RESEARCH SUMMARY
Yield Gaps and Food Security

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Key Findings:

- Technical efficiency of yields is low, providing scope for intensification interventions.
- Technical efficiency of legume crops improved by a larger margin then the technical efficiency of cassava production throughout the N2Africa project duration.
- Variation in regions, implementing partner strategies, and farmer traits accounts for differences in crop efficiencies.
- Significant impact of 6-7% from project interventions on soybean production, but no robust impact of the information and subsidized input package interventions on farmer crop efficiencies for either bean or cassava production.

Agricultural Yields

As rising levels in populations and incomes place greater pressure on world food supplies, the ability to increase agricultural productivity through sustainable means becomes a greater necessity. With uncultivated arable land rapidly disappearing, farms must increase yields from existing farmland in order to meet global demand. Soil quality management, the use of improved seeds, and proper crop pest and disease management are methods that are employable to increase crop yields. Each of these methods require not only financial investments, but also time investment both to learn new management processes and also to ensure proper application of improved processes. Even with perfect application of best management practices in all facets of agricultural production, the fixed constraints of land and water create a ceiling at which yields are maximized. This theoretical yield ceiling is termed 'potential yields' and is determined through locally-calibrated crop simulation models that account for regional soil composition, radiation levels, atmospheric C02 levels, and genetic characteristics of seed varieties under assumptions of unlimited water supplies and perfect management of environmental stressors. Yield gaps are determined as the difference between calculated 'potential yields' and actual yields observed from regional farms. This yield gap value provides valuable information on the extent to which agricultural production can be increased through targeted changes in farm management and can be used to facilitate crop intensification.

Legumes in the DRC

The South Kivu province of the Democratic Republic of Congo (DRC) is a region that is a combination of high vulnerability to food insecurity, consistent low-yields in crop production, and poor capacity of farmers to independently improve yield levels. This under-capacity to address existing low yields is due to several constraints including protracted conflict within the region (resulting in depleted assets and low incentive to invest due to temporal uncertainty), underdeveloped market infrastructure, small farm sizes, and limited wage employment opportunities outside of agriculture. Many of these constraints are long-term and slow moving forces that are difficult to target through localized development projects. What remains key is researching those factors that can be addressed through development interventions that are potentially effective methods for closing farmer yield gaps in order to address food security concerns sustainably.

Intervention

With this objective, researchers from the Netherlands and DR Congo partnered with local non-governmental organizations to implement and evaluate a set of interventions aimed to increase take up and productivity of legume crops under the N2AFRICA project. Grain legumes are important staple crops for poor households in eastern DRC as they provide a rich source of protein in the absence of meat and dairy based alternatives. The set of interventions implemented were designed with two primary targets (i) to close knowledge gaps around improved crop growing techniques and (ii) to mitigate access constraints within markets for improved seeds, fertilizer, and inoculum. The first was undertaken through a farmer extension training program while the second was addressed through crop input packages offered at subsidized rates. Both informational trainings and subsidized packages were provided by N2Africa local partners.

The three comparison groups can be summarized as:

Control– no intervention received.

Training Only – A farmer extension program providing information to farmers on new legume management practices and the availability and proper use of improved legume inputs. Information was dispersed through a village selected 'master farmer' who was then responsible for spreading knowledge throughout the village.

Training + Subsidy – All villages received the same extension services of T2. In addition, on completion of the training program, farmers were offered the opportunity to purchase packages of improved seeds, fertilizer, and inoculum at a subsidized rate of 75% market price.

The project included a total of 905 farmers in 93 villages located across three different 'axes' (northern, western, and southern) in the province of South Kivu. Data was collected using surveys in two waves: baseline (BL) data was collected in 2013 and endline (EL) data was collected in 2014. For the analysis of crop yield gaps, the focus is centred on farmers producing the common bean, soybeans, or cassava. These crops were selected as cassava is the staple food crop for the majority of households within the region while the common bean and soybeans were of primary focus in the N2Africa informational trainings. The figures of this reduced yield-analysis sample are described in Table 1.

