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TAKING STOCK OF SOYBEAN R&D AND USAID'S FEED THE FUTURE PROGRAM IN MOZAMBIQUE

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ACRONYMS

AVRDC	Asian Vegetable Research Development Center
CIAT	International Center for Tropical Agriculture
IAI	National Agricultural Survey in Mozambique
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IIAM	National Agricultural Research Center in Mozambique
IITA	International Institute of Tropical Agriculture
MEAS	Modernizing Extension and Advisory Services
MSU	Michigan State University
NGO	Nongovernmental Organization
RISING	Research In Sustainable Intensification for the Next Generation
TIA	National Agricultural Survey in Mozambique
USAID	United States Agency for International Development

INTRODUCTION

Globally, soybean was the fastest growing field crop in production in the 20th Century. That expanding trend, albeit at a slower pace, is likely to continue well into the 21st Century. Most introductions of new crop species ultimately fail to take off in their targeted countries of destination. Not soybean. Its versatility of use for livestock and human consumption is only rivalled by maize.

Until recently, the pace of expansion of soybean has been slower in Sub-Saharan Africa than in most parts of the world with the exception of Nigeria and, to a lesser extent, South Africa. For example, in 2006, the authors of a priority-setting exercise for agricultural research in Mozambique did not include soybean as one the 24 separate crops or commodities in the study because its economic importance was too low to warrant analytical attention:

Interest is growing in soybeans in Mozambique, and projects have been designed to promote smallholder production of the crop. As yet, these small initiatives have not borne fruit. The value of soybeans is still significantly below our threshold value of $3 million, and there is no guarantee that it will become a smallholder's crop any time soon. IIAM needs to maintain a monitoring brief on soybeans to respond to the needs of varietal testing for projects that try to foment the crop in Mozambique. Soybeans are usually grown on heavier soils in a mechanized setting. The extent to which they are a "smallholder's" crop bears watching (Walker, et al. 2006, p.53).

Ten years later soybean production is very much in evidence in Mozambican agriculture. Since the initiation of USAID's Program in Mozambique in 2008/09 and the Bill & Melinda Gates Foundation's Tropical Legumes Project in 2007/2008, soybean R&D has received widespread support from the international donor community who have funded an array of reliable and experienced partners in diverse dimensions of soybean research and extension. Indeed, donor investment during the past decade in soybean R&D arguably has been greater than R&D for all other legume crops combined. The present report is not exhaustive and does not do justice to all the donors and all the partners that have supported soybean R&D in the last decade. [1]

This investment combined with high market demand has spawned a well-recognized success story (Smart and Hanlon, 2013). Rapid expansion in area under cultivation and production is widely credited and institutionally attributed to the role of the international donor community. One of the salient aspects of soybean's success is its potential for transformative structural change in the Mozambican economy. Soybean production affords the opportunity for upward mobility among the farming community. Successful emergent farms from the ranks of smallholders use soybean as a steppingstone to increase farm size to larger commercial operations.

In 2016, decision-making is at a critical juncture on the role of soybean R&D in USAID's Program in Mozambique. The choices can be summed up by the following questions: Has investment by USAID, other donors, and the Government of Mozambique been sufficient to ensure a robust and sustained

[1] A major omission is Technoserve's role in stimulating production which was funded mainly by a grant from the Netherlands. Switzerland and Norway have also been active in supporting activities that have led to the expansion of soybean in Mozambique. Moreover, we do not address on-going donor investments in soybean R & D, but rather assess those that were completed by 2015 or earlier.

rate of growth in production? Is 50-70 thousand tonnes of production enough to sustain spontaneous adoption into the foreseeable future (Pereira 2013)? Specifically, is the recommendation to invest in an aggressive scaling program in the comprehensively analyzed and cogently argued Kohl's report from mid-2014 still valid? Before we address these questions and identify specific options for investment in R&D, we document the major components that have characterized soybean's expansion in Mozambique in the next section.

Reviewing the Main Characteristics of the Soybean's Expansion in Mozambique

Demand: Not a Constraint but Lower Profitability in the Foreseeable Future

Rapidly increasing consumption of poultry is the main determinant of rising demand for soybean cake in Mozambique (Technoserve 2011). Soybean is also exported in cross-border trade with Malawi. Observers of agricultural development are unanimous that lack of domestic demand is unlikely to emerge as a force dampening production in the next 5-10 years. By 2020, Zambia is the only country projected to have achieved self-sufficiency in soybean-related consumption in southern Africa.

The international price of soybean conditions the profitability of the crop for producers in Mozambique. From its recent peak in mid-2012 of 684 $US/MT, the price of U.S. soybeans in Rotterdam had declined to 370 $US/MT in late 2015. The USDA projects a price of about 385 $US/MT in the next two years. The price spike for agricultural commodities in 2008 and 2009 appears to have run its course.

