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Research Framework for Technology Network and Gendered Knowledge Analyses

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The successful transformation of smallholder agricultural production systems (SAPS) based on the research findings of SANREM LTRAs on Conservation Agriculture Production Systems (CAPS) is critical to achieving sustainable food security impacts on rural livelihoods and natural resource stewardship. The Technology Networks and Gendered Knowledge for Conservation Agriculture Cross-Cutting Research Activities examine the knowledge systems and communication networks, tracing information and resource flows to identify the pathways and mechanisms by which these research findings enter and transform local production systems. It seeks to answer the practical question: what steps can we take to guide the process of technological change in agriculture such that it leads to CAPS for smallholders?

During SANREM Phase III the Knowledge-to-Action Cross-Cutting Activity investigated various strategies and processes used to link knowledge with policy and practices. It was determined that participatory methods adapted to local conditions were most successful, but left open the question as to how participation translated knowledge into action. Buck and Scherr (2009) demonstrate how multiple and collective actors can be involved in iterative learning processes of adaptive management. This learning-by-doing methodology is knowledge intensive involving development of institutionalized mechanisms for multi-stakeholder communication and governance (Moore, 2009). Findings of the SANREM Phase III Gendered Networks CCRA further indicated that the identification of gendered knowledge and space can provide key insight into how markets are constituted and operate. Moreover, the integration of technologies, such as cell phones (Amaya, 2009) can alter and shape bargaining power in networked market relations. However, we need to learn more about relationships between participants and the conditions that foster successful communication for collective technological change.

Working with LTRA research teams, technology network and gendered knowledge researchers will identify linkages between actors involved in the conservation agriculture innovation processes under study and their associated information systems and market chains. This will include activities designed to enhance adaptive gendered practices and participation, equity in access to resources, and knowledge systems.

Identified linkages will be cataloged and described through gendered mapping techniques and the construction of actor linkage matrices. These exercises will clarify who is involved, at what levels of participation, and with what levels of confidence in network partners. Quantitatively, by tracking indicators of technological frames and gendered participation in agricultural production networks, we can better understand how SAPS can be transformed through social learning processes into CAPS. Frames of reference or knowledge systems will be measured by a battery of Likert-scale questionnaire items on conservation, risk averse, and conventional agriculture. Data on these knowledge systems will be associated with identified social network clusters.

These matrices and maps will be made available for LTRA teams to provide feedback to the local community through participatory analysis in workshop exercises.

The Study of Technology Networks

This research will require that we carefully reflect on our shared understandings that form the basis for our communicative competence in agriculture. We need to ask questions about technical change processes: Who is involved? Who should lead the process? How does innovation occur? Is the change a fix within a shared frame of reference composed of knowledge beliefs and perceptions? Does the change require re-negotiating the frame of reference, involving new knowledge and learning? What is the role of learning in the process of innovation? Is learning a matter of information transfer? Or, is learning a matter of developing skills for on-going adaptation? Does learning need to be mutual across the community?

For this investigation to proceed, we will need to focus on two sets of parameters: (1) frames of reference facilitating communicative competence, and (2) the extent and quality of relationships between network participants. Here, we define network as a collective structure of actors (nodes) and relations (ties). Changes in frames of reference among social network nodes will be linked to changes in agricultural production practices to identify the pathways, extent, and quality of network participation leading to the establishment of CAPS.

Frames of Reference

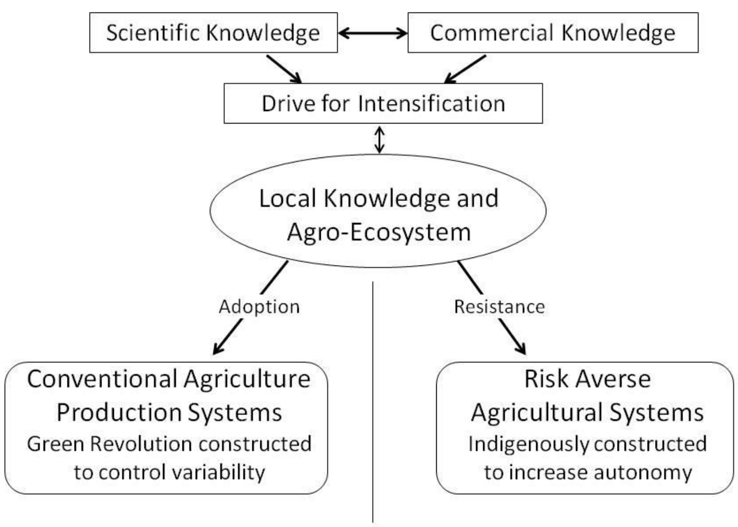
In order to better understand how the process of technological change occurs we use the concept of knowledge networks (Moore, 2008) or often referred to as frames of reference (Bijker, 1995). Composed of knowledge, beliefs, and perceptions, frames of reference are shared systems of rationalization among actors in a system. People and technologies are interconnected in ways that reproduce some types of knowledge and behavioral practices and not others. Knowing is not simply the accumulation of 'objective' knowledge about a perceived external world. Knowing and acting are inseparable. Knowledge networks rationalize socio-material relationships in the agro-ecology. These shared understandings allow us to act and communicate effectively.

Technology transfer seeks to replace components of existing technological frames with 'improved' components. This assumes a relatively stable technological frame of reference. Innovation begins with research on a new technical invention leading to an initial prototype developed by scientists. Early adopters pick up on the first commercialized version and diffusion proceeds until the technology is generalized in the targeted population. This conception of innovation flatters scientists as it places basic research at the origin of innovation. Technology transfer is simply a linear extension of this process –according to the given division of labor the scientist's invention can be handed off to others to transfer. All that is necessary is to tell the world about a new technology, stir up some interest, develop and deliver training programs and demonstrations, and subsequently individuals will make decisions to adopt the technology (at faster or slower rates depending on the relative numbers of early adopters and laggards).

The diffusion of innovations represents the classic formulation of technology transfer and, consequently, of the transmission of knowledge. The goal is to make productivity improvements in farmer practices at the local level through transfer of universally applicable technology developed on agricultural research stations. The diffusion of innovations model is based on two broad assumptions (Rogers, 1983; 1995): (1) behavioral change is dependent on the decision making of autonomous individuals; and (2) scientific knowledge embodied in the technology to be transferred is directly applicable in a farmer's field. Consequently, efforts to change farming practices have focused on isolated choices made by individual farm operators. It is important to point out that this model assumes that the network supporting technical change in agriculture only requires researchers, extension agents, and farmers. The Green Revolution transfer of improved rice, corn, and wheat varieties represents a successful example of this model. Overall, Technology Transfer operates well under conditions where: technological change is a matter of component replacement; shared knowledge systems, trust, and uncontested reciprocal identities extend from conception to execution; and ecological and market conditions are stable and relatively homogeneous (Busch, 1978).

Given the linear process, evaluation of technology transfer has been relatively straightforward. The assumptions allow for the direct linking of investments with outputs in order to simplify priority setting (rates of return) among technologies to transfer (Hall et al., 2001). Questions of equity may be evaluated as a factor-consuming characteristic. With public and private roles pre-defined, market failures are easy to identify. However, system failures are not. Technology transfer envisions users as *homo economicus*. By focusing on the linear transfer of "something" from one actor to the next, any subsequent collective processes of innovation or adaptation and the factors conditioning such processes are obscured.

