Understanding Farmer's Perception to Environmentally Sustainable Practices for Enhanced Food Security Using Fuzzy Cognitive Mapping

Authors:

Jacqueline Halbrendt (Primary Contact)
Natural Resource and Environmental Management, 1910 East West Road, Sherman Lab 101, University of Hawaii, Honolulu, HI 96822, USA
Email: jhalbren@hawaii.edu
Tel: +1808-956-7530
Fax: +1 808 956-6539

Steven Gray
Natural Resource and Environmental Management, 1910 East West Road, Sherman Lab 101, University of Hawaii, Honolulu, HI 96822, USA
Email: sagray@hawaii.edu
Tel: +1808-956-7530
Fax: +1 808 956-6539

Catherine Chan-Halbrendt
Natural Resource and Environmental Management, 1910 East West Road, Sherman Lab 101, University of Hawaii, Honolulu, HI 96822, USA
Email: chanhalb@hawaii.edu
Tel: +1808-956-7530
Fax: +1 808 956-6539

Linsey Shariq
Natural Resource and Environmental Management, 1910 East West Road, Sherman Lab 101, University of Hawaii, Honolulu, HI 96822, USA
Email: lshariq@hawaii.edu
Tel: +1808-956-7530
Fax: +1 808 956-6539

Bir Bahadur Tamang
Local Initiatives for Biodiversity Research and Development, P.O. Box 324,
Pokhara, Gairapatan, Kaski, Nepal
Email: btamang@libird.org
Tel: +977-61-535357

Understanding Farmer's Perception to Environmentally Sustainable Practices for Enhanced Food Security Using Fuzzy Cognitive Mapping

Abstract

Understanding farmer perceptions of conservation agriculture remains a challenge for the adoption of environmentally sustainable practices. Cognitive mapping identifies key factors within agricultural belief systems, which can aid research agencies in developing a greater understanding of community perceptions of farming systems. Surveys conducted with subsistence farmers and NGO/researcher groups in Central Nepal revealed differences in the cognitive models used to guide decision-making. Variations in agricultural perceptions can be attributed to differences in education, farming experience, environment, and culture. This method is applicable for enhancing understanding of cultural values and community perceptions for improved transfer of sustainable agricultural technologies.

Keywords: cognitive mapping, conservation agriculture, Nepal, subsistence farming, agriculture development

Understanding Farmer's Perception to Environmentally Sustainable Practices for Enhanced Food Security Using Fuzzy Cognitive Mapping

Introduction

With the world population having reached an unprecedented 7 billion people, increasing demands are being placed on agriculture systems to produce sufficient yet sustainable yields to feed the growing global community. Given that there are 500 million small farms in the world, from which 80 percent of the food is consumed in Asia and Africa (IFAD 2011), the long-term productive capacity of such smallholder farming communities is an important focus area for research and development efforts to ensure sustainable productivity and soil conservation for global, regional and local food security. Agencies working in the field of conservation agriculture often approach issues of food security under smallholder farming conditions by introducing modern research-based technologies and field-tested practices without regards to understanding the farmers' perceptions of their views of new farming practices/technologies and their impacts on productivity. Therefore, a major challenge with this traditional development approach are the existing gaps between the understanding of what drives the farming community's behaviors and decision-making processes, contrasted with the limited adoption of practices that have been proven to increase yields. Researchers and extension agents promoting 'best practices', such as conservation agricultural methods, without consideration of the local context further exacerbate this issue (Isaac et al. 2009, Oreszczyn et al. 2010).

Evidence has shown that new practices introduced by government extension, NGOs, or other research institutions are often abandoned for traditional practices after development projects have been completed (Bunch 1999, Cochran 2003, Yadav 1987). In an effort to address this challenge, agribusiness professionals must focus on building their human capacity in understanding key factors involved in community members' perception and willingness to try and/or eventually adopt new agricultural practices. By developing shared knowledge of stakeholder perceptions and motivation, shared value can be created within multi-stakeholder engagements. Previous studies have identified factors as broad as education level, gender, economic status, knowledge of natural resources, and social responsibility as important indicators of motivation to learn new farming practices (Kessler 2006, Knowler & Bradshaw 2007). Elements contributing to long-term adoption include personal, social, cultural, and economic factors, along with the ability of the introduced technology to assist in achieving individual goals (Pannell et al. 2006). Yet, a review of conservation agriculture studies revealed that there are few if any influences on adoption that apply universally, therefore specific factors influencing local adoption are highly contextual and vary by location (Knowler & Bradshaw 2007). Thus, it is crucial to approach the introduction of any agricultural development program from a bottom-up perspective, encouraging a community and stakeholder participatory approach wherever possible, and collecting and distilling community values early in the program planning process in order to design project goals and objectives that serve the interests of multiple stakeholder groups. Here, it is proposed that promoting the adoption of new agricultural conservation practices in local communities must begin by understanding the community, researcher, and extension personnel context. Specifically, the analysis focuses on measuring the "mental models" of farm communities, researchers, and extension personnel in order to appropriately frame agricultural behavior change within the existing context of farming practices using mental cognitive mapping. Moreover, evidence shows that community's understanding of cultivation, or agricultural belief systems, reflect local ecological and cultural conditions, which serve to shape the decision-making process on the farm. This is contrasted with researcher and extension personnel's knowledge of the best management practices based on structured scientific field experiments and literature.