Assuming that it is fully transmitted, this 45% price decline will have consequences for production in Mozambique. Incentives for mechanization will be dampened compared to the period of early 2012 to mid2014 when prices in excess of 500 $US/MT prevailed. Soybean area will decline in marginal production sub-regions as the price squeeze magnifies differences in comparative advantage among sub-regions and even districts within sub-regions. Some of the costlier practices such as employing temporary 'ganho-ganho' labor for land preparation will no longer be profitable. However, soybean is still a good option. Its profitability relative to other crops is attractive because of high yield potentials and low input requirements. Recently, a declining trend in the prices of other commodities is not unique to soybean. Moreover, in 2015, harvest prices in April and May at 11-12 MZN/kg and subsequent prices of 16 MZN/kg in June and 18MZN/kg in July were more than sufficient to insure the profitability of the crop (Steve Boahen, personal communication, 2016).

The decline in output price should not diminish significantly the adoption of improved varieties, rhizobium inoculation, or simple crop management practices that are described below because their costs are only about US $50 per hectare. Moreover, the inputs are divisible: farmers can plant as much or as little as they want or can afford.

The Production Environment: High Yield Potential in Well-Defined District Clusters in 's Zone of Influence

Among legume-field crops, soybean is suited to wetter rainfall regimes on heavier soils that drain well. Soybean tolerates water-logging to some extent but does not do well in dryer conditions. It has a high yield potential. Soybean is not as readily attacked by insect pests as most other grain legumes especially cowpea and pigeonpea. On completion of its diffusion process in Mozambique, its geographic distribution of production will resemble that of common bean: spatially concentrated in clusters of

districts of higher production potential. It is doubtful that soybean will penetrate into districts where production potential is below 2.0 t/ha especially when international prices are low as they now are. It is almost certain that soybean production is agronomically and economically sustainable in districts where yield potential ranges from 3.0-4.5 t/ha. About 5-10 of the 27 priority districts in Feed the Future's Zone of Influence appear to be characterized by locales within them with high production potential.

In Sub-Saharan Africa, geographic specialization in soybean production is not unique to Mozambique. Among the States of Nigeria, Benue has the longest history of soybean cultivation and accounts for over 70% of production. Malawi is the largest producer of smallholder soybean in Southern Africa (TechnoServe 2011). Almost all soybean production takes place in the Central Malawi and is concentrated in Kazungu district (Donovan et al. 2012).

The Technology: Improved Varieties, Planting Recommendations, and Inoculation with Rhizobia

Research on soybean dates from the 1980s in Mozambique, but the release of new well-adapted varieties, the production of large volumes of seed, and the systematic validation of prospective technologies in farmers' fields are recent phenomena. These three critical components came together in two separate but highly complementary medium-term (5-7 year) projects funded by the Bill & Melinda Gates Foundation (BMGF) and USAID. These projects were implemented by IITA with many partners in the NGO, private, and public sectors.

Both projects had somewhat similar emphases that complemented each other[2] : (1) developing and identifying a sustainable soybean and cowpea production system through the use of modern production technologies; (2) promoting the diversification of soybean use in rural households through processing and value addition; and (3) training and awareness creation. Geographically, Tropical Legumes II focused on Nampula and Zambezia whereas the USAID grant to IITA was carried out in Tete and Manica in addition to Zambezia.

Well-adapted improved varieties and quality seed are at the heart of technological change in soybean. Varietal generation is summarized by the following noteworthy events:

- The selection of over 1000 elite lines from IITA with IIAM in 2007-2008;
- The subsequent simultaneous selection and transfer of the most preferred varieties by farmers in a participatory format (PVS);
- Five high-yielding and disease-tolerant varieties were released in 2011;
- Continuing elite germplasm introductions and farmers' participatory varietal selection resulted in five candidates for pre-release. These high-yielding, rust-resistant, promiscuous cultivars were in the pipeline when the projects ended in 2014.

[2] The USAID Project focused more on research on testing and identifying adapted varieties and on developing appropriate crop-management practices. The seed-system component was very small in USAID PARTI's proposal because IITA expected IIAM and USEBA to take over seed production after the varieties were released. However, this did not work out as planned; therefore, IITA engaged in foundation seed production to make more seed available to partners to facilitate adoption (Steve Boahen, personal communication, 2016).

Two aspects of this work warrant discussion. Firstly, the soybean varieties released in 2011 were among the first group ever approved for production in the country. Four varieties from Malawi and China were also in the released batch of nine cultivars. Secondly, in 2011, IITA submitted a proposal to enhance flexibility in varietal release in Mozambique (IITA 2015). Compliance with the proposal gave farmers the opportunity to access and plant new varieties that have demonstrated consistent superiority over old varieties, while the Variety Release Committee continues their normal registration process. The Committee, within the pre-release period, may withdraw a pre-released status of a variety that didn't meet their standard or give full release status to a variety that met their standard. This proposal was accepted, and the policy change meant that farmers could select a range of elite materials and were not confined to evaluating only officially released varieties. With simultaneous selection and transfer, the varieties approved for official release could already be in the early stage of adoption in many farmers' fields at the time of release. Farmers' preferences could be factored into the release decision.

