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Differences in farmer and expert beliefs and the perceived impacts of conservation agriculture

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ABSTRACT

Departing from the traditional agricultural model of input-heavy, intensive agriculture via the use of agrochemicals and irrigated water, many international development projects have started to promote conservation agriculture in developing countries. However, relying solely on technical expertise, largely generated outside the rural communities in which they are applied, often does not consider whether local ecological and culturally influenced beliefs are consistent with the technologies being promoted for adoption. We suggest these disconnects can be linked to differing 'mental models' of scientific experts and rural agricultural communities regarding the nature of farming dynamics and predicted impacts of introduced farming practices. Using an agricultural development project in Nepal as a case study, this research seeks to understand the relationship between trends in expert and rural farmer reasoning and predictions regarding the outcomes associated with development technology based on these beliefs. Further, we seek to compare these mental model-based differences with local environmental conditions (using soil measurements) and agricultural outcomes in terms of farm production (i.e. yield). While researchers' mental models predicted that minimum tillage would improve yield, mental models from two of the three villages predicted that yield would decrease. Local soil and yield measurements support the farmers' mental model predictions. Our results indicated that conservation agriculture techniques should not be applied universally, development practitioners should engage in a two-way learning with local communities to benefit from locally situated knowledge.

1. Introduction

With rising populations, increasing demands are placed on agricultural systems to produce greater yields through the more efficient use of natural resources. Worldwide, there are 500 million smallholder farms (<2 ha), in which 80 percent of the food that is produced is consumed within Asia and Africa (IFAD, 2011). As a result, considerable research and international development resources have focused on promoting the long-term productive capacity of smallholder farming communities and improve food security. These development approaches often focus on promoting "green revolution" technologies (Fitzgerald, 1986; Perkins, 1997) and other approaches designed for large-scale production, including conservation agriculture, without regard for adapting these technologies to meet the needs of rural farming communities. Conservation agriculture includes the practices of minimum tillage, improved crop varieties, intercropping, and the use of cover crops that help to mitigate soil nutrient depletion, land degradation, and increase yields (Hobbs et al., 2008). Extensive global promotion of these practices has resulted in 72 million hectares of conservation agriculture systems worldwide with an estimated average growth rate of and additional 7 million ha per year (Freidrich et al., 2012). Moreover, 105 million hectares of no-till agricultural land were recorded in 2008, though this has been primarily on large-scale farms (Derpsch and Friedrich, 2014). Conservation agriculture has been promoted because it requires simple changes in farming techniques, which can be a more

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economically viable approach for rural farms as compared with other soil and water conservation technologies. In the United States alone, it is estimated that the decreased erosion that has resulted from conservation tillage practices resulted in a savings between 90.3 and 288.8 million USD (FAO, 2014a).

This top-down approach of "modern" agricultural technologies for the global South, however, has recently been called into question and there is a lack of evidence to support long-term agricultural and environmental improvement (Giller et al., 2009). In fact, recent studies have indicated that conservation agriculture may not be the most appropriate way to increase farming capacity at the local and community scales due to problems associated with competing uses for crop residues, increased labor demand for weeding, and lack of access to, and use of external inputs (Giller et al., 2009).

In addition to issues associated with the hidden costs of conservation agriculture, many agricultural development programs make global recommendations with little regard for farmers' existing beliefs, or so called "mental models", of existing or new farming practices/technologies and their perceived impacts on productivity. Perhaps because of this disconnect between the way in which researcher and rural farming communities conceptualize new technologies and integrate them into existing decision-making processes, new practices introduced by government extension, Non-Governmental Organizations, or other research institutions are often abandoned for traditional practices after development projects have been completed (Bunch, 1999; Cochran, 2003; Yadav, 1987). More recently, a review of conservation agriculture studies revealed that there are few, if any, universal factors that determine the adoption of new technologies and the factors that influence local adoption are highly contextual and tend to vary due to differing local and ecological conditions (Knowler and Bradshaw, 2007). Thus, it is crucial to consider the bottom-up perspective when approaching the introduction of agricultural development programs, encouraging a community and stakeholder participatory approach in order to design project goals and objectives that serve the interests of multiple farm stakeholder groups (Chambers, 1994; Pretty, 1995). Studies have found that conservation approaches promoted in developing countries as universally applicable scientific methods may actually reflect the particular social and historical contexts of their genealogy, for instance, in the case of biodiversity protection (Goldman, 2011) and soil erosion prevention (Forsyth, 2011). Therefore, when promoting conservation agriculture in international development, it is necessary to critically scrutinize its assumptions and to ask whether the promotion of new technologies, including conservation agriculture practices, are locally appropriate and how different perspectives about agricultural beliefs and expected outcomes can be aligned to increase the success of international conservation development.

This research adopts an interdisciplinary and empirical approach to understand the relationship between trends in expert and rural farmer reasoning and predictions regarding the outcomes associated with development technology based on these beliefs. Further, we seek to compare these differences in understanding with local environmental conditions and measured development outcomes in terms of farm production (i.e. yield). At the center of our study is an interest in comparing differences between expert and locally based environmental knowledge regarding the dynamics of farming systems. These two knowledge systems increasingly interact in the agricultural development sector, including conservation agriculture projects, across the globe. Knowledge systems are typically categorized based on local knowledge (e.g. lay or traditional) or scientific knowledge. Local knowledge is typically drawn systematically from personal experiences or generational knowledge, while scientific knowledge is gained from structured ways of knowing, based on principles that place high importance on reliability, validity, and repeatability of knowledge claims and generalizable implications (Gray et al., 2012). The literature shows that local ecological knowledge is expected to vary given changes in local, social, and environmental conditions (Berkes et al., 2000; Folke et al., 2005). Furthermore, knowledge of ecosystem dynamics gained from historical experience become culturally embedded and are an important part of developing adaptive management strategies (Berkes et al., 2000). The identification of the 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 mechanisms in how rural farmers understand various agricultural practices and their views of introduced practices that are promoted by researchers and extension personnel. Recognizing these key factors will also expose hidden assumptions and blind spots in "scientific" approaches that may be overlooked with the conventional top-down development approach. The specific objectives of this research are: (i) to understand how environmental conditions and social contexts may influence agricultural beliefs or perceptions, (ii) to estimate how these different beliefs may influence the predicted outcomes of introduced conservation agriculture practices, (iii) to assess the accuracy of the predicted outcomes of conservation agriculture practices via empirical farm-based measurements.

Although criticisms of top-down approaches and over-reliance on expert knowledge have been around for some time (Arnstein, 1969), methods that measure the differences between local and scientific knowledge remain under-developed. Further, many models suggest that the promotion of social-learning between development personnel and local communities are qualitative and explain only the general processes that should occur with less attention paid to generating empirical data to validate or reject these suggested models. However, by specifically identifying the differences in perception resulting from local ecological knowledge as compared with scientific knowledge, we can better understand where these differences originate and develop improved methods for creating shared knowledge and improved collaboration. In this study, we seek to understand the differences in perception of the agricultural system by combining aspects of 'mental modeling' (Gray et al., 2014). As a case study, we will use farmers and scientists engaged in an agriculture development project and utilize soil and crop science to better understand how knowledge of agricultural dynamics are initially developed, how these beliefs may influence expected outcomes of introduced technologies, and how these expectations compare to measured agricultural outcomes.