This research seeks to evaluate the differences in knowledge and perception between researchers and extension personnel attempting to introduce beneficial conservation agricultural technologies and rural farmers' perceptions of farming practices and their benefits. Differences are expected to occur from one location to the next, as a result of changing natural resources, environmental conditions, societal pressures, varying levels of education, and cultural perspectives. The identification of these environmental and/or social and cultural conditions that act as pre-cursors to affect farmer decision-making will be invaluable in developing a greater understanding of the underlying mechanisms in how rural farmers understand various agricultural practices and their views of new and innovative practices promoted by researchers and extension personnel. The specific objectives of this research are: (i) to develop community mental maps representing the relevant factors and relative importance of such factors in the decision-making processes for agricultural practices in both researcher and farmer groups, (ii) to use the mental maps to determine the differences in values and perception between the stakeholder groups, as they relate to understanding the components and connection between components of an agricultural production system, and (iii) make recommendations to development practitioners based on the results of this study.

Literature Review

Rural agricultural development is inherently complex, bringing multiple stakeholder groups from NGOs, research institutions, extension, and rural communities together for the promotion of sustainable yet sufficient agricultural production. Many development projects have historically used a top-down model, applying scientifically proven technologies to rural farming systems (Herdt 2012). However, technical expertise does not take into account the local ecological and cultural context that may conflict with project objectives. It has been indicated that, social learning should occur among the different stakeholders to promote an environment of collaborative co-management where parties acknowledge the value of the other's expertise (Schusler et al. 2003). Without such collaboration and the creation of shared value, the potential for long-term adoption of new technologies becomes limited. Through developing a greater understanding of a community's ideas, projects can be designed to ameliorate the pressing needs of the community while promoting improved agricultural technologies; However, this requires an understanding of the temporal and spatial variability of the community perceptions regarding the agricultural system (Agrawal 1995), as well as the ecological attributes and limitations of the local environment. Mental modeling of farmer knowledge can be used to delineate such vague concepts, integrating both indigenous and scientific knowledge and framing this knowledge for practical application (Sicat et al. 2005).

Mental Models

Developing mental models of a farm community is essential for promoting behavior change since mental models serve as a requisite basis for understanding the relationships between important factors leading to whether farmers will adopt a new technology. These models provide a tangible method to represent similarities and differences between the knowledge, understanding, and goals of the various stakeholder groups. Mental models are internal constructs that provide interpretation and structure of an external environment and are therefore an important component of how individuals make decisions. These internal representations are often constructed as individuals navigate time and space, modifying their understanding of the world around them as they become exposed to culture, environmental conditions, and new experiences. The ways in which different representations of the world are organized, socially influenced, and made useful for understanding the management of natural resources has seen increasing attention in recent years (Kellert et al. 2000, Gadgil et al. 2000, Armitage 2003, Brown 2003, Davis and Wagner 2003). Shared mental models in communities are essential to the way societies structure their environments and build expectations and are therefore an important part of an organized society (including the establishment of norms and laws which guide decisions). Individuals and societies with different cultural and environmentally-mediated learning experiences have different theories to interpret the world around them. Denzau and North (1994) state, "Individuals with common cultural backgrounds and experiences will share reasonably convergent mental models, ideologies and institutions and individuals with different learning experiences (both cultural and environmental) will have different theories (models, ideologies) to interpret that environment". This study's framework is adopted as a means by which to understand technological and ecological dynamics and change by examining how factors and their perceptions, collected from community farmers, university researchers, and NGO and extension personnel may influence subjective and/or objective knowledge about the natural environment and how this influences production and management decision-making in the context of rural agricultural development.

Several methods have been used to analyze adoption probability, the most popular including the logit and linear regression models. Unfortunately, these models do not assist in understanding the interconnections between perceptions, cultural and socioeconomics variables and require sufficient data to estimate parameters, which can be difficult to attain in a rural agricultural environment. The cognitive mental mapping and models developed by Kosko in 1986, have been applied in several disciplines from psychology to politics in order to model belief systems of communities and other stakeholders. This study will use the mapping framework developed by Kosko to identify factors and the relative importance of such factors in understanding the decision-making processes for agricultural practices in both researcher/extension and farmer groups.