Simple planting recommendations reinforced varietal change. Narrower inter-row spacing than farmer's traditional practice consistently resulted in higher productivity attributed to higher plant populations. Timely planting in December shortly after the onset of the rainy season gave the highest yields. In North and Central Mozambique, soybean productivity is notoriously sensitive to planting date. In regions of high production potential, each one-day delay in sowing after mid-December leads to a loss in yield of 65 kg (IITA 2015). The dominant soybean varieties are photoperiod-sensitive. Late planting is characterized by less solar radiation in shortening days as the plant matures, increased risk of drought stress, and sub-optimal temperature regimes for plant growth (IITA 2015; Dias and Amane 2011).

Like all legume crops, soybean has the capacity to fix nitrogen from the atmosphere, but it needs appropriate strains of soil bacteria to do so. The response to rhizobium inoculation in soybean in Mozambique appears to be higher than in most legume crops in other countries in Sub-Saharan Africa (IITA 2015). Mixing rhizobium with soybean seed at sowing is very cost effective when there is a yield response, but rhizobial inoculation is a fragile technology option because it has to be imported, quality control is a problem, and availability and access is more limited than for improved seed.

The response to phosphorus is also positive in some locations in soybean's recommendation domain in Mozambique (IITA 2015). Moreover, significant positive interactions between phosphate fertilizers and rhizobia are often obtained in on-farm trials in soybean cultivation in SSA (Giller 2015). However, high cost of phosphatic fertilizers makes their application unprofitable in much of Mozambique where all-weather road density is low and port infrastructure is poor. In this regard, soils research in the USAID-supported Legumes Innovation Lab is relevant because deposits of rock phosphate and dolomite have been found in Mozambique, thereby opening up the possibility of improving access to and reducing the cost of phosphorus and lime (Legumes Innovation Lab, 2015). If the possibility of domestic production is ever realized, phosphorus and lime applications, especially on acid soils, become an increasingly viable option for contributing to productivity growth in soybean in Mozambique.

The new improved varieties were characterized by a 35% yield advantage over the so-called local checks, which mainly were imported varieties from Zimbabwe (Abate 2012). Extensive on-farm validation over time and across space in both the USAID- and BMGF-funded projects suggested that

application of the new technological options would improve average soybean productivity from about 700 kg/ha to 1300 kg/ha in field conditions typical of smallholder circumstances (IITA 2015).

Technology Transfer: Seed Dissemination and Training

Soybean's expanding production in Mozambique has been fueled by large quantities of purchased and distributed seed of improved varieties. In Phase II of the Tropical Legumes Project, the total amount of seed available for planting by farmers for commercial production approached 5,000 tonnes from 2008-2014 (CIAT/ICRISAT/IITA 2015). Mozambique ranked second in seed production among six countries, selected for soybean R&D, in Tropical Legumes II. Soybean in Mozambique consistently exceeded its seed production targets. Nigeria, with about 9,000 tonnes but with more than 10 times Mozambique's national production, ranked first. Relative to its size of production, proportionally more seed was produced by Mozambique for soybean than any of the 13 countries in any of the six legumes included in Tropical Legumes II.

As points for comparison, the quantity of seed produced and disseminated in Mozambique was 85% of the total pigeonpea seed production in the four participating countries of India, Malawi, Tanzania, and Uganda. Groundnut in Mozambique was another priority crop by country observation in Tropical Legumes II. Its total seed production for commercial planting summed to a meager 133 tons, yet groundnut throughout much of the period was cultivated on about 10 times as much area as soybean.

Community seed banks were the preferred mechanism for multiplying foundation seed into certified seed that could be marketed and/or directly distributed to farmers in Tropical Legumes II (Abate 2012). Small-sized seed packets were an attractive means to stimulate smallholders' interest in soybean production and varietal change.

Diverse organizations were chosen for the distribution of the equivalent of certified seed and for further multiplication of foundation seed in the USAID grant to IITA. Notable beneficiaries included IIAM, Mozseeds, Technoserve, Phoenix Seeds, IKURU, CLUSA, Corredor Agro, Miracle Project Mozambique, Lozane Farms, ECi Africa, and individual farmers. Eight other organizations received smaller amounts of seed (IITA 2015). Each with 15% shares, Technoserve and MozSeeds were the largest recipients of seed made available to partners.

Agricultural Extension: Training of Trainers.

Although most of the technology-transfer effort went into mounting hundreds of demonstration plots and training thousands of men and women farmers, training of extension staff in public, private, and NGO sectors was not neglected. Ninety-six extension agents received instruction on soybean production, participatory varietal selection, and on marketing, processing, and distribution in the initial three years of the Tropical Legumes Project (Abate, 2012).