Table 1 **Number of farmers and villages by crop and treatment**

	Control	N2 Only	N2 +Subsidy	Total
Beans				
No. Village	25	31	28	28
No. Farmers	106	122	134	120.7
Soybeans				
No. Village	2	4	6	4
No. Farmers	5	14	11	10
Cassava				
No. Village	26	32	31	29.7
No. Farmers	156	206	175	179
Total Sample				
No. Village	26	32	31	29.7
No. Farmers	210	265	256	243.7

Crop Yields in DRC

Overall mean values of primary crop inputs were similar across treatment groups. The exception to this is plot surface size in the baseline which was 0.2 Ha higher in the 'Training Only' treatment compared to the control treatment average. The change in inputs between time periods was most significant for mean number of household members working on the plot. All three crops saw about one full person reduction in the number of household members who worked on the plot during the season between the baseline and endline time periods. The use of chemical fertilizer increased by 10 percentage points, this rise is driven exclusively by the Training + Subsidy treatment with no change in fertilizer use by farmers in the control or Training-only treatments.

Table 2 **Mean Inputs between time periods**

	Baseline	Endline
Plot Size (Ha) by Crop		
Bean	0.4	0.3
Soy	0.5	0.5
Cassava	0.5	0.3
HH Labour by Crop*		
Bean	3.3	2.5
Soybean	3.9	2.5
Cassava	3.4	2.5
HH Level Inputs**		
Hired Labour	0.4	0.5
Chemical Fertilizer	0	0.1
Organic Fertlizer	0.4	0.4
Inoculum	0	0
***Average number of household members who worked on the plot during the season** **calculated as proportion of farmers using the respective input**		

Figure 1 provides an overview of farmer yields for all three crops by treatment and between time periods. The change in yield levels between baseline and endline was negative only for control group cassava and bean growers, all other crops in each of the treatments experienced increases in yields between baseline and endline time periods.

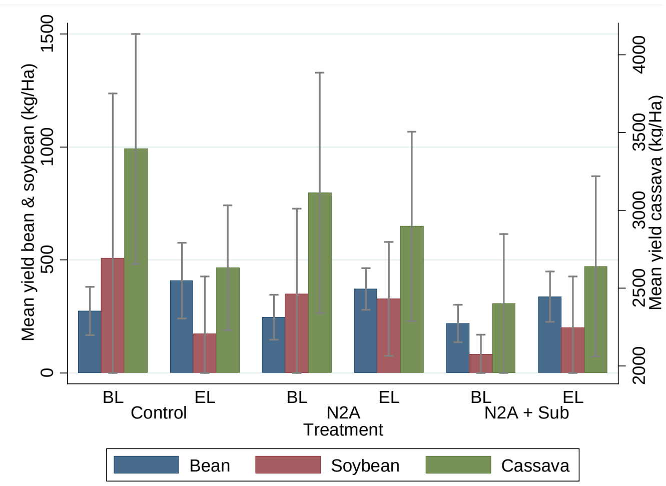

Figure 1 Mean Yield (kg/Ha) per Crop by Treatment Group and Time Period

Beans also appear to have comparatively low farmer yields when compared to a large-scale bean field trial program undertaken within the South Kivu province which had average bean yields of 700 kg/Ha.[i] A mean output that is more than triple average baseline and endline farmer bean yields. The mean of all farmer cassava yields for both baseline and endline are well below output in comparative countries with the Africa wide mean yield being estimated close to 10,000 kg/Ha.[ii] A controlled research trial plot using chemical fertilizer, improved seeds, and intercropping of soybean within South Kivu obtained a yield of over 21,000 Kg/Ha, fully twelve times higher than reported farmer yields. In that same trial, mean soybean yields ranged between 800 – 900 kg/Ha depending on variety planted and use of inoculant.[iii] Comparatively, our sample of farmers obtained a average yields below 500 kg/Ha.

