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Research Strategy Report

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Introduction

The SANREM CRSP is sponsored by the U.S. Agency for International Development (USAID) and host countries around the world. The SANREM vision is to support sustainable agriculture and natural resource management decision makers in developing countries by providing access to appropriate data, knowledge tools, and methods of analysis in addition to enhancing their capacity to make better decisions to improve the livelihoods and the sustainability of natural resources.

The research theme of the SANREM CRSP's current phase is to develop conservation agriculture production systems (CAPS). Our research engages stakeholders of all levels to develop sustainable, localized farming practices. Increasing smallholder's agricultural productivity and local food security through improved cropping systems that contribute to and take advantage of improves soil quality and fertility is our ultimate goal. Also, implementing CAPS farming systems will maintain a year-round soil cover, minimize soil disturbance by tillage, and utilize crop rotation systems. This multi-country program is also comparative, with research identifying common elements that affect CAPS adoption.

The program is structured around the research activities of seven long-term research awards (LTRA) focused on adapting conservation agriculture productions systems to the unique issues found in 13 countries in Africa, Asia, Latin America, and the Caribbean. Each LTRA collaborates with and contributes to four cross-cutting research activities (CCRA). The CCRAs are designed to identify and organize common research elements that will help generalize and expand findings to a wider range of sites and circumstances.

All of our programs and activities contribute to the online SANREM Knowledgebase. The Knowledgebase provides metadata on information resources, such as books, journals, articles, reports, and videos to assist decision-makers with informed sustainable agriculture and natural resource management choices. The Knowledgebase reflects a compilation of the information and insights gained through the first three phases of SANREM and it continues to expand as a result of Phase IV activities. This is an invaluable resource to conservation agriculture researchers, decision makers, and the general public.

Host countries involved in the current phase of this project include: Bolivia, Cambodia, Ecuador, Ghana, Haiti, India, Kenya, Lesotho, Mali, Mozambique, Nepal, Philippines, and Uganda. Within each host country partnerships have been formed with local universities and NGOs as appropriate to specific situation.

LTRA-6: A Conservation Agriculture Production System Program for the Central Plateau of Haiti

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Host Countries: Haiti

Research Team:

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- Caritas/Hinche: Jacques Volcius, Augustin Guedry;
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Introduction

According to FAO, 94.8 percent of Haiti's soils are classified as very severely degraded. It is therefore essential that soil conservation and nutrient-building practices are developed in order to improve agricultural productivity and the quality of life. Conservation agriculture can accomplish this goal through the use of practices that provide continuous soil cover, minimize or reduce soil tillage, and rotate crops. With relatively few exceptions, these practices have yet to be widely accepted by small-holders (Giller et al., 2009). In most instances, significant changes in soil and nutrient management, crops (including use of non-edible plants), planting patterns, weed control, and labor allocation must be made to implement a true conservation agriculture production system, all of which introduce unknown impacts on pest and disease complexes, and thus new risks. It remains to be proven that systems suitable and adoptable for a wide range of agroecological zones and socioeconomic conditions can be developed and deemed adoptable by resource-limited smallholders.

We face significant challenges in attempting to identify both adapted and adoptable CAPS in the Central Plateau of Haiti. Based on our interaction with farmers and agronomists in the Central Plateau, tillage is deemed essential for seedbed preparation, and reducing weed, insect, and disease pressure, whereas non-edible cover crops are not grown, and the common practice of interseeding two or more species in the same field confounds the practice of crop rotation. Conservation practices in Haiti have focused on reforestation, agroforestry/alley cropping, and rock wall construction. Significant disruptions, including a major earthquake, cholera outbreaks, and election-related violence within Haiti in 2010-2011 have also forced changes in timing and approaches to the project implementation plan. These events have had profound influences on populations within the study area and on household circumstances and decision making, forcing us to delay the household survey until the summer of year two. We anticipate that this critical study will begin informing the remaining project early in Year Three. In addition, the limited infrastructure supporting agricultural research and extension in the

Central Plateau has been disrupted by these events, and very little capacity exists in the study region to conduct formal agronomic research. Consequently, we have focused on building capacity in the three research locations through agronomic training and field studies. Agronomists trained at the undergraduate level are collaborating with us, and we have reached out to university and government scientists to build essential networks.

Hypotheses, Goals, and Objectives

The overall hypothesis for this project is that soil-improving CAPS can be developed for smallholders in the Central Plateau of Haiti that are both adapted to the biophysical environment, and are adoptable within the existing socioeconomic environment.

The goal of this research is to understand the socioeconomic and biophysical constraints to CAPS adaptation and adoption, to design and test strategies to work around those barriers in ways that increase agricultural productivity, and to work with smallholders to discover pathways to adoption. This goal will be addressed through the achievement of the following four objectives:

1. Assess the adaptability of existing agricultural production and livelihood systems for transformation into CAPS.
2. Increase agricultural production through development of CAPS.
3. Increase the capacity of smallholders to adapt and improve CAPS.
4. Strengthen human and institutional research and extension capacity for CAPS.

Each of these objectives, with associated research tasks and methodologies are described below.

1. Assess the adaptability of existing agricultural production and livelihood systems for transformation into CAPS: The current system will be described, its priorities, opportunities, and constraints identified, and potential pathways for transformation to CAPS explored as technological innovations are developed. Tasks under this objective will include:
    a. Household Economic Survey. Data to build an integrated household model comes from accepted economic household recall-based survey instruments used before by the PIs in Central and Latin America, Asia, and Africa. The survey instrument focuses on household input use, family time in various activities (income and non-income earning), consumption and sales of goods where applicable, household demographic characteristics, resource/farm and agricultural practice characteristics, management and use of resources within the household, knowledge concerning production processes, and social resources for agricultural production information. An instrument was designed for both the leading man and the leading woman of each household. Prior to sampling, the survey instrument was translated by colleagues at the University of Haiti. Focus groups were held with agronomists and community leaders in the sampling area to pretest the instrument and make revisions before full-blown sampling.
    b. Randomized and Stratified Sampling Strategy. The sampling strategy for administration of the survey instrument was developed with the objective of collecting survey data for at least 500 agriculture-based households

representative of those in the Lower Central Plateau of Haiti. The sampling procedure followed an aerial stratified random sampling scheme common to economics studies such as these and relied on use of high definition aerial photography of the region available through Google Earth. Stratification was achieved according to population density using a grid-based approach that divided the lower central plateau and mountain areas to the west and south into 256 one-square km quadrats. The area chosen was dictated by logistical considerations including accessibility, and partner support also influenced the decision on how and where to sample. Zanmi Agrikol's team of agronomists, agents, and technicians primarily operate in an area south and west of their headquarters in Cange. After consultation with the Zanmi Agrikol and other experts familiar with the region, we located quadrat grids in a sixteen by sixteen kilometer square centered near the town of Duffalty. This area contains various topography and socioeconomic conditions that are largely representative of those on the Central Plateau. It includes the mountain regions of Bois Joli and Balandre; the foothills of Boucane Carre and Porc Cabrit; and the lowland areas of Corporant and Grand Savane. A random sample of 80 of the 256 quadrats was taken for sampling. This random sample included some quadrats with no households and some with as many as 100. Within each selected quadrat, a sample number was chosen according to farm household density in the quadrat relative to other quadrats, and then each household was visited and a coin was flipped to determine whether the household would be sampled. Each household visited therefore had a 50% chance of being selected for sampling. Further, the sampling of any household in the plateau was fully random. GPS points were taken at each household chosen for sampling, and these were checked for quadrat location accuracy as the survey instruments were collected.

c. Construction of Econometric Decision Model. The economic analysis will proceed using these data to develop an integrated household model that links economics, resource quality, and agronomic features of production. The model will illustrate how land use and other household decisions depend on resource quality, as well as input market access, particularly labor, output markets, land tenure, and other household constraints through econometric modeling of these decisions. The contribution of water and soil resources to household income will also be accessed through variability across study sites, and using methods developed in the household economic development literature (Amacher et al., 1996, 2004; Jacoby, 1993; and Singh et al., 1986). Following this, we will evaluate the incentives and the processes by which households make decisions concerning land use in communities within the Central Plateau study sites, and determine the importance of land tenure and road paving to these decisions, and to household income and welfare. This will be accomplished by estimating systems of production functions, labor supply, and consumption equations under an assumption of non-separability arising from family labor and hired labor preferences and constraints. We will use these estimates to construct profit and welfare functions in order to assess the efficiency of switching to CAPS, and evaluate incentives for households to adopt these practices. Finally, we will identify important household variables that induce adoption for CAPS, allowing development of policy recommendations based on both market and non-market instruments. The welfare effect of any change in soil quality or different farming system leading to better soil quality to the household can be measured using expected changes in value of production based on all land uses chosen by the households in the sample, which are functions of labor and capital use decisions, and determining how differences in resource constraints across households in the sample lead to differences in income generated through production. This approach has been used numerous times in the economics literature by the PIs when natural resource degradation has been studied, as it corrects for changes in land and input et al., 2004).

d. Linkage to other SANREM components. Data collected from the producer household surveys and the additional interviews with the non-farm service sector will be made available for cross-cutting objectives designed to construct actor linkage matrices to model both men and women's production networks. A subsample of households surveyed will be included in a follow-up survey of soil and field practices conducted by the Soil CCRA. Analyses will include focus on the gender division of labor (Gender CCRA), knowledge and information networks (Social network CCRA), household adoption decisions and risk factors, and market opportunities. This information will inform the field research of the CAPS system.

2. Increase agricultural production through development of CAPS: In order to develop adapted CAPS that will also address smallholder production and livelihood priorities, we have identified the following key tasks:
   a. Building research capacity to conduct agronomic trials. Since there are no government or university run experimental units in the Central Plateau, field experiments will be conducted at three collaborator-managed sites in the Central Plateau Region of Centre Province. The three locations provide wide microclimate and soil diversity and should provide results relevant to much of the Central Plateau. All proposed research on these "stations" will be replicated (three or four replications) and will use standardized experimental designs (randomized complete block or split block), and will be tested for treatment differences using analysis of variance (SAS). Soils at all sites have been sampled for initial condition characterization (SOM content and fractionation, particle size analysis, nutrient availability, etc.). All soils are of moderate pH (>6) and deficient in available phosphorus. Site characteristics are as follows.
      - Corporant, near Mirebalais, is at an elevation of approximately 200 m a.m.s.l. This is a river bottom location with alluvial soils. The trials are managed by Zanmi Agrikol.

- Lachateau, near Boucan Carré, is located at an elevation of approximately 300 m a.m.s.l. The site is in a valley with colluvial soils and a stony surface. The trials are managed by Zanmi Agrikol.
- Maissade is located at an elevation of approximately 400 m AMSL. Soils have a high clay content and are very structured. The trials are managed by Caritas Diocesaine de Hinche.

Research capacity is being built using cultivar trials. There is high interest in new cultivars on the part of agronomists and farmers in the region, and we are also very interested in testing cultivars that have potential or have performed well in CAPS in similar regions outside of Haiti. Cultivar trials provide a mix of simplicity in treatments and data collection, with complexity in treatment numbers. We are using the standardized CIMMYT lowland tropical maize standard test (15 cultivars) along with three local cultivars, and a set of black bean cultivars recommended by colleagues in the Pulse CRSP in Puerto Rico along with locally recommended or purchased cultivars. We have also extended invitations to scientists at the State University of Haiti - Faculty of Agriculture and Veterinary Medicine to join us as collaborators on the project.

b. Introduction and evaluation of cover crops (on-station). At present, the only cover crops we have observed in fields within the study area include cowpea (sole crop) and pigeon pea (sole crop, or more frequently, interplanted with maize). There are reports of velvet bean being grown in the Central Plateau, but there is no documented research on cover crops. We must introduce and test the performance of a variety of cover crops, since they play essential roles in providing permanent soil cover and weed control in a reduced tillage environment where herbicides are not currently a socially acceptable or economically-viable option. Packaged sets of 12 cover crop species have been provided for all three planting locations in year 2. We will ensure that large blocks of three cover crop species: velvet bean, crimson clover, and spring oats, are available for planting and weed control studies in the spring of year 3. We will also attempt early season plantings of cover crops to assess potential for germination and growth before the planting season begin. Key parameters of interest for all cover crop trials will include percent soil cover, biomass produced, and nutrient content.
c. Cover crop and cropping system modeling. Since we are getting a late start and have essentially no research data on the performance of cover crops, intercrops, or relay plantings, nor the resulting impacts on weed control and crop productivity, we propose to use crop modeling (APSIM or DSSAT) to assess potential performance of these components. Modeling results will provide insight into best bet components we wish to test on station in year 3-5, and on-farm in year four and five. This will require additional soil characterization and addition of weather stations to each research site.

d. Integrate cover crops, planting practices, and rotations into the on-station testing protocols. At this time, data from the household survey are unprocessed. We await information from the survey that will assist us in designing adoptable CAPS specific for the Central Plateau. Regardless, in year three, we will begin assessing improved options for CAPS. Assessments will include replicated studies of maize plantings into three cover crop residues (see item b. above) using various planting methods and weed control strategies. Measured variables will include maize stand counts, weed control ratings, crop maturity date, yield, water productivity (crop yield/mm rain), soil quality/fertility, bulk density, and soil organic matter (SOM). Yields, weed and pest pressures, labor requirements, and total production costs will be calculated for each system to determine if system improvements are being made. As part of the training for agronomists and farmers, studies will be shown to farmers during the growing season for evaluation and feedback. Change in soil properties from initial conditions will be evaluated in CAPS plots that have received CAPS treatments for the duration of the project. This analysis will focus on SOM fractions, bulk density, and soil fertility changes.

e. Conduct farmer managed trials. We propose to conduct two types of on-farm field trials. The first would involve replicated trials with relatively simple experimental designs. These experiments are overseen by collaborating agronomists, and have been initiated for bean variety trials as capacity building experiments. Future experiments would involve comparison of farmer standard methods with strips of up to five other treatments. At this point, such experiments will probably be initiated no earlier than the second season of year 3. The second type of experiments are described in objective 3 below, and will depend on farmers having reasonable access to a local research site, either one of the “stations” or a replicated on-farm experiment.

3. Increase the capacity of smallholders to adapt and improve CAPS: Farmers in the Central Plateau are unfamiliar with research and unaccustomed to working in a participatory environment with university researchers. A key strategy will be to build trust by working with local agronomists and repeated interactions over time to build interest in the value of research. An interactive process of farmer learning will be the core component of a program for establishing adoptable CAPS and developing adaptations to improve production.

   a. Outreach through researcher-managed trials. The introduction of CAPS based on the researcher managed trials on the three Zanmi Agrikol and Diocese of Hinche farms to local farmers and community groups is critical to achieving to goal of developing adoptable CAPS. Only as farmers are exposed to the practices and can observe the results will they begin to explore their practices on their own fields. Transportation is a significant barrier to learning, so it is important that trials be located within accessible walking distances.

b. Farmer meetings, field days, and field schools. A variety of methods will be used to engage farmers with the research effort. In the first two years, agronomists conducted farmer meetings during the dry season to stress the importance of soil conservation and to discuss ongoing cultivar trials. Farmers observed, compared, and discussed cultivar trials during field days. These efforts have created interest in new seed sources and introduced farmers to the role research may play on their farms. In the coming years, we plan to use both field days and more intensive Farmer Field Schools (FFS) to focus on CAPS learning. CAPS trials will be observed from the beginning by end users and opportunities for adaptation encouraged. Each farm site has its own resident agronomist(s) who will provide on-site monitoring of experiments as well as leadership in outreach to local farmers.

c. Farmer managed testing of CAPS. As time progress, and mutual trust allows, we intend to develop simple on-farm, farmer-managed trials that would compare one or two candidate CAPS system with the farmer's conventional system. If we are able to obtain sufficient farmer involvement (usually 30), these trials can be subjected to statistical treatment using each farm as a replicate (Mutsaers, 1997).

4. Strengthen human and institutional research and extension capacity for CAPS: In the Central Plateau, there are no government or university research stations, and a very limited extension presence. As mentioned, research is not a traditional focus of existing agricultural-based organizations, and there is limited human and institutional capacity within the region. Three tasks have been identified:
    a. These farm sites will provide a model for testing a private/NGO system for national agricultural outreach/extension. Each farm center offers a focal point for locally adapted CAPS technological innovation and outreach, as well as for future research.
    b. Short-term training on selected themes for officials, researchers, technicians, and farmers. This objective will support all other aspects of the project.
    c. Long-term degree training. We continue efforts to identify and work with candidates for long term training in the sciences, on-the-job training for government administrators, researchers, and NGO farm agronomists/extension agents.

Summary

We have described the need for adapted and adoptable CAPs in the Central Plateau of Haiti, the constraints we face in addressing this need, and outlined the tasks and methods we will use to move toward our goal. In summary, as we move toward the goal of developing adapted and adoptable CAPS, we anticipate the following outcomes:

1. We will build an integrated household model based on an accepted economic household recall-based survey instruments that has been customized for the Central Plateau of Haiti. This product will inform the CAPS development component concerning barriers and potential

pathways to adoption, and will result in two or more referred articles targeted for journals such as Ecological Economics. Survey completion is expected in November of Year 3. Additional field sampling (Soil CCRA and harvest sampling: Summer Year 3.)

2. We will test adaptation and performance of important cover crops in Haiti. We have been unable to find work of this nature. This product will inform the CAPS development component and result in a referred journal article targeted for an audience such as International Agronomy. Planned plantings: Year 2-5.
3. We will develop understanding of the planting and non-chemical weed control methods necessary for successful reduced tillage systems, including the use of cover crops as smother crops. We anticipate interaction with farmers as well as other professionals in the Conservation Agriculture community will be critical in addressing this need. Planned studies: Year 3-5.
4. We will apply crop modeling techniques to advance understanding of cropping systems, identify potential candidate systems for CAPS development, and refine candidate systems. Year 3-5. Publication in Agronomy Journal, Agroecosystems or Agriculture, Ecosystems & Environment on modeling could result by year 5.
5. We will work with farmers to identify adoptable CAPS practices using focus groups, field days, and farmer field school activities. Year 3-5.
6. We will attempt to implement farmer managed studies testing conventional systems and CAPS side by side in Year 4 of the project.
7. We will identify CAPS or soil–improving components of CAPS that will work, and could be adopted by local farmers by the end of year 5.
8. We will assess the change in soil properties that have occurred. These are likely to have been minimal over the brief span of this project, but must be monitored.

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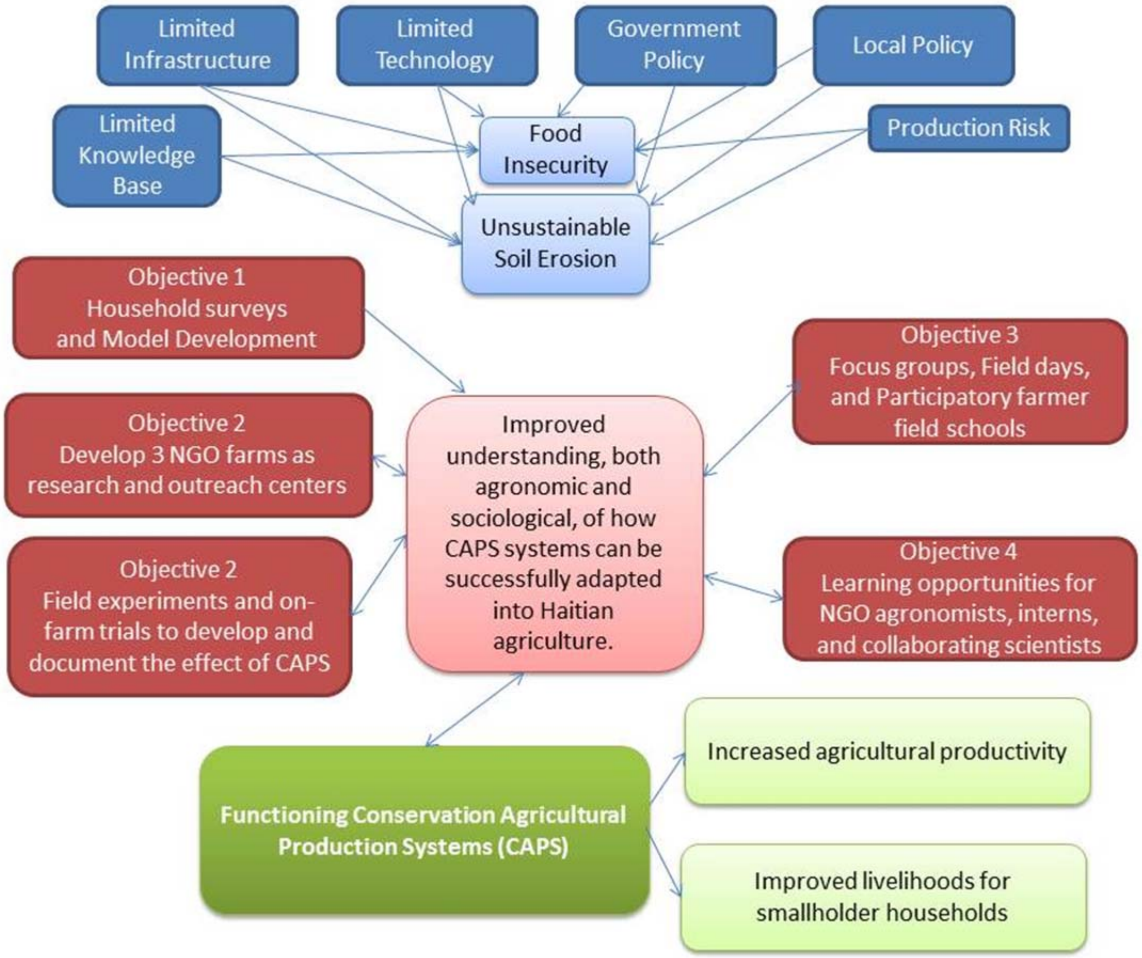

Figure 1 LTRA-6: Scientific and production problems, driving forces, activities, and outputs.

LTRA-7: Conservation Agriculture as a Potential Pathway to Better Resource Management, Higher Productivity, and Improved Socioeconomic Conditions in the Andean Region

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Host Countries: Ecuador, Bolivia

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University of Denver: International Development: Sarah Hamilton;
U.S. Department of Agriculture Soil Plant Nutrient Research Unit: Jorge A. Delgado.

Introduction

The overall goal of our project is to test the concept of conservation agriculture (CA) for smallholder farmers in high-altitude, fragile areas of the Andean Region (Ecuador and Bolivia). As a part of this testing of the concepts, we will evaluate alternative practices and incorporate them into conservation agricultural production systems (CAPS). The research will identify CAPS impacts on: soil health and productivity, farm incomes and their variability, food security, gender relations and other social considerations. Because of these different dimensions of impact and different mechanisms by which actions by humans lead to impacts, we are incorporating a trans-disciplinary focus. Our project involved integrated participation of soil scientists, agronomists, soil ecologists, plant pathologists, entomologists, and social scientists.

Our project views CA as a continuum running from a single or small number of practices to a full-blown CAPS. As a result, we are investigating alternatives to increase agricultural productivity and incomes on the farm in a sustainable fashion through improvements in soil health, better rotations, cost-effective and sustainable pest and nutrient management, and improved water management. Off-farm innovations can raise agricultural incomes and reduce stress on the natural resource base. Acceptance of CA by farmers and its ultimate spread and impact will depend on profitability (compared to alternatives), compatibility with existing practices, institutional considerations affecting incentives to change farming practices, and other socioeconomic considerations. Thus our project integrates physical and agronomic sciences with social science research; we measure and analyze economic and other consequences of farming practices at early stages of the research and seek means of building linkages between on-farm practices and the local economy.

We have established research sites in two sub-watersheds in Bolivar Province, Ecuador and Tiraque, Bolivia. In the upper (Illangama) watershed in Ecuador, potatoes are the main staple and agricultural productivity is constrained by nutrient deficiencies, pests and diseases and erratic rainfall. The lower Ecuador watershed (Alumbre) is characterized by warmer temperatures, predominance of maize and beans, very poor soil quality, low and declining productivity, low incomes, and high poverty. The site in Bolivia is a high-altitude area with low productivity, very poor soils, high populations of pathogens, and low rainfall during critical periods. Agriculture on the site is characterized by predominance of potatoes mixed with small grains and other tubers. We are working among three distinct farming systems facing different agro-ecological conditions.

