CARE-Cornell Collaboration
Final Project Report

Project Name: Alternative Fertilizers Using Indigenous Value Chains in Ethiopia

Project Location: Ethiopia

Project Duration: March 1, 2012 – February 28, 2014 (NCE for Cornell portion to February 28, 2015)

Reporting Period: Final Report

Grant Amount: $172,954

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Introduction

Conversations with CARE leadership from Atlanta and DC began in 2009/2010 in Ithaca to probe interest in collaborative efforts. With financial support from the US embassy in Ethiopia, the Cornell group started to explore research needs and opportunities with various partners in Ethiopia in 2011. After meeting with the CARE leadership in Addis, a core group of scientists formed at Cornell to prepare a proposal to the Impact through Innovation Fund (IIF). The innovation idea was born out of ongoing research in Kenya but formed through conversations with CARE-USA and -Ethiopia into a viable project. The overall goal of the project was to harness untapped agricultural waste streams for the production of fertilizers. One of the first approaches was to investigate slaughterhouse wastes as a source of phosphorus fertilizers, which became the focus of this exploratory phase of developing alternative fertilizers.

Specifically, we were interested in finding out (i) whether we can make phosphorus fertilizers from slaughterhouse wastes that are as efficient as imported fertilizers; (ii) how we can improve its efficiency; (iii) whether there is sufficient slaughterhouse waste present and available in Ethiopia and in what segment of the economy; and (iv) whether farmers value and accept this type of fertilizer. We were conscious that we are not able to perform a comprehensive survey of all alternative fertilizer opportunities in Ethiopia, nor even answer these questions fully for slaughterhouse wastes. Rather, we thrived to probe its feasibility and establish a case for further inquiry. The activities were conducted as a joint project between the GRAD project of CARE Ethiopia and Cornell as well as a local research partner with Jimma University.

Through a series of laboratory, greenhouse and field experiments, we could demonstrate the feasibility of producing indigenous fertilizers with similar phosphorus fertilizer quality compared to imported commercial fertilizers. All farmers that participated in the field research expressed interest in the fertilizers and coarse-scale budgeting demonstrated a significant quantitative technical potential for bone char phosphorus fertilizers in Ethiopia. Little scope seemed to exist with respect to source material for business development on farms, but the potential for subsistence production of such fertilizers was high. Further work is needed to demonstrate the sustainability of the fertilizers, refine their properties, and develop business scenarios for their production and marketing.

Project Goals, Activities and Results

The primary goal of this project was to provide proof of concept and follow-on funding for the development of alternative fertilizers that can be produced in developing countries, using Ethiopia as a case study. The specific objectives were to (1) identify opportunities to restock soils with carbon and nutrients from urban and agricultural environments that can be developed into viable small-scale businesses; (2) develop and/or improve indigenous and low-cost fertilizers and soil conditioners to become commercial products; and (3) provide a proof-of-concept for a recapitalization of soil fertility using local carbon and nutrient resources and markets.

The resource assessment was done at several different levels, including (i) coarse country-level budgeting, and (ii) detailed surveys. The country-level budgeting highlighted the opportunities of

bone char as a significant phosphorus source for Ethiopia with potentially offsetting 28-58% of Ethiopia's annual phosphorus imports, worth US$ 50-105M.

The detailed budgeting included studies both at the household and regional agro-industrial scales. Our preliminary data from smallholder household survey for Awassa and Jimma ecozones show that coffee, maize, chat, fruit crop, sugarcane, enset and tuber crop residues are among the most important crop residues produced by farmers with up to 6.6 ton/year. In addition, each household produces about 3.2 ton/year of animal and chicken manure, 0.7 ton/year of animal bones and 0.5 t/year of ash. Our preliminary analysis indicates that 37% of the agricultural residues are already used as organic fertilizer, and could be appropriated for an improved fertilizer product. The remaining amount is used as fuel (11%), animal feed (46%), and for other purposes (6%).

Our national assessment of agro-industrial waste suggests availability of about 51 million tons of agricultural biomass residues, of which 24 million tons originate from crop residues and the remaining 27 million tons from animal wastes. Coffee, sugarcane and cotton residues are among the most important contributors for the crop residues with competitive needs, while farm yard and chicken manure and bones are among the most important components of the animal wastes.

In addition to agricultural residues, a preliminary survey of key invasive species was conducted. The Federal Government of Ethiopia has identified a number of major invasive plant species and declared the need for their control and eradication. These include thousands of hectares of Parthenium weed, Prosopis and Lantana spp. Our study shows that 98% of the farmers interviewed at Jimma and Awassa identified Parthenium in their fields. The tested invasive Prosopis as a biochar component of indigenous biofertilizer mixes led to a nearly 50% increase in maize growth in greenhouse trials with two out of the four tested soils (Figure 3). It is not clear why Prosopis biochar added to mineral fertilizers was not as effective and what led to the significant increase in the compost mixtures. This warrants further investigation.

