INTRODUCING NEW TECHNOLOGIES FOR SUSTAINABLE AGRICULTURAL DEVELOPMENT IN MONGOLIA: TOWARDS A COLLABORATIVE AND EFFECTIVE EXTENSION SYSTEM

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ABSTRACT

A major goal for Mongolia is to eliminate rural poverty through sustainable rural development. To accomplish this, the agricultural sector must become more profitable and sustainable. Declining crop yields can be addressed by the adoption of new technology. Barriers to introduction of new agricultural technologies were evaluated using an inter-disciplinary perspective.

Field research was carried out to understand the factors affecting Mongolian farmers' decisions to adopt conservation farming practices. A semi-structured survey questionnaire was completed by 42 farmers and 30 extension agents and in-depth interviews were conducted with ten adopter-farmers in Mongolia. The introduction of conservation tillage was used to illustrate a technology transfer system and the challenges it poses.

To most of the farmers, the main advantages of this technology were reduced soil erosion, increased cost efficiency, and higher crop yields. The main disadvantages found were high investment costs, unreliable input supply, and a lack of knowledge of the technology. Factors that encourage adoption of new technologies include government financial incentives, reduced labor requirements, and increased production due to better soil and water conservation. A lack of investment capital, required inputs, and relevant knowledge were all identified as barriers for the utilization of such new technologies. In general, early adopters and non-adopters of conservation tillage differed in that the early adopters tended to have more farmland, livestock, and equipment. The field studies in Mongolia were complemented by field research trials in Canada that evaluated new technologies for weed control in conservation tillage systems.

One key to the successful adoption of new agriculture technologies is an effective and responsive research and extension system. Currently, for Mongolian farmers and extension agents, international projects are the main source of information with respect to new agricultural technologies. The capacity of local research and extension institutions is fairly limited. It will be important to establish better linkages among researchers, extension agents, farmers, and policy makers through reorganization and strengthening of Mongolia’s “top-down” research and extension system. Meaningful farmer participation must take place at all stages of any technology transfer process. Based on these principles, an interdisciplinary, inclusive, and responsive national agricultural research and extension model is proposed.

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Finally, completing a research project and graduate thesis requires a team effort and this is a team product. You all played well on this team and I thank you all sincerely.

DEDICATION

This thesis is dedicated:

To my mother, Bayabajargal Dorj, who taught me how to love and appreciate simple but important things in life;

To my father, Chuluunbaatar Sonom, who always inspired and supported me to climb the steep ladder of professional success;

Thanks, Mom and Dad.

-In Mongolian-

Энхүү Докторын бүтээлээ:

Амьдарлын энгийн болоод нандин чанаруудыг олж харж, хайрлан хүндлэх тэрхүү эрхэм чанарыг өвлүүлсэн, ачлалт ээж Бямбажаргал;

Амжилтын анхны амт, ирээдүйд ихийг бүтээх урам зориг, ухаан баялагаар дэмжин урамшуулсан, хайрт аав Чулуунбаатар;

Нартаа зориулнам.

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1. INTRODUCTION

Interdependence among different disciplines and dimensions of a society is unavoidable. One such component of any society is the agricultural production system; this includes the land, seeds, machinery, and various technologies. But what about the farmers, the people who actually work the land and utilize the technologies in order to generate an income? Farmers and their respective communities bring a human dimension to the agricultural system, which make the system both complete and complex. The biggest challenge for the researchers of agricultural technology is to understand how this human dimension in the agriculture system influences the technologies that are practiced at the farm. It is important for researchers in social science to understand how different technologies are developed and how farming problems are addressed through them, as well as what influence such technologies will have on farming communities. As such, it takes an interdisciplinary perspective to understand the complexity of the agricultural production system in relation to the broader human community.

Mongolia is a land-locked, remote country with very little infrastructure, a severe climate, and low population density. Administratively, the country is divided into 21 Aimags (provinces) with governors appointed by the federal government, and 331 Soums (districts). Geographically, about 70 percent of the country is shortgrass prairie and foothills, 20 percent has desert-like conditions (Gobi desert), and only about 10 percent is forested. The average annual precipitation is 320 millimeters with considerable regional differences. The average temperature is 1.1 degrees Celsius. The average frost-free period is between 95 and 104 days per year (National Statistical Office, 2007).