Objectives

Under the broad goal of the research are six specific objectives:

1. Identify and evaluate production practices and farming components that can be assembled into CAPS for Bolivar, Ecuador and Tiraque, Bolivia
2. Validate candidate CAPS in terms of impacts on: soil health, soil retention, carbon and nutrient balances; sustained productivity; profitability; risk bearing; the environment; compatibility with household livelihood strategies; and social conditions including gender considerations
3. Promote adoption of the most appropriate CAPS by identifying mechanisms to increase their profitability
4. Design and evaluate mechanisms for disseminating results to similar areas
5. Evaluate overall impacts of the CRSP research program along several dimensions including soil health, productivity, economic, social and environmental
6. Strengthen the capacity of government and non-government institutions to develop and disseminate CAPS in the Andean regions of target countries

The core of our research consists of field trials of practices and CA-related components taking place on farmer fields. Our trials include tillage options, soil cover alternatives, new rotations, and physical practices to reduce soil erosion. We also have satellite trials examining alternatives such as biological pest controls, soil amendments, and pest management practices. In all cases, we are evaluating these practices in terms of economic costs and benefits, compatibility with existing practices (and livelihood strategies), impacts on constraints (such as labor availability and gender roles), and off-farm implications. Our experimental components were arrived at following extensive meetings with scientists, dialogue, and consultation with farmer stakeholders. Our criteria for identifying these included: compatibility with existing and alternative practices; expected contributions to soil health and productivity; returns to farmers; acceptance by target audience; and economic considerations such as labor and time availability, finance constraints, riskiness, access to markets, and expected net of cost returns.

Integration between physical and social science investigation is complete. The building block of the linkage is involvement of all scientists in design of the experiments and data collection protocols. For our agronomic research, we collect information on costs of production, timing of input purchases and labor applications, yields and prices, and risk/variability; this information is used to allow social analysis of practices based on experimental data. We also collect information on off-farm linkages such as input purchases, soil loss, etc. This information is being used to evaluate external costs and benefits of on-farm practices; these costs will be included when we evaluate the overall costs/benefits of the CAPS. Thus, on-farm trials will provide information to feed into social analysis, and the resulting analysis will feed back into the evaluation of the private costs/benefits.

Research Hypotheses

Our overarching hypothesis is that, when properly valued, CA will represent an improvement over current farming practices. We are setting up agronomic trials and measurement systems to adequately measure these values. Measurement is a critical issue and we have numerous indicators of soil health and soil conditions, short- and long-term net benefits to producers (private benefits) and off-farm net benefits (run-off, increased local economic activity, etc.).

<u>Sub-component hypotheses</u>

In the agronomic trials, the hypotheses are straightforward and too numerous to detail here. The basic hypothesis across all experiments is that the revised practice is superior to existing ones. As noted above, the definition of "superior" is somewhat vague and we are measuring many dimensions of impact. The null hypothesis is that the difference between the treatment and control along each of these dimensions is zero.

In the social science research, several important hypotheses will be tested:

1. Information weaknesses are creating a divergence between farmer perceptions about net benefits and actual private benefits. That is, because CA is a new concept, short-term costs of establishment may cloud decisions. Our research is designed to take a longer-term perspective.
2. Institutional constraints are inhibiting adoption. If farmers perceive long-term benefits from CA, they may be prevented from adopting because of credit constraints, risk considerations, availability or high costs of inputs. We will investigate these obstacles.
3. Institutional constraints are creating a divergence between private and social net benefits and, as a result, preventing wide-scale adoption. If farmers cannot capture the off-farm benefits (such as reduced siltation in rivers or improved water quality) of their on-farm actions, private incentives for adoption will not be aligned with social incentives.
4. Increased local production of inputs is economically viable and will lead to lower input prices, wider adoption and greater economic impacts of CAPS.

Methods

Research Design

<u>Agronomics:</u> In the following we will give a flavor of our key agronomic experiments in our three study areas. We have taken care that our field experiments follow international standards for randomization with sufficient degrees of freedom to address our key hypotheses.

Tiraque Region - Bolivia

In Bolivia, we face three principal agronomic constraints: inadequate moisture to establish cover crops outside of primary cropping season, extremely poor soil fertility, and high levels of soil-borne pathogens (principally nematodes). At each of the four field sites in Bolivia, a long-term experiment will be implemented that evaluates tillage and cover crop regimes in the context of a potato-quinua-faba bean rotation. Specific treatments are:

1. Traditional fallow
2. Vetch cover crop – harvested for forage
3. Vetch cover crop – retained for a green manure

Poultry manure will be the primary source of supplementary P & K fertility, and will be applied at 30 percent of the generally utilized rate in the fallow or cover crop phase, and 70 percent of the generally utilized rate in the potato phase of the cropping systems. Quinoa and faba bean will not receive any supplemental fertility but may receive biological amendments as they develop after Year 3.

Supplemental satellite experiments are:

- Impact of the microorganism *Bacillus subtilis* as well as other associated microbes on phosphorus solubulization and on the incidence and severity of plant diseases such as *Rhizoctonia* stem canker in potato.
- Effect of application of mineral fertilizer on vetch productivity (two levels of treatment—high and low)
- Impacts of alternative cover crops on soil health, productivity and moisture content.
- Tillage in potato: conventional, reduced, and minimum tillage
- Potato variety evaluation: Waych'a (*andígena*), V2 = Desiree (*tuberosum*)

Upper and Lower Watershed near Guaranda, Ecuador
In Ecuador, we have established two broad types of experiments: small-scale plots on which we are carefully measuring erosion, and large-scale field plots established in a randomized block design. Adequate soil moisture as well as pests, particularly fungal pathogens and insects, are critical constraints in Ecuador, however, soils are overall less nutrient limited than those in Bolivia.

1. Soil Erosion Experiments (on-going)
    a. Upper watershed: Illangama (potato – barley – faba rotation)
        i. Natural pasture control (retained all years)
        ii. Improved pasture + conventional tillage during rotation
        iii. Improved pasture + reduced tillage during rotation
        iv. Oat/vetch + no tillage during rotation
    b. Lower watershed: Alumbre (maize-beans rotation)
        i. Natural pasture
        ii. Oat/vetch - conventional tillage maize – beans
        iii. Oat/vetch - reduced tillage maize – beans
        iv. Oat/vetch – no tillage maize – beans
2. Drainage - Tillage Experiments (on-going)

a. Upper watershed ($potato_i$ - $potato_n$ – fava – pasture or cover crop)
    i. Upslope drainage ditch (+/-)
    ii. Conventional or reduced tillage
    iii. Perennial buffer strips (+/-)
b. Lower watershed (fallow – maize – beans)
    i. Upslope drainage ditch (+/-)
    ii. Conventional or reduced tillage
    iii. Perennial buffer strips (+/-)

3. Residue Management Experiment (new)
    a. Upper watershed (fallow or pasture – potato – barley – faba)
        i. Fallow – no N in crops
        ii. Fallow – NPK in crops
        iii. Improved pasture residue retained + NPK in crops
        iv. Improved pasture residue removed + NPK in crops
        v. Improved pasture residue retained + PK in crops
    b. Lower watershed (fallow or pasture – maize – beans)
        i. Fallow – no N in crops
        ii. Fallow – NPK in crops
        iii. Oats/vetch residue retained + NPK in crops
        iv. Oats/vetch residue removed + NPK in crops
        v. Oats residue retained + PK in crops

Supplementary satellite experiments in Ecuador involve evaluating biological control products containing *Bacillus thuringiensis, Bacillus subtilis, Beauvaria,* and *Trichoderma* spp. Previous research trials have demonstrated these products to be a potentially cost effective and environmentally friendly pest control alternative to conventional chemistries. *Trichoderma* spp. when applied as a soil amendment has also been associated with increased plant productivity.

<u>Soil measurements:</u> As an important determinant of CAPS viability is soil health, we have established protocols to measure dimensions of this. The baseline soil characterization for each site includes: bulk density; soil pH; total C, N, and P; available cations (Mg, Ca, K, P, etc.); and texture. Sampling occurs at 15 to 25 cm depth increments up to 1 m when feasible. One representative sample per replication block is being collected.

The baseline soil characterization for each treatment plot within a site includes: intact soil cores, taken at 0-15 cm. depth with measurement including hydraulic conductivity, water holding capacity at tension, bulk density; and loose soil at 0-25 cm, with measurements of total C & N, available P, inorganic N (N readily available for plant growth), potentially mineralizable N (PMN) (organic N that is likely to become available that growing season), particulate organic matter POM (the SOM fraction > 53 um – tends to correlate well to nutrient availability in SOM).

These soil parameters are key soil quality indicators associated with soil erosion potential and nutrient availability, or both and represent the minimum dataset necessary to characterize the effect of select CAPS practices on soil health. We hypothesize that these parameters could be changed (for better or worse) by the CAPS. Changes in total C & N are not likely to be detected in the short-term (i.e., one rotation cycle) but could be detected over the longer term. Changes in the other parameters can often be detected within a rotation cycle.

The erosion trials measure run-off soil and we conduct a comprehensive analysis of the nutrient profile of this run-off. We are attempting to correlate run-off with weather events and are using existing weather stations (from prior SANREM activities) to do so.

Socioeconomic measurement: As noted, acceptance by farmers of proposed CAPS will be affected by profitability, risk profile, consistency with other livelihood activities, availability of information, availability of inputs, and social considerations such as incentives and peer pressure.

Economic and social impacts*:* We have established protocols for collecting data on costs for all field experiments (in conjunction with the economic impact assessment CCRA). These costs include fixed (equipment) and variable costs, including family labor use and its timing in cultivation and harvest. We collect market data on input prices and availability and product prices. Regular market surveys are being undertaken. Regular participatory assessments are being conducted among farmers and other stakeholders in areas where field experiments are being undertaken. One purpose of these assessments is to identify and evaluate unanticipated social impacts or obstacles to CA diffusion. We will use all this information to measure private costs and benefits (including changes in yield profiles over time due to changes in soil health) of each practice and identify potential obstacles such as input availability or incomplete information. This analysis will include partial budgeting and more comprehensive linear programming models of alternative practices. This analysis is being closely coordinated with the Impact Assessment CCRA. Results of these economic analyses are being fed-back on an annual basis into our agronomic trials, and the team has created mechanisms by which qualitative changes in agronomic parameters are considered during the economic evaluation.

Environmental impacts: Soil erosion test plots include metal-demarcated boundaries, erosion collection points, and mechanisms for monitoring rainfall events. They had been established under the prior SANREM project to measure the relationship between weather events and soil loss, conditioned on management practices. These measurements will be aggregated across the watershed using data on spread of the practices (data will be collected during year three) and SWAT or a similar model. Impacts on down-stream flooding will be estimated (with and without the erosion reduction strategies) using literature values and secondary data. Estimates of off-farm costs will be computed.

Localized impacts on water quality will be measured using counts of macro-invertebrates and a technique piloted by Dr. Wills Flowers during the prior phase of SANREM. Dr. Flowers has found that such measurement is relatively inexpensive to continue and is effective at engaging local stakeholders (particularly young people) in the project and building awareness of the importance of environmental quality.

These analyses will be used to quantify some of the public benefits of CAPS and will be instrumental in measuring the social net benefits of system change.

CAPS adoption and household objectives*:* we are using household data to explore the relationship between household-specific livelihood strategies and the feasibility/desirability of CAPS adoption. We are estimating household-level econometric models to understand: the determinants of livelihood strategies, determinants of market choice for those who produce for markets, and the determinants of on-farm productive efficiency. These econometric estimates will provide information about how external drivers (such as prices, access to information, access to markets and social networks) affect these decisions.

Institutional considerations*:* we are examining a number of other institutional innovations that might affect the incentive structure and better align private and social incentives. These innovations include: increased local input production; better awareness of agriculture-environment links; and mechanisms by which off-farm beneficiaries compensate agricultural producers for their on-farm actions.

CAPS will have greater impact in the Andean region if their production involves linkages to the rest of the economy. We believe that increased local input production can form the basis of these strengthened linkages. We have identified (and tested) a number of biological controls and biological inputs for improved productivity. PROINPA (Bolivia) has a well-developed capacity (a bio-control production facility) to produce biological organisms, but work is needed to refine the particular isolates. We are examining steps to use *Bacilli* from quinoa to control quinoa diseases. At Penn State and PROINPA, several experiments have been performed to isolate endospore-forming *Bacilli* from *Chenopodium quinoa* seeds. This work is ongoing. Isolates that are verified to form endospores will be checked for their ability to solubilize phosphate by utilizing the National Botanical Research Institute's phosphate growth medium. Cultures will be tested for their ability to colonize *C. quinoa* in growth chamber assays and promote growth of *C. quinoa* in a low-phosphate Andean proxy soil. Isolates that promote plant growth, but do not affect nutrient availability will be evaluated for disease suppression and hormonal stimulation. Subsequently we will look at combinations of bacteria applied as consortia to seed that stimulate overall plant growth and productivity while suppressing multiple adversities.

This technical work is being linked to economic work in both countries, where we are examining costs of manufacturing these organisms at different scales. Biological amendments are being produced at varying scales throughout the world. For example, *Trichoderma* is produced at the household scale in many countries in South Asia, but at much larger scales in Central America. Our cost of production studies will be complemented with demand analysis to provide evidence of optimal scales.

Increased awareness of agriculture-environment links are being promoted through our water quality measurement efforts, continuous engagement of community farmer and other groups, and our process of participatory research.

We plan to use the information generated on down-stream costs (flooding and water quality) associated with farming practices to motivate an institutional study of the feasibility of payments for environmental services. In Ecuador, in particular, the government is exploring means of reducing the probability and severity of downstream flooding. This flooding leads to billions of dollars in costs every year and the government is seeking low-cost means of avoiding these costs.

LTRA-8: Improving Soil Quality and Crop Productivity through Farmers' Tested and Recommended Conservation Agricultural Practices in Cropping Systems of West Africa

Principal investigator: P.V. Vara Prasad, Department of Agronomy, Kansas State University

Host Countries: Ghana, Mali

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Introduction

The challenges one faces in trying to increase ecosystem services, yields, and farm level profitability in West African countries largely revolve around environmental and economic constraints. Improving ecosystem services, with a focus on soil quality and water quantity, in West Africa will require the adoption of CAPS that employ intensive crop rotations such as legumes to fix nitrogen and focus on reduced tillage and practices that maintain as much crop residue in the system as possible and integrated nutrient, water and pest management practices.

Goal

This research will help answer critical questions often associated with CAPS for smallholder farmers of West Africa.
These include:

1. Which conservation agriculture practices can positively contribute to productivity, address needs of farmers, and under what specific conditions?
2. What are the positive and negative aspects (trade-offs) of CAPS both in the short term and long term?
3. Can CAPS be adopted by smallholder farmers and if preconditions for adoptions exit in West Africa (Ghana and Mali)?

Specific Objectives

1. Evaluate local conservation agriculture practices that are based on the principles of minimum tillage, direct seeding into residues, retention of crop residue, and

incorporation of leguminous cover crops to improve soil quality, water use efficiency, and cropping system productivity and income.

2. Develop cropping systems (crop rotations and/or intercropping) that improve water use efficiency and nutrient use efficiency through integrated water [e.g., residue, seedbed type, ACN technologies (contour ridging)] and nutrient management practices (combination of organic and inorganic fertilizers).
3. Foster and advance rapid adoption of local CAPS and integrated crop, water, soil and nutrient management practices to improve system productivity, livelihoods and natural resources.
4. Calibrate, assess and use crop simulation models to predict the impact of individual conservation agriculture practices on system productivity, water use, soil carbon sequestration, and economic returns for the experimental sites as well as beyond the sites and across the region.
5. Strengthen capacity of scientists, extension agents, rural communities and farmers through training workshops and demonstrations to document and communicate the benefits of CAPS to facilitate access to inputs, equipment and markets to make conservation agriculture practices accessible and sustainable.
6. Capacity building of host country scientists through short-term training workshops and long-term training by providing graduate degrees (MS or PhD) in the United States and through initiating collaboration and networking group with scientists of other countries in the region.

Research Hypotheses or Questions

Critical research activities and hypotheses tested in this research include:

Establishment of Integrated Long Term Research Experiments with CAPS

Hypotheses: Conservation agricultural practices (minimum tillage, residue management, water harvesting techniques and integrated fertilizer management) would enhance soil moisture, grain yield and profits from maize and/or millet (or cereal – legume) cropping systems.

Comparing Seedbed Type or Residue Management and/or Fertilizer Application

Hypotheses: Mounding of seedbeds improves soil moisture conservation and soil fertility.

Effect of Tillage and Legume Cover Crop on Soil Quality and Yield

Hypotheses: Minimum tillage and cover crop will enhance soil quality and grain yield.

Initial Testing and Phased Adoption of CAPS in Combination with Cereal – Legume Cropping Systems through Farmer Fields Schools (FFS)

Hypotheses: Crop rotation of cereal and legume will enhance nutrient use, soil quality and grain yield.

Evaluation and Production of No till Seed (Jab Planters) and Fertilizer Drill in Small Holding Farmers
Hypotheses: Adoption of new minimum tillage equipment will decrease farm labor, improve systems productivity and family income.

Impacts of Adoption of CAPS on Labor, Farm Income, Livelihood
Hypotheses: Adoption of minimum tillage CAPs will decrease farm labor, improve systems productivity and overall family income and help improve ecosystem services.

Modeling Impact of Tillage and CAPs on Crop Yield and Soil Quality
Hypotheses: Crop models can help upscale and test "what if" question related to long term effects of CAPs within and outside the region.

Linking the Leading Hypotheses/Questions to the Methods

Research in Ghana is being conducted in partnership with scientists from SARI (Savanna Agricultural Research Institute), NGOs, and Wa Polytechnic. Three major cropping systems are involved with soybean, maize and sorghum cropping systems. The experiments are being conducted in four districts (Wa West, Wa Municipality, Lowra, and Nadowli) in the Upper West region of Ghana. Soils are of poor texture and mostly sand and some sandy loam. Rainfall in this region varies from 400 to 600 mm.

Research in Mali is being conducted in partnership with scientists of IER (Institute of Economic and Rural Development) in collaboration with NGOs and ICRISAT-Mali. Four major cropping systems and agroecological zones are involved: (1) permanent millet cropping systems in the Bankass – Koro area (northeast zone, Mopti region); (2) permanent millet cropping system in the Cinzana area (central zone, Ségou region); (3) Sorghum cropping system in Kati area (central zone, Koulikoro region); and (4) cotton cropping system in Koutiala – Sikasso area (southeast zone, Sikasso region). These zones cover annual rainfalls of 500 to 1100 mm.

Specific research experiments in Ghana and Mali are listed below:
In Ghana, four mother trials to evaluate conservation agriculture practices will be initiated. At Nyoli in the Wa West District, one mother trial evaluates the effects of tillage and cropping systems on maize growth, yield, soil moisture balance and carbon. Treatments include three tillage systems (conventional tillage using tractor to plow the land, manual tillage using hoes and minimum tillage in which a herbicide is used to kill weeds before sowing followed by one hand weeding using hoes). Cropping system treatments include continuous maize, soybean-maize annual rotation and soybean/maize intercropping. The experimental design would be split plot with tillage systems as main plot factor and cropping systems as the sub-plot treatment with three replications.

At Tanzu in the Wa Municipal district, the second mother trial evaluates the effects of tillage, cropping system and mineral fertilizer application on soybean growth and yield. Two tillage systems (conventional tillage using disc plow and minimum tillage in which a herbicide is used to kill all vegetation before sowing, followed by one hand weeding) would be tested with two cropping system treatments (continuous maize or soybean-maize annual rotation). Soybean would receive no fertilizer, NPK or P as triple superphosphate at a rate of 26 kg P ha^{-1}. The experimental design would be split-plot with tillage systems as main plot treatments while the sub-plot treatments would be cropping system and fertilizer combinations with three replications.

A third mother trial to evaluate different seedbed types and moisture conservation practices on productivity, water use and water use efficiency of maize would be conducted at Nandom in the Lawra District. Treatments consist of a factorial combination of two seedbed types (flat and tied ridges) and three moisture conservation practices (no bunds, grass bunds, and *Gliricidia sepium* bunds). The purpose of the *Gliricidia sepium* bunds is to serve as a soil cover during the dry-season as well as increase residue returns to the soil and provide fodder for animals. The trial would be laid as a randomized complete block design with 3 replications.

A fourth mother trial to evaluate the effects of tillage, cropping systems and residue management on soybean and maize growth, yields and soil water balance would be implemented at Gbanko village in the Nadowli District. Treatments would consist of two tillage systems, (conventional and minimum tillage), three cropping systems (continuous maize, soybean-maize annual rotation, and soybean/maize annual intercropping), and three residue retention rates (100, 50 and 25%). The experimental design would be split-split plot with four replications. Main plot treatments would be tillage systems, sub-plot treatments would be cropping systems and sub-sub-plot treatments would be residue retention.

In Mali, eight long term experiments (mother) will be initiated at four research stations (Mopti, Cinzana, Sikasso and Koulikoro - Sotuba). In Mopti, the experiments include six treatments (T1 = Control; T2 = Minimum tillage + weed colonized band + Tied ridge + Mix cropping; T3 = Minimum tillage + weed colonized band + Tied ridge + compost pits + Mix cropping; T4 = No tillage + weed colonized band + Tied ridge + Mix cropping, T5 = Minimum tillage (scratching or strip tillage) + weed colonized band + Tied ridge + compost pits + Mix cropping + Cowpea-millet rotation; and T6 = No tillage + weed colonized band + Tied ridge + Mix cropping + Cowpea-millet rotation) replicated three times in a randomized design.

In Cinzana, two experiments will be initiated. Experiment 1 includes two tillage (simple ridges and tied ridges), two crop residues (without residue and with crop residue), and three fertilizer (no fertilizer control, manure -10 t ha^{-1}, and mineral fertilizer 100 kg ha^{-1} DAP and 50 kg ha^{-1} urea in combination with manure) replicated three times in a factorial design. Experiment 2, involves five cropping systems (monoculture millet, continuous millet/cowpea intercrop, continuous millet/peanut intercrop, cowpea - millet rotation, and peanut - millet rotation), two tillage systems (simple ridges and tied ridges) and two crop residue (with and without crop residue) replicated three times in a factorial design.

In Sikkaso, two experiments will be initiated. Experiment 1 includes three tillage (direct seeding, animal tillage, tractor tillage), two fertilizer (farmers practice and recommended practice), and two ridging (no ridging and riding after 30 d) effects on maize ad replicated four times in a factorial design. Experiment 2 includes two crop rotations (sorghum and peanut), two fertilizer practices (farmers practice and recommended practice), and three crop residue (no residue, with residue, and burned residues) replicated four times in a factorial design.

In Koulikoro (Sotuba) two experiments will be initiated. Experiment 1 includes two rotations (maize and peanut), two water harvesting technique (no countor ridges, with contour ridges), two crop residues (with and without crop residues), and two tillage (permanent ridges - direct seeding, and annual ridging) replicated three times and factorial design.

In all mother trials, records of crop and soil management practices, crop growth, yield, residue production, and soil water content would be measured. For field experiments (both researcher-managed and/or farmer-managed), data collection would include plant stands after planting, emergence percentages, development (time to flowering and time to physiological maturity), yield and yield components (grain or seed yield, harvest index). In experiments where necessary, plant growth analysis will be conducted over time to obtain growth response to specific treatments. Cover crop biomass will be measured at crop termination. Cover crop nutrient levels will also be determined.

Data on initial soil analysis (physical, chemical, and microbial) will be collected prior to the start of the experiments and thereafter on annual basis. This will help quantify the effects of treatments over time. Soil type will be classified according to standard published procedures. Minimum data set requirement to facilitate CCRA will be collected. These include soil carbon and soil bulk density at different depths, soil cover, complete soil nutrient status (both macro and micro-nutrients) at different depths. Field capacity and wilting point of soil will also be measured. Inventory all organic and inorganic inputs (types, rates and timing and method of application) will be kept.

Where applicable and necessary, crop plant components (leaves and stems or above ground canopies) parts will be analyzed for nutrient concentrations to estimate nutrient uptake and do the nutrient balance each year.

Environmental data (air and soil temperature), solar radiation, rainfall and wind speed will be measured at standard meteorological weather observation as suggested by International Meteorological Department.

Inventory of all farm inputs, timing of application, type and rate of application, cost, land tenure, labor and other socioeconomic data will be collected to determine the cost–benefit ratio of the treatments and for detailed economic analysis. Economic evaluation will involve estimation of partial budget, cost–benefit ratios and marginal returns. Care will be taken to incorporate the cost and benefits of ecosystems services provided by the technologies that are being tested. We will collect data to understand attitudes and behaviors for CAPS and impacts on the status of women.