From Yields to Yield Gaps

The yield values depicted in Figure 1 constitute the 'actual yield' component of the yield gap equation. Calculating the 'potential yield' is made difficult by the lack of detailed soil, climate, and atmospheric data within the South Kivu region. This poor availability of data rules out the possibility of using a calibrated and precisely estimated crop simulation model. We instead employ a statistical inference technique of Stochastic Frontier Analysis (SFA) and estimate the technical efficiency of farmers based on an implicit production function generated from observed data. This value is reported as a percentage, with inefficiency (100 - estimated efficiency) being attributed to imperfect farm management and input use (see Coelli et al., 1998 for a detailed overview of SFA methodology). Using this inefficiency estimate as a proxy for farmer yield gaps within the region we explore the major drivers contributing to the presence and persistence of unrealized farmer yields for beans, soybeans, and cassava.

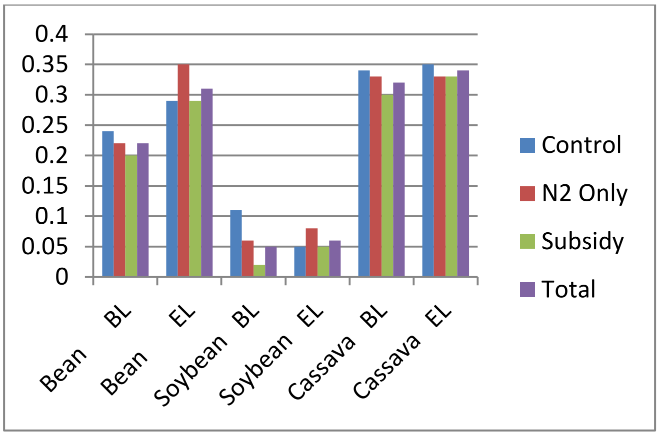

Figure 2: Mean Technical Efficiency of Farmers by Crop and Time Period

Figure 2 details the technical efficiency estimates for beans, soybeans, and cassava. Technical efficiency estimates for beans and soybeans were estimated using additional data observations from a field trial study conducted within the South Kivu province in the growing seasons of 2012 and 2013. The field trial study was conducted under controlled conditions (controlling plot size, improved seeds, fertilizer and inoculum use) and implemented growing techniques that are closely aligned with those covered in the N2Africa informational trainings. This field trial data serves to improve efficiency estimates as it provides yield data produced under improved practices processes. When the technical efficiency estimates of the farmer plots are compared against those of the field trial, the difference in achieved efficiency is obvious. As expected under controlled trial conditions, efficiency levels are higher with lower variation while farmer plots have a lower overall mean and a much wider variation in efficiency levels. Figure 3 provides graphical evidence of this comparison using beans as an example.

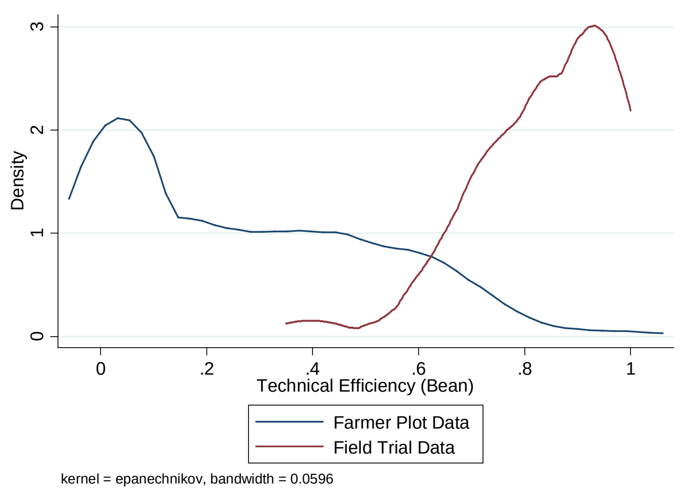

Figure 3 Distribution of Technical Efficiency by Data Source

In order to gain insight on what drives farmer efficiency levels, we regress a series of explanatory variables on the technical efficiency estimates for each of the three crops. These potential drivers include the effects of the information and information-subsidy treatments, the region of production, the partner implementing the treatment, as well as household (HH) characteristics. We control for treatment group effects and time period effects as well.