The mental modeling framework involves a complex form of data collection where study participants are asked to develop determining factors influencing their decisions and the strength of their relationships. These models are external representations that correspond to the way in which study participants have constructed and organized internal versions of external reality in their minds. The mental models have been referred to as simplified mathematical models of belief systems (Wei et al. 2008) and have been used to represent both individual (Axelrod 1976) and group (Özesmi and Özesmi 2004) knowledge. Furthermore, the mapping of these models show how a system operates based on defined components and the causal links between these components. In terms of this study, these components act as quantifiable constructs measuring such concepts as various farming practices in relationship to profits and soil qualities in relationship to yield and/or profits. Participants can either define the components in the system, or be given pre-selected components with instructions that components can be added or removed. In this study the farmers define the components of what determines their willingness to try a new farming technique. Next, participants are asked to indicate connections between system components and indicate the strength of the influence one component has on another. Participants typically draw directional arrows from one component to another and then indicate the level of influence.

In an effort to expand the use of mental models in environmental management and display how agribusiness professionals can adapt this device for application in agriculture development projects, this research concentrates on modeling the agricultural belief system of communities practicing subsistence agriculture in the mid-hills of central Nepal with particular focus on the their perception of conservation agricultural practices such as minimum tillage, continuous year round cover cropping and intercropping. Agricultural belief systems of research and extension groups using the same mental model framework can be compared and contrasted with the farmer perspective to explore overlaps and gaps in stakeholder group perspectives. Insight gained from the subsequent models are intended to demonstrate how one's understanding of the agricultural system can differ between communities, and can shape decision-making regarding cultivation methods, crop selection, and management practices. With this information, researchers and extension personnel can develop adoption strategies with the farm community while fully incorporating their beliefs. The chances of adopting introduced farming practices have a higher probability of success with a community participatory approach and emphasis on shared value systems.

Study Area

The focuses of study in this research are tribal communities in the central mid-hill region of Nepal. The study communities were selected to take part in the study in consultation with a local NGO and were indicated as the most impoverished and at great risk of food insecurity due to their marginal agricultural lands, relatively small landholdings, and potential for malnutrition. The communities studied in this survey are characterized by smallholder subsistence farming households, with typically less than 2 ha of arable land, and limited opportunities available for income generation.

The central mid-hill region comprises 42% of the total territory of Nepal. More than one third of the country's total agricultural land is located in this region, feeding 44% of the country's population of 29.8 million (Thapa and Paudel 2002). For these reasons, it has become a major area of focus for reducing food security vulnerabilities and implementing agricultural adaptations for climate change. Much of the region's agricultural production is from smallholder subsistence farmers using traditional continuous cultivation methods of terracing, plowing with draft power, and monocropping in a rice and maize-based agricultural system. In recent years, however, growing populations and deteriorating agricultural land has led to an increased need for improved agricultural technologies to increase soil and water conservation as well as crop yields. Local NGOs and university researchers have been working in these communities to introduce improved cultivation methods, however, there exists a gap in the agricultural specialists' understanding of the farmer's motivation and willingness to adopt new practices (Kerkhoff and Sharma 2006, Khadka 2010). It is particularly important to consider the differences in perspective of agricultural professionals, whom are often responsible for designing and introducing agriculture development projects, as compared with rural subsistence farmers, whom are expected to adapt their traditional agricultural practices, practices upon which their livelihood rests. Through understanding both the perspectives of farmers and agriculture specialists, it will become more clear where agricultural knowledge overlaps and where agricultural understanding diverges between the groups. Identifying such variation can facilitate the planning process for agricultural development.

Three villages in the central mid-hill region of Nepal were studied, and represent communities highly reliant on agriculture production with limited resources for income generation available. The members of the villages are predominantly from the Chepang tribal group. The selected villages were *Thumka*, in Gorkha District, *Hyakrang*, in Dhading District, and *Khola Gaun*, in Tanahun District. Village size ranged from 16 households in Khola Gaun, to 25 households in Hyakrang, and 36 households in Thumka. In these areas, farming systems are maize and rice based, using predominantly local crop varieties. Additionally, farmers can no longer use shifting cultivation due to scarcity of land and they currently follow conventional tillage practices (full plowing twice before sowing), use relatively low inputs of fertilizer, and leave land fallow and exposed in the winter season. Such practices tend to degrade land quality and result in decreasing crop yields over time.

Recent studies have shown the conservation agricultural practices have been successful in sustaining productivity in lesser developing countries traditionally using the slash and burn techniques. Due to population pressures, the luxury of 'slash and burn', which requires shifting agricultural land every year to maintain productivity, can no longer exist. Therefore, conservation agricultural practices including practices of minimum tillage, improved crop varieties, intercropping, and the use of cover crops would help to mitigate soil nutrient depletion, land degradation, and increase yields (Hobbs et al. 2008). These practices have been successfully adopted in many developing countries with similar terrain and socio and cultural backgrounds such as the focal area of this study.