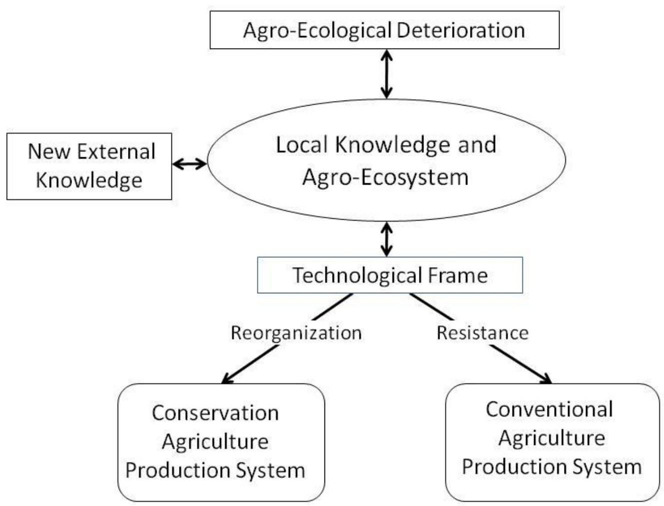
Figure 1: Green Revolution Model of Technological Change/Resistance in Agriculture



The Green Revolution Model of Technological Change/Resistance in Agriculture (see Figure 1) represents the process of introducing 'improved' scientific and commercial knowledge to a local social and ecological system (SES). While presumably it is a matter of imposition or replacement of one system component by another, in actuality two distinct technological frames emerged historically. Either the new knowledge system is effectively translated into local conditions and actors in such a way as to conform with the science developed elsewhere and establish Conventional Agriculture Production Systems; or the existing agro-ecologies demonstrate resistance and do not change – retaining their existing systems of Risk Averse Agriculture. In the first case, this leads to standardization of the environment so as to control variation – much as in a laboratory (Latour, 1987; Law and Hazard, 1999). In the second case, variety is optimized in order to maximize local livelihood options (Moore, 2008; Murdock, 2006).

For the most part, these two outcomes could be rationalized within the linear model of Technology Transfer. The establishment of conventional agriculture was assumed superior and all that need be explained were the exceptions. Risk Averse Agricultural Systems were simply the result of laggards, improper production systems that needed simply to be removed, or failure of the extension service of properly communicate the new knowledge. Farming Systems Research and Extension evolved to address this aberrant farming population. However, as the identification of problems in integrated pest management and natural resource management began to accumulate, a realization began to grow that not all 'positive' change in agriculture was the result of Technology Transfer. Farmers were adapting knowledge taken from elsewhere to their own needs and circumstances (Long and Ploeg, 1989).

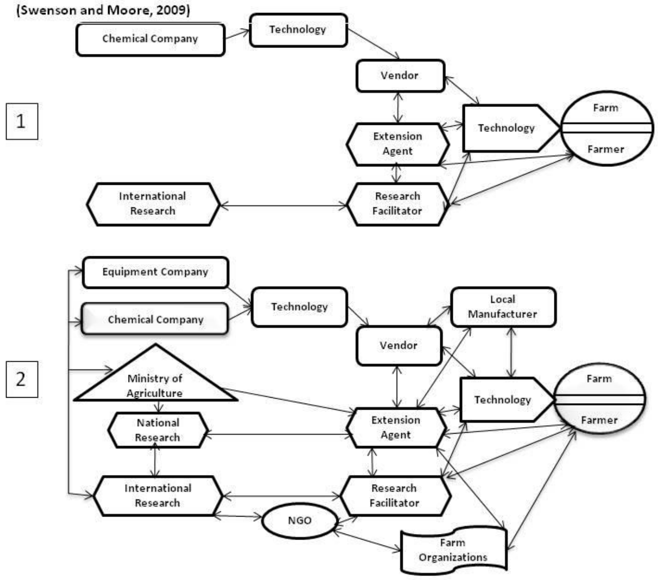
Figure 2: Conventional Agriculture to Conservation Agriculture Model of Technological Change



Adaptive Management emerged as an interactive model of technological change to address problems caused by conventional agriculture. This approach confers greater agency upon farmers and other local actors, introducing a revised conception of technological change in agriculture. Indeed, through adaptive management some local production systems characterized by high levels of inputs and mechanization have been successfully transformed into CAPS. However, the presumed superiority of the new and improved Conservation Agricultural knowledge and practices has not always caught on. For this to occur, it is argued that a change in mindset is required. Farmers, limited by the conventional agriculture mind-set, cannot conceive of attaining high yields without plowing the land (Hobbs, 2007). Changing mindsets, or technological frames, involves developing a shared recognition of agro-ecological deterioration that leads to reframing and extending farm networks to generate alternative solutions (Röling and Jiggins, 1998; Ekboir, 2003). In the development of CAPS systems in Brazil and the United States local experimentation led to expanded networks drawing in partners from the commercial and public sector to provide physical inputs, such as chemical herbicides and no-till planters, as well as shifting the public research agenda (Swenson and Moore, 2009; Coughenour, 2003). It is not a matter of simply training farmers but negotiated social learning that leads to the transformation of whole sets of highly interdependent actors in the conventional farming network.

Figure 3: Network Reorganization for CA in Brazil

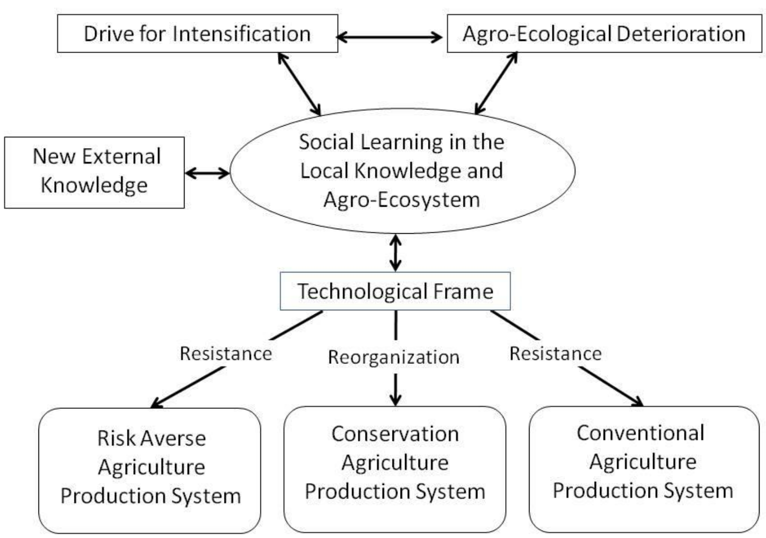
(Swenson and Moore, 2009)



Consequently, the factors shaping technological practices are not simply a matter of autonomous decision making. They may be structured by other actors in the reference network extending beyond the farm gate and sharing a common terminology and perspective. In this model, new knowledge is processed through local filters of beliefs, perceptions, and technological frames, informing farmer and other stakeholder attempts to make sense of it in the practical, everyday implementation of farming practices.

The Brazilian example showcases how the extension of the agricultural network was crucial to securing the development of CAPS. A farmer-based initiative, expressing demand for chemical herbicides and equipment for no-till planting mobilized actors within the agricultural service sector to embrace the developing CAPS technological frame. In Figure 3, the progression of the agricultural production network from 1to 2 demonstrates the network reorganization process necessary to reformulate the conventional technological frame and its replacement with a conservation agriculture technological frame adapted to the Brazilian context. Thus, technological change for conservation agriculture requires 1) a change in mind-set (Ekboir, 2003 and Hobbs, 2007) and 2) a reconstitution of network organization (Swenson and Moore, 2009). During such a potential transition there is often competition between technological frames or knowledge network segments (Bijker, 1995; Moore, 2008; Murdock, 2006). More than

Figure 4: Knowledge Network Relationships for SAPS



one knowledge network organizing and making sense of the same subject, object, or relational observation may exist.

In the case of SAPS, the availability of resources is an additional constraint to the development of technology networks for either conservation or conventional agriculture (see Figure 4). A review of the adoption literature indicates that (1) low access to financial resources for investing in new and improved equipment, (2) alternative uses for existing vegetative resources, and (3) insufficient profit margins to allow for benefits to accrue overtime are additional obstacles to the success of conservation agriculture in smallholder systems (Wall, 2007; Knowler and Bradshaw, 2006).

Drawing upon these key findings, the SANREM network research aims to (1) identify the existing technological frames in SAPS, (2) reveal how they are distributed in local agricultural production networks, and (3) encourage processes of network reorganization for the transformation to conservation agriculture. This will include mapping both the social and spatial relations of smallholders within the landscape. Further inquiry into the qualitative and quantitative attributes of the network will indicate the quality, frequency of contact and resources embedded in social relations. By constructing maps of the connections between clusters of actors, we aim to demonstrate the extent to which network position coincides with these qualitative characteristics and how technological frames change over time. Further, in accounting for local knowledge and perceptions of resources, opportunities, spaces and relations, the research seeks to understand the conditions necessary for conservation agriculture to emerge as the predominant smallholder mode of production.