1.1. Mental models

First introduced by Craik (1943), today the notion of mental models and their use for understanding individual and group decision-making is a widely accepted construct in the social science literature (Jones et al., 2011; Gray et al., 2014). Mental models are the 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, filtered by culture and influenced by 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 within 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 influence decisions.

Individuals and societies with different cultural and environmentally mediated learning experiences may have different theories to interpret the world around them. Agricultural decision-making processes are complex, and it has been suggested that these decisions cannot be unilaterally explained solely from a scientific perspective (Soleri et al., 2000). Approaches that allow for active participation of the target community have been shown to result in cultivation practices that are better suited to the local environment and that empower the community (Ceccarelli and Grando, 2006). In working at the community level, Denzau and North (1994) state that, "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". Our study's framework is adopted as a means through which to understand the interaction between technological and ecological dynamics by examining how factors and their perceptions, collected from community farmers and university researchers, may influence subjective knowledge about the natural environment and how this influences production and management decision-making in the context of rural agricultural development. In this research, we suggest a conceptual framework demonstrating how knowledge is constructed, as well as how predicted outcomes, or beliefs, impact decision-making processes and subsequent actions. As indicated in Fig. 1, we suggest that both environmental and socio-cultural factors contribute to developing beliefs about the dynamics of agricultural systems, leading to distinct differences in the mental models of individuals engaged in agricultural development. Exposure to local environmental conditions can influence an individuals' understanding of the functioning and interrelationship between factors such as weather, soil, and crop production as individuals collect and encode this information in their minds over time. Additionally, these real world experiences are mediated by socio-cultural factors, such as community norms and expectations, which, in part, influence what information is relevant and the behaviors that lead an individual's collection and encoding of the environment over time. These agricultural beliefs are then used by individuals as a foundation for predicting the outcomes of cultivation practices (in terms of factors such as yield, soil condition, food security, and income) and thus influence decision-making regarding the appropriate actions and behaviors adopted. In turn, the agricultural outcomes, which may or may not coincide with the predicted outcomes, may create positive or negative feedback, which would either support the adoption of successful practices or create changes in understanding through learning to adapt beliefs, predicted outcomes and future actions/behavior, respectively. It is proposed that this feedback would ultimately alter the environmental and socio-cultural conditions.

To validate our proposed model in the context of an agricultural development project, this research focuses on modeling the agricultural belief systems of agricultural development experts and communities practicing subsistence agriculture in the mid-hills of central Nepal. Specifically, we focus on measuring the difference in understanding with particular focus on two conservation agriculture practices: (1) minimum tillage and (2) continuous year-round cover cropping. By measuring the difference in these beliefs, we intend to demonstrate how different understanding of the dynamics of agricultural systems found between communities can shape decision-making regarding cultivation methods, crop selection, and management practices. A comparison of mental models from different stakeholder groups can explicitly identify knowledge gaps and incongruent beliefs. Identifying these gaps will facilitate and improve the sharing of information, contribute to clearer communication, and ultimately help to develop shared ownership of conservation plans (Biggs et al., 2011). With this information, researchers and extension personnel can develop adoption strategies or extension materials in conjunction with the farm community.

While this approach is highly localized, requiring research tools that can be modified and analyzed at the community-level, this assessment will garner the type of locally specific information that has been lacking with traditional approaches to community development. Both Giller et al. (2009) and Knowler and Bradshaw (2007) have recognized the need for local adaptations of conservation approaches due to varying environmental conditions and cultural contexts. Moreover, development agencies have supported this approach through the development of programs such as the United States Agency for International Development's Feed the Future Innovation Lab for Collaborative Research on Sustainable Agriculture and Natural Resource Management, which has created a global effort to identify key issues in conservation agriculture implementation by studying communities at the local scale. Such large-scale operations can be used to identify common

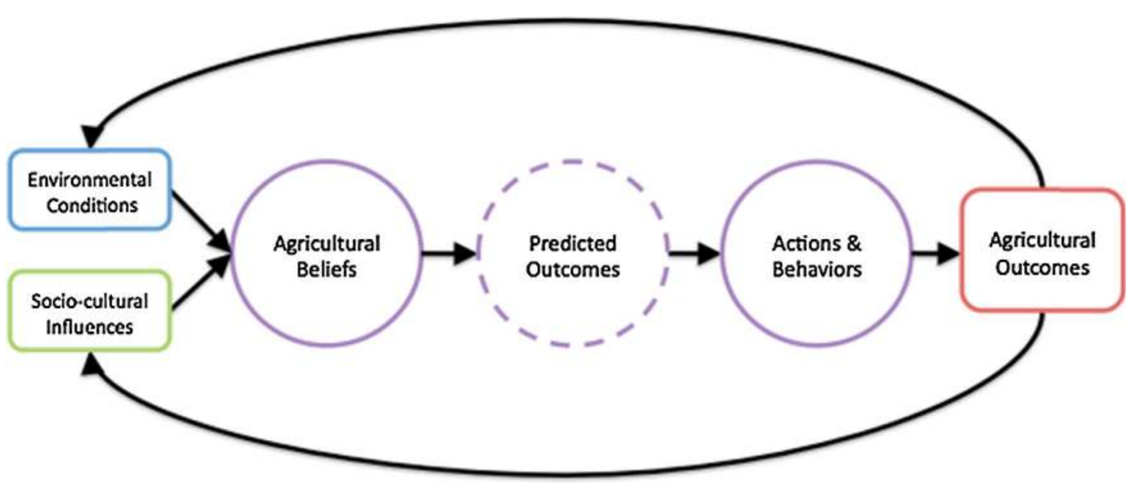

Fig. 1. Conceptual framework for understanding the factors that influence knowledge construction, predicted outcomes based on shared knowledge, appropriate actions and behaviors based on this knowledge, and agricultural outcomes.