The crop simulation model we intend to use is DSSAT Version 4 (Decision Support System for Agrotechnology Transfer – CENTURY improved to handle tillage systems), it includes improved application programs for seasonal and sequence (including crop rotations) analyses that assess the economic risks, and environmental impacts associated with environmental stress, irrigation, fertilizer and nutrient management, climate change, soil carbon sequestration, climate variability, and precision management. It is capable of analyzing biological, physical, and economic components associated with various crops in a crop rotation or cropping system.

For baseline surveys, sufficient care will be taken to quantify (the data using appropriate) and if necessary transform (statistical transformation to allow for normal distribution or for proportions) the data before statistical comparisons. Proper statistical tools used in the social sciences will be used for data analyses. Methods recommended by CCRA leaders will be used while collecting data for ease of comparison across all LTRA locations.

All experiments will be conducted for multiple years (at least two years, often more) before drawing any concrete conclusions. Where crop rotations are involved, at least two complete rotations will be evaluated.

All the data will be analyzed using standard scientific statistical software – mostly Statistical Analytical System (SAS) or GENSTAT. The typical model used for analyses of variance will be procedures of General Linear Models (PROC GLM) or Mixed Models (PROC Mixed). The treatment differences will be compared using standard techniques (such as LSD or SE). For data from simulation models observed and predicted values will be compared using regression coefficients, slopes, error means squares, or d-values.

Research Strategy

Baseline surveys have indicated that the second requirement of the SANREM CAPS (that is permanent ground cover with either cover crop or crop residues) is not compatible with the cropping systems being practiced by farmers in the selected areas. In fact, livestock management is a critical component of each cropping system of Mali. Therefore, cover crops and crop residues were viewed as forage. In addition, the "open grazing-land" system of the off-season period makes very challenging to maintain the soils covered.

Baseline surveys along with discussion of value chain informants and scientists have also indicated that the third requirement of the SANREM CAPS (that is rotation with a legume) will be most convenient with peanut. Peanuts offer the comparative advantage of being used by women on lands (usually degraded) allocated to them.

Baseline surveys have further indicated that any CAPS in the selected cropping systems should include a component on rainfall management or water harvesting or runoff management. Furthermore, any CAPS that would improve soil quality and increase yields should include both organic and mineral fertilizer management.

The above findings in the socio-economic domain will shape research towards developing local CAPS which will not only evaluate minimum tillage, crop rotations with legume and residue management, but also include components such as: (1) rainfall management; (2) organic fertilizers; (3) mineral fertilizers; and (4) live fencing, preferably *Jatropha curcas*. Live fencing with J*atropha* was suggested to encourage permanent ground cover and generate additional income. To develop local CAPS, 'mother experiments' will be conducted on research stations to assess the impacts of these CAPS. "Baby experiments" will be conducted on-farm to demonstrate the impacts of these CAPS. Methods described above will be used.

Transdisciplinary Research Strategy

The key driving forces shaping the scientific problems include (1) low activity clay or naturally poor sandy soils; (2) soil mining practices by farmers; (3) runoff; (4) climate change; and (5) socioeconomic constraints. Scientific models and research activities needed to address these problems, as validated from baseline survey include farmer identified CAPS and SANREM-suggested CAPS. The road map to obtain various objectives is shown in Figure 1. Similarly, the interrelationships between various problems, scientific models, and research activities designed to address them are highlighted in Figure 2. The timeline of various activities is as follows: Activity 1 (Year 1), Activities 2 through 5 (Years 1 and 2), Activities 6 and 7 (Years 2 through 5), Activity 8 and 9 (Year 4) and Activity 10 (Year 5). Most activities will be implemented in both countries.

The main products of this research will be (a) identification of conservation agriculture practices that can positively contribute to soil quality and/or crop productivity; (b) identification of positive or negative aspects (trade-offs) of CAPS both in the short term and long term; and (c) listing of CAPS that are adoptable by smallholder farmers and identification of pre-conditions for adoptions on CAPS in West Africa.

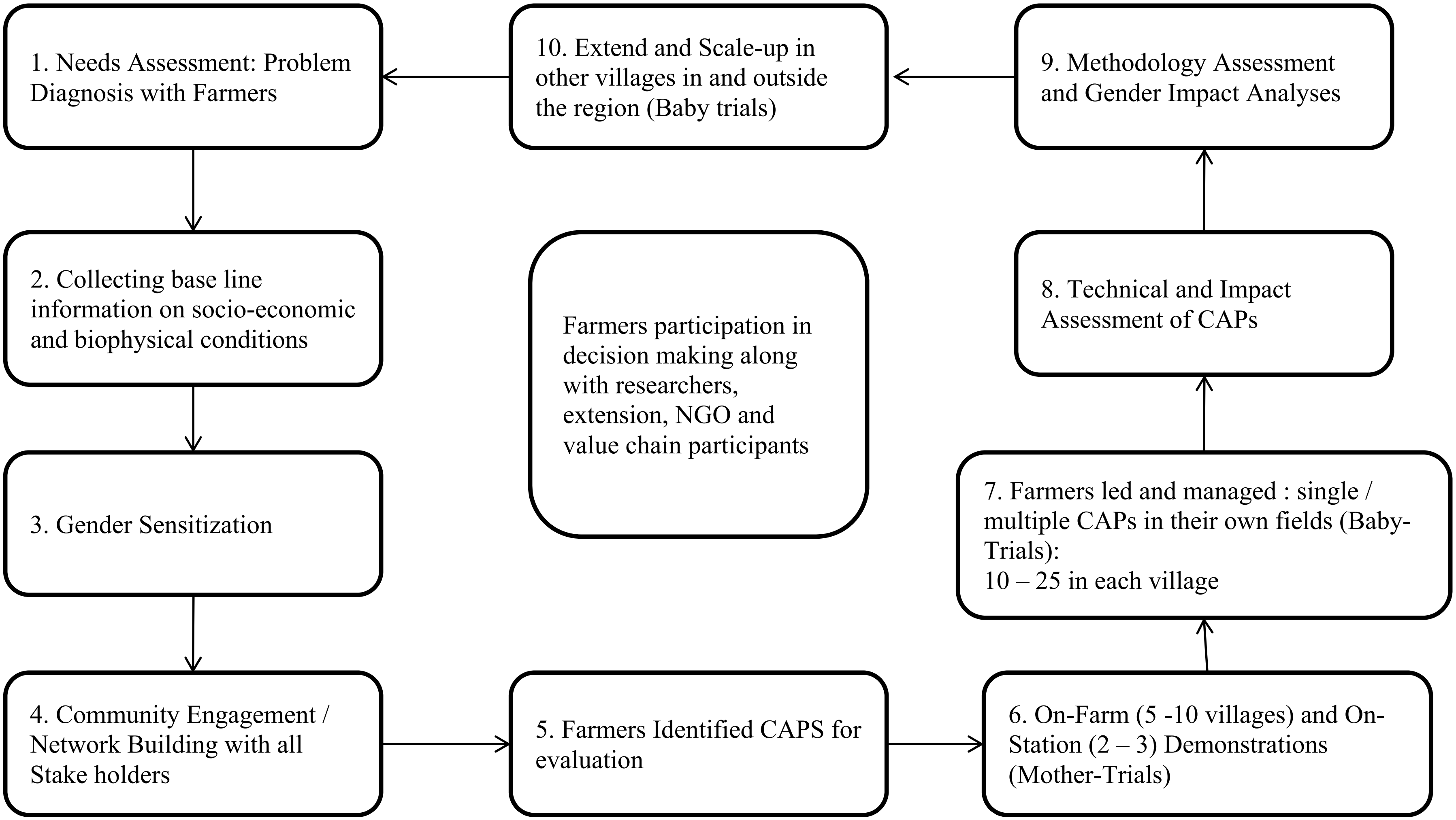

Figure 2. Road map of various activities to accomplish objectives of research.

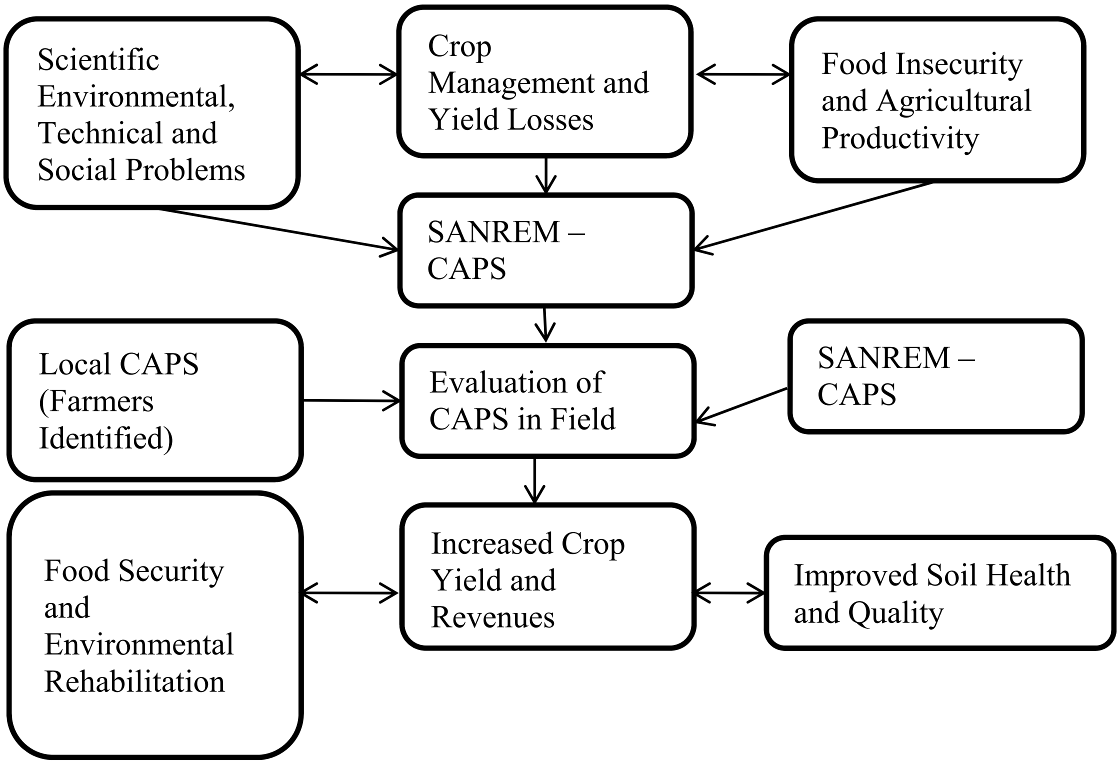

Figure 3. Problems, scientific models and research activities of the project and interrelationships among disciplines.

LTRA-9: Developing Sustainable Conservation Agricultural Production Systems for Smallholder Farmers in Southern Africa

Principal investigator: Neal Eash, Department of Biosystems Engineering and Soil Science, University of Tennessee

Host Countries: Lesotho, Mozambique

Research team:
University of Tennessee: Department of Biosystems Engineering and Soil Science: Forbes Walker; Department of Agricultural and Resource Economics: Dayton Lambert, Michael Wilcox
National University of Lesotho: Department of Soil Science: Makoala Marake
International Maize and Wheat Improvement Center (CIMMYT): Global Conservation Agriculture Program: Patrick Wall
Growing Nations: August Basson

Introduction

Subsistence farmers in Lesotho and Mozambique struggle with food security and often address the shortfall by plowing more land. This approach usually results in lower crop yields due to less timely weeding, limited inputs such as fertilizer being spread across a larger area, and higher erosion rates due to larger tracts of erodible, residue-free fields.

This project will research the structure of and risks associated with existing production systems to determine the effectiveness of different no-till and tilled crop management systems and their adoption. The goal is to find appropriate cereal, grass, and legume cover-crop mixes that protect soils from erosion, build soil organic matter, sequester carbon, limit weed germination, enhance soil fertility, and increase yields and income. Research plots will be established in Lesotho and Mozambique to address the crop science and soil ecosystem components of Conservation Agricultural Systems (CAS). This basic agronomic knowledge will be supplemented by household survey data. The household survey components focus on understanding the local knowledge systems, which ultimately provide the socio-cultural and institutional context where agronomic findings will be disseminated, interpreted, adapted, and sustainably integrated into local production systems. Our transdisciplinary strategy is highlighted in Figure 1.

Objectives

Critical Research Hypotheses Tested

The research goals and objectives can be organized into an Agronomic Systems Knowledge Domain (ASK), a Carbon Systems Knowledge Domain (CSK), and a Farming Systems Knowledge Domain (FSK). The union of these domains forms the core of the project, and is where knowledge (i.e., research findings) is translated into action (i.e., through the experimentation and modification of trial CAS's by smallholder farmers). The domains are therefore mutually reinforcing, whereby the articulation of one knowledge paradigm informs the other; in other words, the research approach is holistic.

There are five specific objectives of this LTRA-9 subsumed under these domains, and are outlined below:

Agronomic Systems Knowledge Domain (ASK)
(1) Integrate cover crops into CAS to protect soil from erosion; provide weed suppression or control; include crop rotations that provide forages for livestock; improve soil quality as measured by soil C; decrease risk and vulnerability to drought.

(2) Determine the agronomic and economic fertilizer rate for maize planted using different planting configurations in no-till conditions.

Research undertaken in Lesotho seeks to determine the optimum fertilizer use under current maize populations and greater maize populations under more intensive CA systems. Our research indicates that greater plant populations are needed to suppress weed pressure and to achieve the higher yields necessary to offset the variable costs (mainly labor) of the CA system.
Different cover crop species and planting dates are under evaluation for effectiveness at weed control and suppression as well as durability of the cover crop as a soil residue cover during the next growing season. Our research results indicate that cover crop establishment at the end of the growing season can reduce weed populations by nearly 100 percent with a continuing effect into the next growing season that extends well past the date of cover crop termination. On the production agronomy side we are evaluating planting dates, plant populations, variety selection, plant populations by fertilizer rate interactions, and mechanical and chemical weed control methods (timing and active ingredient).

Soil quality indicators are being evaluated for inclusion into a minimum soil quality dataset; these factors include soil total carbon (C), soil test values, soil depth, microbial biomass C, slope, parent material, and erodibility (from a qualitative standpoint only). During this research we will use participatory and disciplinary research to evaluate farmer perceptions of amendments, their costs, and their effect upon crop yield and economic risk.

Carbon Systems Knowledge Domain (CSK)
(3) Characterize the composition and contribution of N and C from legume/grass cover crops and determine the best species for maintaining soil residue cover until after maize crop harvest.
To assess the effect of CA on soil C sequestration we are measuring soil CO_2 flux using a Bowen Ratio (BR) unit that essentially measures the energy in and out of the soil ecosystem. These measurements include soil temperature, soil moisture, soil heat flux, net radiation, CO_2 at the top of the crop canopy and two meters above the canopy and moves with the crop canopy, ambient relative humidity, ambient temperature, and wind speed. We expect the BR values to predict whether the soil is a source or sink for CO_2. We have a paired site in Lesotho where we are monitoring the soil quality of a site that has been in fallow for several decades and an adjacent site that has had intensive tillage over the same period. At these sites we have both a conventional plowed treatment and a CA treatment. These nearby sites with contrasting histories provide us with the unique opportunity to evaluate the effects of tillage on soils under long-term fallow and the effects of reduced tillage on a severely degraded soil.

Baseline soil C samples have been collected and will be collected again in year 5. However, the literature suggests that this time frame is really too short to evaluate soil C source-sink relationships regardless of soil management system. We will evaluate soil CO_2 flux along with BR data to try to assess soil carbon dynamics.

Farming Systems Knowledge Domain (FSK)
(4) Determine the short- and long-term impacts of CAS on gender equity especially in terms of household income and economic impact and to involve women in decisions that impact their welfare.

(5) Evaluate ways and means to improve fertilizer adoption rates among smallholder farmers, the degree to which market structure influences fertilizer use, and determine welfare implications based on price margins.

Accomplishing these objectives would be a significant step toward increasing incomes, food security, and gender equity for smallholder farmers in the region. However, due to the absence of fundamental agronomic recommendations for maize– the main food staple– the project is concentrating initially on collecting and assimilating soil and agronomic data to develop basic agronomic and soil fertility research to support local Basotho producers. The insights gained during this knowledge acquisition phase (KAP) will be used to extend the results to local farmers through an adaptive transformation phase (ATP) at study sites and district or inter-district (e.g., "regional") levels.

Methods

The LTRA-9 research strategy is to discover knowledge using two avenues; (1) conduct the basic and applied research needed to develop science-based recommendations for management of the CA systems; (2) to integrate, extend, and adapt this knowledge on local and regional scales.

Leading Hypotheses/Questions and Methods
Objective 1 focuses on the CA ecosystem: soils, climate, weeds, pathogens, pests, and crop rotations, and climate and the resulting impact of these interactions on soil C. Findings from objectives 2 and 3 will provide knowledge to the CA system eventually adapted by the farmer on a local and regional scale. Results from objectives 1 through 3 will be used collectively with results from objectives 4 and 5 to identify adaptive strategies that will improve economic livelihoods and improve the ecosystems. Overall this project will discover knowledge that will lead to adaptation of CAS that will improve soils and provide economic resilience to subsistence farmers. Specific hypotheses and methods are discussed below.

Agronomic Systems Knowledge
ASK1: People apply inappropriate amounts of fertilizers because of their lack of knowledge with respect to fertilizer composition. A combination of participatory and survey techniques will be used to determine how application rates were calculated and resulting fertilizer application rates. Information on current fertilizer application rates and research based recommendations will be combined to form a foundation for educational materials in adaptive transformation phase.

ASK2: Estimating which factors contribute most to variation in yield response is crucial for determining biological and economically optimal inputs rates and management practices. On-farm trials will be conducted in two geographic regions in Lesotho; Maphutseng and Botha

Buthe. In the region surrounding Chimoio, Mozambique, where farmers and extension agents generally feel that fertilizer is not required, a recommended fertilizer level will be compared with the farmers' fertilization practices under both CAS and conventionally tilled conditions on five farmers´ fields in each of three communities.

ASK3: Yields are low because producers do not use enough fertilizers. Due to their high costs, less than optimum fertilizer rates are used on most farms. On-farm trials will be initiated to determine farmer response to fertilizer additions. Results will be incorporated into farmer recommendations.

Cropping Systems Knowledge
CSK1: Carbon increases under no-till. Measure various micrometeorological parameters to calculate the Bowen Ratio under both tilled and CA plots. Results incorporated into scientific literature.

CSK2: Cover crops will shift weed populations and density. On-farm research and subsequent surveys will determine the farmer assessment of this practice. Results will be incorporated into farmer recommendations.

CSK3: Target maize populations are too low for adequate weed control, maximum economic yield, and creating enough soil residue cover. On-station and on-farm research data will be evaluated to determine optimum maize populations under hoe, animal draft, and tractor CAS.

Farming Systems Knowledge
FSK1: There is a need to differentiate between *likoti* which are small basins dug with a hoe and 'mechanized' CA. Wealthier people are more likely to till than to use CAS. Household survey data will be used to create a wealth index (e.g. Silici, 2010) regressed on a binary variable (Maddala, 1983) indicating if CA was adopted. Using a combination of participatory and surveying methods, need to understand drivers of choice to till verses no-till and the interaction between choice and available resources.

FSK2: Wealthy people can afford to till and think that CA is inefficient. The opportunity cost of time is likely correlated with the off-farm income sources and market engagement. An index measuring the opportunity cost of time will be regressed on a binary variable indicating if CA was adopted. Time trials conducted on experiment station will be coupled with survey data to determine the time input required for till versus no-till situations for comparison.

FSK3: Quantity of land holdings are negatively correlated with CA adoption. Acres owned by respondent will be regressed on a binary variable indicating if CA was adopted. Using geospatial econometric techniques, the interaction between land holdings and proximity to household will be examined further. This information will be used in the adaption transfer to assist with site selection.

FSK4: Proximity to land holding is positively correlated with CAS adoption. Walking distance (minutes) to fields is regressed on a binary variable indicating if CA was adopted. Walking minutes are recorded in the household survey.

FSK5: Incentives often exaggerate adoption rates of CA in short term. Survey team will return to Botha Buthe in 2013, revisiting households surveyed in 2011. A variable identifying households still practicing CA in the absence of input support from donors will be regressed on current CA practices.

FSK6: The Increased need for weed control due to the adoption of CA offsets the economic benefit derived from increased yields or lower fertilizer input costs. Survey, on-farm trials, and experiment station data will be used to develop a partial budget that can be used as a tool to examine trade-offs with CA.

Elaboration of Scientific Approaches

CA systems must be economically and environmentally sustainable. The methods selected in the KAP will be used in the ATP; the ATP will result in an approach that culminates from our teams' cultural and collective disciplinary expertise. For example, fertilizer correlation and calibration data will be used to determine subsistence farmer fertilizer application rates. Results from the participatory socioeconomic research will be used to evaluate an effective fertilizer use implementation strategy. Similarly the BR C research data will be used to determine the relative fertilizer rates to grow the plant biomass needed to both protect the soil and sequester the most C. It is hoped that the BR data can also assist with determining the contribution of the winter cover crops to the soil organic C pool.

Fertilizer check strips will be included in each experimental plot. However, the actual fertilizer trials will be dependent upon local soil conditions; for example, in Lesotho no potassium will be applied to the experimental plots, as little or no yield responses have been observed in research trials around Lesotho. Weeds are a persistent problem in agronomic trials anywhere. All experimental plots will be treated with herbicide as needed in order to eliminate any yield reductions due to weeds in the fertilizer calibration work. The experiment will be replicated over three years. Plots will be double-cropped with a wheat rotation following maize. Researchers will work closely with households participating in the experiments with respect to fertilizer placement, pot-hole spacing, and herbicide application scheduling. On-farm plots will not be tilled.

In each research site, we will engage at least 10 farm households to participate in the field trials using each farm as a replicate. Farms volunteering to participate in the program will receive an incentive to participate throughout the trials. On-farm trials will have a simple design that will allow for categorical statistical evaluation; e.g., was there a benefit to fertilizer addition ("yes" or "no" answer to adding fertilizer at rate X or not adding fertilizer). These on-farm trials will be evaluated and modified for the next season by comparing fertilizer rate 2 to the previous years' rate one. In contrast, the experimental plots described below will be on more controlled research sites; e.g., government, university, or local NGO research farms.

The field trials managed on the experimental stations will be analyzed using conventional statistical analysis appropriate for agronomic trials (e.g., Lenter and Bishop, 1993). For example at the field research site in Lesotho we have a randomized complete block design with four replicates. Data from this study will be analyzed with Proc Mixed in SAS. However, the agronomic data collected from large block experimental designs used during the on-farm, farmer-led trials will be recorded in terms of qualitative variables in addition to gross production. For example, following harvest, farmers will be asked whether they thought production from the CAS intervention was better (or not) than their usual management practices. This type of "yes/no" response will be applicable in cases where, for example, a single fertilizer strip is applied in a field, a single strip was planted with a different plant population, or where a portion of the field was managed using one (or a combination of) CAS technologies. Therefore, while it may be difficult to say much in terms of treatment effects using classical agronomic statistical techniques (because of limited or no replications), conclusions can be made with respect to whether a decision maker, from their perspective, found the intervention to be worthwhile. This sort of qualitative data is similar to the information frequently sought in consumer or household surveys. Appropriate statistical analysis of this qualitative crop yield information will be carried out using binary logistic regression techniques (Greene, 2003), in addition to non-parametric approaches useful for such studies.

Profitability of No-till Conservation

Partial budget analysis (CIMMYT, 1988; Lambert et al., 2006, 2007) will be used to compare the profitability the no-till conservation technology with conventional tillage methods. Partial analysis shows that profit is maximized when the value of the increased yield from added N or P equals the cost of applying an additional unit of fertilizer, or when the marginal value product equals the marginal factor cost. Input costs and maize/wheat prices will be obtained from the market survey component of this research.

Socioeconomic Understanding

The socioeconomic dimensions of this project are addressed in Objectives 4 and 5. Objective 4 focuses on the CAS-farm household interface. Objective 5 focuses on the interaction between farm managerial decisions, CAS adoption, and local and regional input and product markets. Because the information collection and analytical methods used to address Objectives 4 and 5 mutually support each other, and because of the necessary overlap of these objectives, we discuss both in tandem below.