Despite such demonstrated approaches to improving agricultural productivity and maintaining the richness of the soil environment, the successful introduction and later adoption of these conservation practices depends on the way in which such practices are introduced, as well as their alignment with the community's existing belief systems regarding the agricultural practices (Isaac et al. 2009). Research agencies such as local NGOs and agricultural universities are beginning to work with subsistence farmers in Nepal to introduce conservation agricultural practices. Two of these groups were selected for survey research to establish the difference in perception from a researcher perspective, as compared with the farmer perspective, in order to build a knowledgebase of the respective groups' perception of the agricultural system and various farming practices. The methods of gathering the data of the mental models of the various stakeholders are described below.

Methods

In an effort to better understand the community belief system, data was collected to create a concept map based on the mental modeling method. Due to the literacy constraints of the respondents, the typical mental model method was adapted and the data was collected orally in two steps. The first step was to understand the farmers' variables in determining the willingness to try a new farming technique based on their views and perception of their traditional knowledge of the farming system. The second step is to determine the strength of the relationship between these variables. At this second stage, additional surveys were conducted with researchers and extension field officers from the Nepal-based NGO, Local Initiatives for Biodiversity Research and Development (Li-Bird), and Tribhuvan University's Institute of Agriculture and Animal Sciences (IAAS) to assess the beliefs, knowledge differences in decision-making related to conservation agriculture, as compared with rural subsistence farmers beliefs and knowledge.

In August 2011, face-to-face interviews were conducted with farmers from the three villages to gather a broad understanding of the variables involved in the village farming system. To develop a general mental model of the Chepang community's view of their agricultural system and farming practices, farmers were asked to name the dependent factors for their consideration of a new agricultural practice. Survey enumerators were instructed not to prompt respondents to ensure that the mental model variables were not influenced by external expectations and perceptions. The most common responses from the initial survey were used in conjunction with accepted agricultural knowledge and a knowledge review of causal relationships to create a concept map of the farmer's perception of the agricultural system. This concept map was then used to develop a more in-depth survey to measure the strength of the relationships between the relevant factors of the agricultural system.

A second survey was conducted in January 2012 with farmers from the villages of Thumka, Hyakrang, and Khola Gaun, as well as with researchers and field staff from Li-Bird and IAAS. The intention of this second survey was to use a Likert scale to determine the strength of the relationships between the variables enumerated in the previous survey. Specific questions related to conservation agriculture technologies were also asked to establish the perceptions of various tillage, soil cover, and cropping methods as they fit into the agricultural system. Responses were coded on a scale of 0 to 6, with 6 representing a very strong relationship between two given factors and 0 representing no perceived relationship between two given factors. Individual responses were then averaged to develop a model representing the community-level reasoning for existing agricultural practices.

Additionally, to develop a basis for ground-truthing of farmers' perception of their local ecological conditions, traditional soil conservation practices, and the possible need for conservation agriculture intervention, soil data was collected. It is crucial to understand the soil conditions in a study area situated on highly sloping land, posing a constant challenge to soil conservation and yield productivity. Soil environment data representing ecological conditions were collected to evaluate whether they have an influence on the farmers perception to try a new conservation practice. Soil samples were collected from the three villages to develop a comprehensive assessment of the baseline variation in soil characteristics, such as nutrients, texture, and organic matter, among the village sites. These data were compared with the abovementioned differences in perception of soil environment (soil moisture and nutrients) to determine any relevant soil factors that may alter the farmers' perception of the importance of the soil. Following initial preparation of the fields for cultivation (i.e., conventional plowing and incorporation of manure amendment), a 5cm-diameter cylindrical coring device was used to collect and composite 10 samples along a transect laid out across each field. Using subsamples taken from the composited soil sample, nitrogen (N) was determined colorimetrically using the Kjeldahl method (Bremner 1960), exchangeable potassium (K) was determined by 1M ammonium acetate extraction, available phosphorous (P) was determined by Bray-1 method, total organic carbon was determined by Walkley-Black method, and texture was determined by the hydrometer method at the Li-Bird soil testing laboratory in Pokhara.

Results and Discussion

The community level mental map, depicted in Figure 1, represents the agricultural belief system of the village farmers, as developed from the factors enumerated in the initial face-to-face interviews and using causal relationships and agricultural knowledge to determine the orientation of the factors. Initial surveys to create the concept map of the agricultural beliefs and perceptions of factors determining productivity and food security of Chepang villages involved 20 face-to-face interviews with villager farmers. Alphanumeric coding on the links between variables represent the survey questions used to assess farmer and researcher/extension personnel opinions of the strength of the relationship.

