in daily decision-making (medium term).
b. Yield increase, 30%.
c. Profit increase, 15%.

In addition to the above, we will:

d. Evaluate the effects of soil properties (silt capacity, witting point) on water stress,
e. Determine limitation (if any) of soil depth on satellite perceptron (water index), hence how it may affect ground truth on water stress,
f. Evaluate how the software help with the management of water stress precisely versus crop health,
g. Evaluate the sensitivity of the tool to slight changes in remote sensing data,
h. Evaluate the confidence level of the proposed software versus ground truth, then calibrate the model for improvement,
i. Evaluate how the result(s) vary from crop to crop,
j. Evaluate the possibility of early identification of reversible and irreversible stress,
k. Substantiate claims (with empirical data) that Capture can precisely determine the soil requirement of phosphorus and potassium for each part of the field over time,
l. Collaborate with organisations working on phosphorus to fine-tune and re-calibrate the model for a better outcome.
m. Work together (AGRA/NAERLS and RFH) to improve the models used in the delivery of crop advisory and extension service remotely.

Later in Q1 of 2021, we will share/publish a technical paper/report that addresses objectives d to m. This initial report focuses on objectives a to c. It seeks to provide AGRA/NAERLS with a framework to drive efficient and effective deployment and adoption of fine-grained data-driven precision farming practice using mobile devices and existing network of CBAs. Within this context, this pilot project was initiated on the basis of review of the outcome/output of using remote crop monitoring systems to support the development and delivery of quality crop advisory services for the maize, rice and soybean value chains.

Results/key findings

Substantial positive change has occurred in yield across all crops at the end of the pilot under review. A sample number of participating farmers (n = 139) saw an increase in their crop yield averaging 58%, nearly twice the expected result; the yield change is the difference for 2020 and 2019 yield data. The outcome varies quite slightly on a state by state basis. Additionally, it demonstrates that Rural Farmers Hub's Capture technology closed the gap in the delivery of personalized crop advisory and extension services to smallholder farmers; each farmer received at least one (1) personalized advisory tailored to their farm and the crop grown monthly.

Other forces may have contributed to the outcome of this pilot as will be elaborated in a technical paper to follow this report; however, when compared with the 2019 outcome (pre-Capture), the outcome is conclusive and positive.

The pilot findings reveal a range of concerns arising partly from the ripple effect of covid-19 pandemic and its attendant uncertainty in the supply of farm inputs such as seeds and fertilizer; but also due to financial issues and the need for price stability and consistent returns.

Tech-driven extension, especially in its relationship with traditional extension, points towards a central role and the need for more adoption and collaboration. Comparisons of yield outcomes from both extension models reveal some differences and how innovation could benefit AGRA/NAERLS CBA and the smallholder enterprise in its network. In the light of accepted extension theory and how it should be delivered looking forward, these differences should be considered. This report makes a series of recommendations based on these findings, extension theory and outcome from the pilot.

Summary of Recommendations

Recommendation 1

That a Strategic Plan for Drone Rental Business be developed by AGRA/NAERLS CBA alongside existing mechanisation strategy as the adoption of precision farming in rural farming is projected to increase in the coming years while this type of program continues to be expanded. Barriers to adoption can be minimized by mechanisation vis-a-vis drones and farm robots. Automated drone flight plan to help fix defects detected by Capture without human intervention looks promising in the future; a shared economy model (think Uber) is sustainable as such service becomes affordable while supercharging the farmer productivity.

Recommendation 2

That a Strategic Plan for Remote Extension Delivery be developed by AGRA/NAERLS CBA as a follow up to this pilot, including outputs, targets and impacts for each objective, to guide expansion of precision farming among smallholders.

Recommendation 3

That AGRA/NAERLS CBA considers a review of the incentive model for the CBAs given their leadership role in capacity building and cross-sector connectivity between the key stakeholders in the industry, within a strategic plan context. This should include mainstreaming them into a network of agro-dealers as retailers or resellers; they should be empowered with training and linked with agro-dealers. Furthermore, another plan can include supporting Rural Farmers Hub in her bid to set up business hubs (nicknamed Experience & Trade Centers) at the LGA level, a place CBAs can call their office with options for storage silos or alternatives, service booking desk for mechanisation jobs, aggregation buffer, meeting point, etc.. By our initial estimate, the startup cost is N2-5 million per unit/hub.