The short- and long-run impacts of CAS on gender equality will be estimated through Participatory Rural Appraisal (PRA), focus groups, and household surveys using some of the techniques described in Nabasa et al., 1995. Of particular interest is how CAS impacts farm household income and time allocation across gender roles. Through PRAs and focus groups we will learn the factors and criteria influencing CAS adoption rates. For households, PRA will include smallholder farm mapping techniques and development of crop production and labor allocation calendars with gender roles differentiated. Focus groups will also provide a context for group brainstorming, problem solving, and working through scenarios provided by focus group leaders. Focus group activities will also provide insight into the demographic profiles of smallholder farmers, and a more generalized understanding of household composition. At a village level, PRA will include community and market mapping to develop a clearer picture of the available social and physical capital and the structure of local markets, including important forward and backward linkages.

These PRA efforts will inform household survey design and village choice. Using household survey techniques, we will evaluate the CAS adoption rates of culturally and geographically variant villages. A cluster sampling strategy was used to survey farm households in the Butha Buthe Province, Lesotho. The cluster sampling strategy follows Lohr (1999) among others. Cluster sampling is practical when list frames are unavailable, data collection of primary sampling units is logistically expensive, or when populations are distributed over a wide geographic area (Lohr, 1999).

Clusters, like stratum, are groupings of individuals in a population. But the selection process of clusters is quite different from the methods typically used to select individuals belonging to stratum. In this research, villages are considered to be clusters (also called *secondary sampling units*, SSUs), whilst individuals are the *primary sampling units* (PSUs). The cluster-based sampling design necessarily assumes that individuals living in the same village are more likely to be more similar to each other than with individuals living in other villages.

Semi-structured interview techniques facilitate communication of personal and household priorities, gender roles, and existing knowledge about CAS technologies. Proportional piling techniques will be used during personal interviews to collect information about the relative importance of crops and livestock to households, and information about income generating activities. This interview strategy assumes that farmer recall regarding crop production over one or several cycles is oftentimes inaccurate and incomplete (Molnar et al., 1996). From proportionate piles, the relative worth of an activity according to a respondent is ascertainable, be it in terms of cash income or food to the household (Mheen-Sluijer, 1998). In these terms, field crop and livestock production and the importance of these activities is understood as a function of time allocated to and output produced by an activity by men and women, and not only as cash income.

LTRA-9 plans to generate sociologic, economic, agronomic, and fundamental nutrient cycling data that will be integrated into farming systems that can be further adapted on the farm. Current results indicate that maize yields—the staple crop in Lesotho and Mozambique—greater than ten times the current national average in Lesotho are attainable with limited chemical application if a winter cover crop is successfully established. These results are encouraging and suggest that food security can be improved if the knowledge gained during the KAP is incorporated into the CAS through the ATP.

Diagrammatic Illustration of the Transdisciplinary Research Strategy

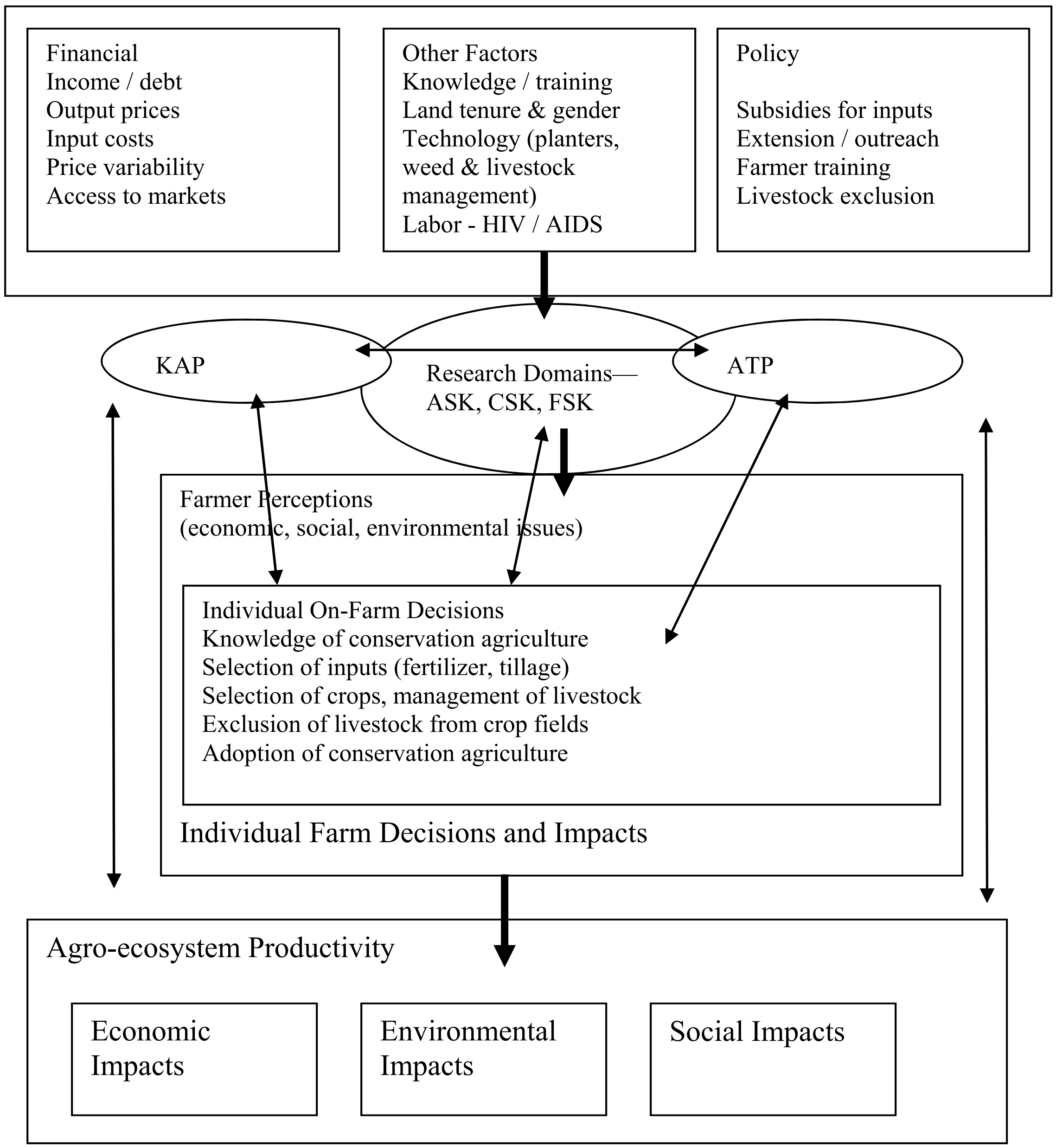

Figure 4. A working model of LTRA-9. Modified from Bradshaw and Smith, 1997

LTRA-10: Development and transfer of conservation agriculture production systems (CAPS) for smallholder farms in eastern Uganda and western Kenya

Principal investigator: Jay Norton, Department of Renewable Resources, University of Wyoming

Host Countries: Kenya, Uganda

Research team:
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Makere University: Department of Agricultural Economics and Agribusiness: Bernard Bashaasha;
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SACRED Africa: Eusebius Mukhwana;
AT Uganda: Rita Ojok;
Manor House Agricultural Center (MHAC): Emmanuel Omondi.

Introduction

The work described below is designed to evaluate CAPS, to provide outreach and training, and to engage local stakeholders at our four study areas in a process of co-innovation. CAPS will be implemented alongside traditional production practices as replicated plots on research institute farms and on the farms of cooperating small holders. Our research strategy includes two broad areas: (1) agronomic crop and soil parameters that utilize on-station and on-farm trials and (2) socioeconomic and market parameters that build upon baseline surveys with additional focused surveys of stakeholder groups and data collection from research plots. The on-station and on-farm trials will serve as focal points for engagement among researchers, farmers, and many other stakeholders in each of our four study areas.

Soil and Agronomic Objectives

(1) How do alternative tillage treatments that eliminate moldboard or disk plows impact soil quality and crop growth over a four-year period? (alternative tillage treatments imposed on traditional cropping system).
Hypothesis: By year four, tillage that leaves 30 percent or more residue on the surface will lead to increases in soil organic matter content and improvement in related soil physical and chemical properties that support crop growth and yield, including increased carbon (C) storage.

(2) How do alternative cropping systems that include nitrogen-fixing cover crops impact soil quality and crop yields over a four-year period? (alternative cropping systems imposed on traditional tillage).
Hypothesis: By year four cropping treatments that include N-fixing cover crops will lead to increases in soil organic matter content and improvement in related soil physical and chemical properties that support crop growth and yield, including increased C storage, C sequestration, and improved crop yields.

(3) How do combined alternative cropping systems and conservation tillage systems affect soil quality over a four-year period?
Hypothesis: Conservation agriculture systems that include combined conservation tillage and cover crops in rotation will achieve the highest increases in soil organic matter content and improvement in

related soil physical and chemical properties that support crop growth and yield, including increased C storage, C sequestration, and improved crop yields.

Methods

Research Design

1. Four study areas, including two high-potential highland sites (Kapchorwa, Uganda, and Kitale, Kenya) and two low-potential lowland sites (Tororo, Uganda, and Bungoma, Kenya) each with the following field study design:
    a. One on-station plot: four replications of nine main treatments (3 tillage x 3 cropping system) plus two nitrogen (N) fertilizer treatments as split plots (top-dressed as calcium ammonium nitrate when maize is about 10-cm tall) (288 total plots, see figure 1);
    b. Four on-farm sites, each as one rep of nine treatments (see figure 1, without N fertilizer splits);
2. On-station plot size is 10m x 10m, for a total (with four reps) of 0.86 ha (2.13 acres). Three acres will be needed to accommodate borders;
3. On-farm plot size is flexible given space and labor constraints, but most are 10m x 10m.

<u>Treatments</u>

To evaluate alternative tillage and cover crop components of CAPS, three tillage treatments and three cropping system treatments will be established at each field site using a factorial arrangement within a randomized complete block design:

<u>Tillage</u>: Each location will have:

1. Traditional (moldboard or disk plow) done as recommended by advisory group;
2. No-till using herbicides to control weeds;
3. Minimum till using herbicides and non-inversion tillage to control weeds.

<u>Cropping systems</u>: Each location will have:

1. Current practice: Maize + edible dry kidney beans intercrop;
2. Alternative cropping system 1: mucuna relay beans in intercropped maize/beans;
3. Alternative cropping system 2: strip-intercrop rotation with 3.3-m wide strips of maize, beans, and mucuna.

Past research shows mucuna to be a best-bet cover crop choice for our study areas because of prolific biomass and seed production, excellent competition with weeds, and positive impacts to soil organic matter and nutrient status.

<u>Fertility</u>: A small amount of di-ammonium phosphate fertilizer (DAP) will be banded near each maize seed as a starter fertilizer. Additional N will be top-dressed at rates to be determined as a split-plot treatment (+N and –N imposed on each plot). We think that yield advantages of additional N fertilizer will diminish by year four in the treatments that include cover crops and conservation tillage. *Note on manure and compost:* While there is interest in use of manure and compost, there is not sufficient livestock confinement near our study areas to provide field-scale soil nutrient replacement for staple crops. We will encourage and possibly evaluate subplot compost trials at realistic rates as partial nutrient supply, but our main treatments will focus on green manure and fertilizers.

<u>Additional treatments</u>: Plot size will be sufficiently large to accommodate small, split-plot treatments, such as partial residue removal, compost, and others. Subplot treatments will be carefully planned to preserve at least half of each plot as the core treatment base-line.

Measurements, Sampling, & Analyses

Described here are sampling protocols for the core plots. Individual researchers (PIs, graduate students, postdocs) will develop additional analyses for individual research projects (see original project proposal for detailed justification and description of methods).

On Station Sampling

Subsequent soil trace-gas (nitrous oxide, carbon dioxide, and methane) emissions, soil mineral N content, soil temperature, and soil moisture content: 0-10 cm depth, rigorous monthly sampling protocol at one highland and one lowland site, with reconnaissance-/corroboration-level sampling at other research sites. These measurements provide important indicators of C and N cycling processes, including C-sequestration and loss, are sensitive to management practices, and, along with subsequent mineral N concentrations, and are key inputs for large-scale process models such as Century and DayCent.

Soil properties (see Table 1):
0- to 10- and 10- to 30-cm depths: One time per year at onset of long rains/planting;
30-60 and 60-100 cm depth increments: beginning and end of study.
Crop and weed growth and development: monthly measurements of crop plant height and physiological stage, and ground cover of crops, weeds, litter, and bare soil (same time as trace-gas/mineral N sampling).

Crop yield: yield of maize and beans will be measured from whole baseline core plots with field scales at the time of harvest. Subsamples will be taken to the lab for determination of dry matter grain yield.

		10-m width, 30 m total			
		Current Practices	Rotation 1	Rotation 2	10-m width, 30 m total
Current Tillage Practice	+N fertilizer	Maize-bean intercrop	Maize-bean intercrop with mucuna relay	Maize Beans mucuna	
	-N fertilizer	Maize-bean intercrop	Maize-bean intercrop with mucuna relay	Maize Beans mucuna	
No-till	+N fertilizer	Maize-bean intercrop	Maize-bean intercrop with mucuna relay	Maize, 4 rows Beans mucuna	
	-N fertilizer	Maize-bean intercrop	Maize-bean intercrop with mucuna relay	Maize Beans mucuna	
Minimum till	+N fertilizer	Maize-bean intercrop	Maize-bean intercrop with mucuna relay	Maize Beans mucuna	
	-N fertilizer	Maize-bean intercrop	Maize-bean intercrop with mucuna relay	Maize Beans mucuna	

Figure 5. On-station design for one treatment block.

Split-split plot design with tillage as main plot, cropping system and N application as splits. To facilitate tillage operations the order of the three tillage practice main plots will be random within each block, but each will occur across the whole block as shown. However, cropping system and N fertilizer subplots will be completely randomized. On-farm sites will consist of one block like this but without the fertilizer treatment.

On Farm Sampling
Trace gas emissions: None.
Soil Properties: All properties measured at beginning and end of study.
Crop and weed growth and development: monthly measurements of crop plant height and physiological stage, and weed cover and/or density by species (same time as trace-gas/mineral N sampling) done by NGO field technicians;
Crop yield: yield of maize and beans will be measured from plots with field scales at the time of harvest. Subsamples will be taken to the lab for determination of dry matter grain yield.

Structure of Interaction Among Researchers and On-site Participants
Structured meetings will generate "co-design feedback loops" for responsive implementation and improvement of experiments. We will strive for a general schedule as follows:

1. Fortnightly during each growing season, local NGO coordinators will visit each pilot farm to monitor progress, provide support, and conduct outreach activities.
2. Monthly, members of the LTRA 10 team (including NGO partners, students, university representatives, local extension agents, participant growers, and others) will visit each of the study sites to collect data and discuss the pros and cons of each treatment;
3. Two times per year (i.e. at least once per growing season), interactive activities targeted toward stakeholder groups such as farmers, agricultural educators, suppliers, buyers and others will be held at each area by the university and NGO partners;
4. Annually, 1) stakeholder advisory group "reflection workshops" led by NGO partners; and 2) internal project planning meetings to review progress. Tele- and/or video-conferencing will be used as necessary.

Data Management
The University of Wyoming Soil Resource Laboratory is responsible for maintaining an updated archive of all core plot soils and agronomic data. Individual PIs, graduate students, and research associates conducting subplot or side experiments are responsible for maintaining data from individual experiments.

Field data collected by NGO partners, cooperating farmers, and others will be collected, entered, and sent to the University of Wyoming by our project field research coordinator.

Timeline
Work on the soil and agronomic experimental phase began in January, 2011, with demarcating on-station and on-farm plots and will continue through the next four years.

Analysis	Lab	Year 1	Year 2	Year 3	Year 4	Total
pH	Moi	1584	0	0	1584	3168
Avail. N	Moi	4608	3456	3456	4608	16128
Extractable P	Moi	1440	0	0	1440	2880
Exchangeable K	Moi	1440	0	0	1440	2880
Organic C	Moi	1584	288	288	1584	3744
Total N	Moi	1584	288	288	1584	3744
Total P	Moi	1584	0	0	0	1584
Bulk density	Moi	1584	288	288	1584	3744
Particle size distribution	Moi	1440	0	0	0	1440
SOM fractionation	Wyoming	1440	0	0	1440	2880
Potentially mineralizable C	Wyoming	1440	288	288	1440	3456
Potentially mineralizable N	Wyoming	1440	288	288	1440	3456
Microbial biomass C & N	Wyoming	1440	288	288	1440	3456
Trace-gas analyses	Wyoming	3456	3456	3456	3456	13,824

Figure 6. Approximate soil sample numbers and location of analyses (Moi University, Eldoret, Kenya, or University of Wyoming). See original proposal for methods.

Socioeconomic and Market Objectives

Our objective is to assess how well the trial CAPS perform economically and socio-culturally, and to identify and quantify economic tradeoffs that may be necessary to implement CAPS.

Research Questions

(1) Does a supply chain for the alternative tillage treatments that eliminate moldboard or disk plows exist in the study area?

(2) If yes, are the inputs accessible, affordable and attractive to the smallholder farmers?

(3) Will the benefit associated with the alternatives cropping systems (nitrogen-fixation by cover crops, increased soil fertility, and higher crop yields over a four-year period be able to cover the costs of inputs and labor associated with the alternative cropping systems imposed on traditional tillage?

(4) Will smallholder farmers adopt CAPS after jointly participating and learning from four years of on-station and on-farm CAPS experiments and trials?

(5) Of what benefit will the existing social networks and social capital among small-holder farmers in the project area be to the CAPS project?

Methods

Economic and sociocultural data will be collected from CAPS trials, both on-station and on-farm, at four study areas in Uganda and Kenya (Table 2). Our partner NGOs will be responsible for visiting trial sites regularly (or hiring part-time employees to conduct regular site visits), ideally on a weekly basis, to gather all recorded socioeconomic data, and interact with trial participants and make personal observations of the CAPs activities to verify data accuracy. Field data collected using standardized/structured data collection forms will be entered into access data bases and sorted/cleaned at the field level before being transferred to the socioeconomic team, who will transcribe and organize it within a standardized database. Data will inform the development of enterprise budgets that qualitatively and quantitatively describe each CAPS' input requirements, opportunity costs, and benefits.

The socioeconomic team will work with farmers to jointly design a simple datasheet to accompany the daily activity journal, this will help ensure that all relevant CAPS related activities are recorded including tasks, number of people involved, gender, age group, quantity and costs of inputs used during those tasks including labor. Co-design will help ensure its ease of use and appropriateness for a wide range of literacy levels. Participating farmers would then be trained to use the datasheet to record information about the input requirements, challenges, and outcomes.

<u>Key CAPS Information Requirements</u>

The following data will be collected:

- Labor requirements for all aspects of the CAPs activities, including land preparation, planting, weeding, spraying, harvesting, postharvest processing, and marketing.
- Agro-ecological information, including rainfall, temperature, pest and disease incidences, and any abnormal events or circumstances.
- Input sources, utilization, and cost.
- Tillage practices, equipment use, and purchase, operation and maintenance costs.
- Weed and pest control methods and costs.
- Gender based technology assessment in terms of suitability, ease of use, health concerns.
- Crop yield, harvest methods, post-harvest handling, and marketing information.

Table 1 CAPS Socioeconomic data collection framework.

			MONTHS					
Outputs	Activities	Responsibility	F	M	A	M	J	J
Baseline survey data	Field data collection	NGO partners						
Standardized datasheet and activity journal. Data on land preparation, and agronomic practices.	Recruitment and training of data enumerators	SANREM						
	Co-design and training of farmers on record keeping	Data enumerator						
	Collection of land preparation data (equipment access, labor and other input requirements and cost)	Data enumerator						
	Collection of planting data (input requirements & cost)	Data enumerator						
	Collection of weeding, equipment access, labor/input requirements, costs, etc.	Data enumerator						
Harvest and yield data for the first season collected.	Collection of crop harvest and yield data: equipment, labor/input requirements and cost.	Data enumerator						

Post-harvest handling and marketing data.	Collection of postharvest handling data, e.g., transportation, processing, storage, utilization, market access, prices, quality, etc.	Data enumerator						
Shared database of CAPs economic and socio-cultural data and information	Design of database	Socio-economic team						
	Data entry	Socio-economic team						
	Sharing of database among team members	Socio-economic team						
	Preliminary data analysis to assess adequacy of data collection protocol.	Socio-economic team						

<u>Marketing System Research</u>
Challenges for developing alternative value chains for farms in Eastern Africa include (1) policy and regulatory environments punitive of small farm innovation; (2) lack of tools and technology for sensing market demand; (3) logistics bottlenecks in input and output markets; (4) inadequate storage infrastructure; and sometimes (5) long-term contractual relationships (e.g., debt or production quotas) that restrict ability to create or exploit new opportunities.

While these issues have been recognized for a long period of time, existing texts on CAR in Southern Africa devote minimal attention to them (IRR and ACR 2005). A notable exception is a report on cereal banking in the Bukoma district and a warehouse receipt system in Zambia (IRR and ACR, 2005; Mukhwana, Nyongesa and Ogeniah, 2005). Consequently research is needed to assess the incidence, dynamics, and severity of these market system constraints to the success of CA in the project area. Primary and secondary data must be collected. Secondary sources will include local, national (e.g., Uganda Bureau of Statistics), development projects, producer organizations, and other sources. Primary data will be collected by questioning a theoretically drawn sample of leading farmers and various marketing agents so that comparisons can be made across local contexts. In research of this type, domain specific samples of 10-12 individuals have been shown to uncover 90-95 percent of variation in phenomena of interest (Arnould and Epp, 2006). The state of knowledge as well as the complex nature of marketing systems is such that collection and testing of reductionist measures is inappropriate for the data collection and analysis task. Our aims are diagnostic and edifying rather than confirmatory and predictive. We expect this research to give us a clearer grasp of the marketing opportunities, constraints, and profitability potentials that farmers considering adoption of CA techniques may encounter. The primary goal for this activity is to provide scientifically-based reasons for policy review, revision, and development of marketing systems that encourage adoption of CAPS.

Hypotheses, Approaches, Outputs, and Timeline
Hypothesis 1: Policy and regulatory factors are punitive of small farm innovation in on-farm marketing**.**
Approach:

- Collect policy documents related to rural input and output agricultural marketing:
  - <u>Expected Output:</u> Summary of official policies related to input and output marketing;
  - Timeline: Year 2

- Use interviews to assess policy related to input and output marketing with responsible parties in government, NGO, and coop communities:
    - Expected Output: Summary of official and unofficial barriers to adoption of CA related to input and output marketing; identification of potential loopholes that can be exploited to foster adoption of CA
    - Timeline: Year 2

Hypothesis 2: Existing tools and technology for sensing market demand limit market efficiency.
Approach:

- Data collection with market channel members about how demand is assessed. Targets: Cooperative Marketing agents; Cereals banks marketers; MPESA operators; Market bulking agents.
    - Expected Output: Report identifying indicators employed by agents to assess supply and demand; assessing efficiency of these demand assessment techniques
    - Timeline: Year 2

Hypothesis 3: Existing upstream and downstream marketing logistics constrain agricultural innovation.
Approach:

- Data collection with farmers and other market channel members about planting and harvest time marketing bottlenecks. Targets: Agrovet managers; Coop Marketing agents; MPESA operators; Market bulking agents.
    - Expected Output: Report assessing strengths and weaknesses of marketing channel dynamics, microfinance options, potential o farmer input buying groups with recommendations for organizational and policy innovations.
    - Timeline: Years 2 and 3

Hypothesis 4: Local storage infrastructure constrains on-farm marketing income.
Approach:

- Data collection with famers and other market channel members about local storage infrastructure, including previous experiences with cereals banks or warehouse receipt systems. Targets: Coop Marketing agents; Market bulking agents.
    - Expected Output: Report assessing adequacy of local storage arrangements, lessons learned from cereals banking and warehouse experiments, with policy recommendations
    - Timeline: Years 2 and 3

Hypothesis 5: Atomized farmer supplier/farmer-buyer relationships constrain innovation in production strategies.
Approach:

- Data collection with famers and other market channel members about farmer-supplier and farmer-buyer relationships, traders access to supply sources, information control, farmer-buyer trust and cooperation.
- Targets: Coop Marketing agents; MPESA operators; Market bulking agents.
    - Expected Output: Report assessing nature of relationships between channel members with recommendations concerning joint farmer actions necessary for shifting balance of power.