The Supply Constraints: The Absence of Nearby Affordable Inputs and the Shortage of Power for Land Preparation.

Input shops in the private sector have made only a negligible contribution to the expansion of soybean in Mozambique (Smart and Hanlon 2013). Unlike in other African countries, such as Ghana, farmers in Mozambique do not have access to improved seed, fertilizer, insecticide, fungicide, and herbicide in a

nearby market within 20-35 kms of the homestead. For Mozambican farmers, small packets of improved seed, *rhizobium* inoculum, and phosphate fertilizers are critical for improving soybean productivity. Until recently, for the most part, they were unavailable from the private sector.

USAID in 2014 has aggressively committed resources to four private sector partnerships that should substantially improve market availability and access to inputs in Feed the Future's zone of influence. Partnerships include (1) NCBA CLUSA, IKURU, and a new start-up enterprise called Phoenix Seeds, (2) the NGO Opportunity International with the Banco Oportunidade de Mozambique, (3) Lusosem Mocambique, Lda., International Development Enterprises and HUB *Assistancia Technica e Formacao*, and (4) Export Marketing Company Limited, Agro Tractors Limited, and a software company Technobrain Limited. This 30.0 million dollar initiative, 11 million from USAID and 19 million in counterpart contributions from the partners, will also strengthen private-sector extension presumably on export crops, such as pigeonpea and sesame, and on crops that substitute for inputs, such as soybean (USAID 2015).

Contract farming, popular for many years in the production of cotton and tobacco, has been proposed as one way to intensify production. Very large farms would supply inputs to small-farm growers who would guarantee that their soybean output would be marketed by large farms and/or poultry enterprises they contracted with (Smart and Hanlon 2013). Unless large farms own soybean processing facilities and price spikes do not occur, it is hard to prevent side selling in soybean production destined for the domestic market. One significant side-selling event would be spell disaster for this production-cum-marketing arrangement.

The paucity of power for land preparation and planting is as constraining as the absence of a functioning agricultural input market. It is aggravated by one overriding empirical fact in soybean production in the North and Center of Mozambique: late-planted material incurs a stiff penalty in forgone yield. With the exception of Tete and to a lesser extent in Manica, Mozambique lags behind almost every other country in Africa in both animal traction, especially for plowing, and tractorization. Soybean is tolerant to temporary waterlogging and is best planted on deeper soils at or near the bottom of the toposequence in the wetter semi-arid tropics or in the dryer humid sub-tropics. Those soils are productive, but they require more power for land preparation. Soybean does not do well on easier-to-cultivate sandy soils that are found throughout Sub-Saharan Africa (Giller 2012). Potential emergent farmers will never achieve upward mobility in farming if animal traction and tractorization do not figure more prominently in smallholder soybean cultivation.

Lastly, anecdotal evidence suggests that women farmers and their associated crops have the lowest priorities for contracting for private-sector tractor services if such services are available in neighboring communities in Sub-Saharan Africa. When draft and mechanical power is constraining, women farmers are in the back of the queue. Being last in line condemns farmers to low soybean productivity.

Farm Size and Soybean Production: Predominantly a Crop Grown on Small and Medium Farms, but this Issue Still Bears Watching.

Soybean fits the stereotype of a mechanized field crop apt for large commercial farm production. If production in Mozambique conformed to this stereotype, its potential to leverage favorable outcomes

on food security, nutrition, or poverty would be eroded. Expanding soybean production would save foreign exchange in substituting for imports without conferring declining price on urban consumers of poultry products. It would be produced with a capital intensity that would be inimical to significantly expanding rural employment in zones of high production potential.

Not all the evidence points to soybean as a crop where the bulk of production comes from small and medium farms. Soybean is not that visible in the Ministry of Agriculture and Food Security's representative national rural income survey (TIA/IAI) that is based on a random sample of the vast majority of Mozambican farms, small and medium holdings defined as cultivating less than 10 and 50 hectares in rainfed conditions. The expansion of soybean production is transparent in these annual and biennial inquiries. The *Trabalho do Inquérito Agricola* (TIA now called the IAI) shows that total production of soybeans increased from about 700 metric tons in 2002 to 5,000 metric tons by 2012 (Mather et al. 2014). But the size of production is only about 25-30% of total output documented in other sources. Presently, the Ministry of Agriculture and Food Security (MASA) views soybean as a large farmer's crop together with sugar cane, tea, banana, and even rice (Ministério da Agricultura e Segurança Alimentar 2015a and 2015b).

