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The core pillars of the agricultural Green Revolution relied on improved varieties and fertilizers, as well as massive public sector support for irrigation and fertilizer subsidies. In Sub-Saharan Africa (SSA), a more balanced approach to agricultural intensification must deliberately focus on better agronomic and natural resource management practices and agro-ecosystem health. Without these supportive pillars, it is unlikely that SSA's rain-fed, capital-deficient production systems which also face a number of resource degradation challenges can truly enter a sustained intensification pathway.

Since fertilizer and seed-based intensification is capital-intensive, there is little hope that the spectacular success witnessed in Asian production systems in the 1960s can be replicated in SSA without a major rethink. At the heart of this rethink is the need for investments in soil and water resources management and erosion control – reducing soil degradation, replenishing soil nutrients, and moisture conservation are pre-requisites in SSA. This should then be accompanied by concomitant and massive investments in fertilizer, seed supply and value chains.

In this brief, we focus on the results from a study on the adoption of a number of practices, which when implemented consistently and adopted widely by many farmers, can generate large gains in productivity plus environmental benefits, thereby contributing to the achievement of sustainable intensification. These practices,

which offer the twin benefits of higher crop yields and improvements in the underlying resource base, are called sustainable agricultural intensification practices (SAIPs): see Box 1 “Feeding the Present and Future: A Doubly Green Revolution”. The SAIPs considered in the study include minimum tillage, crop diversification (legume-maize intercropping and rotations), improved maize seeds, chemical fertilizer and manure and soil and water conservation.

Previous studies that looked at adoption in general or aspects that reflect SAIPs concentrated on single technology/practice, with scant attention paid to the analysis of packages of technologies. In principle, farmers can adopt and adapt technologies as complements and substitutes in multiple ways to deal with their overlapping constraints and opportunities including aspects such as moisture stress, weeds, pests, diseases and low crop productivity.

This perspective has important development and policy relevance. For example, if a set of SAIPs are substitutes, then policy and development could focus on more packages or provide a range of promising alternatives to farmers. Given the heterogeneous capabilities and incentives among farming populations, making available a wide menu of options is one way to ensure that even those with limited resources have some feasible options and therefore a chance to improve on the productivity of their farms, even if only comparatively modestly. Conversely, if a set of

Box 1: Feeding the Present and Future: Looking for a Doubly Green Revolution

Sustainable agricultural intensification is “increasing farm productivity and intensifying food and nutrition production from existing croplands while ensuring the natural resource base on which agriculture depends is sustained and indeed improved, for future generations.” (Montpellier Panel).

Sustainable intensification is in effect, a diversified set of production and management practices that increase agricultural productivity in a manner that conserves the fundamental resource base for production – soil, water, biodiversity and wider agro-ecological systems – for both present and future generations. Its impetus has been driven by the s(low) adoption of Green Revolution technologies and reducing soil degradation, repeated observations that historical successes in agricultural productivity growth such as the Green Revolution in South Asia have also generated negative environmental externalities such as groundwater depletion and soil fertility degradation. This has led to calls for a doubly green revolution (a term popularized by Gordon Conway). Therefore adoption of a variety of practices/technologies that achieve these objectives including minimum/zero tillage, crop diversification, improved seed varieties, fertilizers and investments in soil and water resources management are ways which when *combined judiciously*, can address these environmental and natural resource management challenges without sacrificing productivity.

SAIPs are complements, then it is important to find ways of making these available to the farming communities as packages. This is because given the complementarities between seeds, fertilizers and other SAIPs, the adoption of single practices will not achieve the desired productivity or environmental outcomes. Failure to capture unobserved factors and inter-relationships among adoption decisions of different practices will lead to wrong results. The consequence of this is that we can observe lack of adoption occasioned by poor returns because complementary practices are not adopted, but fail to account for this impact because the model does not adequately correct for these complementarities. For example, many farmers will refrain from planting hybrid seeds unless they can afford fertilizer, yet unless we can analyze this effect it will not be clear that lack of fertilizer is a major contributing factor to low hybrid seed use. As we will demonstrate in the results section, our model helps us to distinguish between these kinds of effects.