Table 2 Work Process

Steps	Description	Deadlines
1.	PIs develop questionnaires on upstream and downstream marketing and give them to NGO partners.	June 2011
2.	NGO partners comment and return draft questionnaires to PIs. We invite NGO partners to incorporate insights gleaned from initial baseline data collection.	July 2011
3.	PIs revise questionnaires and return final copies to partner NGOs.	September 2011
4.	NGO partners administer questionnaire. Per established practice, sample number should be five of each market actor in each zone in which the project is intervening.	October-November 2011
5.	Questionnaires are collated and data is entered into a database and returned to PIs for analysis.	November-December 2011
6.	Draft reports developed by PIs and returned to NGO partners for commentary	February 2012
7.	Reports finalized	April 2012

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LTRA-11: Sustainable Management of Agroecological Resources for Tribal Societies (SMARTS)

Principal Investigator: Catherine Chan-Halbrendt, Department of Natural Resources and Environmental Management, University of Hawaii at Manoa

Host Countries: Nepal, India

Research Team:
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Introduction

The goal of this project is to work with farmers in cooperation with NGOs and university partners to introduce, develop, and disseminate conservation agriculture production systems (CAPS) to increase agricultural productivity, economic returns, and gender equity among tribal societies practicing low-input subsistence agriculture in India and Nepal. This includes minimum soil disturbance, continuous organic soil cover, and appropriate crop rotation that work in concert to improve agricultural productivity while maintaining or enhancing natural resource quality. As a part of this work, we will focus on productivity, soil quality, economic impacts, implications for gender participation, and the role of technology networks in adopting and adapting selected CAPS interventions.

Specific objectives include:

1. Determine the set of CAPS for sustained productivity, labor, soil impact, gender equity, and profitability.
2. Explore stakeholder preferences for CAPS to promote adoption
3. Implement preferred CAPS on-farm for validation, impact on farm household welfare leading to policy recommendation
4. Use a participatory action research (PAR) approach to promote reflection, evaluation, and continuous improvement of implemented CAPS.
5. Build capacity of farmers, local NGOs, and universities to scale up CAPS development for wider dissemination.

To achieve these objectives we will employ participatory methods throughout the project. These will include the selection of CAPS to study, data collection processes and specific measurements, analyses that provide the most relevant and useful information for farmers, the continuous improvement of selected CAPS to optimize performance and the kinds of training and outreach materials and activities that are most effective for farmers and research and development partners. The specific participatory methods and analysis are described in the methods section. We will emphasize the inclusion of women's perspectives on challenges to traditional agricultural systems, preferences for CAPS, and impacts on labor requirements, income, and agronomic and household decision making authority.

To ensure the integration of biophysical and socioeconomic data, research and outreach activities will be guided by a Production-Consumption Livelihood Model, as illustrated in Fig. 1. This figure is configured to present research activities by objectives and highlight the interrelated components of a sustainable production system with maize as the major staple crop. Background surveys will form the basis for understanding the agronomic, soil environment, and socioeconomic challenges in the villages.

Experimental agricultural trials will be combined with preference surveys to determine the CAPS to implement in farmers' fields. Evaluation and adaptive management of CAPS will include income and gender equity as well as agronomic performance and natural resource quality. Capacity building and scaling up of CAPS will include interdisciplinary activities, including student theses and dissertations, workshop presentations, outreach materials, and reporting of data in peer-reviewed scientific papers, and professional presentations.

Objectives

<u>Critical Research Questions</u>

For Objective 1, the critical questions to be addressed are the following:

1. What are the major constraints to improved agronomic performance and household income?
2. What are the threats to natural resource quality or sustainability posed by traditional agricultural systems?
3. What traditional knowledge systems and other sources of information primarily influence farmer decision making about agricultural practices?

For Objective 2, the critical questions to be addressed are the following:
What are farmers' perspectives on the potential improvements to agricultural productivity, natural resource quality, and household income that are achievable with appropriate CAPS?
How do they rank the various CAPS practices and what short- and long-term tradeoffs are they willing to make within specific CAPS?

For Objective 3, the critical issues to be addressed include the effects of CAPS on:

1. Crop productivity, labor requirements, input costs, and opportunity costs of implementation
2. Marketable surplus, value, and resultant farmer income
3. Soil aggregate stability and accumulation of C within stabilized aggregates
4. Soil water infiltration, soil water retention, overland flow, and water erosion
5. Integration of the village economy within existing markets
6. Social institutions that influence participation in CAPS
7. Women's labor requirements and participation in agronomic and household decision-making

For Objective 4, the critical issues to address include:

1. How to evaluate CAPS performance relative to expected outcomes
2. How to adapt CAPS to improve performance or meet adjusted outcomes
3. How to innovate CAPS to fit new agronomic or climatic conditions or market opportunities

For Objective 5, the key outcomes include:

1. Building innate capacity of farmers to communicate their knowledge and understanding of CAPS with other farmers
2. Increasing NGO knowledge of and experience with CAPS
3. Increasing university and professional expertise and enthusiasm for CAPS
4. Building farmer-NGO-university networks at local, national, and international levels to increase collaboration on specific projects, respond to continuing or new challenges and opportunities, and improve communication of CAPS principles, practices, outcomes, and experience

Table 3. Production-Consumption Livelihood Model for CAPS Research for Development

Objectives **Interrelated Research Areas**	**1. Determine the set of CAPS for sustained productivity, labor, soil impact, gender equity and profitability**	**2. Explore farmers preferences for CAPS to promote adoption**	**3. Implement preferred CAPS on-farm for validation, impact on farm household welfare leading to policy recommendation**	**4. Use a participatory action research (PAR) approach to promote reflection, evaluation, and continuous improvement of implemented CAPS**	**5. Build capacity of farmers, local NGOs and universities to scale up CAPS development for wider dissemination**
Economics	Comprehensive farm household data collection -Estimate the cost and economic benefits of introducing CAPS to representative maize-based production systems from experimental plot and on-farm data	Workshops: Determine farmers preferences to CAPS based on the expected changes from adopting CAPS	Post-CAPS Assessment: -Comprehensive analysis of economics of CAPS on farmer's field Analyze the costs/benefits to the farm family in terms of labor, capital, yield, etc.	Determine adaptive management practices to current CAPS systems and evaluate economic impacts	Joint reporting of socioeconomic analysis of CAPS practices Joint publishing of training manuals Joint publishing of journal articles
Soil	Baseline soil data collection and analysis: -soil sample collection during wet growing season and dry fallow season. -analyze soil physical, chemical and organic properties	Workshops: Determine farmer's current soil management practices, their understanding of soil properties, and preferences for implementing improved practices	Observe the effects of CAPS practices, including soil cover, soil permeability & ponding, and soil erosion	Evaluate effects of CAPS on soil physical, chemical, and organic properties -Continued monitoring soil organic matter and nutrient status	Report effects of CAPS practices on soil properties, contrasting research station and farmer management
Gender	Semi-structured interviews with key informants and focus groups regarding: institutional context, market influence, historical context, knowledge systems, community organization.	Meeting: To discuss CAPS knowledge, tradeoff and preferences by gender	Determine the impact of CAPS on gender in terms of labor changes, household responsibilities	Meeting with women's groups to discuss their current adaptive management strategies and adaptation for CAPS	Reports, theses and refereed articles that complement research and development on gender issues for US, India and Nepal students
Agronomic	Design and conduct CAPS research experiment -Collect and analyze data in terms of yield, labor use, other input use -Conduct analysis of agronomic performances	Workshops: Training farmers to the practices of preferred CAPS	Implementation/Monitoring of model CAPS plots on research stations and in farmer fields (10-20 different farmers per village) Observe the effects of CAPS practices on crop growth, weed, pest and disease pressures	Interviews with farmers in research-controlled trials regarding improvements Adjust CAPS and conduct analysis	Summarize and provide training to research staff and farmers on the effects of CAPS practices on crop growth and yields Jointly publish training manuals Jointly publish journal articles on research results
Expected Output	Baseline information agronomic, economics, soil, gender impact from CAPS experiments	Preferred CAPS by farmers Probability of gender preferences of various CAPS based on yield, labor saving, profit and soil environmental benefits Trained local staff and farmers regarding the expected benefit of CAPS based on experimental data	Agronomic, economics, soil, gender impact from CAPS on farmer's fields.	Continuous improvement of selected CAPS to optimize performance implement adjusted CAPS in other villages	Training/outreach materials/activities most effective for farmers and research and development partners Jointly publish manuscripts for academic community Trained students and faculty

Methods

Linkages of Issues to Methods and Transdisciplinary Information Sharing

Objective 1. Determine the set of CAPS for sustained productivity, labor, soil impact, gender equity and profitability to study using PRA

Critical research questions:

1. What are the major constraints to improved agronomic performance and household income?
2. What are the threats to natural resource quality or sustainability posed by traditional agricultural systems?
3. What traditional knowledge systems and other sources of information primarily influence farmer decision making about agricultural practices?

A comprehensive household survey is being conducted in three villages in Keonjhar District of Odisha State, India and three villages in the highlands of Trishuli Valley, Nepal where CAPS will be developed and implemented. At least 30 percent of the village households will be interviewed, approximately 20-30 households per village. Data from the surveys include details of the agricultural system, household characteristics, crop yield, market transactions, marketing strategies and market prices, and resources available to the household to implement CAPS. Gender-specific roles are being documented so that the potential impacts of CAPS can be disaggregated by gender. Survey results will be analyzed using enterprise budgeting to compare the potential effects of selected CAPS vs. current agricultural practices on crop production, household income, gender-specific effects on labor and roles and responsibilities. Results will also be used to determine overall economic impacts to support the relevant cross-cutting research activity (CCRA) by the managing entity.

Farmers and professionals will be interviewed with respect to their knowledge of the agricultural and natural resources in their area that could affect system performance, using the procedures outlined in the Agroecological Knowledge Toolkit 5 (AKT5) knowledgebase system (Dixon et al., 2001). Expected agronomic performance of experimental CAPS will provide potential costs and returns that will be used to develop various CAPS scenarios. As the project progresses, results and experiences will be documented and illustrated in outreach materials that reflect how farmers understand their agricultural systems for use by other research and development organizations and the farmers themselves.

Objective 2. Explore stakeholder preferences for CAPS to promote adoption

Critical Research Questions

1. What are farmers' perspectives on the potential improvements to agricultural productivity, natural resource quality, and household income that are achievable with appropriate CAPS?
2. How do they rank the various CAPS practices and what short- and long-term tradeoffs are they willing to make within specific CAPS?

The second major activity is a set of workshops to determine current farmer's soil management practices and understanding; review the survey and experimental station CAPS/on-farm CAPS results with farmers from the respective villages, introduce them to CAPS principles and a range of practices selected for testing in their village, and solicit their perspective on potential costs and benefits with an emphasis on possible risks and opportunities of adopting CAPS. In this way, we can utilize information collected from the farmers to develop a set of best-bet CAPS and then solicit their specific feedback before implementation in farmer's fields. This information will also improve our ability to select key measurements of costs, benefits, and perceived risks of CAPS, which will strengthen our economic analysis.

These preferences for CAPS will be accomplished through workshop presentations and discussions with approximately 20 farmers per village using an analytic hierarchy process (AHP) for specific combinations of CAPS interventions (Fig. 2). Fig. 2 presents a basic hierarchy, which is made up of three levels. The top level is the ultimate goal of the exercise as determined by the team based on interviews with local village farmers, experts, and discussion amongst the team. The second level consists of decision criteria (objectives) that were considered relevant for the achievement of the goal of sustainable income and was determined based on the literature and discussion. The bottom level encompasses the programs: the four CAP/Non-CAP systems. The systems are compared as to how they satisfy each criterion; and the criteria are compared as to how they contribute to the general goal. Analysis of the rankings of preferred CAPS options will allow for optimal sets of interventions to be combined into CAPS that are most likely to achieve the multifaceted goals of sustainability and are likely to be most appealing to farmers.

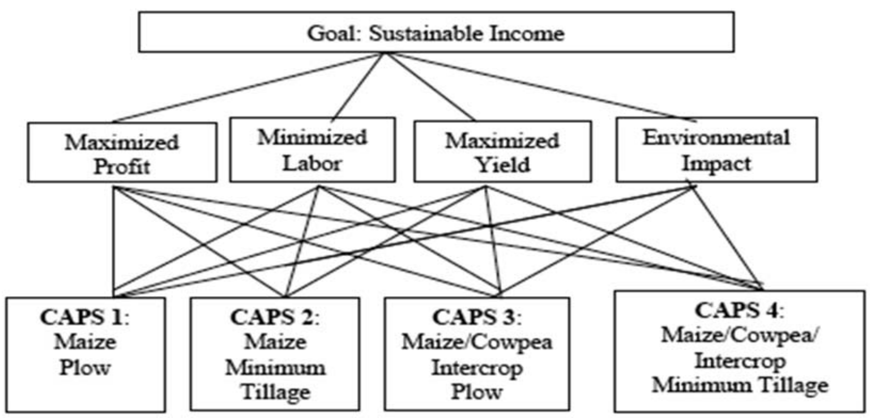

Figure 7. Analytic hierarchy process (AHP) for prioritizing CAPS

Objective 3. Implement preferred CAPS on-farm for validation, impact on farm household welfare leading to policy recommendation

<u>Critical Research Questions with on-farm CAPS implementation are:</u>

1. What are the crop productivity, labor requirements, input costs, and opportunity costs of implementation?
2. What are the marketable surplus, value, and resultant farmer income?
3. Is there soil aggregate stability and accumulation of C within stabilized aggregates?
4. What are the changes in soil water infiltration, soil water retention, overland flow, and water erosion?
5. What will be the impact of the village economy within existing markets?
6. What are the social institutional constraints that influence participation in CAPS?
7. What are the women’s labor requirements and participation in agronomic and household decision-making?

This objective will be accomplished through establishment and monitoring of CAPS plots on research stations and/or in farmer fields. In India, experimental CAPS trials are being tested at the Odisha

University of Agriculture and Technology (OUAT) research and extension station (Krushi Vikasa Kendra, KVK) in Keonjhar District. The experimental plots at the KVK are being implemented on a single terrace of a multi-terraced field, with each plot 6 x 8 m in size. Treatments consist of individual and combined conservation agriculture practices associated with CAPS, including (1) conventional versus no-till planting of maize; (2) sole-cropping vs. intercropping maize with cowpea (*Vigna unguiculata*); and (3) plus and minus post-harvest cover crop planting with the legume horse gram (*Macrotylota uniformum*). Plots are being surrounded by *Gmelina arborea*, a fast-growing multi-purpose tree, to provide a check on soil erosion, green manure to improve soil fertility, a fodder alternative to crop residues, and wood products for energy, construction, or sale. A single replicate of each of the eight treatments was placed randomly within each of three blocks, for a total of 24 plots.

Daily weather information is being recorded by a weather station on the KVK. Details of planting and management methods, crop yields, market prices, and labor requirements and labor costs for various management activities (site preparation, planting, weeding, harvesting) are also being measured and recorded. This data was summarized by treatment and then used to develop hypothetical CAPS scenarios to evaluate potential costs and benefits of implementing conservation agricultural practices singly and in combination. It will continue to be collected throughout the project period to assess trends over time.

Prior to CAPS implementation, soil cores were collected within each plot from 0-5 and 5-15 cm to measure moisture, bulk density and pH. Samples will be further analyzed for plant-available nutrients using mixed-bed ion exchange resin bags to extract plant-available nutrients (Carlyle and Malcolm, 1986). Extracts will be analyzed for inorganic N on a continuous flow autoanalyzer (SEAL Analytical, Mequon, WI). Other plant essential nutrients will be analyzed via ICP emission spectroscopy. Soil aggregate stability will be determined using a standard wet sieving method (Kemper and Rosenau, 1986). Total soil organic carbon (C) will be determined via dry combustion and analysis on a total C analyzer. Every year of the CAPs implementation, soil samples will be collected and separated into physical fractions that represent carbon pools with variable rates of turnover and sensitivity to changes in land management (Six et al., 2002). This will be done by removing the obvious litter mass from the top of the soil and then taking the first few centimeters of soil (which might still contain a large portion of the litter). Partitioning of C among these pools at implementation and during accumulation over time will be determined as for total soil C.

The results will be statistically analyzed using repeated measures multivariate analysis of variance (MANOVA) using the GLM procedure in SAS (SAS Institute Inc., Cary, NC), to determine significant changes by treatment and over time. A randomized complete block or split plot design will be employed with treatments as fixed effects and time as a random effect.

Based on results from the experiment station and outcomes of the AHP, we will implement two selected full-combination CAPS treatments in farmer fields in the target villages in Keonjhar District in years 2 and 3. Prior to implementation, we will hold training sessions with the farmers to introduce them to the CAPS practices and experimental CAPS plots at the Keonjhar KVK. In addition, OUAT and UH faculty and staff will discuss and decide on key research measurements as part of the initial workshop. Farm-level experiments will include both researcher- and farmer-controlled trials. For researcher-controlled trials, we will select a uniform parcel of agricultural area used for maize cropping in each village that encompasses fields of 10-15 different farmers. Individual fields are approximately 0.25-0.5 ha in size. This selection approach is based on advice from our OUAT partners to avoid social tensions that could be created by selecting individual farmers or agricultural fields. It represents a tradeoff between the inferential power of pure random selection and the reduced variance of a uniform experimental area.

A weather station will be installed in the center of the selected area along the border between fields. Sensors will monitor daily maximum and minimum air temperature and average relative humidity at 2 m above the ground, cumulative daily photosynthetically active radiation, cumulative daily precipitation, and average daily volumetric soil water content from 0-15 cm. Based on farmer preferences as analyzed by the AHP, we will select two fully integrated CAPS and compare their performance to traditional agronomic practices. Because farmers will be managing their own fields under the supervision of project staff, each field will be segregated into three plots, with one replicate of each treatment in each field. Thus, a farmer's field will serve as a block. Data collection and analysis will be conducted similar to the experimental trials at the KVK.

Farmer-controlled trials will be located in fields of participating farmers and under their direct management and control, with advice and assistance from project staff. Farmers will be encouraged to establish field trials in a similar design as the research-controlled trials. Farmers will be relied upon to keep records of crop yield and market value of surpluses, labor, inputs, and other costs. Because most of the farmers are illiterate, we will design simplified data sheets to help them record this data, and OUAT staff will make monthly visits to review and collect data from farmers.

In order to control animals in India (not a problem in Nepal) and provide a source of green manure, we will establish a live fence of several rows of multipurpose legume trees along the boundaries of the research parcel. Varieties of *Leucaena leucocephala* or *Leucaena* inter-species hybrids will be selected as the main live fence tree, based on advice and seed collections held by BAIF. *Gmelina arborea* and other species will be included, based on farmer interest and desired uses. Live fences will be planted densely and in several rows to provide both animal fodder as an alternative to crop residues and to create a physically restrictive boundary to inhibit livestock entering the research plots. These live fences are fast growing and in some cases they can be well established within a year.

To understand the effects of CAPS on gender equity and household decision making, qualitative data will be collected using several methods as outlined by Lamb et al. (2010). Interviews via survey and focus group by UH team and SANREM experts will be semi-structured, using the topic list to guide open-ended conversations. Conceptual tools that include resource generator survey, actor time line, mapping exercise, ranking, and network diagram will be used. Fuzzy logic will be used to see if different perceptions by different groups exist in regards to the different CAPS.

In Nepal, the participating villages are in remote areas that are not easily accessible by vehicle. However, our partner the Local Initiatives for Biodiversity Research and Development (LI-BIRD) has experimental areas within each village. We will work with LI-BIRD and the farmers to adapt existing experiments in order to implement an experimental set of individual and combined CAPS. Existing LI-BIRD experiments include identification of land management options in terraced shifting cultivation areas to sustain productivity of sloping lands and introduce crop combinations that improve ecosystem health and family nutrition. We will focus on establishing hedgerows with multiple species to support income generation, food production, and animal fodder to reduce forest clearing to establish new crop fields. Within existing crop fields, intercropping with legumes and maintaining soil cover are existing practices. We will focus on optimal crop rotation and improved fallow practices to maintain soil quality during crop rotations and restore soil quality during reduced fallow periods. The combination of household survey data, experimental results, and workshop training in 2011 will be used for more rigorous and widespread implementation of CAPS in 2012.

Objective 4. Use a participatory action research approach to promote reflection, evaluation, and continuous improvement of implemented CAPS

Critical Research Questions are:

1. How to evaluate CAPS performance relative to expected outcomes?
2. How to adapt CAPS to improve performance or meet adjusted outcomes?
3. How to innovate CAPS to fit new agronomic or climatic conditions or market opportunities?

Farmers will be included in data collection efforts by project staff so they understand both the methods and the information that such data are intended to provide. Farmers will be surveyed directly for information on market sales and prices, labor and material input requirements, and other perceived costs and benefits. All farmers will be trained on how to monitor and record basic crop and system conditions; farmer records in farmer-controlled plots will be an essential complement to periodic collections by research personnel.

We will summarize researcher- and farmer-collected data for presentation in workshops after the end of each growing season. These workshops will reflect on and evaluate how well the experimental CAPS performed relative to conventional practices and systems. Producers in researcher-controlled trials will be asked for their advice on how the system could be improved. Producers in farmer-controlled trials will be asked how they modified the recommended system or adapted over the season to maximize performance. Based on this feedback and with farmer participation, we will adjust CAPS practices and/or performance goals for the remainder of the project period. Producers in farmer-controlled trials will be encouraged to implement specific modifications so that these can be adequately evaluated against standard practices in researcher-controlled experiments.

Objective 5. Build capacity of farmers, local NGOs and universities to scale up CAPS development for wider dissemination.

Critical Research Questions are:

1. How to build innate capacity of farmers to communicate their knowledge and understanding of CAPS with other farmers?
2. How to increase NGO knowledge of and experience with CAPS?
3. How to increase university and professional expertise in and enthusiasm for CAPS?
4. How to build farmer-NGO-university networks at local, national, and international levels to increase collaboration on specific projects, respond to continuing or new challenges and opportunities, and improve communication of CAPS principles, practices, outcomes, and experience?

Workshop and training materials are being developed to support Objectives 1-4 for university, NGO, and farmer partners in the project. These materials are intended to be generally applicable for conservation agriculture research and development with rural, largely illiterate farmers in South Asia. They will be modified based on feedback from stakeholders and deposited in the SANREM Knowledgebase.

We are hiring students and staff to work specifically on this project, providing them valuable knowledge, skills, and experience in not just conservation agriculture research and development but also in developing strong international partnerships to accomplish this work. Students will include US and host-country nationals. We will emphasize recruitment of qualified women for student and staff positions. Graduate assistantships at both the University of Hawaii and our host-country partner universities are being offered.

We are also building a network of local, national, and international NGOs and universities to increase project collaboration and information sharing. In India, we are partnering with the national agricultural foundation BAIF and the international agriculture research organization ICRISAT as well as Odisha University of Agriculture and Technology. In Nepal, we are bringing together the regional NGO LI-BIRD with Tribhuvan University to strengthen the ties between these institutions.

Timeline

Finally, we will present results of our work at national and international scientific meetings and write up the results of our studies for peer-reviewed scientific journal articles. Table 1 includes a timeline of expected conference presentations and journal papers.