The latest published TIA/IAI estimates for 2013-14 indicate that soybean is sown on about 9.0% of small and medium farms in Tete. The incidence in participation for Niassa, Zambezia, Manica, and Nampula was estimated at 1.4, 0.7, 0.7, and 0.5%. These estimates are consistent with about 30-50 thousand small- and medium-households planting the crop during the period 2012-2014 (equivalent to 0.8-1.0% nationally).

Why the TIA/IAI estimates do not show more expansion of soybean in the smallholder sector is puzzling. Compared to other sources, the salience of the crop in Zambezia seems to be severely under-estimated. The same survey data do a good job in documenting upward production trends in other '*culturas de rendimiento,*' most notably sesame. In 2012-2014, about 8-10% of small and medium farm households planted sesame. And the TIA estimates steadily show expanding production of sesame over time. Sesame, as a recently introduced cash crop like soybean, is a good point of reference because in other African countries, most notably Ethiopia, it figures as crop produced on large commercial operations.

Persuasive evidence of the importance of small and medium farms in soybean production comes from the compilation of data in districts, such as Gurue, that have a comparative advantage in growing the crop. This inventory mainly came from organizations like CLUSA that are promoting the crop and had extensive knowledge of production circumstances in the district. In Gurue in 2012, only 100 of the 4400 farms that grew soybean were larger than 4.0 hectares. They accounted for about 10% of production (Hanlon and Smart 2012). The modal size was from 0.5 to 1.5 hectares, which comprised half of the soybean-producing farms.

More recent estimates show that the average cultivated area of soybean over time is increasing (Pereira 2013). In 2013, the average area cultivated was 1.5 hectares per farmer. Pereira (2013) lists several reasons why very large farms face difficulties in growing the crop in Mozambique. We return to this issue in the next section.

Gender in Soybean Production: The Mantra of Eat Some, Sell Some, and Save Some for Seed Seems to be Working.

The concern that soybean as a cash crop would be co-opted by men leaving women farmers behind does not seem to be an issue at this time except for the power constraint in land preparation and planting that was noted above. In visits to 10 villages in Northern Ghana in reviewing USAID's Africa RISING program in 2015, women were as or even more enthusiastic about the prospects for sustainable soybean production as were men. Earlier attempts in the late 1990s and early 2000s to spark women's participation in the crop largely failed because market demand was not well established in local markets. Rising market demand spurred women's interest in the crop. Donor emphasis on training in soybean preparations and nutrition also enhanced the reality that soybean is perceived to be both a men's and a women's crop.

In Mozambique, in 2008-09, a socioeconomic researcher at IIAM and the USAID-funded Soybean Innovation Lab at the University of Illinois conducted an 11-village baseline in Manica, Niassa, Tete, and Zambezia provinces. Many men and women farmers were familiar with soybeans, and a sizable minority in the 2-3 villages in each province had cultivated the crop. No significant differences emerged between men and women in their participation in the production of the crop. The incidence of female-headed households cultivating the crop was about the same as their share in the household community population.

Several of the high production potential zones in Mozambique border or are not that far from Malawi. Cultural barriers are sometimes cited as limiting household consumption in Mozambique (Technoserve 2011). But cultural barriers are not cast in stone. Malawi's proximity presents the opportunity to learn about ways to qualitatively and quantitatively influence household consumption.

Identifying Options to Reinforce and Contribute to Expanding Production Especially from Emerging Farmers.

In 2016, decision-making on soybean R&D in the Program is at a critical juncture in its development in Mozambique. The choices can be summed up by the following questions: Has investment by USAID, other donors, and the Government of Mozambique been sufficient to ensure a robust and sustained rate of growth in production? Are 50 to 70 thousand tons of production enough to ensure continued expansion into the foreseeable future?

The Case Against an Aggressive Scaling Program in 2016

Selective investment in key gaps is still warranted, but a major scaling effort recommended along the lines of Kohl (2014) who proposed a large 3-5 year initiative affecting about 30,000 new beneficiaries, is no longer appropriate and is expected to be a risky venture. Scaling was to take place both at the extensive and intensive margins in area and yield. Successful completion of the program would mean that Feed the Future in Mozambique could divest of support for soybean production in Zambezia and presumably move on and support other more pressing crop priorities or other sub-regions within soybean cultivation. The cost of the scaling initiative was about the only dimension that was not treated

explicitly in Kohl's comprehensive proposal, but the ambitious nature of the targets suggests an investment 5-10 times greater than USAID's grant to IITA from 2009-2014 in its PARTI Program.

One fundamental change in the donor landscape does favor the Kohl proposal. In Tropical Legumes III from 2016-2019, the Gates Foundation has divested of soybean and Mozambique. Therefore, the main alternative supplier to USAID of scaling support for soybean has withdrawn from the crop and the country. That decision was not based on performance of the country program in soybean, but, rather, was motivated by a desire to cover the most widely grown legumes in the biggest producing countries in SSA or states in India (Kai Mausch, personal communication, 2015).