Agriculture is Mongolia's main economic sector and is dominated by nomadic livestock grazing. At the turn of the millennium, the agricultural sector contributed 35 percent of the national gross domestic product (GDP) and 49 percent of total employment (World Bank, 2007; National Statistics office, 2007). As of 2007, the GDP contribution from the agricultural sector had fallen to 21 percent with livestock production accounting for about 78 percent of the total agriculture output (National Statistical Office, 2007). A traditional nomadic lifestyle is still practiced by many rural people. The country's economy is highly dependent on the vagaries of the weather due to the significant impact of seasonal weather conditions on the agricultural industry. According to the UNDP (2009) country report, Mongolia has a per capita GDP of $3,236. In comparison to countries with similar economic conditions, the literacy rate in Mongolia, at 97.3 percent, is extraordinarily high (33rd in the world) (UNDP, 2009). This also holds true for farmers in rural areas; there is only a narrow gap between urban and rural literacy rates. High rates and levels of literacy among the rural agrarian population translate into a relatively high capacity to adopt and adapt new technologies.

In Mongolia, agricultural land includes grasslands, hayland, cropland, and so-called abandoned land. Grassland accounts for 81 percent of agricultural land and is a key foundation for the nomadic herding economy. From the early 1960s to 2000, a total of 1.2 million hectares of rangeland was broken for crop production. As a result of the intensive tillage practices used at the time, much of this land has suffered from erosion and declining soil fertility. Following the transition to a free market economy after 1990, much of this cropland was abandoned as a result of socio-economic changes and/or severe wind erosion (Stevens, 2007). On average, only about 497,000 hectares of cultivated land were used during the last two decades. This means that approximately 60 percent of cropland has been abandoned. Due to declining land utilization, wheat production has decreased by 65 percent compared to 1990 levels; potato and vegetable production is down by 20 percent; and forage production is down by 51 percent. In recent years, only one-fifth of the potentially arable land was planted, and, as a result, only 30 percent of domestic flour needs, 38 percent of potato needs, and 46 percent of vegetable needs have recently been met through local production (Mongolia Consultative Group Meeting, 2002). Various factors have contributed to these declines in production.

Prior to 1990, before the transition to a market economy, Mongolia was self-sufficient in many commodities and exported surplus production including wheat. During that time, under the centrally-planned economy, considerable attention was given to capacity building and human capital. Following the transition, large state-owned farms were converted to private joint-stock companies[1]. This resulted in the creation of many large, medium, and small-sized farms. Privatization of state-owned assets following the transition to a free market economy and multi-party democracy did not necessarily provide equal access to opportunities. The transition to a market economy, poorly managed privatization, and the collapse of the economy brought unemployment, a decline in social services, increased poverty, and many other social problems (Stevens and Rasmussen, 2004). By 1996, cropland under cultivation had decreased by one-third and average wheat yields had fallen from 1.5 tons/ha to 0.7 tons/ha. Consequently, Mongolia started importing food and grains in order to supply the majority of its food needs (Ganbaatar, 1999). This dramatic decline in production reflected the breakdown of the agricultural system, including loss of marketing channels for agriculture inputs and outputs, and also to a lack of knowledge about farm management, agricultural technology, and marketing.

During the transition period of radical restructuring of agriculture, including changes in farm ownership, government-funded public extension services largely ceased to function. Yet, with all these changes, the need for agricultural extension services was quite apparent. One response was the establishment of the National Agricultural Extension Centre (NAEC) in 1996 (Bat-Erdene, 2006).

Although Mongolia's economy has been recovering fairly steadily during the last decade, the agricultural sector still suffers from a lack of productivity and various related challenges such as:

- *Harsh and unpredictable weather patterns*: Very dry summers and cold winters, possibly accentuated by climate changes, create a major challenge for Mongolian agricultural producers. Over the last ten years, average annual precipitation in Mongolia has decreased 10-30 mm, and the average air

[1] Following the transition in 1990, certificates of ownership (or stocks) were issued by the company and given to all share holders, and the shareholders were free to transfer their ownership interest at any time by selling their stockholdings to others.

temperature has increased by 2.5 degrees C (Altansukh et al., 1999; Shagdarsuren, 2007). Drier and hotter conditions reduce crop yields as a result of increased evapotranspiration, reduced soil moisture levels, heat stress, and increased soil erosion.