Table 4. List of potential conference participation and published manuscripts

	Year 2		Year 3		Year 4		Year 5	
	Conference /Proceedings	Refereed Paper	Conference	Refereed/Peered Reviewed Paper	Conference	Refereed /Peer Reviewed Paper	Conference	Refereed Paper/Peer Reviewed Paper
Economics	IFAMA CTAHR Symposium	Economics India and AHP India	IFAMA, CTAHR Symposiu m, East-West Center	Economics Nepal and AHP Nepal	International Economics Meeting, CTAHR Symposium, IGSC	Economic & Environ. Anal. India	Conservation Agricultural Conference, CTAHR Symposium	Comparative Analysis of India and Nepal
Agronomic	American Society of Agronomy Meeting	CAPS for soil and water conservation in India	SICA Workshop and Conference		American Society of Agronomy	CAPS for soil and water conservation in Nepal.	International Conserv. Agriculture Conference	Host-country fellows papers
Soils	Soil Science Society of America Meeting		Internation al Soil Science Society Meeting	Paper in regional journal (India)	Soil Science Society of America	Paper in regional journal (Nepal)	International Soil Science Society Meeting	Changes in soils as a result of CAPS

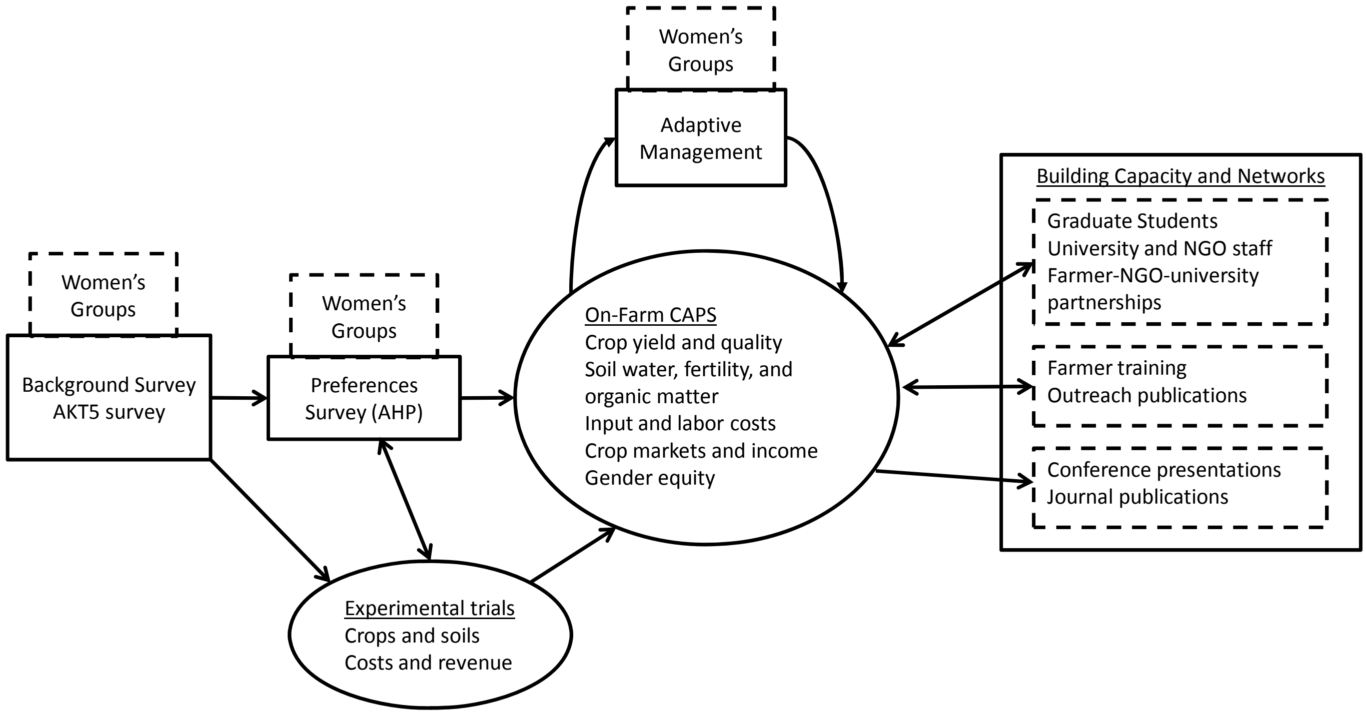

Figure 8. Model of Transdisciplinary Research Strategy

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LTRA-12 Conservation Agriculture for Food Security in Cambodia and the Philippines

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Host countries: Cambodia, Philippines

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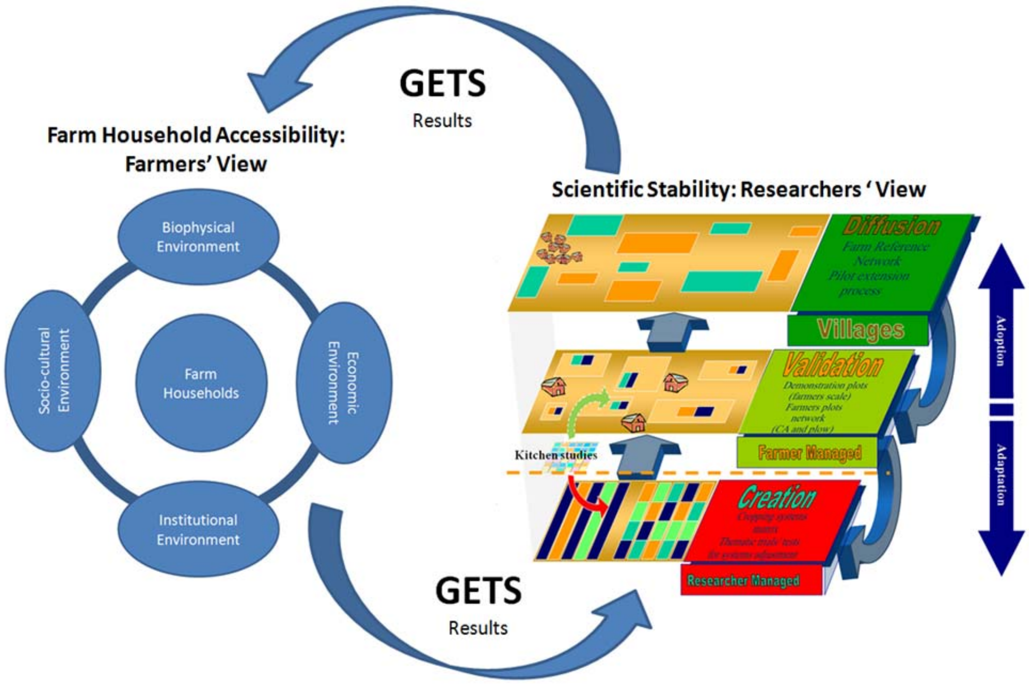
Introduction

Goal

Degraded landscapes are expanding annually in Cambodia and the Philippines, decreasing agricultural productivity, which in turn heightens food insecurity and exacerbates poverty. In both countries, rural poverty is increasing pressure on natural resources like forests, soil, and water. This project will show how conservation agriculture principles and practices of minimal soil disturbance, continues mulching, and diverse species rotations can be adapted for local conditions as the best practices to create sustainable, permanent cropping systems for annual crop production under wet tropical conditions of Southeast Asia.

Conceptual Model and Strategy

The “Creation-Research-Extension-Action-Teaching-Education” (CREATE) concept model is presented in Figure 8. It is a modification of the French action oriented "Creation-Diffusion-Training" method (Séguy and Bouzinac, 2001). CAPS tested are chosen in consultation with farmer groups, local government, scientists, and other stakeholders in the community. Proposed CAPS are analyzed in terms of farmer’s view (Figure 8a) and researcher’s view (Figure 8b). The CREATE protocol is: (1) CAPS is proposed; (2) research on proposed CAPS conducted; (3) CAPS with tested and proven prospects diffused; and (4) necessary conditions provided for feasible CAPS to be adapted or adopted. Biophysically and economically stable CAPS determined from method outlined in Figure 8b are fed back to farmer households. Analysis is conducted on the biophysical, economic, institutional and socio-cultural-gender environments of farm households in relation with stable CAPS to determine farm household feasibility (Figure 8a). Adjustments are made with stable CAPS based on farm household feasibility and results are fed back to scientists for further experimentation.



(a) (b)

Figure 9. CREATE Concept Model Application and Trans-disciplinary Research

The method is repeated until appropriate CAPS is adopted by villagers. While the CAPS are being developed, universities are developing CAPS lectures and textbooks and educating undergraduate and graduate students through classroom and onsite visits.

Research Methods

Baseline Survey to Diagnose Farm Households

In order to develop best-bet CAPS for smallholder farmers, baseline surveys are conducted to understand the bio-physical, socio-cultural-gender, institutional and economic environments (Figure 8a) that affects the households' decision making process to adopt or not to adopt CAPS. Participatory landscape appraisal needs to understand the bio-physical environments of the farming households such as topography, climate, soils, crops, and other vegetation. Understanding the broader household economic environment like land, labor, capital, market, and existing infrastructures is important. A structured household survey is used to gather baseline household and farm production data. Information is gathered from farmer respondents in different villages where farmer-managed participants are located. The farmer household respondent provides information about the household as a whole, such as age, sex, education, status and ethnicity, farming activities, and beliefs and perceptions about farming. Key informant interviews are also conducted as well as focus group discussions among farmers in selected villages.

Determining Best Bet CAPS

Determining best bet CAPS includes finding out appropriate cropping pattern and crops and species selection, acceptable cultural management, integrated fertility and pest management, and affordable equipment like planter, dibbler, and sprayer. Best-bet CAPS are the products of on-farm research which has four stages (Figure 8b): kitchen, researcher-managed, and farmer managed studies, and village diffusion sites. Promising CAPS are initially identified based on baseline surveys, field visits, discussions with scientists, literature reviews, farmer ideas, past experiences, and institutional support. Promising CAPS are then evaluated under researcher-managed experiments for a science based understanding of its effects on crops, environment, soils and household economy. In tandem, farmer-managed experiments are conducted to understand the practicability and complexity of CAPS technologies in the context of women and men farmers' circumstances. Furthermore, fresh ideas and emerging issues are evaluated using small plots about 5 m by 5 m for kitchen studies. Promising results from kitchen studies are fed directly into both researcher-managed and farmer-managed experiments. Kitchen, researcher- and farmer managed studies serve as venues for scaling up in village diffusion sites. Village diffusion sites comprise of farmers who adapt or adopt various degrees of CAPS.

Kitchen studies:

In Cambodia kitchen studies involved un-replicated cereal, legume, root, and cover crops varietal trial plots. In the Philippines, kitchen studies include cereals, sorghum, legumes and root crops varietal trials designed in randomized complete block with three replications.

Researcher-managed studies:

In describing treatments for researcher-managed the following notations were used:

'/' is relayed cropping with planting dates varying,
'+' is planted side by side with the same planting dates

In Cambodia, researcher-managed CAPS plots are in two sites at Boribo on land considered by farmers as degraded. Each site has four main crop treatments under two fertilization levels. Cover crops that function as biological pumps are used in the following experiments. Biological pump cover crops produce maximum biomass and are deep rooted and can extract (or pump) nutrients from deep soil depths. Pearl millet (PM, *Pennisetum typhoides*) and *Brachiaria ruziziensis* (BR) are used as biological pumps. For Site 1 the area is 2.0 ha, and it was started by PADAC in 2009, and continued by SANREM/PADAC 2010. Treatments are:

- T1: Maize and soybean rotation
  Pearl Millet/maize + *Brachiaria ruziziensis* in 2009 and in 2010 continued with *Brachiaria ruziziensis*/soybean + Sorghum + *Stylosanthes guianensis* at two fertilization levels of main crops maize and soybean. There is about 60-70 days biomass production of Pearl Millet, *Brachiaria ruziziensis*, and *Stylosanthes guianensis.*
- T2: Maize monocropping
  Pearl Millet/maize + *Stylosanthes guianensis* in 2009 and 2010 at two fertilization levels of maize.
- T3: Maize and cassava in rotation
  Pearl Millet/maize + *Stylosanthes guianensis* in 2009 and 2010 continued by cassava + *Stylosanthes guianensis* at two fertilization levels of main crops maize and cassava.

- T4: Cassava monocropping
  Cassava + *Stylosanthes guianensis* in 2009 and 2010 at two fertilization levels for cassava.

For Site 2, the area is 1.5 ha, and it was started in 2010 by SANREM/PADAC. Site 2 includes: (i) new associations with maize in order to combine legume-based biomass production as secondary grains (i.e., rice bean, pigeon pea and soybean); (ii) crop rotation between maize and upland rice that targets adoption on small to medium farms which do not produce rain-fed lowland rice; and (iii) mono-cropping of soybean with sorghum as secondary crops, a proven efficient system in a PADAC-CAPS study in Kampong Cham, Cambodia. The treatments are:

- T1: Maize mono-cropping + rice bean as secondary crop
  Pearl Millet/maize + *Stylosanthes guianensis* + rice bean
- T2: Maize mono-cropping + pigeon pea as secondary crop
  Pearl Millet/maize + *Stylosanthes guianensis* + pigeon pea
- T3: Maize and rice in rotation + rice bean and cowpea as secondary crop
  Pearl Millet/maize + *Stylosanthes guianensis* + rice bean and following year by Pearl Millet/rice + *Stylosanthes guianensis* + cowpea
- T4: Soybean mono-cropping + sorghum as secondary crop
  Pearl Millet/soybean + sorghum + *Stylosanthes guianensis*

In the Philippines, researcher-managed CAPS are in Barangay Rizal and evaluated in parallel with traditional plowed cereal monoculture systems which is maize-maize planted after 2-3 plowings and 1-2 harrows in between plowings. The CAPS evaluated are in a strip-plot with four replications, with five CAPS plus a plowed treatment as the main plots and two fertilization levels as sub-plots. These treatments are laid out in 10 m x 20 m plots with each plot split into 'low' (0-30-0 N, P_2O_5, K_2O) and 'moderate' fertility (60-30-30 N, P_2O_5, K_2O) levels. The treatments are:

- T1: Maize + *Arachis pintoi* followed by maize planted alongside establised *Arachis pintoi*
  Before planting, weeds are sprayed with glyphosate at the rate of 720 g active ingredient per hectare two weeks before planting. The maize was dibble planted at 70 cm x 20 cm, making around 72,000 plants per hectare. *Arachis pintoi* cuttings were planted in-between rows of maize spaced at 25 cm apart.
- T2: Maize + *Stylosanthes guianensis* followed by *Stylosanthes guianensis* fallow
  Maize is established similar than for T1. *Stylosanthes guianensis* seeds are drilled in between rows of maize and thinned to 10-15 plants per linear meter.
- T3: Maize + cowpea/upland rice + cowpea followed by maize + cowpea/upland rice/cowpea
  The land is prepared similar than for T1. Maize is established in double rows 30 cm apart with 20 cm between plants, followed by two rows of cowpea at 30 cm apart with 10-15 plants per linear meter.
- T4: Rice bean/maize followed by rice bean/maize
  Maize is established similar than for T1. Rice bean is established two weeks prior to maize harvest.
- T5: Cassava + *Stylosanthes guianensis*
  Land preparation is similar to 1. Cassava cuttings are planted in furrows 100 cm apart and 50 cm between plants, making 20,000 plants per hectare.

- <u>T6: Farmers' traditional practice</u>
  Two times plowed by animal drawn moldboard plow and two times harrowed by animal drawn spike-toothed harrow after every plowing.

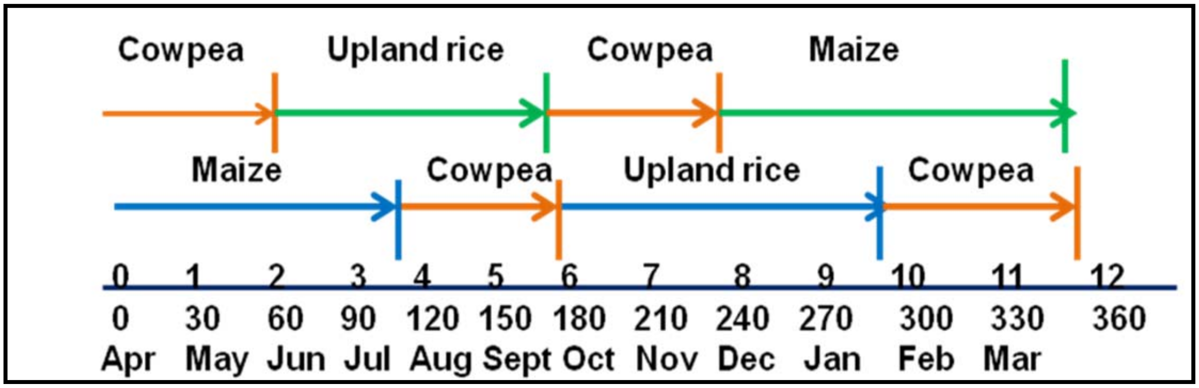


Figure 10. Planting timeline

<u>Farmer-managed:</u>
In describing treatments for *farmer-managed* the following notations were used:

'/' is relayed cropping with planting dates varying,
'+' is planted side by side with the same planting dates

In Cambodia, farmer-managed plots are:

- <u>T1: Pearl millet/maize + *Stylosanthes guianensis*</u>

This treatment is based on a successful CAPS developed by PADAC from experiments conducted in Kampong Cham which commenced in 2004. After year 1 it was found that T1 may not be suited for Battambang which may be due to highly basic soil derived from limestone which impedes growth of *Stylosanthes guianensis*. Adjustments will be made based on results from researcher managed studies and farmer inputs.

- <u>T2: Traditional plow based</u>
  The two treatments have marked sampling areas of four sub-plots 50 m² in size.

At a CAPS workshop in the Philippines, farmers were asked their preferred cropping patterns and they identified eight farmer-managed patterns:

T1: Maize followed by Baguio beans followed by maize followed by Baguio beans

- T2: Maize/cassava + *Stylosanthes guianensis*
- T3: Upland rice + cowpea followed by sorghum
- T4: Maize followed by peanut + cassava
- T5: Sweet corn + peanut followed by sweet corn + peanut
- T6: Baguio beans + maize followed by maize + sorghum
- T7: Maize + *Stylosanthes guianensis* followed by maize + cassava
- T8: Sweet corn followed by pechay followed by maize + pechay

These eight CAPS were implemented in 24 farms owned by 24 farmer households. With eight treatments in 24 farms, three farms (3 replications) were selected for each treatment based on farmer's preferences. Each CAPS treatment has an area of 1000 m^2. In addition each farm has a 1000 m^2 maize-maize plow-based system.

Hypotheses and Research Methods for each Objective

Gender:

Hypothesis: CAPS will decrease women's labor burden.
Method: Random-instant sample measurement will be conducted employing time allocation of women and men in CAPS technologies discussed in Best-Bet CAPS section of this document. Gendered access to and control of resources and services, and decision-making in terms of land, equipment, labor, capital and credit, and education, and training like who has access, who controls and participation of men and women in terms of relations to production will be studied. The activities of the participants will be recorded at the time of visit and what will be recorded is what the participants are doing at the moment that the time interval expires. This technique will require field monitoring and recording of the number of hours a particular task is performed on field in reference to time use allocation by gender. Instantaneous sampling will be observed by the researcher and record the activities of the observed participant. The time diary sampling approach will also be used. Time diary requires the farmers themselves to recall their activities at specific time intervals. A quick orientation-training with farmer-participants will be conducted. In addition, during these surveys, gendered perceptions on indigenous knowledge systems (i.e. beliefs and practices) on soil conservation and the importance of the new CAPS technology will be studied.

Economics:

Hypothesis: CAPS minimize smallholder costs and risks and maximize benefits.
Method: Baseline survey will provide the socio-economic and field data like cost of crop production and yield per hectare of farmer partners**.** Benefit cost analysis of research-managed and farmer-managed studies as discussed in Best-Bet CAPS section of this document will be conducted to measure cost and returns. Economic constraints to production, cost of factors of production; profitability; as well as socio-cultural constraints that includes, farmers' willingness to adopt the technology, price farmers are willing to pay for the use of the new technology and other variables as: characteristics of farmer participants (gender, age, education, ethnicity, etc.), opinion of experts and importantly, the opinion/perception of farmer participants will be identified.

Technology Knowledge Network:

Hypothesis: SANREM-supported farmer groups are effective in training knowledge leaders, in being a means of knowledge transmission, and in facilitating network connections leading to widespread adoption of CAPS.
Method: Qualitative measures and descriptive analysis of data on relations of people engaged in production activities and their various sources of production information, including technological knowledge of farmers shall be studied. Information will be gathered at the same time as random instant sampling is being conducted for gender study. Production subsidies will be provided to participating CAPS farmers who are members of farmer groups. These CAPS farmers will be network connections or 'indirectly paid extension agents' who will facilitate spread of CAPS

knowledge in the farmer group which can lead to widespread adoption of CAPS. In Cambodia, a micro-credit approach through subsidized bank loans and marketing contracts with animal feed producers, coupled with a method to facilitate access for mechanized direct seed drilling and spraying will be provided as an incentive to farmer groups who will adapt conservation agriculture. This approach will be tested if it is effective in promoting adoption of conservation agriculture, hence a key tool in facilitating network connectivity that can lead to widespread adoption of conservation agriculture.

Soil Quality and Yield:

Hypothesis: CAPS improves soil quality thereby increasing crop yield

Method: In the Philippines, soil sampling and analysis will be performed at both researcher-managed and farmer-managed sites in Year 1 (baseline), Year 3 and Year 5. Soil sampling at the researcher-managed site will be done at three different soil layers (0-5 cm, 5-15 cm and 15-30 cm). On the other hand, soil sampling in selected farmer-managed sites will be done at two depths (0-15 cm and 15-30 cm). Both undisturbed and disturbed soil samples will be collected and will be brought to University of the Philippines Los Baños (UPLB) for physical and chemical laboratory analysis. Soil quality parameters to be measured include soil bulk density, soil organic matter, soil nitrogen, soil phosphorus, and soil pH. Laboratory analysis will be carried out using standard methods. In addition, in-situ infiltration measurements will be performed at the researcher-managed site using a double-ring infiltrometer at the specified sampling years. Infiltration capacity curves and cumulative infiltration will be developed using infiltration models such as Horton's, Green-Ampts or Philip's equations for both CAPS and conventional plow-based systems. The soil moisture content will also be measured at the researcher-managed site using time domain reflectometry at 0-15 cm and 15-30 cm depths. Soil sampling and analysis will also be performed after harvest of the main crop to serve as basis for analyzing any temporal variability of the soil quality parameters under both CAPS and conventional plow-based systems. Crop yield, residue and biomass production will be measured as well. The data of the soil quality, yield and biomass production will be statistically analyzed (ANOVA and t-tests, etc.) and the soil quality, yield and biomass differences between CAPS and conventional plow-based systems will be assessed.

In Cambodia, soil quality, yield and biomass production will be monitored in 15 CAPS farmer managed and 15 plow-based farmer-managed sites. Yield and biomass will be measured in both researcher- and farmer-managed sites.

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CCRA-6: Economic Analysis and Impact CCRA

Principal investigators: Michael Bertelsen, and George Norton**,** Virginia Tech

Introduction

The economic challenges to CAPS adoption are among the most formidable obstacles that confront LTRAs and their collaborating host country partners. While the benefits to participating smallholder farmers and their families are short-term time savings (e.g., land preparation, weeding) and longer-term increases in soil fertility and erosion control that result in greater yields, income and food security, there are also substantial short-term costs of adoption (e.g., applications of herbicides, soil amendments, specialized equipment, risk and uncertainty associated with new, intensified management systems). Additional benefits (e.g., ecosystem services, including carbon sequestration, reduced siltation of streams, recharged aquifers) accrue to higher-level systems over time. The relative importance, magnitude, and distribution of benefits and costs vary over the geographical distribution of production systems covered by the LTRAs.

In order for wide-scale adoption and impact to occur, the fundamental economic research problem is the same in all regions: what farm-level production system(s) and sequencing of CAPS elements will minimize smallholder costs and risks while maximizing benefits and adoption? The specific elements to be sequenced in our research will be those identified by each regional program as being the subject of the research, and as such will differ by program, country, and sub-watershed. For example, CAPS elements in the Alumbre sub-watershed in Ecuador include items such as cover crops, deviation ditches, and reduced tillage. This cross-cutting research activity assists the LTRAs in developing a common methodology for addressing the general question raised above. This CCRA helps in standardizing the gathering of data and knowledge required to analyze the consequences of systemic (field and farm level) changes produced by adoption of CA technologies and practices. To the extent possible, the analysis also considers eventual aggregate or market-level economic impacts. These economic impacts can be compared across regions to provide insights into general strategies that promote wide-scale adoption of CAPS.

Objectives

1. Identify field- and farm-level production system(s) and sequencing of CAPS elements, in each country and watershed addressed in LTRAs, which will minimize smallholder costs and risks while maximizing benefits and adoption.
2. Assess broader economic and environmental impacts of CAPS.

More detail on the methods is provided below, but briefly, for the first objective the approach is to discuss with regional programs the farming systems and CAPS elements they are addressing, to design a farm-level optimization model (described below) that can be used as a template and adapted to each site for analysis of these systems. The model will be applied first in one regional site and then adapted to others depending on their situations and desires. Two types of adaptations across sites will need to be made. First, the crops and CAPS elements need to be included that are specific to each watershed. Second, the coefficients related to input use, production and prices, labor and credit availability, soil erosion, etc. will need to be determined for each site.

For the second objective, technology adoption surveys will be employed and the results combined with per unit costs changes to assess aggregate economic benefits. Ecosystem services will also be identified and valued if they appear to be of sufficient magnitude.

Questions addressed

1. What are the costs and benefits of CAPS in cropping systems/practices and related animal and forestry sub-systems?
2. What are the "optimal" systems in the various regions of the project, and is there an optimal sequencing of CAPS elements in each watershed studied?
3. What are the broader economic and environmental impacts of wide-scale CAPS adoption?
4. What policy or other changes are required to bring about CAPS changes?