The Study of Gendered Knowledge

In the development context, technology transfer practices have often excluded or overlooked the experiences/needs of women and the gender relations which mediate access to resources. Regarding conservation agriculture production systems (CAPS) for small holders, this may have serious consequences. In Sub-Saharan Africa, women carry out most of the agricultural work: according to the International Food Policy Research Institute, women produce 78% of Africa’s food (IFPRI 2001). The feminization of agriculture has been growing in Latin America as well (Katz, 2003; Deere, 2005; McEvoy, 2008; Lastarria-Cornhiel, 2006). A major concern is that CAPS may shift the labor burden to women due to increased weed pressure in the early phases of a conversion from till to no-till practices (Giller, 2009). Alternatively, increased use of herbicides also has gendered impacts; affecting assets, labor, health and knowledge. Thus, the incorporation of gender considerations may be key to successful development of CAPS for smallholders. Gendered knowledge, beliefs and perceptions are the critical foundation for the social learning necessary for successful adaptive management. Women’s vital role in agricultural development has long been recognized (Boserup 1966) . This is becoming more relevant to comtemporary changes in smallholder agricultural production systems.

Gendered knowledge research seeks to accomplish two main objectives 1) to recognize and understand women’s farmers existing agricultural knowledge as relevant to conservation agriculture 2) to build upon existing knowledge in the development of conservation agriculture through social learning processes. It is useful to review the classical distinction between sex and gender. While sex refers to male/female bodies, gender refers to learned characteristics inculcated in members of communities according to their particular culture. Together with ethnicity, race, class, age, educational level and other cultural and social attributes, gender shapes the human experience. This includes the knowledge used for resource management decision-making. The gendered creation and development of knowledge is based on divisions of labor, where men and women have different roles, responsibilities, and experiences within their households and communities. They often manage different crops and plants for different purposes using different practices. As a result, men and women possess different knowledge and skills and are motivated by different needs and constraints.

Indeed, women's knowledge in the household and regarding crop production is often so subtly interwoven into production practice that it can come to be characterized as tacit knowledge. Unfortunately, applications and generalizations about women's knowledge have sometimes been abused to confine and limit women's potential as workers and laborers. For example, it in many cultures it is commonly believed that women have greater patience and dexterity, and as such are hired to jobs with the longest hours and subjected to perform tedious hand labor, while men are hired for alternative work that is higher paying and less physically taxing (Regmi and Weber, 1997). In proposing a shift in frame of reference, it is important that generalizations regarding women's skills and knowledge not be used to subjugate them in reorganized agricultural production networks.

Women's multiple roles necessitate and perpetuate the development of complex and sophisticated agricultural knowledge and skills. For example, women's knowledge has been demonstrated as essential to maintaining and conserving plant biodiversity (Howard, 2003; Turner, 2003) and may illuminate opportunities for locally adapted forms of conservation agriculture. Howard describes the multiple roles that women assume as housewives, gatherers, gardeners, herbalists, and plant breeders, and their corresponding knowledge and skills including technical knowledge, culinary traditions, uses of wild plants, species diversity of home gardens, herbal medicines, and selection criteria for seeds. Additional factors such as increasing opportunities for wage labor for males may also affect the extent to which women bear the responsibility of maintaining traditional plant knowledge (Voeks, 2007).Women are also primarily responsible for passing on knowledge to younger generations or other members of the household (Turner, 2003). As suggested by these examples, women posses different types of knowledge than men. The focus on women's knowledge (tacit and formal) and skills may contribute to the sustainability of the SANREM conservation agriculture agenda.

It is important to recognize that knowledge is produced within locally specific social, cultural, and political contexts, reflecting particular interests, beliefs and perceptions (Gururani, 2002). When knowledge generated through different gendered experiences is assumed to be synonymous with traditional, local, and indigenous knowledge, it is not critically examined as a cultural production affected by unequal power dynamics. Research has found a "key tension" between locally based, indigenous technologies that "provide poor rural women with rights, autonomy and self-determination and are generally within their financial budgets" and "modern, external technologies that rural women prefer to use because it reduces workloads and saves time" (Bob, 2004). Focus must be restored to viewing gender relations as evolving processes of action and perception within and across genders. Reframing this dynamic to identify the structures and norms which promote or prevent women from producing and expressing their knowledge, beliefs and perceptions (Gururani, 2002) opens the opportunity for women to negotiate for positive conditions supporting successful conservation agricultural production.

Gender further influences the composition of social networks and inherently, access to resources. These include land, water, seeds, labor, education, credit and information—all of which are crucial to social processes of innovation in technology development for conservation agriculture. Women are much more likely to be in informal networks largely composed of women and posses fewer relations through which they may directly access production resources (Thanh, 2009; Fernandez-Baca, 2009). Understanding the differences in the composition of men and women's social networks can increase awareness and improve bargaining power of women producers. Thus, incorporating a thorough study of gendered knowledge networks in the process of developing conservation agricultural production systems for smallholders will be a key aspect of the SANREM research.

Research by the Technology Networks and Gendered Knowledge CCRA's will be carried out in multiple phases over the research period. Data will be collected through 1) the use of focus groups, 2) a survey module integrated into the LTRA baseline survey activities, and 3) an additional survey of agricultural service sector actors to understand the current functioning of technology networks and account for physical spaces in the landscape and how these are linked to gendered knowledge and relationships.

Overview of CCRA Survey Implications for LTRAs

Researching gendered knowledge and technology networks for conservation agriculture will require a combination of qualitative and quantitative methods.

Qualitative work will be carried out through participative methodologies with focus groups, feeding into the quantitative baseline surveys. Early focus group work will emphasize identifying and describing key resources, evolving conditions for staple crop production, mapping access to tangible and intangible assets, and perceptions of the interrelationship between environmental conditions and agricultural production. In later years of the project, follow up focus group activities will involve participatory analysis of strategic ties in the social network and allow groups to brainstorm ideas for how to overcome obstacles confronted in implementing conservation agriculture. Focus groups will be conducted separately for men and women with later comparison of results within the mixed groups. Data collected from focus group activities will serve five primary purposes:

1) Locate gendered knowledge and access to key productive assets
2) Allow qualitative comparison across all seven regional SANREM CRSP project sites,
3) Inform local refinement of the survey instrument,
4) Establish existing differences in gendered knowledge networks regarding agricultural production,
5) Enhance interpretation of the quantitative survey data

As stated, a primary use of the qualitative data is to refine and adapt the household survey questionnaire items to the local context. A technology network survey instrument will be designed as a module for the LTRA's baseline questionnaire. One component of this module will be based on a position generator model adapted from Lin and Erickson (2008) and designed to map the relations between clusters of agricultural service sector actors including producers and suppliers of agricultural inputs (seed, herbicide and pesticides), equipment manufacturers, extension agents, and local or regional leaders, etc. Respondents will be asked to report on the diversity of their agricultural network contacts as well as additional data to indicate the type of relations with different service sector actors. This includes data collection on the frequency, quality, initiation, and resources accessed through a network relation. The second component of the survey module will identify the dominant technological frames in the actor networks through a battery of Likert-scale measures. It is expected and encouraged that each LTRA research team include additional, more locally adapted technological frame items. Host country team members will also need to translate concepts used in surveys and focus group discussions into locally used terminology. A sample of key agricultural service sector actors identified by focus groups as essential to the functioning of the local agricultural production network will also need to be interviewed using this module. By administering both a baseline and follow up survey, the goal is to document changes in network dynamics as they relate to the prevailing technological frames and the technical change in agriculture fostered by the project.

In summary, the SANREM Technology Networks and Gendered Knowledge CCRA's will rely on a combination of data collected by ME and site researchers. In the first year, the PI will be asked to identify one site from their broader research region. The ME will make a visit to each of the sites to initiate work with focus groups and to integrate CCRA data collection modules into the design of the general survey to fit site specific contexts in conjunction with the country teams. Subsequently, it will be the responsibility of the site researchers to include the survey modules as a part of their household survey and survey a sample of agricultural service sector workers. This data will be reported back to the ME for analysis. In years 2 and 3, follow up work with the focus groups and country teams will emphasize enhancing capacity in key relationships. In year 4, focus group meetings and the inclusion of the module in the follow up household survey will demonstrate changes in technological frames and production networks for conservation agriculture. Economic data, including measures of adoption, are expected to be collected as part of these surveys as well.