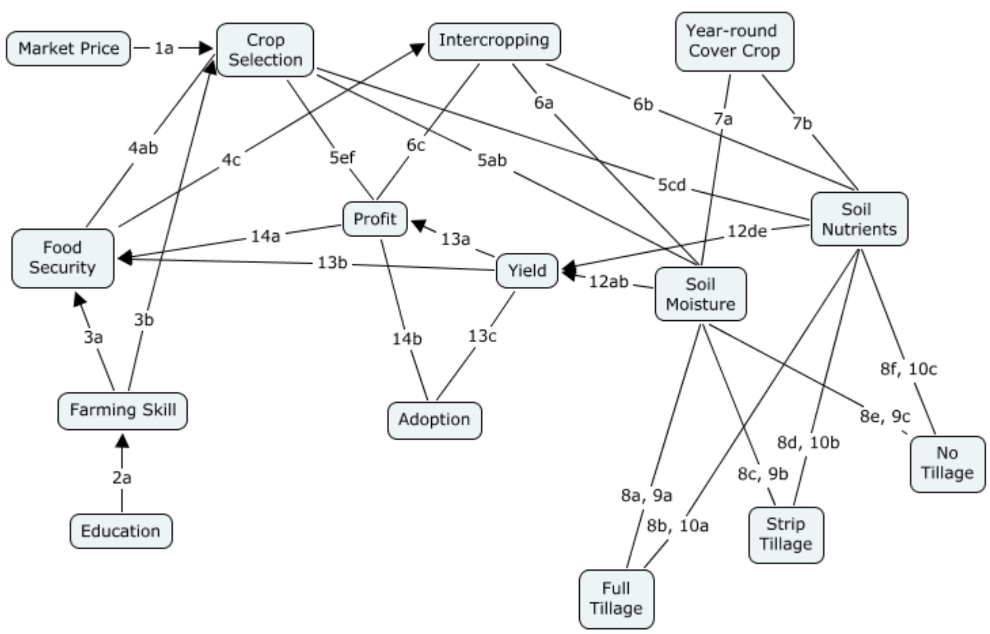


Figure 1. Community concept map depicting agriculture beliefs factors of Chepang villages in the central mid-hills of Nepal.

With the information outlined in the concept map, surveys were conducted to determine the strength of their relationships. Of the 106 surveys conducted, the survey respondents represented members of both NGO/Research institutions and farmer groups from the three villages. The demographics of the survey respondents are listed below in Table 1. Each village has about 30 households with over 60% of households participating in this study. The gender distribution for the NGO and Researcher respondents was approximately 35:65 percent, female to male ratio, while in the villages the ratio was more evenly distributed at 45:50 percent. All NGO/Research respondents had a minimum of a secondary school education, with the average education being at the Bachelor's and Master's levels, for NGO/Research and University respondents respectively. Village farmers had an average minimum pre-school education, with the exception of Hyakrang, where respondents had on average a primary school education. Of the village respondents, average ages ranged between 33 and 40 years. Age demographics were not collected from the Li-Bird and IAAS groups.

Table 1. Survey respondent demographics, listed by group.

Group	**Description**	**Total no. respondents**	**Gender**		**Average Age**	**Average Education**
			Female	**Male**		
Li-Bird	NGO/Extension	25	10	15	--	Bachelor's
IAAS	Research	26	8	18	--	Master's
Thumka	Village	19	8	11	36	Pre-school
Hyakrang	Village	19	10	9	33	Primary
Khola Gaun	Village	17	10	7	40	Pre-school
TOTAL		**106**	**46**	**60**		

The agricultural beliefs factors from the initial farm surveys and representing important farm practices and their causal relationships are represented in Figure 1. Some of the important factors in relation to conservation agricultural practices are: crop selection, intercropping, tillage practices and soil characteristics as they relate to yield and profitability. While statistical analysis was conducted to measure differences among the village and research/extension groups for each of the factors in the concept map (Figure 1), the majority of responses showed no significant differences in the perception of the strength of the relationship between factors. This indicates that the relationships were all perceived as important and there is a high level of overlap of the agricultural belief systems among the various groups. Nevertheless, an analysis of variance showed some differences between particular factors, outlined below.

The relative importance of soil moisture in relation to full tillage and strip tillage was significantly different among the study groups (Figures 2 and 3). Respondents in Thumka village consistently held an overall lower perceived value of the relationship between soil moisture as it relates to full tillage and strip tillage. In terms of the effect of full tillage on soil moisture, Thumka village respondents showed a weaker relationship as compared with the other villages and the NGO and researcher groups (Figure 2). The perceived relation between soil moisture and strip tillage, however was more varied. While Thumka respondents again showed a weaker relationship between the two factors, the NGO and researcher groups rated the relationship between soil moisture and strip tillage as significantly stronger (Figure 3). Soil data collected at the village sites showed that farmers' fields in Thumka were associated with silt-and clay sized particles, which are indicative of weathering and associated with greater fertility and water holding capacity. Therefore, it follows that a village where soil water holding capacity is greater, Thumka in this case, overall soil moisture may be perceived as less important in the consideration of tillage practices. In the case of the researcher and NGO groups, their perceptions showed consistently stronger relationships between the types of tillage and soil moisture, as compared with Thumka. This is particularly relevant to observe, as agricultural practices relating to introducing new tillage methods may not be as well-received in Thumka, where a weak relationship is perceived between tillage and soil moisture. Viewing the farmer needs and perceptions within the scope of the ecological context, it becomes clear that local environmental conditions may influence the local mind-set.