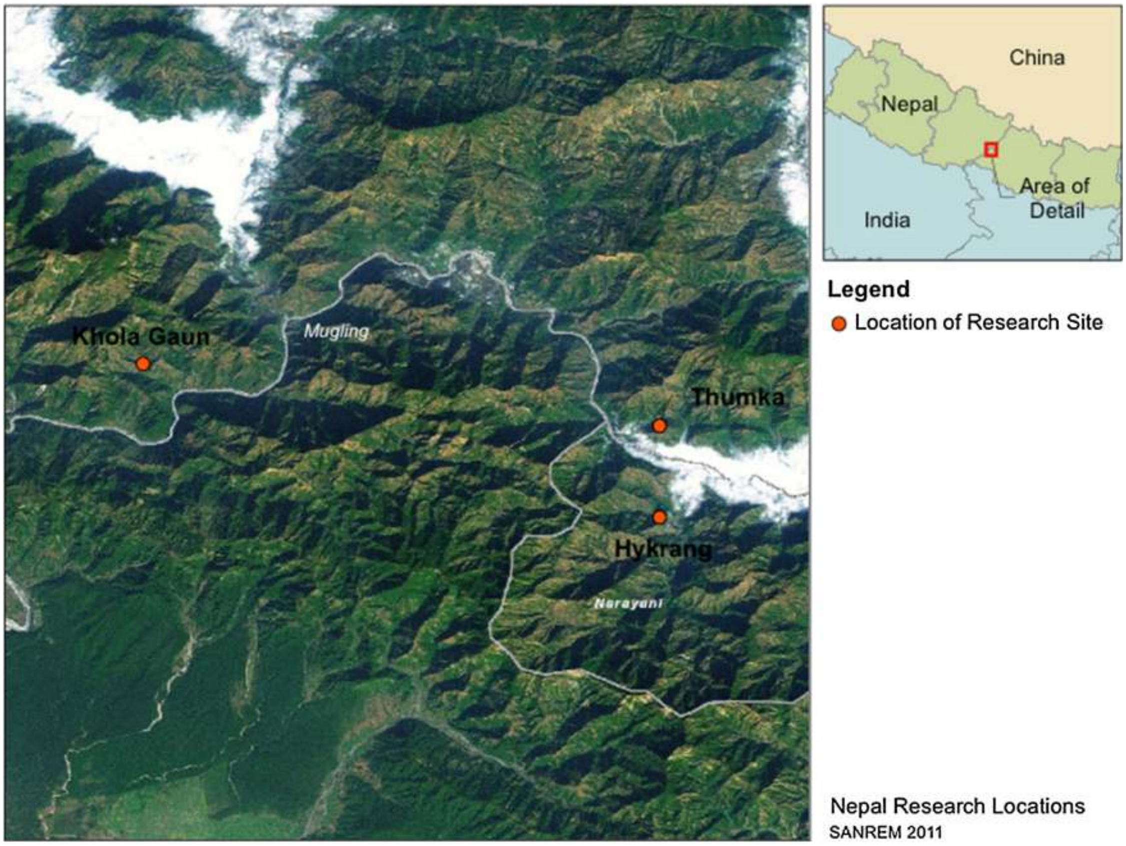

Fig. 2. Map of study area, Central mid-hills, Nepal. Map credit: Linsey Shariq, 2011.

challenges, allowing for the scaling up and application of the research findings in similar geographical and/or cultural situations.

1.2. Study area

This study takes place in three rural communities in the central mid-hill region of Nepal engaged in a conservation agriculture-based development project. The study communities were selected to take part in the study in consultation with a local Non-Governmental Organization and were indicated as highly impoverished and at great risk of food insecurity due to their marginal agricultural lands, 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 sole cropping 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 Non-Governmental Organizations 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.

Three villages in the central mid-hill region of Nepal (Fig. 2) 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 sizes included 16 households in Khola Gaun, 25 households in Hyakrang, and 36 households in Thumka. Available demographic data for the villages are shown in Table 1. 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

Table 1
Village demographics.

Village	No. of households	Average annual income (USD)	Average family size	Education level	Average farm size (ha)
Thumka	25	554.12	10	Primary	0.62
Hyakrang	36	622.31	7	Primary	0.63
Khola Gaun	16	626.95	6	Primary	0.58

All data shown represent the average per village (Reed et al., 2012).

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.

The characteristics of the villages in our study site, as rural farmers engaged in farming on marginalized land, typify many areas commonly subjected to international agriculture and conservation development. Recent studies have shown that conservation agriculture practices have been successful in sustaining productivity in lesser-developed countries traditionally using "slash and burn" techniques. Due to population pressures, the abundance of land required to implement slash and burn, which requires shifting agricultural land to fallow plots every year to maintain productivity, is has been steadily declining and the practice is now seldom used in the study area. The conservation agriculture practices of minimum tillage and the use of cover crops are an alternative that may 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 social 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 appropriateness of the practices for the local environment, 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 Non-Governmental Organizations and agricultural universities are beginning to work with subsistence farmers in Nepal to introduce conservation agriculture practices.

2. Methods

2.1. Measuring agricultural beliefs

As a way to measure the differences in mental models between stakeholders engaged in a conservation agriculture development project, we used a parameterized and semi-quantitative concept mapping technique called Fuzzy-logic Cognitive Mapping. Originally developed by Kosko (1986), Fuzzy-logic Cognitive Mapping was originally developed as a way to structure expert knowledge under conditions of uncertainty. Due to its flexibility to model any domain, this has been applied in several disciplines from psychology to politics in order to model belief systems of individuals as well as those of communities. This study uses Fuzzy-logic Cognitive Mapping to identify mental model representations of factors and the relationships between environmental conditions (e.g. soil moisture and soil nutrients), farm-based dynamics (crop yield, crop sales, crop selection) and introduced technologies (e.g. conservation agriculture practices). This method was selected to quantify differences in group beliefs since it serves as a tangible method to represent similarities and differences between the understandings of the various stakeholder groups through explicit knowledge representation from individuals that can be aggregated to understand trends in community beliefs (Gray et al., 2014).

Due to the literacy constraints of the farm respondents, we used an adapted application of Fuzzy-logic Cognitive Mapping to develop mental model representations in two steps. First, we conducted initial interviews with rural farmers in all three villages to gain an understanding of their beliefs about which variables and their relationships are important to understanding farm dynamics. Second, based on these interviews, we developed a quantitative survey to construct a cognitive map for individuals within villages and for experts that could then be aggregated by group to understand trends in beliefs in each of the groups in the study.

2.1.1. Initial interviews

In 2012, face-to-face interviews were conducted with farmers from the three Chepang villages to gather a broad understanding of the variables involved in the village farming system. To develop a general mental model of the three Chepang communities' view of their agricultural system and farming practices, first the farmers were asked to name the important factors of the farming system and to describe their understanding of farm dynamics. 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 to understand the variables and the causal relationships between variables to create a general concept map (Fig. 3) intended to represent the typical understanding of