We surveyed 518 households in four locations across Ethiopia (Jimma, Hawassa, Debre Zeit, and Worer). In addition, we conducted surveys on 10 farms each in Hawassa and Jimma before and after field trials that demonstrated the performance of the bio-fertilizers. The 518 households had, on average, 5.5 household members and 1.7 ha of land. Mixed agriculture (crops and livestock) was the primary source of income among households surveyed. On average, the self-reported income was $194USD/person/year. Even though most farmers utilized imported commercial fertilizers, very few farmers had heard about bio-fertilizers or were using them. Of the ten farmers that experimented with bio-fertilizers, none reported that bio-fertilizers can be bought and they had not experimented with it. While three out of ten farmers stated before the field trials, they would not be interested in the tested bone char fertilizers, all farmers voiced interest in using bio-fertilizers after they had tested them. In addition, farmers interested in bio-fertilizers even before the trials mentioned that they would increase the proportion of bio-fertilizers. The amount and possible P offsets that can be achieved with bone char bio-fertilizers in the studied 518 households varied widely depending on scenarios of bone use, animal slaughtering rates and P additions to soil. Offsets of P ranged from less than 1% of recommended fertilizer additions to exceeding it nine-fold. Satisfying needs for entire farm operations or even making bone char P bio-fertilizers a marketable product using bone resources on individual farms are unlikely to succeed. More appropriate for household-produced bone char P bio-fertilizers are use on their own kitchen gardens for home consumption. For larger-scale field crop agriculture, aggregators along the production chain have to be explored to potentially reach scale.

The laboratory and growth experiments showed that bone char had a similar amount of total and available phosphorus as commercial and imported triple super phosphate. Laboratory experiments also showed that including biochar as a compost feedstock may improve compost nitrogen retention. In 2013, three trials were conducted to further investigate this finding: (i) a greenhouse trial investigating the effects of a wide range of biofertilizers on maize grown in four different soils from Ethiopia; (ii) an on-station researcher-managed trial investigating the long-term effects of a narrower range of biofertilizers on crop yields of maize on a highly weathered and acid soil near Jimma; and (iii) an on-farm and farmer-managed trial investigating feasibility of the technology on farms and the perception of farmers in two soils (acid soil near Jimma, and neutral soil near Awasa). The commercial phosphorus applications could be substituted by the bone char in the farmer-managed field trial which has to be confirmed using repeated experiments. Biochar-compost mixtures were also successfully increasing crop growth, but the mechanisms are unclear and require further work.

Our preliminary study on farmers' fertilizer choice and preference for crop production also show that 58% and 68% of the farmers prefer a mixture of both inorganic and organic sources as a source of fertilizer at the Jimma and Awassa study sites, respectively. Up to 25% of the farmers also indicated that they are willing to pay for pure organic fertilizers, while up to 70% of the surveyed farmers indicated they are willing to pay for the combination of inorganic and organic fertilizer sources of plant nutrients.

Several proposals arising from the project activities have been successful. Activities under the BMGF-funded "Re-invent the Toilet" program to utilize human wastes as fertilizers has been funded at $110,000 for the Cornell work. ATA funding of about $150,000 has been secured which will support one graduate student to investigate business opportunities for producing and distributing bone char fertilizers. A project on climate-smart agriculture was funded by The World Bank to CARE with a subcontract to Cornell, in which soil fertility and carbon status is being mapped across Ethiopia with the intent to develop recommendation for improved soil management. In a main project phase, which will be negotiated in 2015, the project team intends to propose the use of indigenous fertilizers as one of the options for sustainable soil management. The Global Environmental Facility (GEF) has agreed to fund the long-term field trials at Jimma University with $200,000 over the coming three years. Bridging funding was provided by the McKnight Foundation ($140,000) for 2015 to probe farmer acceptance and experimentation. We explore the opportunities to fund extension-implementation projects with a significant monitoring-evaluation activity in ongoing and future CARE project in Ethiopia (and beyond).

Successes and Challenges

Successes/key findings

- The technical potential for production of a locally-produced phosphorus fertilizer based on bone wastes in Ethiopia is large, potentially offsetting 28-58% of Ethiopia's annual phosphorus imports, worth US$ 50-105M.
- The phosphorus content and availability to plants of bone chars is as good as imported commercial fertilizers, making it a technically viable alternative to imports.

- After testing the bone char fertilizer, all participating farmers were interested in utilizing it.
- Follow-on funding was secured in the amount of about $500,000 to probe business scenarios and complete the greenhouse and field trials to a stage where the first publications can be generated.