Nevertheless, three other considerations loom large in making an aggressive scaling campaign early in 2016 less attractive than in mid-2014 when Kohl made his proposal. First, the marked decline in the international price of soybean may erode the profitability of a large technology transfer program. Second, the agency's large investment in its partnership program late in 2014 to support input marketing is a partial substitute for a large scaling initiative. Strengthening seed production and private-sector extension are important dimensions of that effort. Third, the truly impressive record of soybean seed production of improved varieties – equivalent to 5,000 tons for planting at the farm level and counting – was not appreciated at the time that Kohl drafted his report. Five thousand plus tons of seed distributed by the Gates Foundation's Tropical Legumes I and II and USAID's IITA Project should have been sufficient to fill the profile in the handful of districts with high production potential in Zone of Influence where these projects were active. This quantity of seed should have been more than sufficient to trigger spontaneous adoption. Aggressive technology transfer in the wake of such an impressive record of seed production is likely to reach the point of diminishing returns very quickly because high production potential only occurs in 4-5 contiguous district clusters in Mozambique.

The success of any ambitious scaling program in food crops in Mozambique hinges on the production and uptake of quality seed of new varieties. The argument for scaling relies on the assumption that the system is broken and material is not getting out or is not reaching its intended beneficiaries quickly enough. In 2016, the soybean seed system is far from perfect, but considerable progress has been made as summarized in the 2015 IITA Report to USAID:

> *The soybean seed sector has improved remarkably over the last few years because large quantities of seeds were produced domestically instead of importing from Zimbabwe and also farmers are increasingly depending on seeds produced by others instead of using their own saved seeds which in most case sufficient to plant only small areas. Thus, more farmers are buying seeds but mostly on credit through community-based organizations, farmers' groups and development organizations for repayment after harvest. We believe that this model has been successful but will require more time to be self-sustaining. Until the seed companies become well established, the community-based system will remain important and continue to be important in the future as a sustainable seed production and delivery model alternative to a private enterprise driven seed sector (p. 19).*

Furthermore, seed is technically easier to produce for soybean than for several other legumes of interest to the Feed the Future program. Pigeonpea outcrosses and needs an isolated production environment to attain high levels of purity. All farmers in the village have to grow the same variety if the

aim is community seed production. Groundnut is characterized by a very low multiplication ratio that requires large amounts of seed to translate into appreciable quantities of production. Indeed, partially because of poorly articulated seed systems, varieties released in the colonial era still loom large in groundnut production in South India and West Africa (Walker and Alwang 2015). With the advantage of hindsight and from the perspective of seed systems, pigeonpea could well be the crop in the Feed the Future portfolio that would most benefit from an aggressive program of technology transfer. Export demand for the crop is strong, and pigeonpea has a very low profile in seed systems in Mozambique. Business as usual means, at best, only small quantities of seed and, at worst, no seed. Improving the quality and quantity of pigeonpea planting material requires what Smart and Hanlon (2013) refer to as "a boots on the ground" approach. For pigeonpea, there is no fall-back option of importing seed from a reliable regional private-sector producer such as SeedCo.

Exploiting the Country Presence of IITA for Soybean R&D

Both the USAID and BMGF funded programs that were implemented by IITA and were described above achieved impressive results in terms of adaptive research and technology transfer. Both programs appeared to be highly cost effective. With the closing of the Tropical Legumes Program in Mozambique, IITA's country presence in Mozambique lost one of its important donors. IITA has proved to be a reliable and cost-effective partner with an institutional comparative advantage in research, and it also engages in development well through a broad range of partnerships in the public, private, and NGO sectors.

If it already has not been made, another grant similar in scope to the one in 2009-2014 would seem technically feasible and economically desirable at this time. Such a grant, drawing on that experience, would appear to be the appropriate size of investment in a scaling-cum-adaptive research program in 2016. It would also entail significantly less risk than a very ambitious scaling program.

This proposed work could be carried out in the remaining high production potential districts in Zambezia, Tete, and Manica. The emphasis could also shift to the new cohort of varieties that were still in the pipeline in 2014. Trial results suggest that yield gains have been made in varietal selection as these varieties appear to be higher yielding than the first batch that was released in 2011. They may also have other new attributes that are valued by farmers.

Evaluation of past results should play a greater role in the future. Assessment should focus on adoption outcomes in communities with access to seed and nearby communities, the estimated level of diffusion in the district of interest, and the demand for specific varietal characteristics by men and women farmers. Dissemination of soybean recipes and training of women and men farmers should also continue. Linking with the Soybean Innovation Lab (SIL) at the University of Illinois would potentially strengthen this work as this is one of SIL's priority research areas. Likewise, the nutritional effects of introducing soybean in the diets of vulnerable household members need to be assessed.