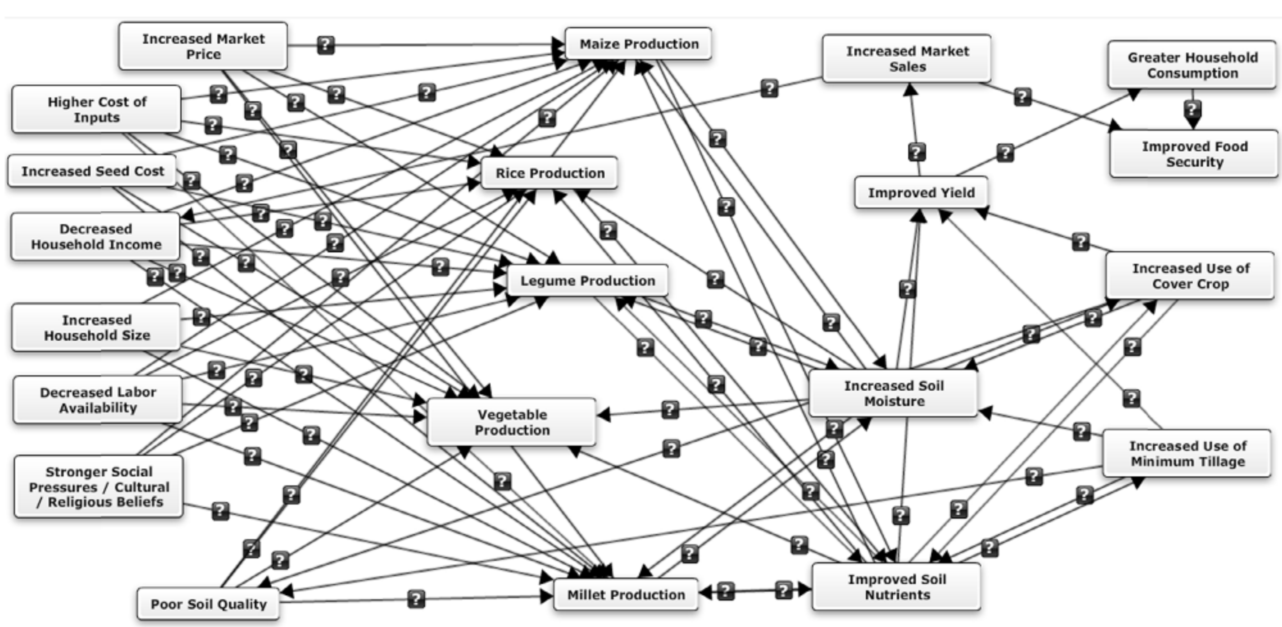

Fig. 3. General concept map of factors in the agricultural system. Constructed using fuzzy-logic cognitive mapping software *Mental Modeler* (Gray et al., 2013).

farmer's perceptions of the agricultural system. This concept map was then used to develop a more in-depth survey to be administered to individual farmers and researchers to measure the strength of the relationships between the relevant factors of the agricultural system collected from the initial interviews.

The Fuzzy-logic Cognitive Mapping-based survey developed from initial interviews was administered to farmers from the three villages of Thumka, Hyakrang, and Khola Gaun, as well as with agronomy researchers from Tribhuvan University's Institute of Agriculture and Animal Sciences (IAAS). Using a series of individual questions, this survey asked farmers to validate and define relationships between variables mentioned during the initial interviews and define the relationship between variables using a Likert scale. For example, soil quality and crop yield were two variables identified in the initial interviews. Participants were asked if soil quality influenced crop yield. If participants indicated there was a relationship, follow-up items asked them to define the relationship as positive or negative and the degree of influence of that relationship using scale from strong negative (−1) to strong positive (+1). Each variable was defined to avoid the risk of misinterpretation or varying understandings of the variables. Individual survey responses were then translated into an adjacency matrix to determine the level of influence of one factor on another for Fuzzy-logic Cognitive Mapping-based scenario analyses following methods described by Ozesmi and Ozesmi (2004). To develop trends in community beliefs, community models were developed by taking the arithmetic mean of individual survey results, representing each of the three villages and the researcher group perspectives of the existing agricultural production system. Specific questions related to conservation agriculture technologies, not included in the initial interviews, were also included in survey to link the conservation agriculture practices of tillage and soil cover to perceived dynamics of the agricultural system. As the farmers were unfamiliar with the specific conservation agriculture practices of minimum tillage and cover cropping, basic descriptions of these cultivation methods were provided without detailing their expected attributes so as not to influence the responses.

2.1.2. Belief-based predictions of conservation agriculture

After survey responses were aggregated into four community models (one for each village and one for experts) by combining the individual adjacency matrices, two scenarios were run to assess the predicted changes to agricultural systems. These represented the introduction of two conservation practices: (1) minimum tillage and (2) year-round cover crop. These scenarios were used to predict the perceived changes to the agricultural system based on the strength of the relationships between factors, determined using the averaged models of each village and the experts. For the scenarios, matrix calculation was used to determine possible changes to the model under specified conditions by subtracting a scenario condition from the steady state conditions following methods described by Kosko (1986) and elaborated by others (Ozesmi and Ozesmi, 2004; Gray et al., 2012). The identified conservation agriculture variable/s in the community models were then subjected to Kosko's "clamping" method to introduce an increase in select variables to understand changes in the agricultural systems when variables were artificially increased or decreased. For example, in the first scenario, minimum tillage was artificially increased to a value of 1 in the matrix calculation for each community model to show the predicted impacts of the practice on the other model components. Based on the strength and direction of the relationships expressed in Fig. 3, the results from the scenario analysis show the response in terms of estimated relative change in each variable included in the community models. Similarly, the second scenario involved artificially increasing the value of the cover crop variable to 1. Scenario outputs for the two conservation practices were compared by variable for each group. Comparisons of the two conservation scenarios indicated how villages and experts anticipate the impact of introduction and/or implementation of (1) minimum tillage and (2) year-round cover cropping, based on differences in their beliefs about agricultural dynamics.

2.2. Conservation agriculture outcomes

To compare the mental model-based predictions of conservation agriculture practices to measured agricultural impact, we also evaluated crop yield in conservation agriculture experimental plots in each of the three villages. On farm experimental plots were established on 8 representative farms in each of the three villages during the cropping season of 2012. Treatments for comparison included (1) a simulated farmer practice of fully plowed maize (March–July), followed by a relay planting of millet (July–September) intercropped with cowpea, and concurrently (2) strip tillage with maize, followed by a relay planting of millet intercropped with cowpea. An analysis of variance was used to determine significant differences of crop yield under minimum tillage as compared with the farmer's practice of conventional full tillage.

2.3. Environmental conditions

In addition to understanding the relationship between mental model predicted impacts of conservation agriculture compared to measured outcomes, we also wanted to evaluate differences in how environmental conditions may impact beliefs. To accomplish this, multiple soil physical and chemical analyses were conducted in the villages to determine pre-existing agricultural conditions and identify localized differences in soil conditions. Further, these measurements were compared to community models of soil characteristics (soil moisture and soil nutrients) to understand if variation in soil contributed to the agricultural beliefs of farmers. Baseline soil samples (0–5 cm and 5–10 cm depths following plowing) were collected in March 2011 from each farmer plot in each village. Bulk density, percent organic matter (Walkley–Black method), percent nitrogen (Kjeldahl titration method, Bremner, 1960), available K and P (ammonium acetate extraction), pH (in water), and texture (hydrometer method), and coarse materials (non-organic, >2 mm) were determined in the LI-BIRD Plant and Soil Nutrient Laboratory, Pokhara, Nepal. A subsample of soil was transported to the Virginia Tech Soil Testing Lab, Virginia Technological University, Blacksburg, VA. There, an inductively coupled plasma analysis was used to determine P, K, Ca, Zn, Fe, Cu, and B concentrations (mg kg^{-1}) on Mehlich-I extractant (Mehlich, 1967). Base saturation, effective cation exchange capacity and Ca, K, P saturation were calculated using the inductively coupled plasma results. A principle components analysis was conducted using PC-ORD (software version) to assess and characterize the chemical and physical properties of on-farm soils at the 0–5 and 5–10 cm depths from each of the villages. Linear comparisons among village means were conducting using PROC MIXED in SAS (v. 9.x.x) to identify statistical difference for selected variables.