Methodological Advancement

To properly study this composite adoption phenomenon, the study on which this brief is based used the most recent analytical method. This method, the Multivariate Probit Model, is based on choice theories in economics and modified in agricultural economics to study farmers’ choices of agricultural technology options and practices. These models enable agricultural economists to determine why one technology is not adopted compared to another, something that cannot be done by simple observation and household or farm census. In this brief we are concerned with what explains farmers’ choices of technologies as dictated by their agronomic and economic interdependence.

Data Collection and Sampling

Household and plot-level data were gathered from four countries – Ethiopia, Kenya, Malawi and Tanzania through the Sustainable

Intensification of Maize-Legume Cropping Systems for Food Security in Eastern and Southern Africa (SIMLESA) program. Among the aims of the program is to “increase the production of maize and legumes in the region while confronting soil and land degradation and high levels of economic and climatic risk, accentuated by severe climate change impacts.”

In total, household and plot-level data from 4,719 farm households operating 9,837 maize plots were collected across the four countries, covering 64 districts and 728 villages. A multi-stage proportionate random sampling procedure was employed to select villages from each district, and households from each village. The survey was conducted by the International Maize and Wheat Improvement Center (CIMMYT) in collaboration with the countries’ national agricultural research institutes (NARIs).

Key Results and Features of the Study

The farming systems in these countries consist of small holdings. More than 80 percent of the people depend on agriculture for their livelihood. In each of the countries surveyed, rain-fed agriculture dominates. A wide variety of crops are grown, but maize is the dominant crop and covers the largest share of smallholders’ farmland. Legumes such as beans, groundnuts, cowpeas and pigeon-peas are also traditionally grown and are an important part of the farms’ economic and physical ecosystem.

The descriptive results from the data on which the study was based found that all plots in Kenya, 99 percent in Malawi, 97 percent in Ethiopia and 83 percent in Tanzania received at least one SAIP. All six practices were found on 12 percent of the plots in Kenya, 3 percent in Malawi and less than 1 percent in Ethiopia. The