Research has shown that the conventional full tillage method, by breaking the surface of the topsoil, allows for increased water infiltration into the soil. In combination with soil composition and texture, full tillage can be associated with higher soil moisture content, as compared with a strip tillage approach (Licht and Al-Kaisi 2005). Nevertheless, a full tillage approach can increase the risks of erosion and runoff, while reduced tillage mitigates such risks. All of the village groups viewed strip tillage as less correlated with soil moisture, however, the research and NGO groups perceived a stronger relationship between the two factors. This could be attributed to the researchers' knowledge of strip tillage attributes, farmers' limited exposure to alternate tillage methods, or local experience with soil runoff of soils that have not been tilled.

Figure 2.

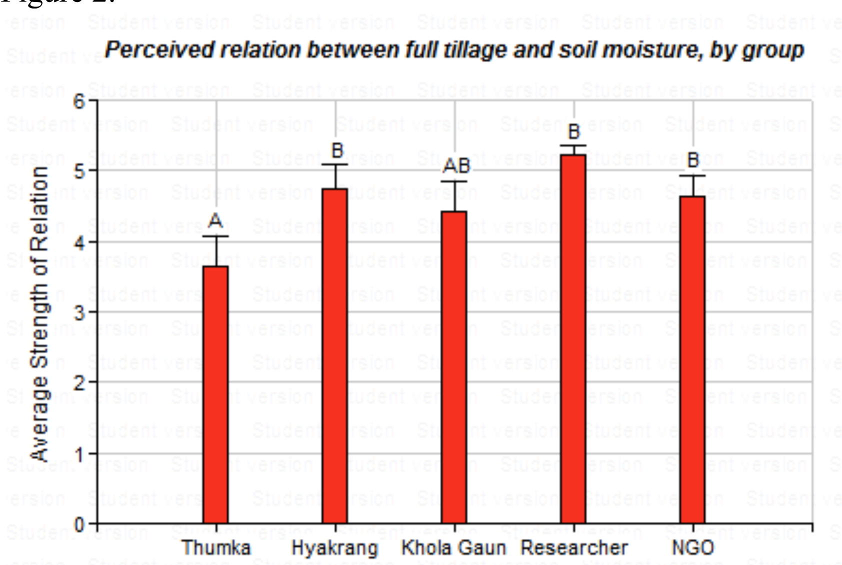
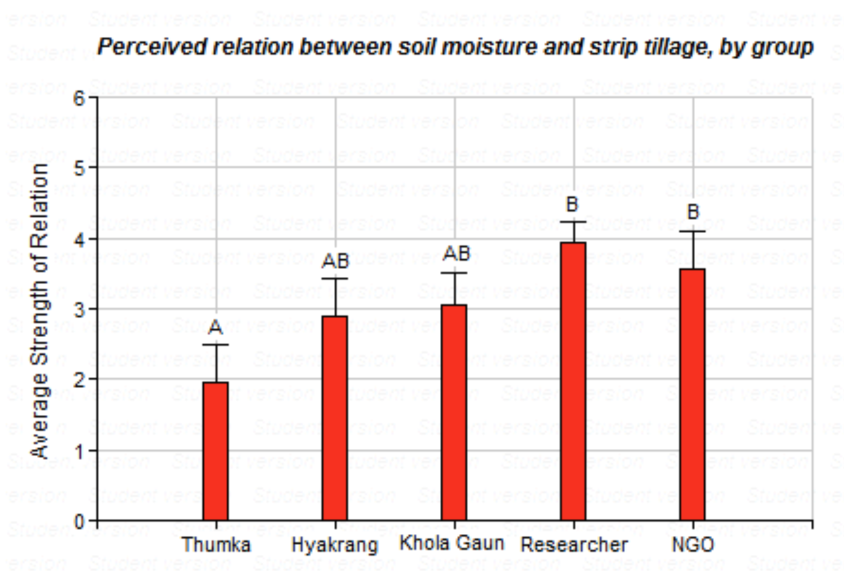
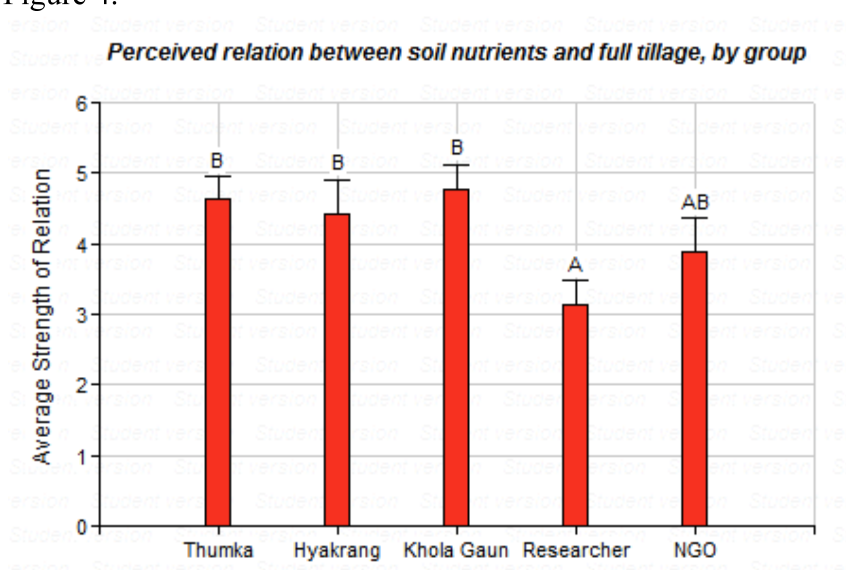