Recommendation 4

That AGRA/NAERLS CBA should explore a 5 year Strategic Plan with about 2,000 farmers in a cluster with a production output target of around 1 million tonnes of combined maize, paddy rice and sorghum annually. The productivity of this cluster will be highly dependent on irrigation options that allow for 2 batches of production per year, adequate mechanisation (power tools and drones), and precision farming practice.

Section 2. **Introduction**

Agriculture is the largest sector in the Nigerian economy and employs two-thirds of the labor force. However, the sector is plagued by persistently unpredictable (and often low) yields, which have remained essentially unsolved over the past 30 years. Nigeria's stagnant agricultural sector is no longer able to support its large (200 million) and rapidly growing (2.5%) population. As a result, Nigeria has become increasingly reliant on food imports, which have now reached $4.1 billion annually.

The extension landscape is still not there in terms of adoption rate of fine-grained data into farming best practices as traditional farming methods are no longer effective due to climate change, which is altering weather patterns and soil conditions. It is no longer enough to just deploy agricultural workers, known as extension agents. Notwithstanding, chronic underfunding of extension means that the vast majority of smallholder farmers no longer have access to extension. It is estimated that Nigeria's 7,000 extension workers are able to cover only 6% of the country's 38 million smallholder farmers.

This pilot is focused on how technology can help close this gap with crop advisory technology solutions such as RFH's remote extension delivery platform, the strength of which is precision management of crop health & soil nutrients with cloud-based automated sampler that creates intelligent maps to plan precision fixing of identified defects or anomaly in crop growth. During this period, we demonstrated how our web-based and mobile platform helped provide agricultural advisory services to under-served smallholder farmers in Kaduna and Niger state using a combination of

proprietary algorithm and satellite data to generate real-time farming advice that is delivered to farmers in person or via SMS/voice call.

Prior to this pilot, our previous performance history showed that using this solution helped farmers increase their yields by an average of 35%, with their income increasing by an average of 17%. Other outputs include improved climate resilience, improved food security, and increased adoption of technical knowledge by the farmers.

Section 3. **Methods used**

The pilot is based on research, conducted specifically for the project, and comprising:

- interviews with individual farmers (of maize, rice and soybean) involved in the pilot,
- collection and analysis of sample soil from pilot plots in 4 LGAs in Kaduna state in view of comparing such outcome with predictions by Capture,
- daily/weekly monitoring and evaluation of how crop is responding to growing conditions and inputs by remote sensing, including previous crop performance to similar conditioning, with due consideration for applying remedies to fix any identified defect in time and optimally, and
- training of, and field demos with CBAs drawn from the pilot communities to extend personalisation and localisation.

Analysis of the data collected was carried out using standard qualitative and quantitative techniques.

Section 4. **Target/farmer demography**

The agricultural sector in Nigeria employs around two-thirds of the entire labour force, and is projected to grow steadily. This growth is driven by a series of factors, most importantly the government's commitment to encourage domestic production. An example of this is the Agricultural Promotion Policy, introduced in 2016, which outlines measures to fund, coordinate and improve the quality of extension services.

To achieve this growth, it will be critical for Nigeria to invest in the productivity of its smallholder farmers. Around 88% of Nigeria's farmers (roughly 38 million) are smallholders, defined by FAO (2020) as farmers with less than 10 hectares of land. This pilot targets the smallest farmers who manage less than 1 hectare of land, which is 43% of the Nigerian market. In the medium term, and as cooperation between AGRA/NAERLS CBA and Rural Farmers Hub continue to grow, coverage should be expanded to farmers managing 1 to 2 hectares, who constitute 21% of Nigeria's market.

Section 5. **Theory of change**

Inputs:

Capture periodically acquires satellite data of the pilot farms from an external provider, then adds its digital library of 12 farming best practices, and a network of CBAs.

Activity:

Capture's algorithm then processes the satellite data to identify which practices the farmer should carry out at the present time. This advice was primarily delivered directly to the farmers by the CBF and our network of remote agents. The CBAs conduct regular check-ups to ensure that the farmer is implementing it correctly. Sometimes, the advice is sent to the farmer via SMS.

Outputs:

Based on the pilot project, using Capture increased the farmer's yield by an average of 58% (as at the time of reporting). The introduction of additional agricultural services in the future are likely to further increase yields.

Outcomes (short-term):

- Increased income: With increased yields, income for farmers and CBAs also increases.
- Better understanding of farming and technical skills: On top of learning best practices, farmers also learn how technology can help them boost yields, a common knowledge gap in rural Nigeria.
- Integration of farmers into agri-services network: The electronic registration of farmers allows them to easily access additional services in the future, such as tractor/drone rental, chemicals, and fertiliser sales.