3. Results

There were a total of 103 survey respondents representing members of university/researcher ($N = 25$) and the villages of Thumka ($N = 31$), Hyakrang ($N = 25$), and Khola Gaun ($N = 22$). The demographics of the survey respondents are listed below in Table 2. With the village sizes ranging from 16 to 36 households, over 50% of households in each village participated in this study.

Table 2
Survey respondent demographics, listed by group.

Group	Description	Number of participants	Gender		Average Age	Typical education
			Female	Male		
IAAS	Research/ University	25	12	13	27	Master's
Thumka	Village	31	16	15	33	Primary
Hyakrang	Village	25	14	11	40	Primary
Khola Gaun	Village	22	11	11	39	Primary
TOTAL		103	53	50		

The gender distribution for the researcher/university respondents was 48% female and 52% male, while in the villages the average female to male respondent ratio was distributed at 53:47 percent. The majority of respondents were the male or female heads of household or the key decision-makers for agricultural activities. All research/university respondents had a minimum of a secondary school education, with the average education being at the Master's level. Village farmers had an average education at the primary school level. Of the village respondents, average ages ranged between 33 and 40 years with researcher/university respondents' average age of 27.

3.1. Differences in agricultural beliefs

The community cognitive maps generated for each group indicated differences in the dynamic relationships and relative influence between factors for the four groups (Table 2). The differences between community-level models were identified by assessing the overall structure of the models for the relationships between variables including whether they were positive, negative and the strength of the relation. Each of the models varied somewhat with the complexity of the researcher model higher than those of the villages. The researchers had an average of 60 (St. Dev. = 9) perceived connections between factors, while the villages of Thumka, Hyakrang, and Khola Gaun had 46, 46, and 50 connections, respectively (St. Dev. = 12, 12, 13). While the village models had less connections overall, the number of connections between factors varied by village as compared to the researcher's averaged model. Table 3 outlines the key differences between the groups for the relevant factors relating to crop production and soil conditions. The values show a strong negative (−−), negative (−), positive (+), strong positive (++), or no perceived relationship between the factors (0). In many cases, minimum tillage was perceived as having no relationship with soil or yield; however, both Hyakrang and Khola Gaun perceived a negative relationship from minimum tillage on soil quality and yield.

Fig. 4 shows the variables and the relationships included in the initial interviews used to develop the individual mental model survey and the four group-level cognitive maps for the villages and the expert group. Positive (blue) and negative (red) perceptions are indicated for each relationship, with the thickness of the line indicating the strength of the relationship on average. The influence of any one variable on the rest of the model is determined by the strength and direction of the transmitting and receiving variables directly connected to that variable. The greater interconnectivity of the researcher community model (Fig. 4a) indicates that this group perceives causal relationships between more variables in the system and generally views the system as more complex in terms of its network structure. The researchers are expected to derive their understanding of the agricultural system from formal and generalized knowledge, which may not always be applicable to local farming conditions. In contrast, farmers derive much of their understanding from experience and local ecological knowledge, resulting in a simplified model that may be more reflective of the local environment.

3.1.1. Differences in belief-based impacts of conservation agriculture

For the first conservation agriculture scenario, in which conditions of minimum tillage are introduced, the clamping method was applied to the factor "increased use of minimum tillage". The results are represented in Fig. 5 as the predicted changes to the model under minimum tillage and indicate how farm dynamics are expected to change under this condition. The scenario results indicate that the strongest differences between the predicted impacts with the introduction of this technology are apparent in the factors relating to soil conditions and crop yield. With respect to soil moisture and soil nutrients, all groups except Hyakrang village expected improvement from the introduction of minimum tillage. However, in terms of soil quality, the scenario analysis showed that all groups except Hyakrang and Khola Gaun villages expected an improvement to soil quality. Similarly, with regard to crop yield, Thumka village and the researcher group showed a positive change in terms of increased yield, while Hyakrang and Khola Gaun expected a decline in yield. For each of the abovementioned factors, the researcher group showed the strongest positive change in the model, as compared with the village responses.

In the second conservation agriculture scenario, introducing cover cropping during the fallow season, the factor "increased use of cover crop" was clamped as artificially high. The results, shown in Fig. 6, demonstrate that all study groups show similar expectations under this condition and would expect a strong positive change to soil nutrients, soil moisture, crop yield, and soil quality with the introduction of a cover crop. Again, the researcher group showed the strongest agreement in expected change as compared with the village groups. In terms of soil quality, Thumka

Table 3
Key differences between groups in community cognitive models.

Transmitting factor	Receiving factor	Researchers	Thumka	Hyakrang	Khola Gaun
Soil quality	Millet	–	0	0	–
Maize production	Soil moisture	–	0	–	0
Maize production	Soil nutrients	–	–	–	0
Rice production	Soil nutrients	–	–	0	0
Legume production	Soil moisture	+	0	0	0
Millet production	Soil moisture	–	0	–	0
Millet production	Soil nutrients	–	–	–	0
Soil moisture	Millet production	+	0	0	+
Minimum tillage	Soil quality	+	0	0	–
Minimum tillage	Yield	+	0	–	–
Minimum tillage	Soil moisture	+	0	0	0
Minimum tillage	Soil nutrients	+	0	0	+