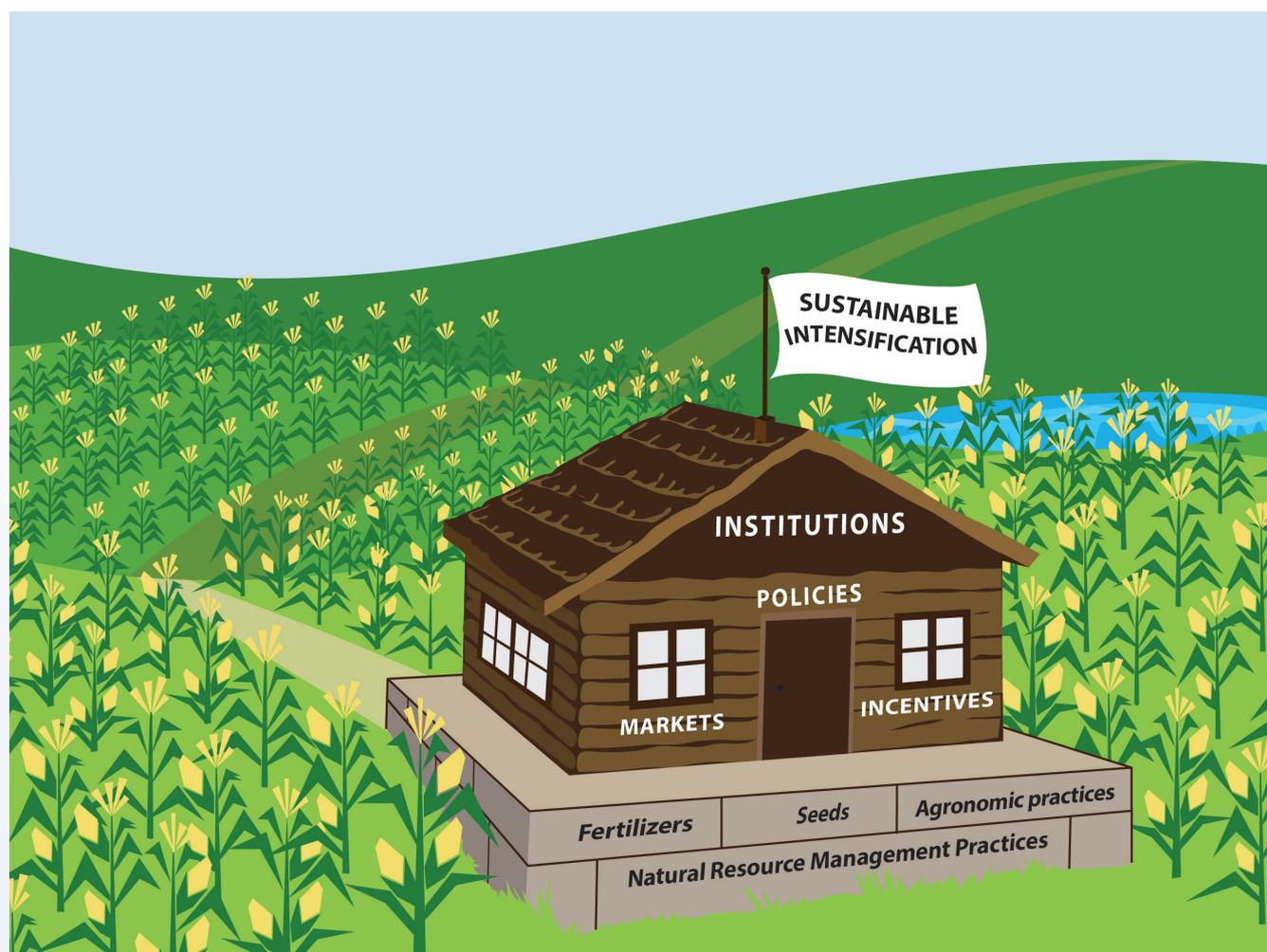


Figure 1. The house of sustainable intensification

Figure 2. What do farmers groups, markets and assets have to do with it?



probability of finding three or more practices was 75 percent in Kenya, 45 percent in Malawi, 15 percent in Ethiopia and only 5 percent in Tanzania.

Complementarities among SAIPs

- Fertilizer and improved seed were complimentary; adoption of one improved the use of the other as well.
- There is some substitutability between fertilizer and manure, with fertilizer adoption decreasing by 20 percent in Ethiopia, 4 percent in Malawi and 3 percent in Tanzania when manure is present in the adoption equation.
- In Tanzania, the probability of adopting fertilizer increased from 4 percent (in plots where fertilizer is used alone) to 8 percent when the technology combination involved minimum tillage, soil and water conservation (SWC) and improved varieties.
- In Ethiopia, adoption of crop diversification and SWC was slightly less than 20 percent but doubled in the presence of all the other SAIPs.