- *Inadequate and outdated technologies and equipment*: Since privatization, most agricultural equipment on crop farms (including tractors and combines) has deteriorated and lost functionality. Repairs were not feasible and replacement parts were not available, so it was not possible to maintain farm equipment in good working order, let alone replace it with more up-to-date technology. Outdated and inefficient farm equipment makes it difficult to cultivate, plant, and harvest effectively, which results in poorer quality crops and reduced yields.

- *Problems procuring and applying inputs:* The high and increasing cost of imported inputs such as fertilizer and crop protection products puts them out of financial reach for many producers. Also, in many instances, inputs are simply not available, or are not delivered or made available in a timely manner. These challenges are compounded by poor application practices and malfunctioning equipment. Taken together, these problems undermine agronomic and economic success for individual farmers, but also put the efficacy and sustainability of the whole crop production system into question.

- *Lack of knowledge and management skills*: Under the new market-mediated conditions, access to knowledge and information on appropriate farming practices and effective use of new agricultural technologies is frequently spotty and unreliable.

- *Lack of effective marketing and distribution*: The breakdown of marketing channels for agriculture products and inputs creates significant income and cash-flow problems for farmers. This has had serious impacts on farm operations and on net returns.

- *Lack of capital*: On the heels of the transition to a free market economy, a crisis in the banking sector, inflation, high interest rates for both capital and production loans, and the termination of direct and indirect subsidies that were formerly provided by the government have all hurt Mongolian farmers' cash reserves and equity. At the time of writing, there was still no comprehensive agricultural finance and credit system in Mongolia. Many agricultural enterprises, including nomadic herdsmen and small-scale crop farmers, suffer from a lack of capital—and borrowing power—for developing their operations.

Since Mongolia began its transition to a market economy, every elected government has tried to implement programs to rehabilitate the crop production sector. These have included the promotion of a soil conservation program[2] through subsidized input supply and long-term, subsidized loans for equipment. The transition to democracy also opened doors to many international partners and increased access to external funds. During the last two decades, many internationally sponsored programs and projects in agricultural development have been implemented in Mongolia.

Although initiatives sponsored by international and bilateral donors reflect goals of a strategic nature, they tend to focus on particular projects and are not necessarily coordinated with national development priorities. Linkages to national research and extension institutions are also frequently absent. Augmenting the knowledge and various capacities of local research and extension institutes and personnel is crucial for the sustainable development of agriculture. The crop and livestock sectors in Mongolia suffer from low productivity, which contributes to low incomes and also to resource degradation. Institutional constraints in the areas of research, extension, and credit impede the introduction of new crops and farmer adoption of resource-conserving

[2] One of the major government programs to support farmers and boost agriculture production in Mongolia was "Fallow Project—2001". The purpose of the program was to support the application of minimum tillage and conservation farming technologies, which can reduce soil tillage costs, soil erosion, and improve soil moisture by reducing traditional mechanical soil tillage. Through this program, MNT 2.5 million was provided to crop farmers for the purchase of fuel and herbicides to ensure good fallow for the next season. This resulted in 275,000 ha of good quality fallow (with good weed control, water conservation, and even soil surface) out of which, 6,600 ha was chemical fallow. Farms that prepared chemical fallow had higher yield, but still could not completely achieve their production goals. This was, at least in part, because of inability to fully implement recommended minimum tillage practices and the full technological package.

technologies. The government of Mongolia has recognized and emphasized the centrality of agriculture in effectively addressing rural development challenges. It has, for example, supported the introduction of new technologies together with more effective technology transfer methods (Stevens and Rasmussen, 2004).

Damage caused by natural disasters and severe climatic events are among the serious challenges to sustainable agricultural development. These risks lead to declines in pasture productivity and crop yields, and to the mortality of large numbers of animals. These risks also lead herders and grain farmers to actively seek new methods and technologies that are more suited to the challenges of a changing environment, and more capable of sustaining and increasing production. To effectively address these agronomic, economic, and ecological challenges, there is a need for new scientific investigations and guidance, better training for research and extension personnel, and training opportunities for the farmers themselves. The situation also calls for enhanced coordination and collaboration and better dissemination of information.