Methods

For Objective 1, a farm-level linear programming model (Hillier and Lieberman, 2010) is being developed that maximizes economic benefits to small-holder farms subject to various levels of reduced soil erosion. The economic benefits in the model depend on productivity and cost changes. Data on yield and cost differences by crop and farming practices for each site are obtained for the LTRA experiments. Soil loss is measured as well on the LTRA experiments. Other objectives of CAPS such as improved organic matter could be included in the model if they are measured in the LTRAs. The model facilitates an assessment of the likely economic benefits attainable through adoption of innovative conservation agriculture techniques. The model allows for an analysis of the implications of varying weights on economic (such as profits) versus environmental objectives (such as reduced soil erosion) and of the effects of changing government policies.

The linear programming model is initially being developed and tested with data from the Ecuador site. Linear programming models are not statistical techniques, but mathematical (and normative) models that utilize budget, biophysical, and other data and assumptions to maximize (or minimize) an objective function (such as maximizing farm income over a period of time) subject to constraints such as land, available labor by month, credit, and amount of soil loss. The model will be run for Ecuador first and then will be adapted to the other sites where there are data being generated from CAPS experiments and where the model is needed. The model is designed (and constrained) initially to replicate the current production system and then the constraints are relaxed so that the model can to choose an optimal program given the objectives and the full set of available practices and constraints for that system. If economists in a specific regional program prefer to use an alternative approach to farm-level impact assessment rather than linear programming to achieve the same objectives, the Impact Assessment CCRA will work with and support them to the degree they desire. If a particular LTRA has not made progress to the point of generating biophysical data with respect to specific crops and CAPS elements, then CCRA-6 will wait until that progress has been made before helping it do a linear programming analysis. CCR-6 will provide LTRAs with as much instruction as they desire and are ready for in impact assessment. It is likely that Cambodia will be the second site for which impact modeling with the LP model will occur.

Application of the LP model will require characterization of biophysical and socioeconomic conditions of the main production systems (cropping, livestock, and forestry sub-systems) in the target regions. The biophysical and socioeconomic data come from the LTRA experiments, discussions with project scientists, farmer surveys, and/or use of other qualitative methods. For each CAP, data are needed on yields, changes in input use (purchased or provided including family and other labor), and changes in biophysical factors such as erosion and (if available from the LTRAs) soil and water quality.

The products of the linear programming analyses will be assessment of the most profitable mixes of crops and conservation agriculture practices for specific watersheds. The models allow for varying the levels of factors such as the amount of soil loss and estimating its effects on the income objective. The effects of introducing polices can also be examined in the models. For example if a farm level subsidy is provided for adopting particular practices or if subsidized credit is made available, the effects can be examined on income and adoption of practices.
For Objective 2, a survey a producers in the various regions where technology adoption has begun will be completed in Year 5 of the project. The purpose is to determine the number hectares that are adopting practices generated on the project. The per-hectare benefits (income, reduced soil loss, or other) will be multiplied by the number of hectares affected to determine aggregate impacts. Often such an analysis would take into account possible effects of the added production on market level prices. However, given the newness of the project, such price effects are likely to be minimal and will not be included. It may however, be possible to attempt to measure the non-market benefits of the reduced soil loading in streams and rivers if there is enough adoption. The adoption survey will also gather information on demographic characteristics of adopters to help assess distributional effects of the program.

Timeline

Year 1: Develop LP model for one watershed (in Ecuador and part of an MS thesis work).
Year 2: Gather the necessary budget and other data to run the model and prepare a report based on the analysis in the MS thesis. Discuss with each regional program their interest in utilizing the linear programming approach for impact assessment in their region. If they prefer an alternative approach to impact assessment, discuss what they plan to do with it.
Year 3: Prepare instructional materials on the farm-level impact assessment methods (including what data is needed and how they are obtained) and discuss them with each LTRA. Apply the model in one or two additional regional sites (one of which is likely to be in Cambodia).
Year 4: Prepare the adoption surveys for application later in year 4 and in year 5. Apply the LP model to other regions if they are ready with data.
Year 5: Administer adoption surveys in all regions that have released CAPS elements to farmers. Conduct Objective 2 analysis in those regions as well. Prepare a summary impact report for the project.

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CCRA-7: Gendered Knowledge

Principal Investigator: Maria Elisa Christie, Virginia Tech

Introduction

The Gender CCRA (Gendered Perspectives for Conservation Agriculture: Local soil knowledge and crop-livestock interaction) is qualitative, case study-based research carried out in collaboration with individual LTRAs and the Soils and Technology Networks CCRAs. It will produce policy recommendations and research that aim to improve the success of CAPs while reducing inequities between women and men.

Its overarching goal is to identify gender-related factors that contribute to the success or failure of CAPS.

Understanding local knowledge, beliefs, and perceptions of soils—both women and men's—is one of several essential components for potential adoption of CAPS. Women possess specialized agricultural knowledge in areas such as soil quality and crop-livestock management which may differ from that of men's based on their practices, access to and control of assets, and other factors; this may provide incentives (or disincentives) for women's participation in CAPS. Research will consider relationships between local knowledge and scientific data.

The Gender CCRA will work with the Soils CCRA to link beliefs and perceptions about soil quality—based on descriptors in local languages—with lab analyses of soil samples. With the Technology Networks CCRA, it will build on quantitative survey data about sources of information and attitudes (technological frames) concerning agricultural production practices at the household level, and collaborate to map knowledge networks using qualitative methods. It will collaborate with individual LTRAs to train host country teams including students in research methodology and carry out data gathering during PI visits and US student research.

The strategy and methods described below build on exploratory fieldwork in FY 1 which served to test methodology and obtain initial data in the following countries: Mali, Ghana, Uganda, Ecuador, Kenya, and the Philippines. Fieldwork begins in Bolivia in FY 2, and in Nepal and the Philippines in FY 3.

Gendered Knowledge and Access to Assets

Women's and men's different gender roles necessitate and perpetuate the development of complex and sophisticated agricultural knowledge and skills. For example, women's knowledge is essential to maintaining and conserving plant biodiversity (Howard 2003; Turner 2003) and may illuminate opportunities for locally adapted forms of conservation agriculture. Women are primarily responsible for passing on knowledge to younger generations and/or other members of the household. Even though women are often not the formal decision-makers in the household or community, their participation in the development and evaluation of proposed CAPS is necessary because this will involve a reallocation of their resources including time and labor. Interactions among households, livestock, and soils in terms of allocation of biomass create competition and integration opportunities for CAPS. The focus on gendered knowledge (tacit and formal) and skills may contribute to the sustainability of SANREM's conservation agriculture agenda.

Objectives

Questions

1. What are women's and men's local soil knowledge, beliefs, and perceptions; soil management practices; and access to agricultural resources, including land, information, and soil inputs?
2. What are the gendered landscapes linked to knowledge, beliefs, and perceptions of soil quality and soil management practices?
3. What is the gendered nature of access to and control over animals, animal feed, and animal by-products in context of crop-livestock interaction?

Hypotheses

1. Women will more often use descriptors related to soil fertility while men will describe soil more in terms of physical properties.
2. Women are more likely than men to express attitudes which support conservation agriculture production practices.
3. Men are more likely than women to adopt practices that maintain crop residue on staple crop fields.
4. Maintaining crop residue cover on the soil will reduce women's access to animal feed.

Background

The Gender CCRA integrates socioeconomic and biophysical sciences: it draws on theoretical frameworks from the discipline of geography (particularly feminist political ecology) and from ethnopedology—both fields that bridge the social and natural sciences. Its contribution will be to create connections in the overlap between the studies of place and gendered landscapes from cultural ecology on one hand, and the focus on soils in ethnopedology on the other, from a feminist political ecology (FPE) perspective. FPE looks at issues of power in gendered spaces, gendered knowledge, and everyday life. Cultural ecology addresses the interaction between humans and their environments. The geographical approach in political ecology originates in the 1970s at the intersection of cultural ecology and political economy (Zimmerer and Bassett, 2003). Blaikie and Brookfield's (1987) definition of political ecology included the relationship between land degradation, the land manager and society; their work set the foundation for the integration of natural and social sciences to understand complex human-environmental issues through political ecology.

Feminist political ecology (FPE) is informed by political ecology and feminist theory (Rocheleau et al., 1996). It emerged in the 1990's as an approach to the study of gender, environment, and development. Drawings from the feminist critique of science, it resists the "gender-neutral objectivity" of male-dominated science that separates work, knowledge, and science and ignores women's everyday lives and livelihoods. FPE links the household, community, and landscape, recognizing that environmental knowledge is gendered, local, and "situated," influencing men, women, and the landscape differently (Rocheleau et al., 1996; Haraway, 1988). From this perspective, the inclusion of local and gendered knowledge systems of natural resources is needed in community-based conservation agriculture production systems.

Drawing from natural and soil sciences, ethnopedology provides an approach to local knowledge, beliefs, perceptions, uses, classification, and management of soils by local people. Ethnopedological research shows that they have extensive knowledge of the soil and land, that such knowledge is transferred by generations, and that it is received and perceived differently by gender and age. Furthermore, ethnopedologists argue that studies of soil knowledge should not only include knowledge about landscape and socio-political processes, but also how the scientific and local knowledge can fit together (Barrera-Bassols et al. ,2006; Barrios and Trejo ,2003; WinklerPrins and Barrera-Bassols, 2004; Zimmerer 1993).

Methods

The Gender CCRA uses a series of qualitative research techniques at household, community, and field levels. These include: focus group discussions, participatory mapping, interpretation of photographs and soil samples, socioeconomic activity charts, structured and unstructured interviews, participant observation, timelines, and transect walks. These together with household survey methods and data analysis employed by the Technology Networks CCRA and the laboratory analyses of the Soils CCRA will allow triangulation of data and signal gaps requiring further research. The Gender CCRA will employ the Gender Dimensions Framework (GDF) to organize and guide collection and analysis of data. The GDF incorporates the following four dimensions: access to and control over key productive assets, including information; beliefs and perceptions; practices and participation; and laws, rights, policies, and institutions, and the cross-cutting dimension of power (Rubin et al., 2009).

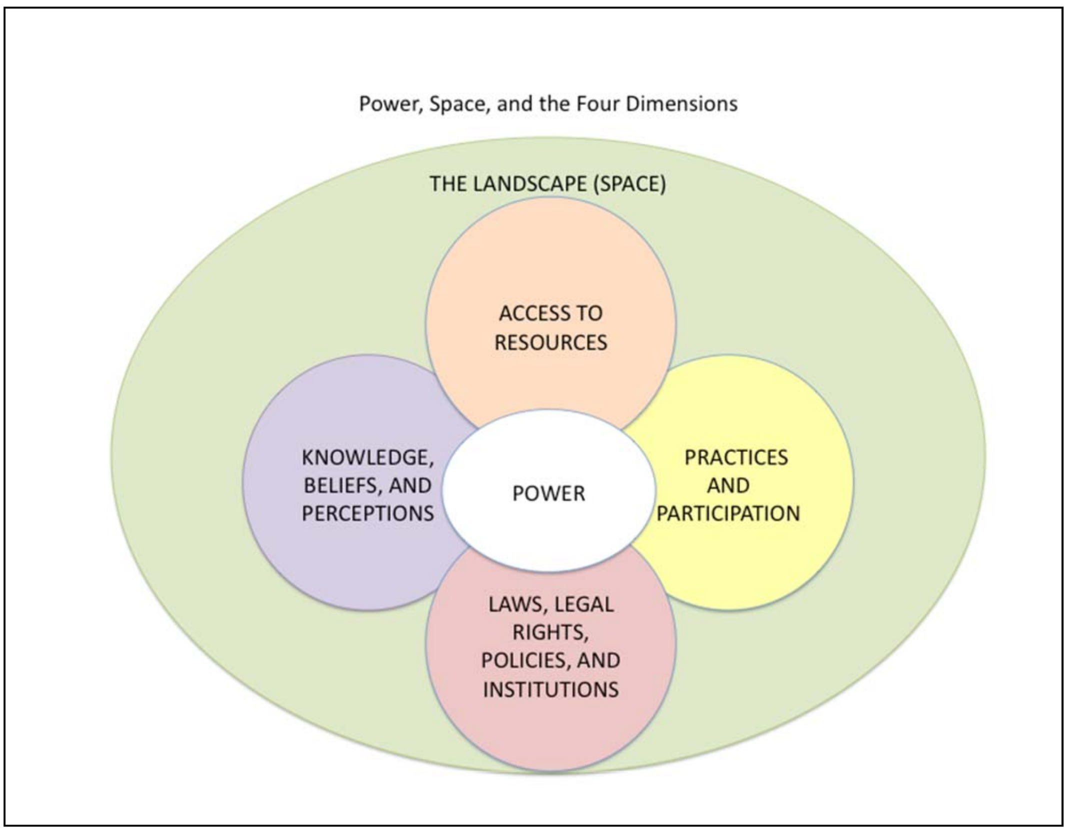

Figure 11. Power, space, and the four dimensions

The Gender CCRA integrates a cross-cutting dimension of space and landscape into the GDF. This dimension brings together perspectives from political ecology, feminist political ecology, and ethnopedology literature. It will link soil knowledge, beliefs, and perceptions; soil management practices, and access to resources to the physical landscape and people's perceptions of the landscape.

Multiple methods will address questions pertaining to the GDF within the scope of this research. The following provides examples the application of this framework and how key questions will be addressed through multiple methodologies. The chart is not comprehensive. Some of the exercises will be carried out in focus groups and address community soils as well as in household visits and transect walks and address the farm level.

Table 5. Chart of research questions and methods

Dimension	Research Questions	Prompt Questions by Method
Knowledge, beliefs, and perceptions	Do men and women have differences or similarities in soil knowledge, beliefs, and perceptions? How do men and women describe soil and soil types?	Focus Group and Household Visits "How do you know where to plant different crops?" Soil sample exercise 1. "Describe the soil." 2. "Which one is better?" 3. "How do you know?" List of community/farm soils 1. "What types of soil are there in your community?" 2. "What are their characteristics?" Soils map 1. "Where are the different soils located?" 2. "Which are the best and poorest soils?" Soils photo interpretation 1. "What soil practices do you see here?" 2. "How do animals affect the soil?" Soils Timeline 1. "How has soil quality changed over the last 30 years?" 2. "Has this affected women and men differently? If so, how?"
Access to Resources	Do men and women have different access to soil types and soil amendment inputs, including animal manure?	Access, control and labor map 1. "Who decides what crops to plant?" 2. "Who decides where to graze livestock?"

Dimension	Research Questions	Prompt Questions by Method
	Who controls access to animal feed and by-products?	Soils Map 1. “Who uses what soils?”
Practices and Participation	Do men and women use soil differently?	Socioeconomic activity chart “What labor is carried out by men and/or women?” Household Visit 1. “How do you care for the soil?” 2. “Who grazes the livestock?”
Laws, Legal institutions	Can women inherit and sell land? Do they need their husband’s approval?	Do women participate in farmer or village-level associations? Why or why not? How?
Space and Landscape	Where do men and women use soils in their farm landscape? Where are the best and worst soils? What does the landscape look like?	FIELD VISIT AND KEY INFORMANTS 1. “Has the landscape changed in any way to affect the soils or crops?” 2. “Are there any features of the landscape that affect how you manage the soil or crops?” 3. “What landscape features make the best or worst soil?”

Using maps, photos, and field visits, farmers will identify and describe different soil types, including their “best” and “worst” soils at the community and farm level. Photos will be used to elicit perceptions of soil quality and of CAPS components; they will be taken directly from the region of study and include depictions of a tilled field, a field with crop residues, and grazing livestock. In focus groups, they will be given a sample of good soil (high in organic matter, moist, etc.) and one of poor soil (dry/muddy/sandy/hard) for agricultural production found in their region. Descriptors of soils will be compared with lab results and examined for gender differences. In addition, after farmers identify soil types on their land through hand-drawn maps, plots will be mapped using GPS, and soil samples taken. The samples will be collected by the Soils CCRA in accordance with its scientific protocol and analyzed at the Virginia Tech soils lab. Sources of knowledge, beliefs, and perceptions about soil quality will be explored through household interviews and analyzed in conjunction with the Technology Networks CCRA.

The socioeconomic activity chart exercise aims to identify men and women‘s roles in the productive and reproductive sphere and help determine areas of knowledge based on their activities. Seeking to answer “Who does what?” will help develop strategies to increase women‘s and men‘s participation and benefits.

Participatory mapping is central to the research strategy due in part to its ability to communicate perceptions and worldview without words and to facilitate the participation of women who are more often less literate and able to express themselves in public than men. It also overcomes some of the limitations of working with indigenous peoples through translation as well. Once completed, the maps serve as a two-way teaching tool, first for the farmers to teach researchers about their cropping systems, and secondly for researchers to discuss CAPS with farmers. By conducting this exercise in the early and final years, the research will be able to track changes in beliefs and perceptions regarding soil quality and soil management.

Strategy
The Gender CCRA will build on existing research and interest in LTRAs 7 (Andes), 11 (South Asia), and 12 (Southeast Asia). The primary sites are: the lower and middle watersheds of Tiraque in Cochabamba Province, Bolivia; Thumka village in Nepal, and the upper and lower villages of Claveria in Misamis Oriental, Mindanao, Philippines. Research will draw on previous work including the study of soil knowledge from SANREM Phase III in the Philippines and Bolivia (Cassio and Motovalli c. 2009). To ensure scientific soil sampling design and analysis, as well as to synergize efforts, the Gender CCRA will work with sites where the Soils CCRA has already collected samples, as in Nepal, or in sites where the Gender CCRA will serve as the impetus for soil sampling, as in Bolivia.

A participatory, farmer-led approach will be linked to a technical, scientific perspective. Methods will bring together techniques using satellite imagery and GPS with participatory mapping. At the same time it will consider both farmer's experience and description of soils based on their life experience and access to traditional knowledge, and information provided by outside technical experts and laboratories. While these will not be compared for "accuracy" or which approaches the "truth," it will bring local knowledge and skills into focus while it critically considers the supposed neutrality and accuracy of the scientific method.

There are seven phases in this CCRA. The initial exploratory visit (Phase 1) includes team meetings and training, and a rapid gender assessment using focus group discussions with gender-segregated groups of women and men. This will initiate longer-term research in Phase 2 by graduate students and/or host country teams. In Phase 3 data will be processed and analyzed: qualitative data will be analyzed using the Gender Dimensions Framework described above. This will be correlated with hard data from the soils CCRA and will integrate quantitative data from the Technology Networks CCRA. Phase 4 consists of presentation and publication of results. In phase 5 findings will be presented to the community and HC teams for their input and to fill gaps. In Phase 6 focus group discussions including participatory mapping exercises and follow-up interviews with key informants will take place to assess changes in beliefs and perceptions regarding soils, and in access to assets including knowledge, soil inputs and livestock. The final phase (7) year will analyze methodological challenges and opportunities for multi-disciplinary approaches. Final research findings will be presented and submitted for publications in 2014.

Table 6. Timeline

Phase	FY 1 (2009-2010)	FY 2 2010-2011	FY 3 2011-2012	FY 4 2012-2013	FY 5 2013-2014
1	Ecuador, Ghana, Kenya Mali, Philippines, Uganda		Nepal (N)		
2		Bolivia (B)	Philippines (P)	N	
3		Phase 1 countries only	B, P	N, P	N
4		Phase 1 countries only	B	B, N	
5			B	B,N,P	
6					B,N,P
7					3 CCRAs

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CCRA-8: Technology Networks

Principal Investigator: Keith M. Moore, Virginia Tech

Introduction

The goal of the SANREM CRSP Technology Networks cross-cutting research activity is to determine factors facilitating innovation and scaling out of conservation agriculture production systems (CAPS) for smallholders. Comparing technology network findings across LTRA research sites will reveal characteristics of the structure and functioning of agricultural networks that enable system level problem solving for successful smallholder CAPS development. We argue that technological change leading to sustained adoption of smallholder conservation agriculture production systems (CAPS) involves more than just the introduction of CA practices by a transforming agent (extension/NGO) but also the building of shared understandings and supportive relationships with other partners in the community and agricultural service sector. Critical to these shared understandings is a shift toward conservation agriculture knowledge and attitudes and away from conventional and risk-averse agricultural production perspectives.

Objectives

Our study focuses on three objectives:

1. Identify the knowledge and attitudes (technological frames) concerning agricultural production practices held by actors in the network
2. Describe the structure of information and physical resource flows between these actors
3. Determine critical network pathways and opinion leaders facilitating technological change among farmers and their service sector partners

Methods

Structure of Comparative Research

This cross-cutting research is designed to piggyback on LTRA baseline and follow-up surveys planned for years 1 and 4. A priority concern is for the LTRAs to collect core data sets in the same standardized format (see below) for rigorous hypothesis testing. Two target groups (farm households; and agriculture service sector and community actors) need to be surveyed to obtain a minimum network analysis dataset at each site. Collaborative data gathering activities have already been initiated at the household level with the three Africa-based LTRAs and we look forward to adding others in the near future. This set of cases from Africa will provide a solid foundation for comparative analysis.

While this research applies standard quantitative data collection and analysis techniques, the overall design involves a comparison of network case studies from each of the LTRA sites. Within site comparisons of network parameters before and after the initiation of LTRA field research will provide the foundation for site level hypothesis testing. Cross site comparisons of network case studies will allow for assessing the differential impact of each site's network structure and functioning.

Sample Designs

Household survey sample designs will be based on the strategy that each LTRA finds appropriate to their baseline data collection objectives. Where possible both men and women in each farm household will be interviewed with separate survey instruments (USAID requires that data be disaggregated by sex). A minimum sample size of about 120 farm household men and 120 farm household women per site is recommended. While panel data would be preferred, statistically sound samples of the target population from year 1 and year 4 will suffice. Samples should be drawn from the population targeted for CAPS field research, demonstration and transfer. Survey respondents should not be spread across too many communities/markets. Networks are expected to be within the radius of related villages (that is, within the reach of the same local/weekly market and extension service zone). It need not cover all regions of an LTRA's research site. It is recommended that students be used (men and women) as interviewers (LTRAs may already have identified preferred data collectors). They need to be well trained with respect to the questionnaire items and the expectations of the survey. The CCRA is available for consultation and assistance in implementation.

The sample design for the agricultural community leaders and service sector agents in each site will be based on the population identified by respondents to the household surveys, focus group participants, and local informants (who may figure as part of the sample as well). Project partners in contact with the target population should also be included. A sample size of 20 to 40 respondents should be obtained and this may saturate the local population of community leaders and service sector respondents. Snow-ball sampling would be the preferred method, but is unlikely to be feasible across these sites with available time and resources. It has been determined that surveying this latter target group is beyond the manageable interest of the LTRAs and will therefore need to be done by members of the Technology Networks CCRA team.

<u>Survey Instrument Modules for Minimum Dataset</u>

LTRAs are provided with two questionnaire modules (see Table 1) for incorporation into their household baseline surveys. The first focuses on the knowledge, beliefs and perceptions of the farmers and their supporting partners (in the service sector and the community) concerning farming practices. See Table 2 for the list of items. The second addresses the relations between farmers and other local actors involved in the implementation of agricultural practices. A suggested list of agriculture service sector and community actors is presented in Table 3, but should be verified and adjusted based on qualitative interviews and focus group activities in conjunction with routine LTRA research and/or the Gendered Knowledge CCRA. Table 4 presents the set of questions and closed-ended responses for each actor listed. Household baseline data on agricultural (particularly conservation agriculture) practices collected by each LTRA will be used as an objective point of reference on farmer behavior during the follow-up survey. Each LTRA team will translate the items in Tables 2 and 4 into local languages with the rest of their questionnaire. A version of these items is also available in French.

The survey instrument for community leaders and service sector actors is composed of Module 1 and 2 (Table 1), and routine identification information. It can be completed quite quickly if there are no other questions that the team would like to address of these actors. It is possible to add other questions to this survey instrument, if desired. Interviews could be conducted individually by researchers as they have occasion to meet these partners when working in the zone. However, the CCRA will be available to help conduct these surveys as scheduling permits.

Table 7. Summary of Baseline and Follow-Up Household and Service Sector Survey Modules

Survey Module	Surveys administered separately to men and women at the household level and to agricultural service sector actors in years 1 and 4 as part of routine LTRA baseline survey activity		
	Brief description	Objective	Type of Data Collected
Technological Frames	Polls agricultural production perspectives along 3 dimensions: -Conservation Agriculture -Conventional Agriculture -Risk Averse Agriculture	Identify distribution of technological frames within and among agricultural production network partners	A battery of Likert scale items designed to measure the extent to which individuals typify a conventional, conservation, and/or risk averse technological frames.
Position Generator	Identifies positions (nodes) and characterizes relations (ties) between actors distributed within the network	Map relations between actors	Information about network relations between interdependent people with different livelihoods: the resources exchanged, the quality and frequency of interactions, interaction initiators, gendered nature of interaction.