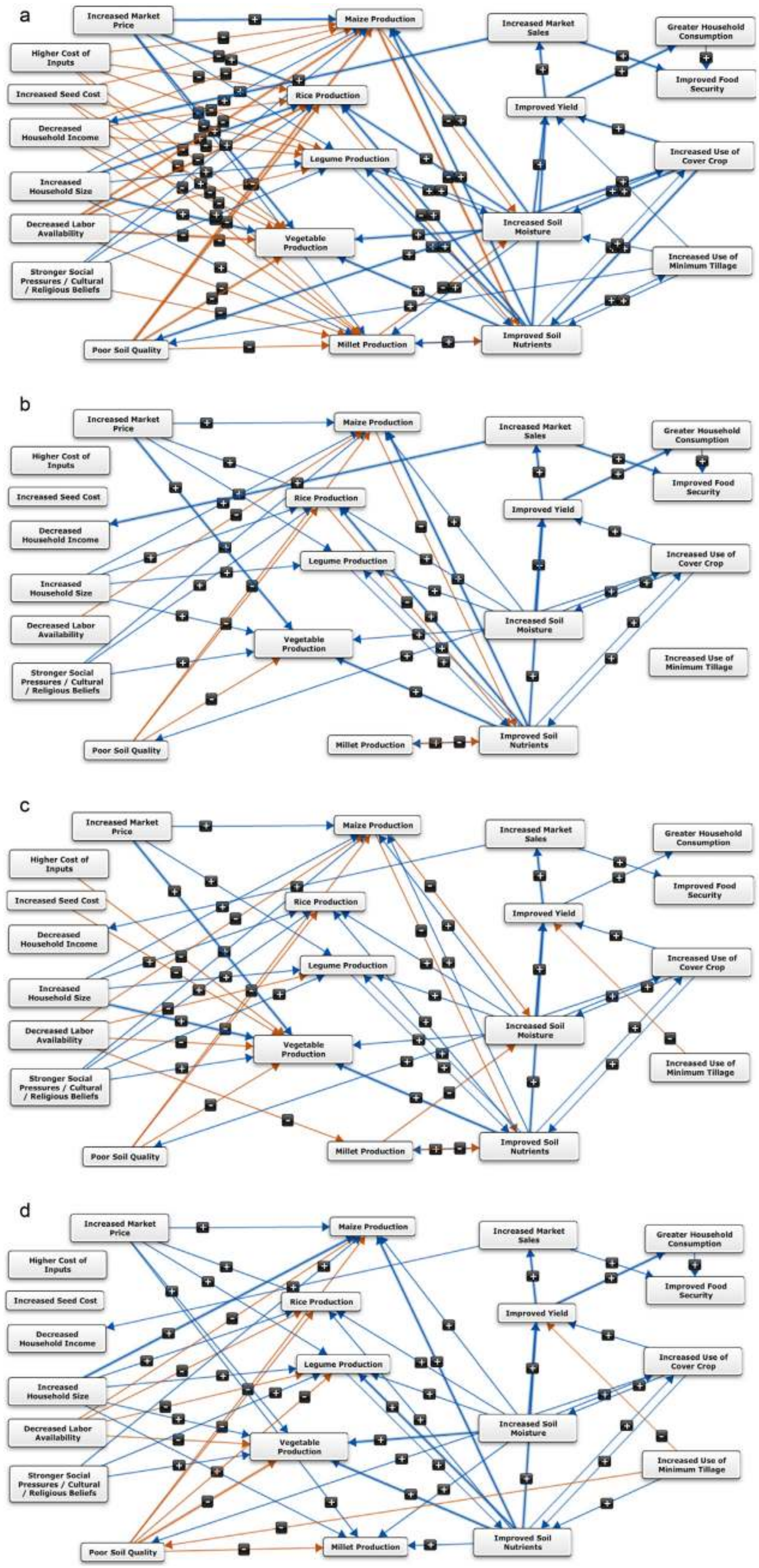

Fig. 4. (a)–(d) Averaged community models of environmental, farm-based, and conservation agriculture dynamics for the study groups: (a) Researcher, (b) Thumka, (c) Hyakrang, and (d) Khola Gaun. Constructed using fuzzy-logic cognitive mapping software *Mental Modeler* (Gray et al., 2013).

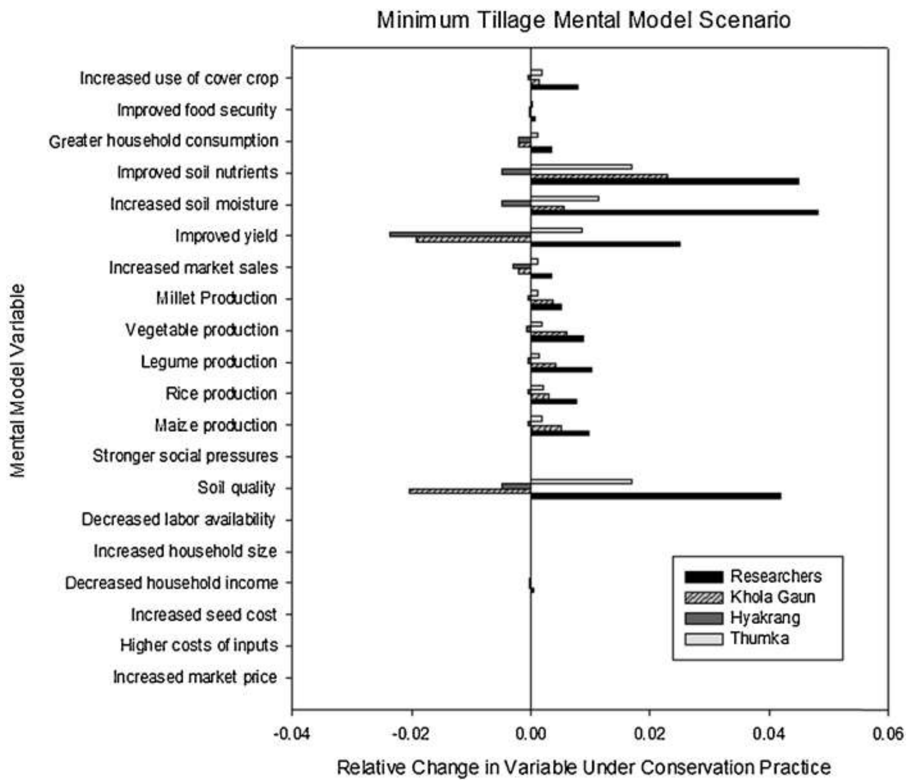

Fig. 5. Relative strength of factors under a minimum tillage scenario. Values represent relative change from the steady state condition and are aggregated by group. *Note*: This figure represents the perceived changes to factors as a result of increasing minimum tillage. Relevant results are those that compare the groups to each other for only one factor and not across factors. Higher + or – values indicate stronger agreement among the group.