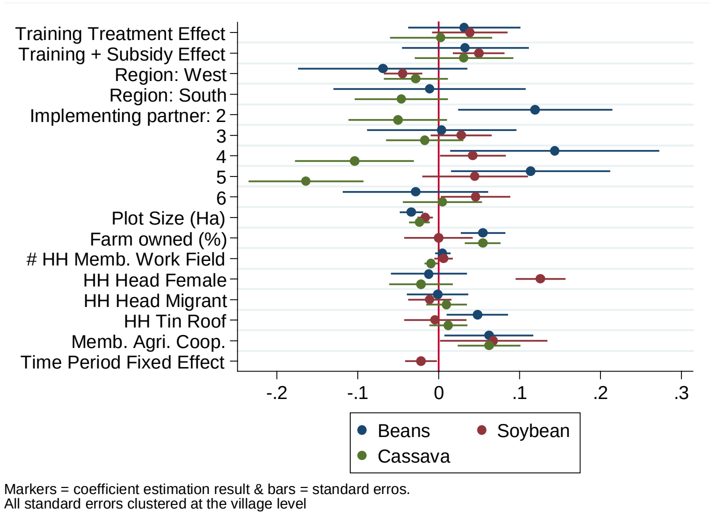

Figure 4: Estimated Effects on Technical Efficiency by crop

In Figure 4, markers signify the estimated effect while the error bars indicate whether the effect size is statistically differentiable from zero (horizontal line). Both treatments have estimated positive effects on farmer technical efficiency levels, however the only effect that is significantly different from zero is the combined training and subsidy treatment on soybean technical efficiency. The informational treatment has an essentially zero effect estimate on cassava technical efficiency, which is unsurprising given the trainings specifically targeted legume production. However there does appear to be some spillover effect on cassava technical efficiency from the combined training + subsidy, likely due to the cross-crop benefits of fertilizer, which was included in the input packages.

Regional and implementing partner effects vary both in sign and magnitude depending on the crop. These results accurately reflect the variation that was faced both in the regions that the projects were implementing in and the systems through which they are implemented. This is an inherent trait of any large and cooperative multi-organization development project as structures, policies, and local conditions of operation are unique to each organization. Farm ownership, measured as the percentage of total land farmed that is owned by the farmer, has a positive relationship with the technical efficiency of cassava and beans, but no relationship with soybean. Female headed households have much higher technical efficiency in soybean production, but lower technical efficiency for cassava and bean production. Wealth, proxied by the residence structure having a tin roof, has a positive relationship with only bean technical efficiency, but no correlation to the technical efficiency of soybean or cassava harvests. Having a member of the household be a member of a local agricultural cooperative has a positive relationship with the technical efficiency of all three crops, suggesting that the knowledge and benefits inferred from cooperative membership are not crop specific.

Conclusion

The technical efficiency of farmers within the eastern region of the DRC are extremely low, and while technical efficiency cannot be directly expressed as a crop yield gap, it does provide an indication of the extent to which improvements can be made in farm management processes in order to improve yields. Based on our results, knowledge transfer through training programs potentially have a small effect on improving farmer technical efficiency, however only for soybean production is this effect distinguishable from zero. Combining subsidy offers with the training scheme has no greater effect on technical efficiency then just the training program. This result could be stemming from the subsidized package price remaining above either the farmer willingness to pay, i.e. the package remains too risky of an investment, or is above the farmer ability to pay, i.e. the farmer wants the package but is financially constrained. We are currently unable to distinguish between these two effects with the data available.

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[i] Calculated directly from N2africa field trial dataset. Access to the dataset made possible by the N2africa Program.

[ii] Howeler, R. L., Thomas, N., Holst Sanjuán, K., Sanjuán, K. H., Quirós, H., Isebrands, J. G., ... & Ramírez Montero, M. (2013). Save and grow: cassava. A guide to sustainable production intensificationProduire plus avec moins Ahorrar para crecer (No. FAO 633.6828 S266). FAO, Roma (Italia).

[iii] P. L. Woomer, F. Baijukya, R. Abaidoo, A. Turner, S. Boahen, M. Dianda, J. de Wolf J. Sanginga, D. Mongane, J. M. Walangululu, N. K. Karanja, J. Mhango, G. Kasongo, H. Colial, A. Fernando, S. Kantengwa, M. Uwizerwa, I. Chabata, T. Mombeyarara, B. Zamasiya, 2012. Narrative country reports month 30, www.N2Africa.org