A Network Methodology for the Study of Technological Change

Previously, research utilizing social network analysis methodologies has focused on a diffusion framework, where adoption or resistance is studied by tracing resource flows through a population (Crona, et al, 2006). However, as indicated above, the study of innovation processes, especially for conservation agriculture is more complex than a simple diffusion process. Rather, production behaviors are the result of shared perceptions, knowledge, and beliefs in technological frames. In order to understand and encourage processes of change, we thus need to understand how existing technological frames are situated in network spaces and dynamics.

Ideal Types for Existing Technological Frames

Technological change in agriculture occurs within a complex adaptive system framework where human and non-human actors shape the technological frame (Bijker, 1995; Clark and Murdock, 1997; Latour, 1987). In multiple studies, it has been acknowledged that moving to a conservation agriculture production system requires a change of mindset or reconfiguration of productive knowledge (Swenson and Moore, 2009; Coughenour, 2003). Bearing this in mind, a key priority in studying the transition to CAPS is to map the predominant technological frames in the seven research sites and how they change over the research period. While production systems will vary greatly by locality, a review of the conservation agriculture literature suggests three ideal types for technological frames (Ekboir, 2003; Coughenour, 2003; Ploeg, 2008; Swenson and Moore, 2009; Morton and Brown, forthcoming) in agricultural production systems: conservation agriculture, conventional agriculture, and risk averse agriculture. By administering the Likert questionnaire in years one and four, the research hopes to track how the technological frames have shifted through the duration of the project. The following subsections outline these ideal types:

Conservation Agriculture:

Conservation agriculture producers are concerned with controlling erosion and maintaining the health of their soils while improving yields. The ideal type producer is fully committed to the three principles of Conservation Agriculture Production Systems (CAPS): minimizing soil disturbance, maintaining a permanent vegetative cover, and rotating crops. Conservation agriculture producers are also willing to experiment with different mixes of fertility inputs and methods for weed and pest management to find optimum yield outcomes.

Conventional Agriculture:

The conventional agricultural producer is motivated by the need to maximize profit and/or yields. As a result, producers are committed to specialization in particular commodities and base their planting decisions on the marketability of their final crop. Often accomplished through large-scale monocultural production systems, conventional agriculture producers will apply fertilizer, chemical pesticides, and herbicides up to the point it is profitable for them to do so. Conventional agricultural methods also emphasize mechanization of land preparation and harvest. This includes tilling the soil before, and often during, production. These producers will be interested in the development of labor saving technologies to lower input costs and will advocate the use of science to improve yield and profit margins.

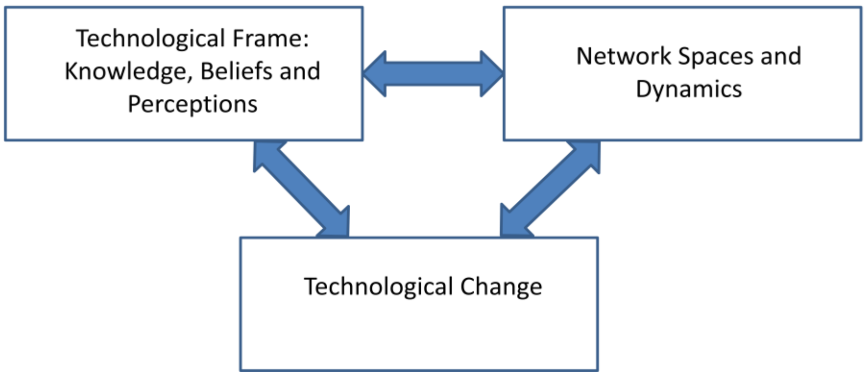
Risk Averse Agriculture:

The risk averse producer strives for autonomy and independence in agricultural production. This involves a careful balancing of productive activities to bring a final product to the market and a number of reproductive activities to ensure the sustainability of the farm household. Characteristics of different risk averse producers are highly contextualized, but often involve smallholder systems in some form of multifunctionality or co-production. This may include reliance on off-farm income in addition to farming, a decision to spread crops and or inputs across different locations, or the use of intercropping systems. To access resources necessary for production, risk averse producers prefer to rely on their personal networks for exchange rather than purchase their goods from the open market. While the risk averse mentality is likely the predominant technological frame in the agricultural systems under study, the highly localized nature of what it means to be risk averse in the different SANREM contexts will require close interaction with the country teams and the producers themselves. For this reason, it is especially important for the LTRA teams to provide additional local indicators to supplement the Likert scale questionnaire provided by the ME.

Hypothesis Testing for Comparison Within and Across Research Regions

Hypothesis testing will rely on data collected in three key areas over the 5 year research period:

Figure 5: Data Collection Areas for Hypothesis Testing



For the upper two categories, data will be collected through qualitative research activities and the knowledge framework survey described above. Measures of technological change will be coordinated with the Economic and Impact Analysis CCRA and the individual LTRA teams in the conduct of their household survey. This three pronged structure for hypothesis testing generally will be used to examine how networks, attitudes and beliefs play a significant role in technological change in agriculture across all seven SANREM CRSP regional sites.

Technological Frame Hypotheses:

Producers holding a conservation agriculture frame will adopt Conservation Agriculture
Producers holding a risk averse frame will not adopt conservation agriculture
Producers holding a conventional agriculture technological frame will not adopt conservation agriculture
A transition towards a conservation agriculture frame of reference over the project period will be highly correlated to the adoption of conservation agriculture

Network Hypotheses:

Producers with more diverse networks are more likely to adopt conservation agriculture
Producers who actively exchange knowledge with other farmers will adopt conservation agriculture
Decentralized networks will have higher rates adoption rates of conservation agriculture
Producers with greater gender balance in their networks are more likely to adopt Conservation Agriculture

Gendered Beliefs and Perceptions:

Men's adoption of CAPS is more likely due to greater access to productive resources.
Women's adoption of CAPS is limited by their lack of access to productive resources.
Women agricultural producers will be more risk-averse than men agricultural producers.
Men producers will be more supportive of conventional agriculture than women.

Women are more likely than men to believe tillage is required for crop production.
Women are more likely than men to believe crop rotation is required for weed and pest management.
Women are more likely than men to believe permanent crop cover is required for growing a healthy crop.

Women's Empowerment Hypotheses:

Women's access to and control of assets, including information will increase by the introduction of CAPS.
Women's control of physical and social spaces creates opportunities for the adaption of conservation agriculture practices by women.
CAPS will increase the burden of labor on women, at least in the short term.

Qualitative Data Collection Methods:

Data Collection in focus groups

Qualitative work in the SANREM CCRAs for Gendered Knowledge and Technology Networks will draw from the Actor Oriented Approach developed by Biggs and Matsaert (2004) and also utilize a number of exercises to allow focus group members to discuss the resources used in production as well as the perception of those resources. Initial focus group activities will include a resource generator activity to identify the resources necessary and available for staple crop production, the development of an actor timeline and gendered maps of men and women's agricultural production networks and exercises designed to gauge perceptions of physical resources. Follow up work with focus groups will use a determinants diagram to brainstorm solutions to problematic relations. Generally, focus group activities will be conducted separately in groups of men and women, with the large group coming back together to share results for comparison.

In all focus group activities, it will be important for researchers to take note of the language used by participants, and record it as such for ethnographic purposes. This is especially important when documenting knowledge, beliefs and perceptions as the words people use are embedded in their worldview. When a researcher "translates" what respondents say into the scientific language he or she considers appropriate, the data is filtered through a different worldview and its meaning significantly altered. This is complicated by the fact that in most cases projects will be working with populations using languages or dialects other than the primary language of HC scientific institutions. This means that at least some of the researchers working with these CCRA will need to be fluent in the vernacular and help with the initial data gathering as well as the interpretation and analysis. Understanding the changing use of language throughout our project will be essential to meeting our goal of documenting changes in technological frames.