Outcomes (long-term):

- Increased food security: A productive and adaptable agricultural sector strengthens food security for Nigeria, one of the world's fastest growing populations.
- Increased youth employment: We believe that by adding technology and efficiency to agriculture, our digital extension model can attract more young people to farming, helping to create youth employment opportunities and bridge the agricultural sector's age gap.
- Increased climate resilience: Capture's algorithm accounts for changing climate conditions, reducing the need for farmers to expand into resource-stressed regions. The use of best practices also reduces the use of resources such as water and fertilizer, reducing environmental impacts.

The pilot program contributed to at least five (5) of the UN Sustainable Development Goals: #1 (No Poverty), #2 (Zero Hunger), #8 (Decent Work and Economic Growth), #13 (Climate Action), and #15 (Life on Land).

Section 6. **Baseline survey and pilot activities**

Baseline survey

Before commencing the pilot program, we carried out a baseline survey (n=202) in Niger state (Paikoro, Katcha). Our goal was to collect information on the present status of crop yield, income (estimated), and the farm productivity before any type of intervention can affect it (e.g. application of insights generated by Capture). Due to limited number of human capacity, we adopted a hybrid data collection approach; while the CBAs carried out in-person survey;

- Cropping history
    - Crop was grown in the last 2 farming seasons,
    - Planting and harvest dates for each crop in both season (if applicable)
    - Yield for each crop in each in both seasons (if applicable)
- Good agronomic practice
    - If they used fertilizer and at what rate per hectare
    - If they used some form of mechanisation or power tool
    - If they know their farm size, what percentage of the total is cultivated, and reason for not cultivating 100% of farm
- Purchasing power
    - Ease of access to microcredit
    - If they ordered for soil testing in the last 2 seasons or at any time in the past
    - How much they invest in fertilizer purchase
    - Willingness to pay for crop advisory service
- Hierarchy of (individual) needs based on self-assessment; e.g, if a farmer had to pick only one of 3 options (fertilizer, premium seed, chemical), which would s/he choose?

Pilot activities

Capture is easy to use and tailored for use by CBAs and extension agents to meet the needs of rural smallholder farmers. Below is a sample user journey:

a. A farmer is registered by a CBF nearest to him/her, and their geographical coordinates are recorded on the platform using the provided mobile app.
b. Satellite data of the farm is processed using a proprietary) algorithm that generates recommendations based on the farm's current status. These recommendations can be viewed by the CBF at any time using any Android phone via the browser with minimal internet data usage. Recommendations include amounts of fertilizer appropriate to the farm's current situation, state of crop health, and irrigation techniques.
c. The farmer receives recommendations from the CBF via a phone call, in-person (through farm / home visit), or in near real-time via SMS.
d. RFHub manages and maintains this network of CBAs and extension workers who regularly visit farmers to check on their progress. Before the pilot went live, training was provided to the CBAs and EAs in Kaduna and Niger states. RFH also provides periodic training to the CBAs with on-site demonstration to help them better understand how

to remotely monitor the status of farms and provide farmers with additional guidance, if necessary.

Section 7. **Key findings**

Through a network of CBAs, this pilot delivered personalised crop and soil health insight to 1,000 farmers in Kaduna and Niger state of Nigeria, resulting in an average 58% increase in crop yields for Maize, Rice and Soybean; we project a 35% increase in income. Given that our benchmark yield was exceeded in this pilot by nearly 2x, the Impact Money Multiple of not less than 15x will be correct; that is, for every ₦1 AGRA/NAERLS CBA invested for this pilot, the farmer got ₦15 extra in direct income.

Yield data (by state)

	Kaduna		**Niger**	
Total number of farmers	700		300	
# of farms reporting yield	200 (Kubau, Lere)		200 Dagodnagbe, Nwogi	
# of farms affected by flood	93 (Kubau)		95 (Katcha)	
Avg yield change, y-o-y (%)	18.31		180	
Total yield, ton	321.95		30.04	
Total area cultivated, ha	41		28.47	
Average farm size	0.39		0.84	
Average productivity, ton/ha	7.85		1.06	
	2019	**2020**	**2019**	**2020**
Average yield, ton/farmer	2.80	3.04	0.57	0.88
Average yield per crop, ton *Rice* *Maize* *Soybean*	 2.67 3.02 2.48	 2.97 3.22 2.65	 0.56 0.56 0.35	 0.92 0.96 0.69

We are yet to fully ascertain the scale of the impact of flood that affected farmers in some parts of Niger state (particularly in Katcha). We have only received yield data from the following LGA: Paiko (Dagodnagbe) and Katcha (Nwogi) in Niger state; Kubau (Kuli) and Lere in Kaduna state as at the time of this report.