SeedCo should be viewed as a partner in future work and not as a competitor. One or more of the IITA-IIAM released materials may show wider adaptability in southern Africa. Small quantities of the materials were distributed to other countries in the region in the USAID-IITA Project. The project should be open to and encourage the outcome that SeedCo may find production of a more widely accepted released variety profitable in unsubsidized conditions and may begin supplying seed of that variety

regionally. Such regional recognition of varietal change generated by the project would be a major achievement.

Investing in Selective Maintenance R&D

Prospects for increasing soybean production from small and medium farms are conditioned by results from what we refer to as maintenance R&D that focuses on specific constraints, opportunities, and needs for assessment. In general, supporting this work does not involve large budgetary expenditures or project activities could be sized to meet budgetary resources. Priorities include the following:

Assuring a Steady Supply of Quality Inoculants

In the near term, seeing that smallholders have access to *rhizobia* is arguably the most important component in technology diffusion of improved varieties and practices. This aspect is more relevant to soybean than any other legume among Feed the Future's priority crops.

USAID-Supported AfriFUTURO Program's so-called "inoculant surge" in the Beira and Nacala Corridors should be fertile ground for understanding what worked and what remains to be done in meeting the demand for *rhizobia*. The longevity of suitable *rhizobia* strains in farmers' fields is an issue that warrants diagnostic research on nodulation. Did the surge lead to sustained and rational use of inoculum after this phase of the project was completed in 2015?

Techncial assistance from the Gates Foundation's N2 Africa Program can help in addressing specific aspects of supply stability and quality. Unfortunately, Mozambique only figures as a first-tier country in that program.

USAID has a long history of investing in biological nitrogen fixation (http://www.ctahr.hawaii.edu/bnf/). Since 1975 and for more than two decades, USAID funded the NifTAL (Nitrogen Fixation by Tropical Agricultural Legumes) Project at the University of Hawaii. NifTAL conducted research, product development, and outreach activities to improve and transfer effective biological nitrogen fixation technologies for sustainable agriculture in developing countries. Fortunately, the Mission in Mozambique also has considerable technical expertise in addressing this area and in identifying specifc private- and public-sector linkages for improving the flow of quality inoculum to farmers.

Timely Socioeconomics Research

Evaluation, in general, and socioeconomics research, in particular, has lagged behind the increasing R&D activity for soybean since 2008. Early adoption studies are a priority. In 2016, two years will have passed since both Tropical Legumes II and the USAID grant to IITA were completed. The time is ripe to document the level of and derive lessons from technology uptake in the districts where those two projects were active.

Estimating the uptake of technologies in the 2008-09 baseline in 10 communities in Niassa, Zambezia, Tete, and Manica is high on the Soybean Innovation Lab's research agenda in 2016. This research will be carried out by the same IIAM economist who implemented the baseline and will be partnered by a SIL's participating agricultural economist from the University of Missouri. Both the retrospective project

research and the baseline study should be informative of what worked, what did not, and what is identified as left to do.

Other punctual questions and issues also need better definition. What is the potential for contract farming in soybean in small and medium farm populations in Mozambique? MSU economists have intensively studied contract farming in cash crops, especially in cotton and tobacco, throughout Sub-Saharan Africa. They should be able to draw implications from that work to assess the prospects for contract farming soybean in a rapid appraisal.

What is the present level of smallholder and medium holder participation in soybean cultivation and production? Has soybean now surpassed the 1% threshold of small and medium holder participation in Mozambique? Hopefully, the 2014-15 and the 2015-16 TIAs will not face any problems in implementation, and their results will shed light on this issue. Updating the work of Smart and Hanlon (2013) for 2016 in Gurue District would be complementary to the findings in the national surveys because the area and production of large commercial farms would be included in those estimates.

What is Mozambique's regional comparative advantage in soybean production by landholding size and technology type? Another way to phrase this issue is: Where, how, and by whom is soybean most efficiently produced especially when international prices are low or, perhaps, have returned to normalcy in the wake of the 2008-09 price boom. The issue of the country's and sub-region's comparative advantage from the perspectives of both private and social pricing and costs is most effectively addressed in a multi-level study at the regional level and carried by estimating a Policy Analysis Matrix (PAM). This work would essentially quantify how competitive Mozambique is in soybean production regionally and internationally even though one realizes that Mozambique will be a net importer of soybean for some time.

Staying the Course with CLUSA and Enhancing Supply of Mechanical and Draft Power for Emergent Farmers

Substituting tractors and oxen for "enxadas" for smallholders is a high priority area that has long been neglected in Mozambique. It requires a longer term commitment and greater public-sector support in MASA in farmer training and in strengthening interactions with the private sector (Rafael Uaiene, personal communication 2015). In the short term, training oxen for ploughing is a specific priority. Machine threshing of soybean is another.