Challenges/lessons learned

- Numerous logistical and experimental challenges were encountered. These ranged from farmers choosing to leave the project (about 10%) to hippos destroying the experimental fields in Awassa (100%). Import and installation of equipment delayed the start of the project and led to less than satisfactory experimental preparation in the 2013 cropping season. For this reason, the 2014 cropping season is needed for the first conclusive field data.
- The limited on-farm experimentation limited our ability to probe the willingness to pay for the alternative fertilizer. This will be done in more detail with a new student and new funding (ATA) in 2015.

Human Interest Story

Ms Zinash had doubts that the inputs given by the project would be as good as the fertilizer she is used to buying from the store. She was curious, however, to try it out and joined the group of farmers that the IIF team recruited. When the harvest came closer and the effect of the inputs became clearer, she was astonished by the size, appearance and performance of the maize crop that received indigenous fertilizer and also by the yield increases as compared with the local fertilizer mixes. She said: “I have never thought that I would be able to use bones, charcoal and other wastes that we normally dispose as fertilizer together with inorganic fertilizer in my maize field to improve my crop yield. I will definitely continue to work with the team in the future”.

Publications

Published:

Abiven S, Schmidt MWI and Lehmann J 2014 Biochar by design. *Nature Geoscience* 7, 326-327.

Simons A, Solomon D, Chibssa W, Blalock G and Lehmann J 2014 Filling the phosphorus fertilizer gap in developing countries. *Nature Geoscience* 7, 3.

Zwetsloot M 2014 MS Thesis, Cornell University

Zwetsloot M, Lehmann J and Solomon D 2014 Recycling slaughterhouse waste into fertilizer: how do pyrolysis temperature and biomass additions affect phosphorus availability and chemistry? *Journal of the Science of Food and Agriculture*, published online DOI:10.1002/jsfa.6716

In preparation:

Zwetsloot M, et al 2014 Phosphorus Availability from Rendered Bone Char in an Acid, P-Fixing Soil Influenced by Wood Biochar and Soil Exploration Capacity of Maize (*Zea mays*). In preparation

Hestrin R et al 2015 Ammonia retention in composts with biochar. In preparation

Gebermedhin et al 2015 Plant growth after additions of charred biomass to four Ethiopian soils. In preparation

Solomon et al 2015 Crop yields with alternative fertilizers in an acid soil. In preparation

Simons et al 2015 Socio-Economic Survey and Farmer Level Cost-Benefit Analysis of Bone-Char Fertilizer Production. In preparation

Amsalu et al 2015 Biomass resources for biochar-based indigenous fertilizers in Jimma and Awassa, Ethiopia. In preparation

Photos


Photo 1 and 2: Project team members visit the GRAD area farmers near Awassa and discuss soil fertility constraints (2012).

Photo 3: Visit to innovative farmers (2014).


Photo 4: Participating farmer in field trials (2014).

Expenditure Report

The expenditures include the month of November 2014.

Item	CARE	Cornell	Total
Personnel	42,148.63	39,205.69	81,354.32
Professional Services			
Materials, Services and Consumables	3,432.50	20,016.47	23,448.97
Equipment		1,549.8	1,549.8
Travel and Transportation		19,824.78	19,824.78
Rent and Utilities		292.8	292.8
Sub-grants to partners			256.54
Financing/Depreciation/Miscellaneous	5,259.88	256.54	5,259.88
Total	**50,841.01**	**81,146.08**	**131,987.09**

Budget Narrative

Personnel
Research Associate at Cornell University and Coordinator at CARE

Professional Services
None

Materials, Services and Consumables
Laboratory analysis costs (nutrient and carbon analyses), facility user fees, laboratory supplies (filter papers etc), sample shipment costs

Equipment
NICO NH_4N specific probe, laptop computer

Travel and Transportation
Domestic and international travel expenses, fuel, fleet expenses

Rent and Utilities
Greenhouse space rental

Sub-grants to partners
None

Financing/Depreciation/Miscellaneous
Procurement of program fertilizers and bio char materials; per-diem for data collector, stationary, communication and other running costs; poster printing charges-results presented at conferences/meetings

The Cornell budget still contains $40,966.91 to complete the analyses and writing of publications for the field trials and product development, for which a current no-cost extension through February 2015 has been granted.

Conclusion

The technical potential for bone char fertilizers in Ethiopia is significant. If only the slaughterhouse wastes are used as a source of fertilizers, Ethiopia could increase its crop production by an estimated 50% over the short term. However, the economic, managerial and acceptance potential of such a technological development is not sufficiently understood to embark on a country-wide program or encourage business development. Longer-term field studies have now been financially secured through GEF (UNEP) for the coming three years, and studies on business development and farmer acceptance began with funding from ATA.