Choice Model Results

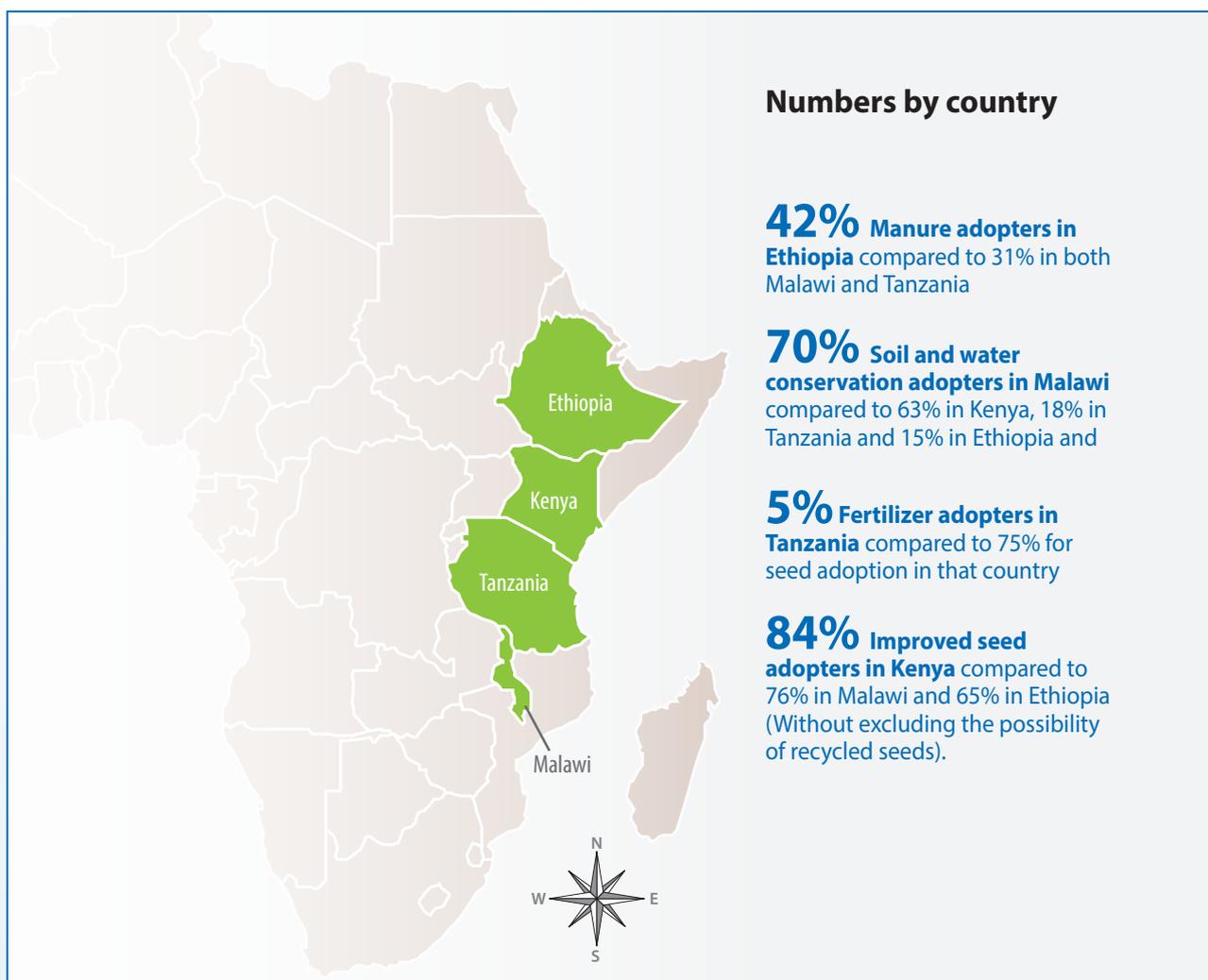
- Farmers who are *organized in groups* showed a tendency to adopt improved varieties and fertilizer (in Kenya), SWC in Malawi and crop diversification and minimum tillage in Ethiopia.
- *Political connection:* There were mixed results with respect to political connection (with reference to households that had relatives or friends in leadership positions in government institutions). The variable had positive incentive effect in Kenya and Ethiopia but negative in Malawi and insignificant in Tanzania.
- The *value of the household's farm assets* had a positive influence on the likelihood of adoption of manure (in Kenya and Tanzania), SWC in Ethiopia (in the case of livestock ownership).
- The *education level of the decision maker* positively predicted manure use as well as adoption of improved varieties in Kenya, crop diversification in Ethiopia and improved varieties in Malawi and Tanzania.

- Households *close to markets* were more likely to adopt crop diversification and manure in Ethiopia, improved varieties in Malawi and crop diversification and minimum tillage in Tanzania. This confirms the role of markets as a shaper of incentives and opportunities needed to invest in agricultural technologies. In fact, the further the households were from markets, the less the chances that they would implement minimum tillage and SWC in Ethiopia, crop diversification in Malawi and fertilizer in Tanzania.
- *Salaried income*: Salaried income was associated with higher probability to adopt SWC in Kenya. Probability of manure use was lower in households with a salary earner, suggesting that in some cases, the comparative advantage of off-farm income can trump on-farm agricultural investment.

Regional Overview

In the study results (summarized above) we noted that there are a large number of factors that were statistically significant in explaining the application of the various SAIPs. In each country, each SAIP had at least four different variables that explained its adoption. The highest number of variables affecting adoption of any one practice was 14 in the case of SWC practices in Malawi. In fact, fertilizer use, SWC and manure use were affected by the greatest number of factors across all four countries. Altogether, there was great variation across the four countries in the factors that explained the adoption patterns of the SAIPs considered here.

A large number of factors affected adoption patterns in various ways, suggesting a number of things. First, when looking within and



between countries, there is variability in the data, reflecting the many constraints and multiple levels of resources, networks, institutions and other factors that still impinge on or are needed to facilitate agricultural improvement. When the implementation of these SAIPs become widespread and many farmers have adopted them, then many of these factors will cease to be statistically important in explaining adoption. For example, if most farmers can access credit irrespective of their initial financial condition (meaning credit markets are able to support the farming system such that those without own capital can access it in credit markets), then cash income or other indicators of liquidity will not be very important in explaining adoption.