The goal is not that every smallholder will own a pair of oxen, or even have access to a tractor in their community. The bar should be set lower in Mozambique with the objective that a smallholder should be able to rent a pair oxen from other farmers in the same community or should be able to contract for land preparation with a tractor owner living in a nearby community. Organizing in associations and cooperatives promoted by CLUSA is one way to make power more available for land preparation and planting.

Tailoring Conservation Agriculture to Emergent and Small-Farm Circumstances in Soybean Production with Pre-Emergent Herbicides

Soybean agronomy is well known in conventional agriculture. Agronomists have produced informative extension bulletins that serve as the basis for translation into local languages on how to grow soybean in

Mozambique (Soybean Innovation Lab, undated). Producing soybean with minimum tillage is one way to tackle the widespread power constraint that smallholders face. Unfortunately, conservation agriculture is still more hype than reality in Sub-Saharan Africa; it is usually long on idealism and short on economics. In Mozambique, such systems will not be adopted if they increase the demand for seasonal labor.

However, soybean-maize rotations in Mozambique seemingly lend themselves to minimum-till systems more than most other field-crop rotations. Like Malawi, demand for crop residues for animal feed in Zambezia and Niassa is negligible. In the medium term of 5-10 years as input markets improve, it is likely that small- and medium-scale farmers will begin using pre-emergent herbicides. Over 50% of farmers in northern Ghana now apply pre-emergent herbicides. Having access to herbicides significantly increases the technical and economic feasibility of minimum-till maize-soybean rotations. Farmers need to be actively involved in the design of such systems.

Engaging in Exploratory Research on the Adaptation of Mung Bean and Black Gram in Mozambique.

When the international price of soybean was hovering between $350-450 per tonne in 2015, the import value of a tonne of black gram in India averaged more than $1,000 and the import value of mung bean approached $1,200 at the end of the year. 2015 was a year of peak prices for Indian pulse imports because of a poor monsoon in India and flooding in Myanmar, a very large exporter of pulses to India. Nonetheless, import demand will be strong even in years when the monsoon is normal. Total Indian imports of mung bean and black gram together are valued at about $US 0.6-0.7 billion annually.

Mung bean *(Vigna radiata)* and black gram (*Vigna mungo*) were domesticated in India, and they are grown in and adapted to tropical Africa (Jansen 2006 and Mogotzi 2006). Mung bean is much better known than black gram. In 2014 and 2015, Mozambique sent 71 shipments of mung bean to India. Farmer associations promoted by CLUSA are producing mung bean in Mozambique.

These two *Vigna* species are not as drought resistant as cowpea nor do they have the yield potential of soybean. They do not tolerate waterlogging as well as soybean. Firm market demand is their strength: think of a crop that produces like cowpea but fetches over twice the market price. They can also be consumed domestically.

If mung bean and black gram are well-adapted to large niches of the North and the Center, they represent an option for marginal soybean producing districts in Feed the Future's Zone of Influence. When exported, they, like pigeonpea, can be sown to arrive at the time of seasonal high prices in India. They are not easily produced in temperate agriculture. As 2015 demonstrated, their export prices are unlikely to be positively covariate with international prices for soybean. Planting a small area to them and/or to pigeonpea is a way to diversify income for soybean producers.

Exploratory research is needed on the degree that these two heavily traded pulses are adapted to different production realities in Mozambique. The Asian Vegetable Research Development Center (AVRDC) has germplasm of varying durations and characteristics for both crops particularly for mung bean which is one of its mandate crops.

Conclusions

What is most striking about soybean R&D in Mozambique since 2007 is the sheer apparent size of the investment in numerous facets of production, marketing, and consumption not only by USAID but also by other donors. Now is the time to pause, take a breath, and evaluate what happened.

A large scaling program along the lines of the Kohl report is not relevant at this time and could quickly be characterized by diminishing returns. The international price of soybean has declined by 45% since 2012. The area of high production potential is ample in some aspects but quite limited nationally and even in terms of USAID's Zone of Influence. More seed of improved varieties has been produced and distributed for soybean than for all the other legume crops combined. Relative to its value of production, the expenditure on soybean R&D appears to be several orders of magnitude greater than any other food crop in the country. Yet, only about 1% of small- and medium-scale holders plant the crop.

Refunding the IITA grant for another phase in the remaining districts of high production potential that were not covered in Gates Foundation's Tropical Legumes Program seems an appropriate course of action to follow. Historically, adoption of improved soybean varieties has been high in Africa but the velocity of varietal change has been surprisingly slow (Alene et al. 2015). For example, in 2010, farmers in Nigeria were on average still planting varieties that had been released in the late 1980s and early 1990s. Successful completion of another phase of the IITA grant could put Mozambique at the forefront of modern varietal change in soybean production in Africa.

Priorities for maintenance R&D are discussed in the paper. Filling these missing gaps will help to flesh out and sustain the success story of expanding soybean production in Mozambique. Evaluation of varietal diffusion, crop management, and inoculum use will identify others that will add to soybean's momentum.

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