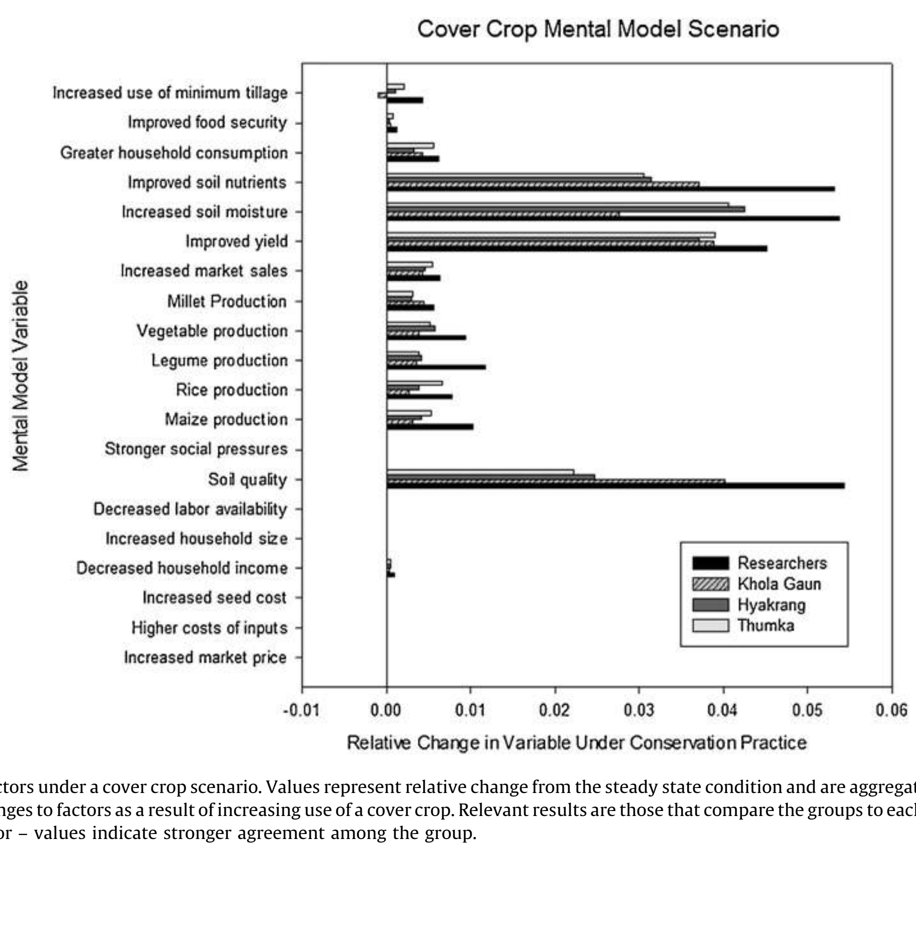

Fig. 6. Relative strength of factors under a cover crop scenario. Values represent relative change from the steady state condition and are aggregated by group. *Note*: This figure represents the perceived changes to factors as a result of increasing use of a cover crop. Relevant results are those that compare the groups to each other for only one factor and not across factors. Higher + or – values indicate stronger agreement among the group.

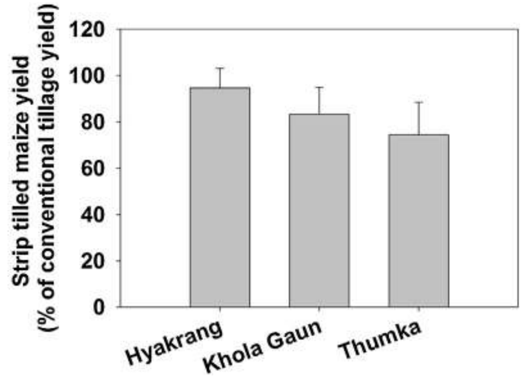

Fig. 7. Yields from minimum (strip) tilled plots expressed as a percent of yield compared to traditional (full) tillage plots in each village. Nepal 2012. Mean values are from 8 fields in each village. Error bars are mean standard errors.

village also showed stronger agreement regarding the positive effect of cover cropping, as compared with the other villages. These results indicate that there is homogeneity in the expected impact of increasing cover crop across all groups.

3.2. Measured conservation agriculture outcomes

Average maize yield in 2012 was 1917 kg/ha for Hyakrang, 1554 kg/ha for Khola Guan and 1373 for Thumka. Yields in Hyakrang were statistically higher than in the other two villages. However, there were consistent trends in experimental yields among the villages with regards to the effect of minimum tillage. Maize yield in minimum tilled plots was on average 16% lower than yield in full tillage plots. Yield reduction associated with minimum tillage was most evident in Thumka with a 26% reduction in maize (Fig. 7).

3.3. Environmental conditions

The results of the soil analysis indicate clear distinctions between soil properties across the three villages (Fig. 8). Both Hyakrang and Khola Gaun showed a higher proportion of sand content, which is characteristic of lower water retention and relies on a higher percent organic matter for productivity. Organic matter was found to be high in Khola Gaun, where available nitrogen, phosphorus, potassium, and higher rates of ECEC were also present. Hyakrang showed lower values for percent organic matter, as well as available P and K, though Thumka was also found to be lacking in these nutrients though had high percent organic matter. When compared to the community beliefs, this is consistent with Thumka not perceiving a strong relationship of tillage with the other agricultural factors. Both Hyakrang and Khola Gaun related tillage with crop yield, which was consistent with the condition of the village soils requiring incorporation of organic matter for improved production.

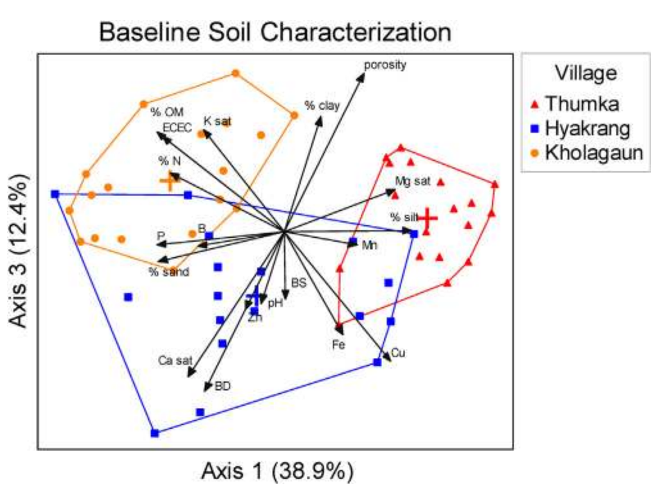

Fig. 8. Principal components analysis of baseline chemical and physical properties of soil collected from both the 0–5 cm and 5–10 cm depths. Nepal 2011.

4. Discussion

Rural agricultural development is inherently complex, bringing multiple stakeholder groups from Non-Governmental Organizations, 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 established technologies to rural farming systems (Herdt, 2012). However, technical expertise often fails to take into account the local ecological and cultural context that may conflict with project objectives. Research in the field of ethnobotany highlights the need to quantify analyses of local systems to better understand the constraints and opportunities within the geographical and cultural landscape as well as to recognize the cultural importance of the environment (Alcorn et al., 1995; Reyes-García et al., 2007). Based on our results, the introduction of unfamiliar concepts and dynamics of conservation agriculture, such as minimum tillage or cover cropping can be perceived as either consistent or inconsistent with existing community beliefs. We suggest that these differences in how experts and local communities may view introduced technologies may be impacted by (1) expectations at different temporal scales, (2) variation in environmental condition, and (3) variation in social-cultural conditions and previous interactions.

4.1. Differences in agricultural beliefs and predicted impacts based on differences in temporal scale

Measuring differences in understanding of farm dynamics, especially in areas where soil properties or other environmental conditions are distinct may result in clear differences in the anticipated impact of development technologies, however this is not always the case and appears to differ depending on the technology promoted. For example, in our study, the effectiveness of minimum tillage was viewed by two of the three villages as having potentially negative impacts on yield, while all groups anticipated positive impacts for cover cropping. Measured yield observed in minimum tillage plots supported the majority expectation among the villages that minimum tillage will reduce yield. Interestingly, the trend for reduced yields was greatest in Thumka, the village in general agreement with the researchers' prediction of positive yield effects from minimum tillage. Admittedly, benefits from minimum tillage, when realized, are generally observed over the long-term. Forsyth (2011) describes the tendency for generalized cause and effect statements, such as "tillage causes erosion" to be held as dogmatic truths regardless of context. That may explain in part the strong belief held by the researcher community of the beneficial effects of minimum tillage. This also calls into consideration the long-term versus short-term expected gains.