Some things occurred during the pilot that was not adequately anticipated for, while others did not happen as expected.

- The flood incidence was predicted by a climate modelling we use internally through an external provider. Efforts to communicate this discovery to farmers during our weekly remote check-ins was not successful. We failed to keep record of the specific geography of the farmers that received this communication, what can tell is that the warning was not heeded to by the farmers who received them.
- There was inadequate communication and communication from some of the CBAs at most stages of the project. It is common for a couple of key tasks demanded of them not to be heeded to (e.g. georeferencing, baseline survey, harvest data collection, etc). There are complaints of inadequate remuneration as the reason for this situation.
- The application of the advice generated by Capture would have been a lot easier, faster, and optimized with some form of mechanisation.

The success of this pilot also addresses at least 5 UN SDGs — #1 (No Poverty), #2 (Zero Hunger), #8 (Decent Work and Economic Growth), #13 (Climate Action), and #15 (Life on Land) — with further impact still possible in the future. ***See accompanying document (attachment/appendix)*** for the performance breakdown for individual sample farmers as at the time of this report.

Section 8. **Main recommendations and conclusions**

Drawing from this pilot, there is a possibility that output potential can vary drastically for various crops in different ecological zones. So far, the select crops (maize, rice and soybean) were highly receptive to our advisory service when applied to control for variable fertilizer rate and manage crop health status. Most of the soil in the study area was fairly homogeneous, indicating a conservative to minimal impact of such on the outcome.

It is not clear that the present result is indicative of future performance, our approach is measurable, and makes farming better when predicting yield potential and return on investment is factored.

The implication for CBAs and extension agents working with farmers and agribusiness is tremendous as (software) technology helps improve crop productivity and reduce cost of production. Knowing specific crop performance characteristics via remote sensing can help CBAs and farmers identify management zones within farms where an understanding of growing conditions are necessary for maximum profit potential. Lastly, young persons, who are the future of the tech-revolution in agriculture, can help drive practical understanding of the realm of possibility with this solution. This activity can help increase the understanding and awareness of agricultural stakeholders and the public on the potential that technology has to offer our agricultural industry as it evolves.

Recommendations

- AGRA/NAERLS CBA should develop a Strategic Plan for Drone Rental Business model as the adoption of precision farming in rural farming is projected to increase in the coming years while this type of program continues to be expanded. Barriers to adoption can be minimized by mechanisation vis-a-vis drones and farm robots. Automated drone flight plan to help fix defects detected by Capture without human intervention looks promising in the future via a shared economy model (e.g. Uber).
- A Strategic Plan for Remote Extension Delivery should be developed to guide expansion of precision farming among smallholders.
- A broader pilot in 2021 with more farmers across different ecological zones in Nigeria to further study the complementarity of precision farming tools like Capture and existing network of CBAs with respect to improving the crop yield and livelihood of smallholder farmers.
- Given the size of the impact, it will be interesting to survey each participating farmer to ascertain their readiness to continue paying for such advisory service by themselves looking forward as this can be used as an avenue to further incentivize the CBAs through sales commission, given their leadership role in capacity building and cross-sector connectivity between the strategic partners involved.
- Rural Farmers Hub should be further supported to set up physical business hubs (nicknames Experience & Trace Centers) at the LGA level.
- There should be a 5-10 year Strategic Plan for a permanent model cluster for studying this further using the same farmers (up to 2,000) with a combined annual production output target of around 1 million tonnes of combined maize, paddy rice and soybean.

Conclusion

The characteristic challenge of extension service delivery to smallholder farming in Nigeria is the unclustered distribution of a large number of small farms, making it impossible to provide personalised crop advisory tailored to each farmer's need face-to-face. This pilot model provides a framework for closing extension delivery gaps (particularly in the crop advisory sector) which is applicable immediately and provides sustainable impact on farmer's livelihood through significant improvement in crop yield. The development of a strategic plan, against an understanding of precision farming, and a network of agents, is fundamental to the scaling up Remote Extension Delivery sustainably.