Figure 3.



In terms of the relationship between soil nutrients and full tillage, respondents from all three villages indicated a higher strength of the relationship, as compared with the researcher group (Figure 4). This may indicate a difference in perception based on a diverse knowledge, or lack thereof, of conservation agricultural practices. While the research group has a broader knowledgebase of the impact of different tillage practices and alternative approaches to improving soil nutrients, the rural farmers have traditionally implemented full tillage to all fields as a necessary component of cultivation.

Figure 4.



Agriculture development agencies need to consider identifying the influences of the local ecological context, as well as the needs and perceptions of the community during the planning, introduction, and implementation stages of a project to minimize redundancy or rejection of a project. Given the differences outlined between researcher and village perceptions of the relationships between soil and tillage practices, it is evident that soil conditions, in combination with agriculture knowledge and experience, can affect the perception of cultivation and crop needs within the larger agriculture belief system. Such factors relating to the agricultural knowledge and experience of the rural farmers are important to be considered by research and NGO groups in developing and introducing agricultural projects. Differences in perception of these vital components of agricultural production in terms of economic and ecological variables are important for researchers and NGOs to understand where and how new agricultural practices may be introduced to villages with vastly different needs in terms of livelihood sustainability in the face of varying natural resource limitations and ecological challenges.

Conclusion

As the results of this research have shown, there are a number of factors that add to the perception and fundamental agricultural knowledge of rural subsistence farmers, as well as of researchers and NGO workers. This study first determined the factors important to farmers based on their perceptions and current farming practices, particularly in regards to conservation agricultural practices such as tillage (full or strip). Minimum tillage practices, such as strip tillage, are important to improving soil conservation and developing sustainable yields for food security and income generation. From the identified set of factors and their relationships to agricultural farming system, the study further determined that different villages and groups (farm communities compared with researchers/extension personnel) weighed these relationships differently due to experience, knowledge and the social, cultural, and ecological conditions of the groups and/or villages.

In terms of the relationship of soil conditions and conservation practices, such as minimum tillage, with yield and adoption, there are significant differences among the villages and the study groups. The researchers and extension personnel perceived a strong relationship between soil conditions and conservation practices, which are consistent with scientific research. However, the implications of such varying perceptions means that extension personnel seeking to promote conservation agricultural practices in villages with differing ecological constraints may require alternate intervention strategies to accommodate the needs and perceptions of each community. Communities with fertile soils and a weak perceived relationship between soil fertility and conservation agriculture practices may be reluctant to adopt soil conservation methods despite evidence that such practices are generally beneficial to adopt. In contrast, communities with soil deficiencies and a stronger perception of the linkage between soil fertility and conservation agriculture practices may more readily adopt introduced soil conservation technologies.

Developing knowledge of village perceptions with regards to the need for conservation practices to enrich the soil and increase yields can aid extension practitioners in devising alternate agricultural intervention strategies. Agricultural experience, local soil conditions, and traditional or learned knowledge all contribute to the community decision making process of whether to adopt new agricultural practices over the long term. Planning for agriculture development projects must therefore consider the local context and perception from both the farmer and researcher/NGO perspectives to develop mutual understanding and improve the project design for the benefit of multi-stakeholder groups. This research has demonstrated two important needs for practitioners and policy makers. First, the success of adoption of any introduced agricultural practice requires knowledge of the agricultural belief systems of farmers and other stakeholder groups, such as researchers and extension personnel, such that gaps in perceptions of the agricultural system are recognized and incorporated into the development of implementation strategies. Second, it is crucial that agriculture development agencies utilize interdisciplinary teams or involve interdisciplinary extension personnel to develop a complete understanding of the agronomic, ecological, and social context of a community-based project. As shown by this study, simply understanding how rural farmers think and approach agricultural decision-making does not create solutions. It is through the supplemental discovery of the ecological and social basis driving these perceptions that a more complete picture of community needs and perceptions is developed and sustained productivity can be better promoted.

