Soil fertility and livestock management from cell phone

Charles K.D. Adjasi, Stellenbosch University and University of Groningen

Summary

This brief documents the potential impact of a digital mobile based app on integrated soil and livestock fertility management practices as an intervention to increase the productivity and yield of smallholder farmers in Africa. Estimates show that the intervention results in a benefit cost ratio (BCR) of 3.23 in two years when applied to maize farming in Ghana. The benefits consist of the increase in yield amounting to USD 413,045 from the impact of soil fertility management practices. The mobile application is estimated to cost USD 170,000, in design, an additional USD13,600 in integration of Integrated Soil and Livestock Fertility Management (ISFM) documentation and a USD 8,500 sensitization cost. It has an annual maintenance cost of USD 34,000 after deployment. The potential for this intervention is high given the BCR and there is room for rapid scale-up from the low intervention cost. The potential for scaling across Africa is also possible albeit with some variation in terms of BCR-Kenya (BCR of 10.49) and Malawi (BCR of 2.00). Overall the benefits are substantially higher and the intervention costs are spread thin when one estimates with a 5-year horizon. A major challenge though is the rather wide variation in the estimated impact on yield of ISFM practices. Nonetheless there is still a potential higher benefit if more smallholder farmers' benefit.

The problem

There are two main problems that this intervention addresses. First is the issue of low productivity and yield and the second is the associated cost of investing in widely scalable interventions. These are elaborated on further. Economic activity and social livelihood in most African countries is driven mainly by agricultural activity (African Development Bank 2019, FAO 2019). Majority of households' welfare is thus dependent on smallholder crops, fish and or livestock farming. The agricultural sector is however wrought with many inhibitions and challenges, ranging from gaps and segmentations in productivity, and market access which have prevented the sector from growing rapidly out of its largely subsistence base. Poor soil and livestock fertility as well as poor production management and generally low access to quality agricultural extension advice appears to be some of the inhibiting factors to productivity and yield. Agriculture in Africa is therefore reduced to an activity within a poor ecosystem of management, poor yield and subsequently poorly linked value chains or in some cases no value chain at all. For this reason, households derive relatively low and uncompetitive incomes from agricultural activity. This in turn reduces the potential development and growth impact of agriculture in Africa. For agriculture to grow out of its challenges and contribute more towards economic development and household welfare, it needs to attract much higher yield and productivity. Attempts to increase productivity have been largely around use of fertilizers, improved seedlings, soil/crop management, pest control. In the case of livestock, it has been largely around feedstock, breeding disease and pest control and extension officers. A critical issue in dealing with productivity and yield is the ability to link all sectors of the smallholder farmer's farm activity in a manner which reduces the segmentation and information problems across the production, processing and market access. A well-structured information system provides the actors (including smallholder farmers) with access to and linkages between production, processing and market access information at a regular and affordable cost. The use of Integrated Soil and Livestock

Fertility Management (ISLFM[41])-an integrated approach that is adapted to local conditions, traditions and practices has recently been noted as a high impact approach to increasing yield. Several studies[42] have shown that ISFM has a high impact on crop yield. For instance, a study by Roobroeck et al (2015) shows estimates in the magnitude of 60%-188% of increase in maize yield from ISFM interventions in Africa. Work by Adolwa et al (2019) also show that ISFM adoption increases maize yields by up to 27% in Tamale (in the northern region of Ghana and which is not a majority producer of maize) and 16% in Kakamega in Kenya. On the income side some studies (Benin et al 2011, 2012) estimate agricultural income increase of 37%–95% as a result of farmers' training. The same integrated approach is applicable to livestock management. Karen et al (2017) also estimated that milk production in Uganda increased by 20% as a result of farmer training on livestock fertility and production management.

A challenge with this however is the ability to reach the numerous smallholder farmers with such a solution. Andam et al (2018) show that ISFM training may not reach the intended beneficiaries and produce the unintended outcome of no impact. It is also estimated in a report by Roobroeck at al (2015) that a 5 year scale-up programme for smallholder farmers would cost between USD 40 million (dry Sahel regions of Africa) and 60 million (moist savannah regions of west, east and southern Africa) Attempts at using local media e.g. radio broadcasts have their own shortcomings; the broadcast time may be inconvenient for the farmer, feedback sessions, troubleshooting issues will be difficult to incorporate in a radio broadcast. So although ISLFM can help increase productivity, the cost of scaling up across multiple smallholder farmers is however also large.

The analysed solution

A digital approach enables obtain a real time training on productivity management. The approach is a mobile phone application based on Unstructured Supplementary Service Data (USSD) for GSM phones. This mobile phone-based app provides the farmer with learning tools and or videos on ISFLM practices. These include soil productivity, fertilizer management, water, disease, pest etc. management. For livestock, feed supplementation (especially for free-range/semi free range), pasture management, fertility, herd size, animal husbandry-housing and brooding and breed stock management, vaccination and disease prevention. It also provides information on agro pastoralism, mixed crop-livestock farming and pastoralism. It further provides the farmer with and information and communication platform to market her produce as well as access information on prices and markets.