Resource Identification Activity:

One of the large group exercises is a resource identification activity. A review of the conservation agriculture literature indicates that there are several resources necessary for successful conservation agriculture (Swenson and Moore, 2009). These include physical inputs, such as seeds, fertilizer, pesticides, and herbicides; planting and harvesting equipment, and access to financial resources, such as agricultural credit. However, the highly contextualized nature of smallholder agricultural production may have additional resource requirements specific to a given area. The purpose of the resource identification activity is to identify current resources used in agricultural production and facilitate a conversation about what constitutes a resource or input for agricultural production. A generally shared conception of resources is important for later activities intended to situate the flows of resources through the networks as well as for a discussion of gendered access and control over these resources and other assets.

Practices and Participation Exercise:

This 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?" it will help develop strategies to increase women's and men's participation and benefits. This will provide a list of activities in both the productive and reproductive spheres, with a breakdown by gender and age. It will also note where the activity takes place. Mixed gender focus groups will first be introduced to the exercise with a flipchart showing some productive activities (such as preparing the land, selecting seeds, planting and weeding), and some reproductive activities (such as collecting firewood for fuel, preparing food, child care; they will be asked who carries out the activity and where; the facilitator will fill in the chart. The chart should have a place to check whether women, men, both men and women, and children or youth carry out the activity(See appendix II for an example). The groups will then divide into a women's and a men's groups to list activities and fill out their charts. When the groups come back together plenty of time is required for discussion; differences in perception always arise, as when a task is the responsibility of men to supervise but women carry out the task. The discussion will provide an opportunity to reach some consensus on the division of labor, and often leads to a recognition of women's contributions. It also makes clear some of the gender-based constraints and opportunities for the project.

Gendered Actor Linkage Maps:

Inspired by Matsaert (in Matsaert et al 2005) and Rocheleau (1995), we build upon the example of the Actor Linkage Map and participative mapping exercises to allow focus groups to construct their vision of their agricultural production networks. Given a flip chart and pen, gender segregated groups will be asked to map their production process, using arrows to indicate the directional character of interactions with human and non-human resources allowing producers to gain access to resources necessary for agricultural production. In order to construct an actor linkage map, focus groups will be asked to identify the persons and places through which resources necessary for agricultural production may be accessed. By focusing on a particular resource, such as fertilizer or advice, and then asking the group to identify through which persons they access the given resource and where these persons are located, researchers will be able to map resource flows within production networks. The researchers will emphasize that the group should identify these relationships spatially (e.g., whether planting crops occurs in the home garden or an outlying field). Participants will also be asked to signal whether men or women or both have access to or control over resources or other assets reflected on the map. While the final product of these maps will be highly attuned to their regional context, comparing the maps drawn by men and women in the same region or intra-gender across regions can provide an important foundation for more rigorous statistical analysis (Biggs and Matsaert, 2004).

The participatory construction of maps may also be an important empowerment tool for both men and women in allowing them to make visible their perceptions of their spaces and relations

(Rocheleau, 1995). In carrying this out with women-only and men-only focus groups and then bringing these together to discuss their maps, opening conversation about gender differences may serve to raise awareness about obstacles to collective wellbeing and also increase opportunities for researchers to understand the perspectives of participants. Mapping exercises also prompt groups to consciously discuss their networks in the process of agreeing on what a map should look like (Biggs and Matsaert, 2004). Once completed, the maps also serve as a two-way teaching tool, first as a prop for the men and women to teach the researchers about their production systems and secondly for researchers to identify crucial points for production enhancements to be made for conservation agriculture and to discuss various linkages. In working with groups over the longer term, changes in maps can indicate men and women's perceptions of change.

The Actor Timeline:

Capturing the major events and innovations that have shaped the current system, the development of actor timelines allows researchers and participants to learn from what has been done before by openly discussing the role of different actors in the agricultural system over time (Biggs and Matsaert, 2004). In application to the study of technology networks, the actor timeline provides researchers insight into the historic interactions between producers and service sector actors in shaping current production systems. As a result, developing actor timelines can be crucial to identifying key persons or groups of persons for the study of the actor network. Additional inquiry into the different resources used historically in production can also provide a broader picture of what is available.

An important consideration in the development of the actor timeline is that historical discussions can be a politically sensitive process, especially if a group or person has been treated unfairly. Memory is also highly subject to individual experience. Therefore, the development of actor timelines must be treated carefully recognizing that there may be both dominant and minority stories in the same histories. For this reason, timelines might best be developed among separate groups of the young and old to provide more coherent positional narratives.

Timelines will be developed with both producer groups and with individual informants in the service sector to provide a qualitative indication of the technological frames from which different clusters are approaching agricultural production. Developing actor timelines with different genders is also a telling and useful exercise, as is tracking the gender of the actors charted on the timeline and how this changes over time. It will help draw a picture of the past and allow comparisons in changing gendered practices during the period of the project. Findings can be used to understand the gendered knowledge possessed by both women and men and how these might be differentially leveraged for a transition to conservation agriculture.

Environmental Beliefs and Perceptions Exercise:

In this exercise, focus groups will be asked to evaluate different soil types and pictures of fields under various styles of agricultural production. For the soils, the groups will be given a "good" (high in organic matter, moist, etc) and "poor" soil (dry/muddy/sandy/hard) for agricultural production found in their region. The groups will then be asked to report on which soil is better and why. Moreover, participants will be asked to report as to whether they believed the soil in question has always looked this way. If change is suspected, researchers will follow up with a probing question as to how and why the soil has reached the state it is in currently. The soils will be presented to the groups in shallow trays or bowls so that the members can easily interact with the soil physically. The observations of the focus group members in how they examine the soil will be carefully recorded, as will their perceptions and answers to probing questions. Again, as with the attention to the precise language used by participants in order to maintain some sense of the worldview in which it is embedded, it will be important to note precisely *how*—such as smelling, tasting, touching—people evaluate the quality of the soil.

In the second component of this exercise, focus group members will be asked to describe the quality and potential of several fields using photographs. To the extent possible some of these pictures should be taken directly from the region of study and thus will vary by locality, but will be selected to represent a range of agricultural production systems from a field under conservation agricultural production to a field experiencing soil erosion/ another environmental problem caused by conventional and/or a risk averse practice. The members then will be asked to describe what is going on in the picture, and what factors may have led to the field getting into the state in which it appears. Through their descriptions, the research will identify beliefs about soil potentials and uses. These observations will also be carefully recorded. By conducting this exercise in years one and four, the research will be able to track the extent to which the SANREM projects have changed beliefs and perceptions regarding production practices and environmental conditions.

The Determinants Diagram (Follow up tool for use in years 2-3):
Once the resources, maps, and timelines have been established; the incorporation of a determinants diagram into follow up work in years two and three with local focus groups may help guide the process of technological change. The determinants diagram allows for participants to focus on particularly problematic relationships and encourages discussion of how they may be strengthened (Matsaert, et al 2005). Beginning with a single relationship in the network, focus group participants are encouraged to discuss opportunities and constraints surrounding that particular tie. As producers confront difficulties in implementing conservation agriculture, working with a determinants diagram can bring to light both human and non-human actors in the agricultural system as well as develop positive ideas for moving forward with technology development. The ideas developed and data collected from the determinants diagrams made with men and women's focus groups may contribute positively to SANREM project achievements.

