Can conservation agriculture improve soil quality and sequester carbon in the short term for dryland smallholders in the developing world?

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Introduction

The Sustainable Agriculture and Natural Resource Management (SANREM) Collaborative Research Support Program (CRSP) implements multidisciplinary and multi-institutional applied research that mobilizes science and technology, fosters innovation and improvement in the social, economic, and environmental sustainability of agriculture and natural resource management, and leads to improved food production, secure livelihoods, and expanded trade opportunities and capacities for stakeholders. Phase IV research activities are focused on increasing smallholder food security through the introduction of conservation agriculture production systems (CAPS). In October 2009, SANREM CRSP began its Phase IV research on conservation agriculture in Haiti, Bolivia, Ecuador, Ghana, Mali, Lesotho, Mozambique, Uganda, Kenya, India, Nepal, Cambodia and the Philippines. This phase will continue through September 2014. The research is implemented through seven US-based universities, who share $15 million in funding from USAID. The global research program is managed by Virginia Tech, where four cross-cutting research activities (CCRAs) facilitate data quality control so that results across project sites can be compared at the end of the project. The CCRAs are Soil Quality and Carbon Sequestration, Economic and Impact Analysis, Gendered Knowledge, and Technology Networks for Conservation Agriculture. Phase IV research and capacity building activities will develop and demonstrate locally sustainable CAPS for smallholder rain -fed crop production systems that improve food security and the productive capacity and ecosystem services of degraded and productive agricultural lands.

The overarching goal of the Soils CCRA is to determine if dryland smallholders in the developing world can increase soil organic carbon (SOC), and hence soil fertility, by adoption of conservation agriculture (CA). We know that CA increases SOC under mechanized agriculture in the developed world, but it is unclear if such increases are feasible in the developing world for dryland smallholders growing staple crops. There is also an interest to determine the potential for carbon sequestration in these systems, which may potentially lead to payments under carbon trading schemes. Coordination of soil and agronomic investigations among all 13 developing countries before and after CAPS are implemented is critical to measuring soil fertility and carbon sequestration changes due to CAPS. We are coordinating all long term research activities' (LTRA) data collection so that we can make meaningful and scientifically verifiable comparisons across all project sites. Our specific objectives are to:

1. Quantify SOC in host country project sites before and after CAPS implementation.
2. Identify CAPS cropping systems or biophysical elements that improve soil fertility.
3. Relate increased soil fertility to site-specific socioeconomic environments.

We will also facilitate LTRAs and host-country partners to build capacity regarding biophysical data collection from CA plots vs. current practice controls, in order to determine effects on production and the ability to produce sufficient biomass to protect the soil and increase SOC.

Material and Methods

We will collect bulk density and SOC data at the 0-5 and 5-10 cm depths from selected researcher managed plots, and will include current practice control plots. Since sampling and shipping of soil samples from each and every researcher-managed plot will be cost- and laborprohibitive, selection of specific plots for sampling will be determined at each site according to those "best-bet" CAPS trials which will have shown the most promising success as a technology that can 1. Incorporate as many of the CA principles as possible, 2. Have a good chance to improve soil quality over time, 3. Improve production capacity over current practices, and 4. Have the greatest potential for adoption. Samples from the 0-5 and 5-10 cm depths will be sent to Virginia Tech, where we will build a Time Zero soil library, so that analyses can be conducted under one laboratory for comparative purposes. The library will also serve as an archive for LTRAs or other researchers that may require Time 0 soil samples from our project areas. To the extent possible, GPS data will be recorded from all field sites in order to provide accurate maps and GIS data relevant to crop production in the region.

Soil samples will be composited from at least 16 cores, sieved to pass through a 2 mm sieve, and air-dried prior to shipping. The requirement for at least 16 composite cores represents the number of cores needed to reach a diminishing return between the labor expended and the number of samples needed to determine a minimum detectable difference (MDD) in SOC. Grain yield will be measured by weighing subsamples after harvest. Above-ground biomass will be measured using quarter-meter quadrats, and percent ground cover will be determined using line transects. Total carbon and nitrogen contents will be determined using dry combustion. Fields with a history of liming or those on calcareous soils will be treated with acid to account for carbonates. Particulate organic matter (POM) is a size-based fractionation and will be determined at Time 0 and again at the end of the experiment using procedures described by Gregorich & Beare (2008). This may be combined with density-based fractionation procedures to determine labile and recalcitrant SOC pools. Fractionation procedures may be altered if an alteration will offer better opportunities to determine treatment differences in accordance with the timeframe remaining in this phase of the program.

Anticipated Results and Discussion

Although this will be an expensive soil library to build, it will provide data quality control across global project areas by analysing samples under one lab. We will quantify changes to soil fertility and carbon sequestration due to CA treatments over time. It will also serve as an invaluable asset for those LTRAs who continue research beyond the timeline of Phase IV, as well as for those researchers who may require reference samples for future comparisons. One challenge with determination of carbon sequestration rates is that SOC may not significantly increase over the timeframe of this program. A global data analysis from 276 paired treatments indicated that an average of 0.57 ± 0.14 Mg C ha_{-1} yr_{-1} was sequestered after changing from conventional tillage to no-till, except in wheat-fallow rotations where no change was found (West & Post, 2002). The study noted that an additional 0.20 ± 0.12 Mg C ha_{-1} yr_{-1} can be sequestered by including rotations (except changing from continuous corn to a corn-soybean rotation, which resulted in non-significant treatment differences in SOC accumulation). In our CAPS systems, which employ both minimum tillage and crop rotations, we might therefore reasonably expect to sequester approximately 0.77 Mg C ha_{-1} yr_{-1}, such that after three years we may accumulate approximately 2.3 Mg C ha_{-1} yr_{-1}. However, the authors note that C sequestration rates reach a maximum in about 5-10 years after conversion from conventional agricultural practices, so after three years of our CAPS trials, we may reach C sequestration rates that are approaching their maxima, thereby increasing our chances of finding significant differences in SOC between treatments. Rather than rely on total SOC changes alone, we will quantify labile and recalcitrant SOC fractions, which can be more sensitive indicators of short - term management changes and their effects on soil fertility (Conant *et al.*, 2004). We collaborate with other CCRAs to implement transdisciplinary research, specifically quantification of soil fertility parameters in relation to gendered knowledge of soil fertility in host-country areas, and also investigations of SOC for carbon credits in conjunction with the Economic and Impact Analysis CCRA.

One of the main goals of the Soils CCRA is to provide support to LTRA and host -country institutions to assist in biophysical data collection. Support may include building the capacity of host-country soils labs, in-field training on determining bulk density, or supporting LTRAs to implement components of CA, such as minimum tillage, as part of their research plans. We are currently evaluating methodology to determine the differences in greenhouse gas (GHG) and other gas (i.e., NH_3) emissions from CA and traditional practices at two sites (with three replications each) in Ecuador. Additionally, we are involved in the assessment of soil fertility under minimum tillage and crop rotations as part of an on-farm experiment in Thumka, Nepal. This experiment will, among other things, determine the land use ratios under the differing systems.

References

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