Second, the cross-country comparisons also showed that the unconditional household-level adoption rates in the four countries raise important questions. For example; in livestock-abundant Ethiopia, manure adoption (at 42 percent) was somewhat higher than in Malawi and Tanzania (31 percent). In terms of crop diversification, the Ethiopian maize system appears to be predominantly monoculture with only 19 percent of households implementing some crop diversification, while the lowest rate of crop diversification in the other three countries was 61 percent in Malawi. In terms of SWC, Malawi exhibited the highest rates (70 percent) followed by Kenya (63 percent), and Ethiopia and Tanzania having 15 percent and 18 percent respectively.

In regard to fertilizer adoption, the results showed that with a state-dominated fertilizer procurement system in Ethiopia, the proportion of households adopting chemical fertilizer was still 46 percent according to our data, compared to 89 percent in heavily subsidized Malawi and 87 percent in Kenya where the fertilizer market is largely driven by the private sector. Tanzania had the lowest fertilizer adoption – a situation which needs closer examination in future research. Regarding improved seed adoption, Tanzania, which had the lowest fertilizer adopters (5 percent), fared much better in terms of improved seed adoption at 75 percent, which was comparable to Malawi (76 percent) and higher

than Ethiopia (65 percent, without excluding the possibility of recycled seeds). With the most privatized seed-production system, Kenya had the highest number of households adopting improved seeds (84 percent).

As discussed previously, there was a general tendency for fertilizer and seed adoption to go together. However, the aggregated results for Tanzania appear to be inconsistent with the need for simultaneous seed and fertilizer adoption. If similar adoption patterns persist in Tanzania (or elsewhere for that matter), the full benefit of improved seeds may not be realized, especially in the long run when soil nutrient mining is likely to impose serious constraints on crop production.

Key Policy Lessons to take away

Farm and micro level perspectives

- If a number of SAIPs are complements (and the study reported here showed that some of them they are) then it is imperative to find ways of proffering these as packages because adoption of single practices will not achieve the desired productivity and environmental outcomes.
- The importance of social networks suggests the need to support collective institutions but also other organizations such as service providers to assist in accessing markets, inputs, information and credit.
- Investments in rural advisory services and extension can help counter the low education levels of rural populations. Using the agricultural extension infrastructure as a tool for widespread adult education can be a useful policy innovation.

Given their interrelatedness, it is incumbent that policies or programs that support better seeds and fertilizer must also take on-board agronomic and natural resource management practices as indispensable adjuncts to sustainable intensification.

- Given the confirmed interrelatedness of the technologies considered, it is incumbent on all those working on sustainable intensification to ensure that policies or programs that support fertilizer and seed must also take on-board agronomic and natural resources management practices as indispensable adjuncts to sustainable intensification.

Regional and big picture messages

Why is the state-dominated and cooperative partnership in Ethiopia able to create a fairly successful seed sector with adoption rates higher than those for fertilizer? Does this have something to do with fertilizer import costs or other fiscal policies? Would Malawi's fertilizer adoption rates still be in the 80 percent range under a different regime without subsidies? Granted, the present empirical efforts preclude any reasonable answers to these questions and such answers would require careful empirical and scenario simulations. Nevertheless, this brief overview illustrates the value of these cross-country comparisons, suggesting certain similarities, but also what appear to be important

differences. We present these differences as a precursor for further analysis and policy dialogue.

Our results suggest that much work remains to be done to widen (as much as possible) the opportunities for farmers to access the resources and services needed to adopt all manner of agricultural practices from better seeds to new agronomic methods. This offers the best chance for a balanced intensification process in East and Southern Africa.

Would Malawi's fertilizer adoption rates still be in the 80% range under a different input support policy regime that did not involve subsidies?

This brief is based on Kassie, M., Teklewold, H. Jaleta, M., Marennya, P. and Erenstein, O. (2013) Understanding the Adoption of a Portfolio of Sustainable Intensification Practices in Eastern and Southern Africa. Under review in the Journal of Land Use Policy.

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