Table 1: Summary of qualitative research methods

Qualitative Research Methods	To be used in gender segregated focus groups (n=10-15 each) in all seven SANREM regional sites to collect qualitative data on production network history, key actors, gendered knowledge, and to proactively strengthen problematic network relations. Also to be used in informal interviews with agricultural service sector actors		
For use in years 1 & 4	**Brief description**	**Objective**	**Type of Data Collected**
Resource Generator	Exercise to identify how resources such as knowledge, advice, inputs, marketing assistance etc are accessed through the social network	To identify key resources for agricultural production in the region for the construction of maps and incorporation into the position generator survey	List of resources (information, advice, fertilizer, herbicides, pesticides, etc.)
Practices and Participation	List activities (productive and reproductive) and who carries them out	Understand how people spend their time in tasks that directly or indirectly support their livelihoods. Identify places (field, garden, market, mosque) where these take place.	Gender and place of activities. List of activities that people undertake and may present gender-based opportunities or constraints.
Mapping exercise	Arrows used to plot relationships between key actors. Identify key resources and who controls access to them	To visualize the links between actors that mobilize agricultural resources Map relations important to obtaining access to resources for men and women's production networks. Mark gendered differences between access and control	Qualitative data on Network structure and position Spatial mapping of resources and key relationships crucial to agricultural production Perceptions of key relationships
Actor Timeline	Timeline of innovation focusing on key actors	To understand the dynamics of an innovation system and identify key actors. Obtain historical, descriptive data for the development of contextualized comparison	Qualitative data on knowledge beliefs and perceptions of production histories
Environmental Perceptions Exercise	Participants asked to - evaluate and explain their perceptions of two soil samples -rank three pictures of fields ranging from CA-erosion	To understand local perceptions of resources for agricultural production and how they are degraded, maintained or improved	Qualitative data on knowledge beliefs and perceptions of the resources in agricultural production
Determinants Diagram (for follow up work in years 2 &3)	Group exercise focusing on understanding particular relationships or lack thereof.	Used for in-depth analysis of an actor linkages (e.g. issues of control and trust) to improve communicative competence	Qualitative descriptions of actor relationships

Quantitative Methods for Data Collection: The Household and Agricultural Service Sector Actor Survey

The Position Generator

The position generator method is focused on identifying and analyzing ties between agricultural production system actors or node clusters. Based upon social capital position generator research, it is anticipated that there will be common clusters of actors across the cultures and regional research sites (Lin and Erickson, 2008). These will likely include producers of given agricultural products, input suppliers (seed, herbicide and pesticides), equipment manufacturers, extension agents, and local or regional leaders. Within the agricultural producers, there may also be formal men or women's farming organizations. Additionally, there are likely to be locally specific and highly important market actors (such as a man that picks up agricultural products on his truck and transports them to market or a woman who controls access to market booths) or politically important figures such as a local headman, priest or imam, etc. that may have a role in directing agricultural decision making. Developing the position generator for each site will begin with these likely cross-cutting network positions and then integrate the site specific actors. The survey also will collect information specific to interaction with that node on the quality and frequency of interaction.

The position generator will be administered individually as a module of the household survey and to a representative sample of service sector actors. It asks respondents to report on different facets of their interaction with a cluster of actors. The example below shows how the position generator should be constructed for interactions with extension agents, but the same questions would be used for the respondent to report on all of their ties to different clusters in the agricultural network. By sampling at the cluster level, the research takes advantage of the opportunity to collect data on multiple characteristics of a relation, such as resources accessed, the direction of the tie, location and events, frequency of the interaction, and quality of the relationship as proxy for trust in what is exchanged. Collecting data on gender of both the respondent (through the general information on the household survey) and the cluster (right column), also allows the research to examine how men and women's networks may be composed differently. In addition to including clusters for service sector actors, the position generator instrument will also include clusters for men and women's producer associations in addition to interactions with producers in general. Membership in these formal associations will be indentified in the general information in the household survey. Subsequently, the inclusion of a general producers cluster and an association model will allow the research to examine the important role of formal farm associations in gendered access in social networks.

Table 2: Sample Questionnaire Item for Position Generator (one for each identified actor)

	What resources are accessed through interaction?	Who Initiates the contact most of the time?	Location and Events: Where do you interact?	Frequency: How often do you interact?	Quality: Can you trust resources exchanged?	Gender:
Extension agents	a. Advice b. Information c. Seed d. Fertilizer e. Pesticide f. Herbicides g. …(to be developed directly from the resource generator focus group exercise) h. Other_______	a. Always them b. Mostly them c. 50/50 d. Mostly me e. Always me	a. Farm b. Store c. Office d. Market e. NGO Office f. Community center g. Farmer field day or event __________ h. …..(to be developed directly from the focus group exercise) i. Other________	a. Weekly b. Biweekly c. Monthly d. Seasonally e. Yearly	a. Always b. Most of the time c. Somewhat d. Rarely e. Never	a. All male b. Mostly male c. 50/50 d. Mostly female e. All female

Likert Scales to Measure Technological Frames

The second component of the quantitative survey will be the inclusion of 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'.

Table 3: 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

The table below summarizes the components of the survey by their objective and type of data collected.

Table 4: SANREM CCRA Baseline Survey Modules Summary Table

Survey for gendered knowledge and Technology networks	Survey administered separately to men and women at the household level (n=250 per site and to agricultural service sector actors (n=60 per site) in years 1 and 4		
	Brief description	**Objective**	**Type of Data Collected**
Position Generator	Survey to identify positions (nodes) and relations (ties) between actors distributed within the network	Map relations between actors	Network relations between people with different livelihoods Information about the resources exchanged, the quality of interactions, frequency of interaction, direction of interaction, gendered nature of interaction.
Technological Frames Survey	Survey to identify local distribution of technological frameworks -Conservation Agriculture -Conventional Agriculture -Risk Averse Agriculture	Identify distribution of technological frames within and among production networks	Quantitative description of knowledge, beliefs and perceptions through a battery of Likert scale questions designed to measure the extent to which individuals typify a conventional, conservation, and/or risk averse frame.

Appendix I: ME Focus Group Itinerary for working with a SANREM Research Site Community

This itinerary will be used as a baseline for the ME work during visits in the initial year of the project to the seven research sites and reflects the activities described in the section on qualitative research methods. The LTRA team support will be essential for guiding discussion in men and women's groups, and for translating charts into local languages and for translating results to English. Specifically, meetings will be held prior to focus group work to prepare and assign facilitator and recorder roles as well as brainstorm to tackle any obstacles to which the LTRA host country team may be particularly attuned. After the focus group work, the LTRA and ME teams will also need time for post-field reflection. This discussion should call attention to key findings and surprises and offer the opportunity for the translation/duplication of charts and timelines for continued use by the LTRA host country team and the ME.

Focus Group Itinerary for Working with a SANREM Research Site Community
Morning Session: 4 hours
Lunch: 1 hour
Afternoon Session: 2 hours 20 minutes
Total: 6 hours 40 minutes

Timing	Discussion Format	Activity Description	Prompt Questions	Data Collected
20 minutes	K Moore ME Christie	Blessing, Welcome, Introductions Overview of SANREM research project, voluntary participation, Outline of the day, Rules of the Game Recorders and notebooks for each group	Old and young, women and men This is a research project: we are here to learn from you and help you learn about how to create options to improve your production systems. How would you improve your agricultural production systems?	Sign in & general information about the participants
30 minutes 5 minutes	Full Group Activity Full Group Instructions	**Resource Generator Activity/Access to Assets:** Ask group what resources are necessary for agricultural production? **Explain Focus Group Activity: Practices and Participation** Divide into groups of men and women	How do you produce staple food crops in this community? What information do you need for production? Do you lack access to something that would allow you to be more productive?	List of resources for inclusion in the position generator survey instrument

Timing	Discussion Format	Activity Description	Prompt Questions	Data Collected
45 minutes	Focus Group Work	**Practices and Participation Activity:** What are the activities and roles of men and women in both productive and reproductive spheres? Raise awareness on importance of factoring in reproductive activities as supporting productive ones and noting the gender division of labor.	Who does what, where? Prepare a list of activities they might suggest and begin filling out chart in whole group before breaking out into two.	List of activities and qualitative data on gender roles for CA
5 minutes	Reconvene	Direct men and women's groups back for full discussion		
30 minutes	Full Group Discussion	**Practices and Participation Discussion:** Women present for 10 minutes Men present for 10 minutes Discuss differences for 10 minutes	How do roles complement each other? What are shared activities? What activities are distinctly gendered?	Refined qualitative data
20 minutes	Break	Light snacks		
5 minutes	Full Group Instructions	**Explain Focus Group Activity: Gendered Actor Linkage Maps** Divide into groups of men and women		
45 minutes	Focus Groups Work	**Gendered Actor Linkage Maps Activity:** Map resources and actors involved during agricultural production, have groups designate by gender access to and control of these resources	What are the places and spaces physical resources are accessed? Who has access to certain resources? Who controls access? Who are the people interacted with during production?	Maps for gender comparison, confirmation of actors to be included in the larger survey
5 minutes	Reconvene	Direct men and women's groups back for full discussion		
40 minutes	Full Group Discussion	**Gendered Actor Linkage Maps Discussion:** Men present for 10 minutes Women present for 10 minutes Discuss differences for 20 minutes	Why do the maps look the way they do? What differences between the maps do the groups see as significant?	Refined maps
60 minutes	**Lunch**	Allow participants to socialize, set up for the timeline and picture activities.		
5 minutes	Full Group Instructions	**Explain Focus Group Activity: Actor Timeline** Divide into groups of men and women	Has production always been this way?	