Subsistence farmers must inherently make decisions based on short-term prospects, as crop yields comprise their livelihood and lack of alternate income severely limits food security. Noted short-term variability, including positive, negative and neutral effects, in the field response to the introduction of conservation agriculture can reduce the overall attractiveness to farmers of adopting such practices (Giller et al., 2009). Furthermore, farmer beliefs may be based more heavily on personal experience as well as knowledge passed down from previous generations of subsistence farmers with similar short-term objectives (Thrupp, 1989). In contrast, researchers may draw from multiple sources of information, generating a broader understanding of the agricultural system, including longer temporal expectations of land dynamics, and can view conservation agriculture within the subsistence farming system objectively, seeking long-term conservation impacts and without the immediate pressures of crop yield gains. Such differing perspectives in terms of timeframe may account for the basis of predicting the outcomes of introduced conservation agriculture practices; Farmers base decisions on immediate and apparent positive outcomes, while researchers maintain a broader perspective of change over time.

4.2. Differences in beliefs and predicted impacts based on environmental conditions

Our results indicate that there are critical differences between the villages in terms of existing soil conditions that may lead to differing locally based perceptions of introduced conservation agricultural practices, their impact on soil moisture and nutrients, and the subsequent effect on crop yields. The soil analysis showed that each of the villages had distinct soil qualities, which would call for different optimal cultivation practices for sustained crop yields.

For the two conservation agriculture scenarios, minimum tillage and cover cropping, the differences in perceptions between the groups were primarily observed with minimum tillage. Overall, there was agreement among the groups in the perception of the effects of cover cropping. Namely, expected improvements to soil quality and crop yield. However, there was more agreement among the researcher group, as compared with the villages, that this would occur. The minimum tillage scenario showed a mixed response in perceived effect to the farm system. Both Hyakrang and Khola Gaun perceived minimum tillage as having a negative impact on yield and soil quality, with Hyakrang also predicting a decline in soil nutrients and moisture.

In Khola Gaun, the rocky condition of the soil would result in numerous challenges for cultivation, including low nutrient retention capacity, limited water storage, poor soil aggregation, and risk of erosion (FAO, 2014b; Hall, 2014). This indicates that successful cultivation would be heavily reliant on incorporation of organic materials into the soil through tillage to improve soil fertility and structure (FAO, 2014b). This would promote nutrient availability in the soil and thus be a critical cultivation practice. Hyakrang soils showed much variation in soil properties, and may indicate a similar reliance on tillage. Such observations also support the farmers' need for short-term benefits from introduced practices. While soil organic matter and the need for incorporation of organic matter into the soil is reduced over time with conservation agriculture (Giller et al., 2009), practices such as minimum tillage do not address the short- and medium-term needs of farmers for sufficient soil nutrients.

Additionally, such varying local ecological conditions lend themselves to different adaptive management strategies, which over time develop into locally specific beliefs regarding the agricultural system (Berkes and Folke, 2002). In the case of soil conditions, the villages have developed management strategies (such as incorporation of organic matter) that have been proven successful in the past. Several researchers have identified the value of indigenous knowledge and suggested that such knowledge be incorporated into participatory approaches for resource management (Sillitoe and Marzano, 2009; Berkes et al., 2000). These types of methods, which allow different knowledge systems to be compared, are generally lacking (Gray et al., 2012). Additionally, explicitly comparing differences in mental model representations using methods similar to what is demonstrated in this study may support more collaborative decision-making and develop understanding that reduces institutional barriers (Roling and Jiggins, 1998).

4.3. Differences in beliefs and predicted impacts based on socio-cultural conditions

Lastly, our results indicate that one of the villages showed community beliefs more consistent with the researchers as compared to the other villages. The close proximity of Thumka to the highway, accessibility to the market, and a greater degree of intervention by Non-Governmental Organizations, as compared with the other villages, may partly explain the similarity between Thumka and researcher communities' expectations regarding the impact of minimum tillage. Namely, increased levels of contact with agricultural Non-Governmental Organizations, may build farmers' trust in the agencies' capacity to introduce beneficial practices over both the long- and short-terms. This is reiterated by previous studies that have shown a positive correlation between institutional support and access to information with greater adoption of introduced practices (Bohlen et al., 2014; Kebede et al., 1990; Daberkow and McBride, 1998; Knowler and Bradshaw, 2007).

Nevertheless, power relations between development experts and local communities in the global South may make it difficult for farmers to question the developmentalist ideas introduced by government or Non-Governmental Organizations (Mitchell, 2002). To address this disconnect, it has been suggested that, social learning should occur among the different stakeholders engaged in development projects as a way to promote conditions of collaborative co-management where all parties acknowledge the value of the other's expertise (Schusler et al., 2003). 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, spatial, and social variability of the community perceptions regarding the agricultural system (Agrawal, 1995), as well as the ecological attributes and limitations of the local environment. It is also crucial that development practitioners be reflexive about the situatedness (c.f. Haraway, 1989) of approaches, concepts, and knowledge used in international development.

5. Conclusions

There are a number of factors that add to the perception and fundamental agricultural knowledge of rural subsistence farmers, as well as of researchers. This study first determined the factors important to farmers based on their perceptions and current farming practices, particularly in regards to conservation agriculture practices, such as tillage, and coupled this data with measured environmental variables and agricultural outcomes to compare among them. From the identified set of factors and their relationships to the 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 study groups. Researchers perceived a stronger positive relationship between soil conditions and conservation practices, which are consistent with scientific research for the long-term benefits of conservation agriculture. There are also differences among the villages in their perception of the relationship between tillage and soil moisture as well as between soil nutrients and yield. This has been linked to different ecological conditions, such as soil, as well as the farmers' inherent need to focus on the short-term benefits of cultivation practices. The implications of such varying perceptions means that extension personnel seeking to promote conservation agriculture practices in villages with differing ecological constraints may require alternate intervention strategies to address the immediate concerns of subsistence farmers while keeping future goals of conservation in mind. This includes fostering increased mutual understanding of agricultural beliefs, both from a farmer-to-researcher perspective and vice versa. 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. Researcher interactions with farmers should consider such local ecological variation and take in to account farmer's local ecological knowledge, as well as their agricultural priorities and concerns.

Developing knowledge of village perceptions with regards to the need for conservation practices to enrich the soil and increase yields can aid researchers and extension practitioners in devising optimal agricultural intervention strategies to meet the needs of communities and conservation objectives. Agricultural experience, local soil conditions, and traditional or learned knowledge all contribute to the 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/development agency perspectives to develop trust, mutual understanding, and improve the project design for the benefit of multi-stakeholder groups. Additionally, plans should incorporate short-term successes to meet farmers' immediate needs while contributing to long-term ecological sustainability. This research has demonstrated two important needs for practitioners and policymakers. 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.

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