Acknowledgements

Appreciation and thanks are owed to the participating survey respondents and enumerators, and our partners in Nepal, Li-Bird and IAAS. This project was made possible through the funding of USAID/SANREM-CRSP.

References

Agrawal. A. 1995. Dismantling the divide between indigenous and scientific knowledge. *Development & Change* 26:413-439.

Armitage, D.R. 2003. Traditional agroecological knowledge, adaptive management and the socio-politics of conservation in Central Sulawesi, Indonesia. *Environ. Conserv.* 30: 79–90.

Bremner, J.M. 1960. Determination of nitrogen in soil by the Kjeldahl method. *Journal of Agricultural Science* 55: 11-33.

Brown, K. 2003. Three challenges for a real people-centered conservation. *Glob. Eco. & Biogeo.*12: 89–92.

Bunch, R. 1999. Reasons for non-adoption of soil conservation technologies and how to overcome them. *Mountain Research & Development* 19(3): 213-220.

Cochran, J. 2003. Patterns of sustainable agriculture adoption/non-adoption in Panamá. Thesis. McGill University, Montreal, Canada.

Davis, A., and J.R. Wagner. 2003. Who knows? On the importance of identifying experts when researching local ecological knowledge. *Hum. Eco.* 31: 463-489.
Denzau, A.T., and D.C. North. 1994. Shared Mental Models: Ideologies and Institutions *Kyklos* 47(1): 3-31.

Gadgil M., P.R. Seshagiri Rao, G. Utkarsh, P. Pramod, and A. Chatre. 2000. New meanings for old knowledge: the people's biodiversity registers programme. *Ecol. Apps.* 10: 1307–1317.

Herdt, R.W. 2012. People, institutions, and technology: a personal view of the role of foundations in international agricultural research and development 1960-2010. *Food Policy* 37: 179-190.

Hobbs, P.R., K. Sayre, and R. Gupta. 2008. The role of conservation agriculture in sustainable agriculture. *Phil. Trans. R. Soc. B* 363: 543–555.

IFAD. 2011. The world's population is about to hit 7 billion. International Fund for Agricultural Development. http://www.ifad.org/media/events/2011/7billion.htm (Accessed 26 Oct 2011).

Isaac, M.E., E. Dawoe, and K. Sieciechowicz. 2009. Assesing local knowledge use in agroforestry management with cognitive maps. *Environmental Management* 43: 1321-1329.

Kellert, S. R., J.A. Mehta, S.A. Ebbin, and L.L. Lichtenfeld. 2000. Community natural resource management: promise, rhetoric, and reality. *Soc. & Nat. Res.* 13: 705–715.

Kerkhoff, E.E. and E. Sharma (Comp.). 2006. Debating Shifting Cultivation in the Eastern Himalayas: Farmers' Innovations as Lessons for Policy. International Centre for Integrated Mountain Development, Kathmandu, Nepal, June 2006.

Kessler, C.A. 2006. Decisive key-factors influencing farm households' soil and water conservation investments. *Applied Geography* 26: 40-60.

Khadka, R. 2010. Transition from slash-and-burn (*Khoriya*) farming to permanent agroforestry in the middle hills of Nepal; and analysis of costs, benefits, and farmers' adoption. Thesis. Norwegian University of Life Sciences, Ås, Norway.

Kosko, Bart. 1986. Fuzzy cognitive maps. *International Journal of Man-Machine Studies* 24(1): 65-75.

Knowler, D., and B. Bradshaw. 2007. Farmers' adoption of conservation agriculture: A review and synthesis of recent research. *Food Policy* 32: 25-48.

Licht, M.A., and M. Al-Kaisi. 2005. Strip-tillage effect on seedbed soil temperature and other soil physical properties. *Soil & Tillage Research* 80: 233-249.

Oreszczyn, S., A. Lane, and S. Carr. 2010. The role of networks of practice and webs of influencers on farmers' engagement with and learning about agricultural innovations. *J. Rural Studies* 26: 404-417.

Pannell, D.J., G.R. Marshall, N. Barr, A. Curtis, F. Vanclay, and R. Wilkinson. 2006. Understanding and promoting adoption of conservation practices by rural landholders. *Australian Journal of Experimental Agriculture* 46: 1407–1424.

Schusler, T.M., D.J. Decker, and M.J. Pfeffer. 2003. Social learning for collaborative natural resource management. *Society & Natural Resources* 15: 309-326.

Sicat, R.S., E.J.M. Carranza, and U.B. Nidumolu. 2005. Fuzzy modeling of farmers' knowledge for land suitability classification. *Agricultural Systems* 83: 49-75.

Thapa, G.B., and G.S. Paudel. 2002. Farmland degradation in the mountains of Nepal: A study of watersheds 'with' and 'without' external intervention. *Land Degradation and Development* 13: 479-493.

Yadav, R.P. 1987. Agricultural research in Nepal: resource allocation, structure, and incentives. International