Timing	Discussion Format	Activity Description	Prompt Questions	Data Collected
30 minutes	Focus groups Work	**Timeline:** Ask groups to develop a timeline for staple crop production. How has crop production changed? What were the influential events? Who were the influential people?	How was it when the oldest among you were growing up? How is it now? What changed? When and why?	Timelines for comparison across genders, context of actor relationships; cohort effects
15 minutes	Break	Allow groups to socialize, reset activities if necessary		
5 minutes	Full Group Instructions	**Explain focus group activity: Environmental Beliefs and Perceptions Exercise** Describe the soils and pictures. Explain this as an opportunity for scientists to learn from them. Separate into men and women's groups before discussion begins.		
30 minutes	Focus Group Work	**Environmental beliefs and perceptions exercise:** Give the groups five minutes to examine the different soil types and classify them. Ask them to explain what is occurring in the picture.	Describe the picture. What is the condition of the soils? Who/what is responsible?	Qualitative data on attitudes and perceptions of groundcover and production systems Note senses used to examine soil
5 minutes	Reconvene	Direct men and women's groups back for full discussion		
30 minutes 30 minutes 20 minutes	Full Group Discussion	**Timelines:** Women present for 10 minutes Men present for 10 minutes Discuss differences for 10 minutes **Environmental Beliefs and Perceptions Exercise:** Women present for 10 minutes Men present for 10 minutes Discuss differences for 10 minutes **Closing discussion and feedback:** What was most interesting? Did anything surprise you? How will ideas carry forward? Discussion of future SANREM project work	What are the differences in the timelines? Were different things significant to the different groups? How did they rank the pictures? Were the attitudes similar or different in the gendered groups? What are your recommendations?	Refined timeline qualitative data Qualitative data on gendered perceptions of local history Refined perceptions qualitative data

Appendix II: Practices and Participation Chart

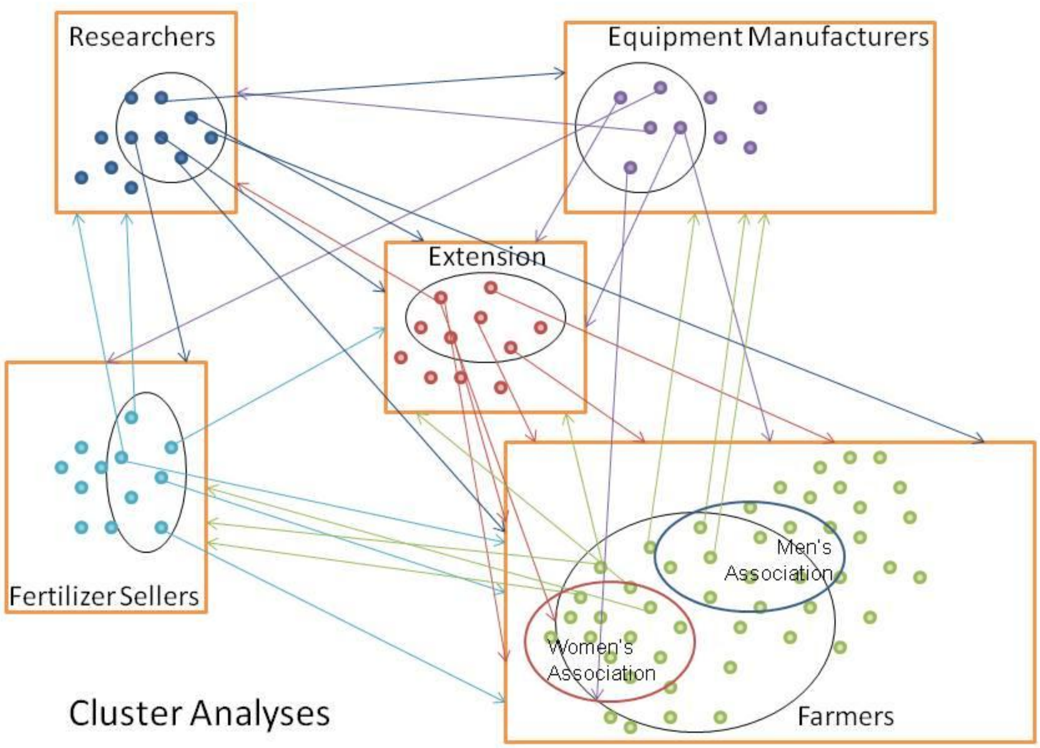
Activity Profile

Socio-economic activities	Women	Men	Both men and women	Children	Location
Productive activities					
Main paying activities					
1.					
2.					
3.					
Non-paying productive activities					
1.					
2.					
3.					
Reproductive activities					
Non-paying household work					
1.					
2.					
3.					
Non-paying community work					
1.					
2.					
3.					
Leisure time/education and entertainment					
1.					
2.					
3.					

Appendix III: Analyzing the Data

Cluster Analyses

The most challenging element of the SANREM network research methodology is that network surveys usually collect data on an individual actor basis rather than between clusters of actors, as described in our methods section for the position generator. Because of the scale of survey, we will operate at the level of clusters of similar social actors. These will likely include: fertilizer merchants, agricultural extension officers, men's and women's producer associations (if present) etc. Effectively, the mapped networks in our study will probably look like this:



In the diagram above, we have modeled the type of data that will be collected through the position generator process. For each "occupation", we will take a sample (in line with the sampling procedures set by the LTRA's and in discussions with the ME for the additional agricultural service sector actor surveys). In the diagram, this is represented by the ovals around the individual nodes. The nodes, or individuals sampled, then report on their general interaction with other groups, as represented by the orange square. Therefore, unlike normal social network analyses that can pinpoint individuals as targets for intervention, this research will only be able to make recommendations for problem relationships between sectors rather than between individuals. Thus, in reporting the research, we will be careful not to move between scales by generalizing any findings down to the individual level. However, local partners may be able to use this information for more targeted interventions. In scaling up agricultural production systems, we are more interested in the relationships between clusters of actors (e.g., institutions) than actors within clusters. In any case, many of the same tools used to analyze individual social networks can be used to study our actor cluster networks.

Networks defined by clusters are likely to be equally as vulnerable to centralization of information or control over information. For example, actor betweeness centrality is a measure used to describe the extent to which an actor controls the transmission of information from one actor to another in a network (i.e. does a single actor serve as an information conduit or are there multiple nodes through which information can be accessed) Betweeness centrality is used at a cluster level to measure the extent to which information transmission between groups is controlled by an intermediary.

Equally, another kind of centrality, degree centrality is also used at the actor level but applicable in a cluster context. Degree centrality is used to measure the "connectedness" of a node in a network. Clusters that have more connections to other clusters, will have higher degree centrality. Moreover, in measuring at the cluster level but using individual surveys, the data leaves itself open to many ways of calculating ties between networks, these include: the number of individuals reporting a tie or the proportion of individuals reporting a tie. Such triangulation will increase precision of findings and their interpretation.

Total network analysis measures also retain their usefulness in the cluster model. Specifically, total network measures are designed to capture a broad picture of what is occurring in an actor network. These measures include measures of density, group betweeness 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 can be determined by taking total network density, based on the proportion of ties to the number of actors in the network. At the cluster level, it is very likely that production network will have control concentrated between certain groups that transmit agricultural information discovered by researchers to producers, as can be measured by group betweeness centrality (Knoke and Yang, 2008). There is also likely to be variations among the surveyed actors in their number of connections to diverse actors in the network, which can be measured by taking a group degree centrality. The variation in ability to connect to diverse actors is likely to be extremely important for producers in their adoption of conservation agriculture. By measuring changes in degree centrality over time, the research can get a sense of the distributional effect of the SANREM research for agricultural producers.