The application does not require the use of smart phones however farmers can run troubleshooting programmes by enquiring and reporting (via MMS, i.e. text and pictures) soil, production, seedlings and feed etc. conditions for feedback via their mobile phone app. They can take advantage of the app to also access market information about prices and available markets. It also creates a large database of information which can be utilized by financial intermediaries in structuring suitable credit products for smallholder farmers. A prime benefit of this intervention is the ability to scale up ISLFM training at a lower cost. In the absence an intervention like this the ability to scale up ISLFM training in a number of African countries is curtailed as a result of the enormous cost implications. Consequently, productivity increase in agriculture will still be meagre in Africa. The intervention is applicable to most if not all African countries (since agriculture is a major contributor to most of the economies in Africa) but is tested with three Ghana, Kenya and Malawi. The choice is

[41] The usual approach is separated-Integrated Soil fertility Management (ISFM) for crops and livestock fertility management for livestock.

[42] See Hardwick et al (2005), Katengeza et al (2019) on the impact of ISFM in Malawi, others include Altieri and Nicholls (2003), Place et al (2003), Vanlauwe et al (2011) and Mponela et al (2018)

based on countries representing different ecological zones in West, East and Southern Africa (Sahel and moist savannah) particularly for an agricultural based intervention. For instance, Ghana's agro-ecological zone consists six types; Sudan Savannah, Guinea Savannah, Coastal Savannah, Forest/Savannah transitional zone, Deciduous Forest zone and the Rain Forest zone. Kenya also has six agro ecological zone systems but with a different typology consisting of Agro-Alphine, High Potential, Medium Potential Semi-Arid, Arid and very Arid zones. Malawi has four main zones also different from Ghana and Kenya; the Lower Shire valley; the lakeshore plains and the Upper Shire valley. These are different zones but most of which also accommodate maize farming albeit with different yield potentials. A similar case would hold for North and Central Africa as well. These countries also represent the main income groups (low income and lower middle-income groups) and also help to gauge the sensitivity of estimates to the various country contexts. Most of the assumptions as well as all estimates for benefits and costs are based on maize as a sample commodity.

The costs and benefits

The mobile application is estimated to cost USD 170,000, in design, an additional USD13, 600 in integration of ISLFM documentation and a USD 8,500 sensitization cost as shown in the table below. It has an annual maintenance cost of USD 34,000 after deployment. The estimated benefits from this intervention consists of a 49% in yield amounting to USD 413,045 (Table 2) from the impact of soil fertility management practices. One challenge with the benefit is the estimate for yield. Reports on the yield impact of ISFM are quite varied and wide across Africa.

TABLE 1 COSTS

Costs	Value (USD$)
Application design cost	170,000
ISLFM doc integration cost	13,600
Sensitization cost	8,500
Maintenance cost	34,000

The assumption for 49% increase in yield of maize is therefore based on median values taken from the array of estimates. It is also worth noting that the benefits exclude other factors like access to market outlets and market prices and access to credit or generally to financial intermediaries which are not directly estimated. Additionally, another benefit, the reduction in average cost of farming as a result of ISFM, is not estimated.

TABLE 2 BENEFITS

Benefits	Value (USD$)
Increased yield in agriculture (e.g. maize)	413,045

The BCR for the intervention is estimated at 3.23 using the case of Ghana for the period of 2 years. The BCRs for two other countries Kenya (10.49) and Malawi (2.00) are also estimated to show the wide variation (mainly due to the differences in number of farmers and the base yield values for maize per country). For each country there are two other scenarios (a short term-1-year horizon and a relatively longer term-5-year horizon) to assess sensitivity of the intervention to estimates. The lowest BCR is 1.18 for a 1-year intervention in Malawi and in Kenya it is 6.17, whilst the highest BCR is 19.97 for a 5-year intervention in Kenya and 3.81 in Malawi. The variation in the BCRs across countries also serve as an alternative way of sensitivity analysis.

TABLE 3 BENEFIT COST RATIOS

	Ghana	Kenya	Malawi
BCR (5 Years)	5.57	18.07	3.45
BCR (1 Year)	1.90	6.17	1.18
BCR (2 Years)	3.23	10.49	2.00

Following the wide variation in the impact of ISFM on yield, further sensitivity analysis is done by reducing the yield impact to 30% and 15% respectively. The results on Table 4 show that BCR reduces across the countries as expected. From a two-year point of view, the relative benefits from a 15% increase in yield diminish substantially for Malawi (BCR of 0.32) and Ghana (BCR of 0.99). The benefits still remain attractive on a longer-term basis though.