Critical Research Hypotheses

Two sets of hypotheses will be explored in order to achieve study objectives. The first set tests the relationship between technological frames and agricultural practices. The second set addresses network relationships directly, testing them from the perspective of service sector actors, farmers, and the network as a whole. It is recognized, given the variety of circumstances for each LTRA and research site, that it may not be possible to test all hypotheses. It is nevertheless important to retain the overall structure of the research strategy to provide the best possible rigor for the comparative analyses.

<u>Technological Frame Hypotheses:</u>

1. Producers holding a conservation agriculture technological frame will adopt Conservation Agriculture.
2. Producers holding a risk averse technological frame will not adopt conservation agriculture.
3. Producers holding a conventional agriculture technological frame will not adopt conservation agriculture.
4. A transition towards a conservation agriculture technological frame over the project period will be highly correlated with the adoption of conservation agriculture.

Technology Network Hypotheses

Group 1: Transmission of Technological Frames from Service Sector Actors to Producers

1.1 Service sector clusters who control the dissemination of agricultural information (high betweeness centrality) will be associated with higher adoption rates among producers
1.2 Service sector clusters with increased control over time over the dissemination of agricultural information will be associated with higher adoption rates among producers
1.3 Highly connected service sector clusters through which agricultural information passes (high degree centrality) will be associated with higher adoption rates among producers
1.4 Increased connectivity of service sector clusters over time will be associated with higher adoption rates among producers

Group 2: Structure of Farmers' Networks and Technological Change

2.1 Farmers who seek out agricultural information from diverse service sector clusters will have higher rates of technology adoption
2.2 Farmers who increase the diversity of service sector clusters from which they access agricultural information over time will have higher rates of technology adoption
2.3 Farmers who passively receive agricultural information from diverse service sector clusters will have higher rates of technology adoption
2.4 Farmers who report receiving increased agricultural information from diverse service sector actors over time will have higher rates of technology adoption
2.5 Farmers who frequently exchange agricultural information other farmers will have higher rates of technology adoption
2.6 Farmers who increase their interactions with other farmers over time will have increased rates of technology adoption

Group 3: Total Network Comparison for Technological Change

3.1 Networks with greater density of relationships between clusters in year 4 will have higher rates of technology adoption
3.2 Networks that experience increased density of relationships between clusters over time will have greater rates of technology adoption.
3.3 Networks where information flows are more centrally controlled (group betweeness centrality) will have higher rates of technology adoption
3.4 Networks that experience consolidation of information control over time will have higher rates of technology adoption
3.5 Producer networks with less dispersion of connectedness to actor clusters (actor degree centrality) in year 4 will have higher rates of technology adoption
3.6 Producer networks that experience increased cluster connectedness, reflected by moving from a high variation of actor cluster degree centrality to lower variation of degree centrality (group degree centrality) over time will have higher rates of technology adoption

Data Analysis
Data collected through household and agricultural community and service sector surveys will be entered and stored in either SPSS or Excel. SPSS will be used to prepare and analyze the data for the hypothesis testing. UCINET 6 will be used for network indicator development and analyses. Its complementary program, NETDRAW will be used for computerized mapping of the agricultural production networks.

Response coding has been designed into the questionnaire items facilitating data entry and analysis. Data analyses will be conducted by site and between surveys periods within sites. Primarily descriptive statistics and qualitative comparisons will be made between sites. When data quality allow for statistical comparison between sites, this may also be done.

<u>Likert Scales Measuring Technological Frames</u>
This component of the household survey includes a number of Likert scale questions designed to determine whether an individual holds a conservation, risk averse, or conventional agriculture technological frame. Each measure will be given a scale of 1-5, with the respondent asked to indicate the extent to which they agree with a statement. A response of 5 should be used to indicate that the respondent 'strongly agrees', 4 'agrees', 3 'unsure/non-committal', 2 'disagrees', and 1 'strongly disagrees'. Factor analysis will be used to construct and validate internally consistent technological frames for each site studied. These may vary by gender and this aspect will be examined.

Table 8. List of Technological Frame Items

Conservation Agriculture 1) Land is one's heritage to be preserved for future generations 2) One should maintain a permanent crop cover 3) Timely weeding (before setting of seed) is important to a successful harvest 4) Tillage causes land degradation 5) Rotating crops is always best practice Conventional Agriculture 6) Farm income should always be reinvested to grow the business 7) Applying chemical pesticides is always necessary 8) Inorganic fertilizer is best to improve soil quality 9) Planting decisions are always based off of current market prices 10) Crops should only be grown for sale 11) One should always strive to grow the most on one's land. 12) Land preparation for crop production begins with plowing.	Risk Averse 13) Farm labor should be replaced by more efficient herbicides and machines 14) Engaging in multiple productive activities is always better than doing just one 15) It is better to grow staples within the household or community than purchase them. 16) Farm production is necessary to feed the family 17) Spreading crops and inputs across multiple plots is always necessary 18) Crop residues should only be fed to livestock and poultry 19) The staple crop should be planted on the majority of the land *every* growing season 20) Earning off-farm income is more important than a large harvest

Network Focused Analyses

Given the scale of the study, the analysis of position generator data for service sector actors and community leaders will operate at the level of 'occupational' clusters. Betweenness centrality (i.e., the degree to which a node is the shortest pathway to connect all other nodes in the network) will be used at the cluster level to measure the extent to which information transmission between groups is controlled by a single intermediary. Degree centrality (i.e., the number of ties that a node has) will be used to measure the connectedness of a node in a network. Clusters that have more connections will have higher degree centrality. Total network measures will capture a broad picture of what is occurring in an actor network. These measures include measures of density, group betweenness centrality, and group degree centrality (Knoke and Yang, 2008).

One of the major goals of the network research is to measure levels of communication between different actor clusters. This will be done by comparing technological frames shared among network partners.

Cluster level analysis also allows for easier comparisons across cultures as production systems tend to have similar types of actors (producers, input suppliers, extension, etc.), even if the relations or the titles of the actors themselves are very different. When the same position is perceived differently in different cultures, the position generator approach has been used successfully for cross cultural research (Lin and Erickson, 2008).

Table 9. Initial suggestions for list of agricultural service sector and community agents

Village chief	Leader of women's organization
Family member	Leader of youth organization
Vendor in weekly market	Agent of research institute
Vendor in an urban shop	Agent of another project
Teacher in village	District assemblyman
Tractor owner	Extension agent
Minister/Priest/Imam in village	NGO agent
Leader of farmers' organization	

Table 10. Questions about contacts with agricultural service sector and community agents

What resources are accessed through interaction?	1. Seed 5. Tractor 2. Fertilizer 6. Land 3. Pesticide 7. Labor 4. Herbicide 8. Other_______
What form of information is accessed through interaction?	1. Advice or consultation 2. Only information 3. None
Who Initiates the contact most of the time?	1. Always them 4. Mostly me 2. Mostly them 5. Always me 3. 50/50
Where do you interact?	1. Farm 5. NGO Office 2. Store 6. Community center 3. Office 7. Farmer field day 4. Market 8. Other________
Frequency: How often do you interact?	1. Weekly 4. Seasonally 2. Biweekly 5. Yearly 3. Monthly
Quality: Can you trust resources/info provided?	1. Always 4. Rarely 2. Most of the time 5. Never 3. Somewhat
Gender:	1. All male 4. Mostly female 2. Mostly male 5. All female 3. 50/50

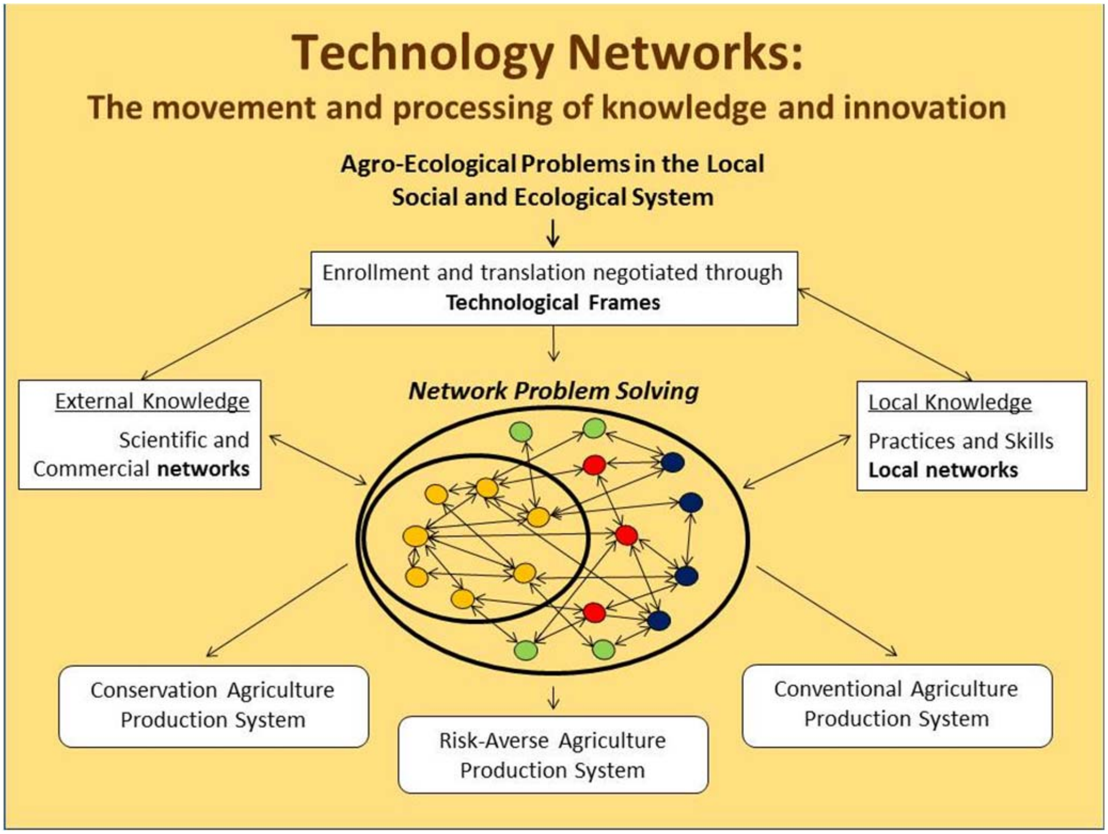

Figure 12. Agro-ecological problems in the local, social, and ecological system

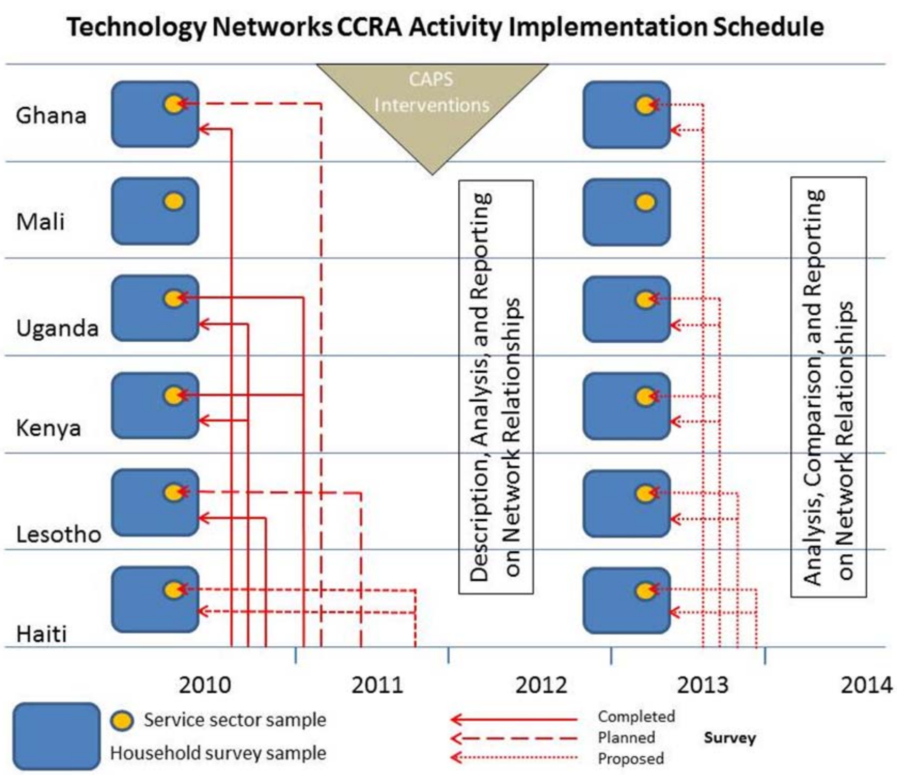

Figure 13. Technology Networks Implementation System

CCRA-9: Soil Carbon and Soil Quality

Principal investigator: Michael Mulvaney, Virginia Tech

Introduction

The overarching goal of this 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 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 conservation agricultural production systems (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.

Objectives

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.

Hypothesis: CAPS increases SOC and soil fertility in smallholder dryland systems in the developing world without reducing productivity.

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 labor-prohibitive, 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 our laboratory here at Virginia Tech, where we will build a Time Zero soil library, so that we can run analyses 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.
Shipped soils 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 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. For example, assuming a soil contains 40 Mg C ha^{-1} with a standard deviation (σ^2) of 17 Mg C ha^{-1} and a covariance of 10 percent, the MDD of SOC is 11.2, 7.5, 5.0, 3.5 Mg C ha^{-1} for 4, 8, 16 and 32 composite samples taken, respectively, at the 95 percent confidence level (Garten and Wullschleger, 1999). We anticipate receiving approximately 3 treatments (including the control) x 2 depths x 3 sites x 4 reps = 72 samples from each country at Time 0 (totaling 936 samples), to be repeated again at the end of the experiment. The total number of treatments sampled will depend on budgetary and labor constraints. Each of these anticipated 72 samples is a subsample from at least 16 composited cores mentioned earlier. Although this will be an expensive library to build, it will provide samples that can be analyzed under one lab, as well as 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.
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 and Beare (2008). This procedure may be altered if another procedure or alteration will offer better chances of determining treatment differences in accordance to the timeframe remaining in this phase of the project.

Status Report

We have applied for and have been issued a Compliance Agreement and Soil Import Permit by the USDA and are now prepared to receive soil samples from all foreign sources. Our subsequent application for maintaining the soils library for more than 6 months was granted. Most LTRAs are just beginning implementation of researcher-managed trials, and to date we have received Time 0 soil samples from Ecuador and Lesotho. More samples from Bolivia, Lesotho, Cambodia and the Philippines are currently being prepared for shipment.

The Soils CCRA has directly facilitated the research plans in Lesotho, Ecuador, and Nepal over the last several months. We have trained local partners in soil sampling protocols, both in composite sampling and intact sampling, as well as in the determination of slope and squaring of research plots. We have also provided soil permits and instructions on how to export soil samples to the United States, as well as importing sampling equipment into areas where no such equipment is otherwise available. In Ecuador, we helped the soils lab to build a soil hydraulic conductivity apparatus for the determination of several key soil physical properties. In all cases (Lesotho, Ecuador and Nepal), we helped to determine research plans that incorporate elements of CA into field trials.

As part of our cross-cutting research, we plan to collaborate with Gender CCRA to assess the gendered differences of soil fertility in Bolivia, Haiti, and the Philippines. We are also currently planning to add soil fertility quantification to the baseline household surveys in Haiti, which should take place this summer, in collaboration with the Economic and Impact Analysis CCRA.

Challenges

Incomplete data set. While we anticipate receiving Time 0 soil samples from all the project sites, it is possible that LTRAs or their project partners will not be able to send us soil samples from their project sites and/or may collect the samples in an inappropriate manner. The Soils CCRA has offered to pay for shipping costs associated with this objective. If needed, and if our budget allows, we will travel to the sites to collect these samples ourselves or assist the LTRAs in sample collection. In addition, we are dependent on the LTRA project partners to determine grain yield, above-ground biomass, and percent ground cover. It may be assumed that we will likely have an unbalanced dataset, in which case we intend to handle those data using non-parametric statistical methodology.

Carbon sequestration rates. 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 and 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.

Alterations to the original research plan

After discussing the need for 0-30 cm SOC data with the Economic and Impact Analysis CCRA, we have decided to drop this variable from the minimum dataset. Since we may expect increases in SOC only in surface horizons, we will assume SOC increases to be non-significant at deeper depths. Carbon market models will model the *increase* in SOC due to CAPS, so non-significant increases at deeper depths should not affect the model.

Due to time, cost, and labor involved, we have decided to forego density fractionation of SOC on Time 0 soil samples, particularly because we don't expect any differences within sites at Time 0. However, we still plan on conducting particulate organic matter (POM) analyses on Time 0 samples, in addition to total organic carbon (TOC), because this analysis is relatively quick and cheap, and will provide additional information about the quality of SOC at Time 0.
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. As such, we are open to new collaborations from any host-country or institution, and see our role as one that augments partner research objectives to fill gaps in knowledge about CA in their respective countries.

Timeline

Global soil carbon. The timeline to accomplish the global soil carbon objective is dependent upon the establishment of researcher-managed CAPS in each project country. Therefore, the timeline for collection of Time 0 soil samples is stretched, but should hopefully be accomplished by the end of 2011. Analyses of received samples will begin upon the hire of a GRA in Fall 2011. The timeline may be longer if soil samples from LTRA sites are not received in a timely manner.

Gendered knowledge of soil fertility. The role of the Soils CCRA collaboration with the Gender CCRA is to provide supporting documentation that will quantify the soil fertility status of the soil samples that are described by the Gender CCRA. Please refer to the Gender CCRA Research Strategy for proposed timelines for data collection, analyses, manuscript preparation and submission.

Soil organic carbon for carbon credits. At the end of this project, if SOC differences are found between Time 0 and Year 3, we plan to use our data to investigate the potential for carbon payments based on SOC sequestration in collaboration with the Economic Impact Analysis CCRA. This necessarily cannot happen until the end of the project.

Greenhouse and other gas emissions from CA and traditional practices in Ecuador. 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. Data collection to meet this objective would probably require 6-12 months, so manuscript preparation would not begin until Winter 2012 at the earliest.

On-farm assessment of soil fertility under minimum tillage and crop rotations in Nepal. This is an on-farm experiment conducted in Thumka, Nepal. There are three seasons in this part of Nepal. The first season will remain constant with a maize-pumpkin-local cowpea intercrop. The treatments consist of tillage treatments and the second season crop rotation. The treatments consist of

1. Full tillage, millet during second season
2. Full tillage, commercial cowpea during the second season
3. Full tillage, millet-commercial cowpea intercrop during the second season
4. Strip tillage (75 cm), millet-commercial cowpea intercrop during the second season.

This experiment will determine the land use ratios under the differing systems. The third season default is currently bare ground, although with farmer participation, we hope that we may be able to plant wheat if climatic conditions allow. Composite soil samples and bulk density samples were taken in March 2011. The lead for this project is the University of Hawaii, and the Soils CCRA has been invited to contribute intellectual and material support. Manuscript preparation and submission will be conducted by researchers at the University of Hawaii, with co-authorship by the Soils CCRA leader.

Short term (0-3 years) publication plans

- SOC changes under conservation tillage and high biomass cover crops with organic mulches – manuscript submission proposed for May 2011.

- Soil quality and conservation agriculture in the developing world – poster presentation at the Second International Conservation Agriculture Workshop and Conference in Southeast Asia, July 7, 2011.
- Decomposition of peanut residue under conservation and conventional tillage – manuscript submission proposed for October 2011.
- Carbon and nitrogen mineralization of peanut residues in a sandy loam soil– manuscript submission proposed for March 2012.
- Greenhouse and ammonia emissions from conservation agriculture in Ecuador – manuscript submission proposed for Winter 2012.

<u>Long-term (3-6 years) publication plans</u>

- Potential for carbon payments based on SOC sequestration rates of CA in the developing world. This will only happen if we can find SOC differences between CA and traditional practices within the timeframe of this phase of the project. If so, the proposed publication would occur in 2015 in coordination with the Economic Impact Analysis CCRA.
- On-farm assessment of soil fertility under minimum tillage and crop rotations in Nepal. Manuscript submission in coordination with the University of Hawaii and LiBird, likely to occur sometime in 2015.
- Other. As we assist in data collection among the LTRA sites, opportunities for further collaboration and publication will present itself. For example, Neal Eash and I are currently discussing greater collaboration in Lesotho in order to determine the nitrogen (N) contribution from a grazing vetch cover crop to a subsequent maize crop.

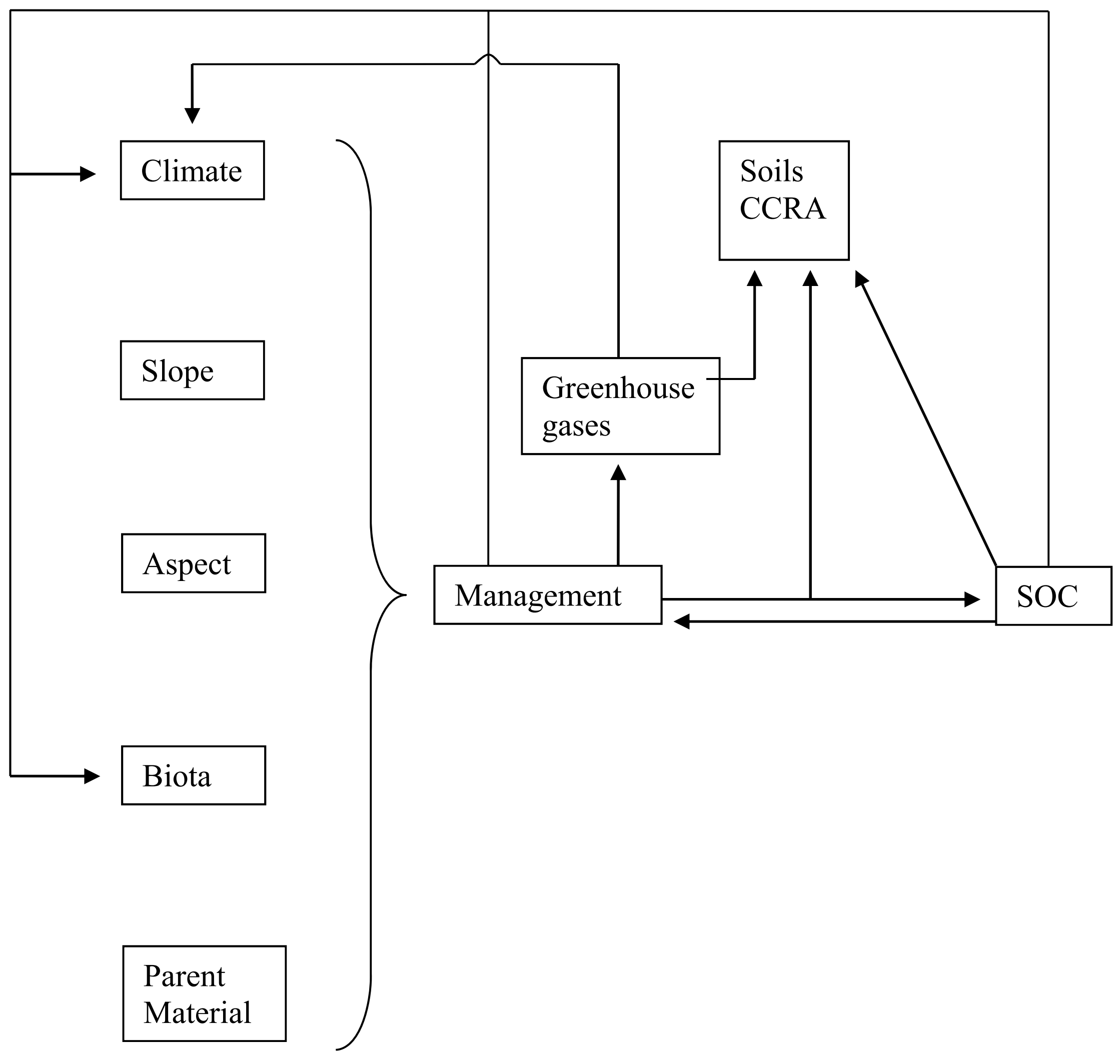

Figure 14. Schematic diagram showing the transdisciplinary research strategy of the Soil Quality and Carbon Sequestration CCRA.

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