Through using a position generator, it is not necessary to measure networks at the individual level. Sampling on the cluster level will allow for data that can be more easily compared 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. Even 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). An important advantage of the research methodology is that developing customized survey instruments for each study region will enable the data to capture contextualized information about knowledge networks to more accurately measure change over the research period. Using the same methodology and metrics in the surveys across the regions is what will allow for the collection of a general data set for cross-cultural comparison. In the following section, the weaknesses and strengths of the research methodology inform the choice of three groups of testable hypotheses.

Qualitative Analysis

The data collected with the focus groups will provide substantial information for qualitative analysis. Comparison of men and women's narratives for agricultural production and the composition of their networks will show how both men and women can contribute to processes of technological change in agriculture.

Organizing Network Data

The Actor Linkage Matrix (ALM) will be the primary mechanism for organizing data (Biggs and Matsaert, 2004). The ALM will be constructed for both the focus groups and for the larger research findings by placing the indentified actors into a matrix similar to the one shown below:

Sample Actor Linkage Matrix

	agricultural producers	fertilizer sellers	pesticide sellers	equipment manufacturers	extension agents	researchers	local leaders
agricultural producers							
fertilizer sellers							
pesticide sellers							
equipment manufacturers							
extension agents							
researchers							
local leaders							

Constructed in excel, each of the cells will be used to store information about the relationships between actors. For interaction with focus groups, the ALM is a very convenient form to summarize relations between groups. In comment boxes, additional qualitative information can be stored. For focus group analysis, the main advantage of constructing the matrix is that is gives the research teams a way of thinking about actor network relations in the larger context and stores a large volume of data. Moreover, the ALM shows all possible relations within the network, and may serve as a natural starting point to identify and work on problematic relations through the determinants diagram.

ALMs constructed for the quantitative data will have a much larger volume of information. Extending the application of the ALM proposed by Matsaert (et al,2005), the master ALMs constructed by the ME for each region will use a pivot table to store information about the quality of the information accessed through the relation, the frequency of contact and the genders of different contacts, and where applicable, resources accessed through a given relation. In obtaining data in all these areas, the ALM will be able to examine patterns in relations that facilitate or inhibit technological change.

The table below summarizes the use of the ALM as a tool for organizing data.

	Brief description	**Objective**	**Type of Data Collected**
Actor linkage Matrix	Record links between actors in an excel matrix, using a pivot table to store additional information about a relation. This may include frequency of interaction, quality, direction of initiation, etc. Quantitative data in the actor linkage matrix will be imported into Ucinet 6 in order perform quantitative analysis.	To summarize and analyze findings. For planning, monitoring and evaluating change	Quantitative and Qualitative data regarding network structure and position

For quantitative analysis, UCINET 6 will be used for the creation of matrices. Its complimentary program, NETDRAW can be used for computerized mapping of the agricultural production networks. While UCINET 6 does not have the same capability to store qualitative data as excel, the program is designed to calculate a number of the network measures described above, including centrality and density measures.

Appendix IV: Operationalizing Knowledge Network Hypotheses

Methods employed by social capital researchers and social network analysts offer powerful tools for developing an understanding of the structure of social relations within these production systems. While the social capital concept has become increasingly broad over the past two decades (Van Deth, 2008), it is relevant for our purposes as we are interested in relationships of trust (Putnam, 1993) and the ability of actors to access resources embedded within these relations (Van Der Gaag and Snijders, 2004).

Recent research on social capital has pushed for an increased triangulation of surveys and polling, focus group work, and qualitative documentation of local histories (Van Deth, 2008). Following this research, the SANREM methodology will use participatory methods with focus groups to have men and women's groups to create timelines and map their production networks following the Actor Oriented Approach developed by Stephen Biggs and Harriet Matsaert (2004). Focus group findings will be used for qualitative analysis and to identify resources and occupations for the generation of a more widely distributed survey to understand scaled-up community level agricultural production networks for conservation agriculture (Van Der Gaag and Snijders, 2004; Lin and Erickson, 2008).

Social network analysis methods will be used to develop hypotheses and examine the functioning of the constructed actor networks. While quantitative social network analysis dates back as early as the end of the nineteenth century and has been used extensively as a tool to study organizations, more recently it has also has been used successfully in the development context. Some examples include the use of social network analysis as a means for analyzing communication patterns in natural resource co-management schemes, (Kiptot, et. al 2006) and the dissemination of knowledge and seeds for agroforestry techniques (Crona, et. al 2006). However, the majority of studies which apply social network analysis to a development context follow a diffusion framework (Shrum, 2000), or the idea that knowledge or seeds move through social relations largely unchanged. Yet, in light of adaptive management literature, it is clear that sustainable technological change requires the transformation of resources in their application in the network. In the following sections, we posit a number of hypotheses for testing that examine the structure of social networks in relation to their ability to inhibit or enable social learning processes in knowledge networks.

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

This set of hypotheses examines how clusters with greater ability to disseminate and control information flows in the network influence technological change. The basic logic is that service sector actors holding a conservation agriculture frame and with direct farmer contact will likely transmit that technological frame to agricultural producers. However, the manner in which information flows through the network plays a key role. In the first two hypotheses, we emulate the traditional technology transfer model with a measure of betweeness centrality. Betweeness centrality is a measure of the extent to which a node in a network controls the flow of information between other nodes in the network (Knoke and Yang, 2008). In the traditional technology transfer model, extension agents have high betweeness centrality because they control flow of an innovation from researchers to farmers. We seek to measure betweeness centrality in two ways. In the first hypothesis, we will examine the "end result", whether or not in year four high betweeness centrality is associated with higher adoption rates. The second measure is looking at network changes over time, holding that a network that becomes more consolidated will have higher adoption rates. However, we expect both of these hypotheses to be rejected, as it is believed that innovations are most successful when integrated more fully into the network and where information reaches producers through a diverse set of intermediaries.

Similarly, the second set of hypotheses in Group 1 examine how highly connected agents holding a conservation agriculture technological frame influence technological change processes. The third hypothesis tests whether clusters of service sector actors with a high number of contacts with people outside of their occupational cluster (and thus more exposed to different ideas than those with fewer contacts) will be associated with higher producer adoption rates. The fourth hypothesis tests whether SANREM approaches to increase connectivity of service sector actors are successful and if such efforts yield the desired outcome: increased adoption of CA practices.

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 Hypotheses: Structure of Farmers' Networks and Technological Change

The structure of producer networks is likely to be highly influential on their capacity for technological change. Individuals with diverse social networks, meaning that they have contacts to a number of different types of people, are likely to be exposed to more ideas and opportunities. Here, it is hypothesized that producers with diverse network connections will be able to access information more freely, thereby increasing their chances of technology adoption. The first four hypotheses examine such diverse relationships, differing on the key point of who is taking the active role in seeking or transmitting knowledge.

The fifth and six hypotheses examine how farmer to farmer interactions might play a role. Successful conservation agriculture producers have often relied on on-farm experimentation and sharing experiences with other farmers to develop best practices for conservation agriculture in their region (Swenson and Moore, 2009). These hypotheses look at highly developed farmer exchanges and how changes for increased inter-farmer communication affect rates of adoption. Disaggregating data by sex (men or women farmers) will also be useful to test for significant differences between the functioning of men and women's technology networks.

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 Hypotheses: Total Network Comparison for Technological Change

While the above hypotheses examine the roles and network attributes of particular clusters within the network and then are compared across clusters, this last set of hypotheses intends to examine production networks from the overall network level examining how interactions between all clusters shape processes of technological change. The first two hypotheses examine the idea of whether or not highly connected network systems are more successful than less connected and more isolated network systems. Hypotheses 3 and 4 model the technology transfer paradigm at the network level, looking at how linear, tightly controlled information flows influence adoption rates. Studying total network attributes across the SANREM study regions will indicate ideal types of successful network systems to provide broad recommendations for building technology networks. The distributional effects, or variation between opportunities of individuals in the network under study is measured in hypothesis 5 and 6. Hypothesis 5 posits that sites that have more equality in network opportunity in year 4 will have higher rates of technological change, while hypothesis 6 seeks to examine the effect of a network moving towards greater equality over time.

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

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