TABLE 4 BCR BASED ON LOWER YIELD

	Ghana	Kenya	Malawi
30% increase in yield			
BCR (5 Years)	3.41	11.18	2.13
BCR (2 Years)	1.98	3.32	1.23
15% increase in yield			
BCR (5 Years)	1.71	5.59	1.06
BCR (2 Years)	0.99	3.24	0.32

Discussion

Due to the low-cost nature and reach of the intervention, there are substantial benefits from scaling up. The productivity gains from effectively practicing ISLFM practices will boost smallholder agriculture and propel it into higher levels. A further advantage is that scaling up will not incur additional design cost except for maintenance and sensitization cost associated with managing higher volumes. The potential for scale-up is also very far and wide reaching in Africa. This is because of the strong presence of agriculture and smallholder farmers in the economy of African countries. An added merit is the already high density of mobile penetration rate in Africa which also makes the application easily accessible to smallholder farmers. A challenge could be the pain points and potential disputes with local Telcos in revenue sharing. Nevertheless, these risks are reducible with higher adoption and advanced discussion with Telcos for their committed support. There is need for protection of privacy and information from the database that will be gathered from farmers. This requires appropriate regulation framework to prevent abuse of the data. There is also the potential extra cost from further electricity use to maintain servers and back-office operations.

References

Adolwa Solomon Ivan, Schwarze Stefan and Buerkert Andreas (2019) Impacts of integrated soil fertility management on yield and household income: The case of Tamale (Ghana) and Kakamega (Kenya) *Ecological Economics* Vol 161 July 186-192

African Development Bank (2019) African Economic Outlook, African Development Bank Group, Abidjan, Cote d'Ivoire

Altieri M.A., Nicholls C.I. (2003) Soil fertility management and insect pests: harmonizing soil and plant health in agroecosystems *Soil and Tillage Research* 72 (2) 203-211

Andam, K, Makhija, S and Spielman, D, (2018). Evaluation of the impacts of a soil fertility training project on farm productivity in the Volta Region of Ghana, 3ie Grantee Final Report. New Delhi: International Initiative for Impact Evaluation (3ie)

Archibald Dan and Elmasoeur Ashitey (2018) Grain and Feed Update GAIN Report USDA Foreign Agricultural Service

Benin, Samuel, Ephraim Nkonya, Geresom Okecho, Josee Randriamamonjy, Edward Kato, Geofrey Lubade, and Miriam Kyotalimye. (2011). Returns to spending on agricultural extension: the case of the National Agricultural Advisory Services (NAADS) program of Uganda. *Agricultural Economics* 42: 249–67.

Benin, Samuel, Ephraim Nkonya, Geresom Okecho, Josee Randriamamonjy, Edward Kato, Geofrey Lubade, and Miriam Kyotalimye. (2012). Impact of the National Agricultural Advisory Services (Naads) program of Uganda: Considering Different Levels of Likely Contamination with the Treatment. *American Journal of Agricultural Economics* 94: 386–92.

Food and Agriculture Organization (2019) GIEWS Country Brief Ghana Global Information and Early Warning System on Food and Agriculture

Food and Agriculture Organization (2019) GIEWS Country Brief Kenya Global Information and Early Warning System on Food and Agriculture

Food and Agriculture Organization (2019) GIEWS Country Brief Malawi Global Information and Early Warning System on Food and Agriculture

Hardwick Tchale, Sauer Johannes, Wobst Peter (2005) Impact of Alternative Soil Fertility Management Options on Maize Productivity in Malawi's Smallholder Farming System, ZEF –

Discussion Papers on Development Policy No. 98, Center for Development Research, Bonn, August 2005

Macours Karen, Behaghel Luc, Gignoux Jeremie, Kamugisha Rick, Kugonza Jane, Mangheni and Margaret Najjingo (2017) The Impact of Farmer-to-Farmer Training on Agricultural Productivity in Uganda Abdul Latif Jamal Poverty Action Lab Evaluation Report

Katengeza Samson P.,Holdena Stein T, Fisher M. (2019) Use of Integrated Soil Fertility Management Technologies in Malawi: Impact of Dry Spells Exposure *Ecological Economics* 156 (2019) 134–152

Mponela P., Kassie G.T., and Tamene L.D. (2018) Simultaneous adoption of integrated soil fertility management technologies in the Chinyanja Triangle, Southern Africa *Natural Resources Forum* 42 172–184

Place F., Barrett C.B., Freeman H.A., Ramisch J.J., and Vanlauwe B. (2003) Prospects for integrated soil fertility management using organic and inorganic inputs: evidence from smallholder African agricultural systems *Food Policy* 28 (4) 365-378

Roobroeck Dries, Van Asten Piet, Jama Bashir, Harawa Rebbie and Vanlauwe Bernard (2015) Integrated Soil Fertility Management: Contributions of framework and practices to climate-smart agriculture GACSA, CCAFS, IITA, AGRA Publication

Sonobe Tetsushi (2018) The impact of management training on small enterprises in developing countries: Lessons from Ghana, Tanzania, and Vietnam International Labour Organization Issue Brief No 9, April 2018

Vanlauwe, B., Kihara, J., Chivenge, Pypers P. Coe R and Six J. (2011) Agronomic use efficiency of N fertilizer in maize-based systems in sub-Saharan Africa within the context of integrated soil fertility management *Plant Soil* 339 1(2) 35-50