To ensure that the development of rural Mongolia is sustained, efficient, and effective, extension services must be established that mobilize the energies and insights of all relevant stakeholders—including primary agricultural producers. A key factor for sustainable agricultural and rural development is the full and meaningful participation of farmers and other rural people. Involving farmers more fully will help to: a) improve the relevance of research to meeting local agricultural development challenges, b) enhance the development of a research system that is responsive to the needs and concerns of producers, and c) support the exchange and dissemination of information and knowledge that is necessary both for sustainable agricultural production and for development of a sustainable (regional and national) research and extension system (Gerber, 1992).

The current “top-down” system of agricultural research and extension in Mongolia does not allow farmers to participate in relevant decision-making processes and generally limits interactions, linkages, and effective communication between researchers, farmers, and other stakeholders. Although the Mongolian federal government established the

NAEC in 1996, it still has little connection with national research institutes, other researchers working in areas related to agriculture, or with farmers. More communication and coordination is needed between the different actors in government, as well as in the education, research, and extension sectors. This is one of the keys to better management and application of information and technologies for the improvement of agricultural production systems in Mongolia (Gungaadorj and Davaadorj, 2009).

Achieving sustainable rural development and eliminating rural poverty is a priority goal for Mongolia. Achieving this goal presents interdisciplinary challenges. A successful and sustainable agriculture industry can only be achieved when social, economic, and environmental factors are taken into consideration and treated as a closely related and interdependent set of concerns. Indeed, in order to improve the social and living conditions of rural communities, the rural economy must become more viable and this will happen only if the agricultural industry becomes more profitable and ecologically sustainable.

A first step to achieving improved agriculture production and social and economic conditions of farming communities is to better understand knowledge management systems–how knowledge is created, transferred, and utilized with particular emphasis on Mongolia's agricultural research and extension system. A clear conception of the roles and responsibilities of all agriculture research and extension stakeholders is required, as is an understanding of the socio-economic factors that influence agriculture producers and researchers. It will likewise be necessary to know more about the perceptions and viewpoints of Mongolian agricultural producers, and about the barriers they encounter with respect to the adoption of new technologies and techniques. Such knowledge will contribute to a better understanding of existing practices and contingencies, and is required to support the development of a more holistic and integrated system of agricultural research and extension.

The current agricultural research and extension system in Mongolia ignores interrelations and interdependences of the multiple dimensions that exist in the agricultural system as a whole. Gaps between the key stakeholders of the system are great. Collaboration among key players in the system are minimal. The independent functionality of actors weakens the system rendering it unsustainable, ineffective, and inefficient. Therefore, introducing a new model towards a collaborative and effective agricultural research and extension system will help fill the gaps and create important linkages among the actors for a sustainable agriculture system.

1.1. Objectives

Addressing sustainable development challenges in Mongolian agriculture requires an interdisciplinary understanding of farming systems, agronomic challenges and environmental realities, and the potential and limitations of competing agricultural technologies. It also requires an understanding of the structure and operating practices of Mongolia's agricultural research, training, and extension system. These latter concerns are central to this thesis since the principal goal of this project is the elaboration of an alternative model for the development of these institutions.

The understanding of factors affecting farmers' decisions to adopt conservation farming practices and a deeper understanding of farming systems and the potential barriers to implementation of new practices was required in order to be able to develop a model for a more effective and responsive extension system for Mongolia.

The agronomic, sociological, and extension research carried out—both field work and library work—were complementary to each other and useful in both providing the knowledge required to write this dissertation and to fulfill the interdisciplinary educational goals of this doctoral program. The research drew on three main disciplinary fields, each of which itself is a complex combination of specialties and subfields:

1. Agriculture science (Department of Plant Sciences and Soil Science, University of Saskatchewan)—field experiments on different weed control methods including tillage and herbicide were carried out in order to understand the

researcher point of view towards solving farm problems by generating and disseminating new information and technologies;

2. Rural sociology—a field study using both quantitative and qualitative methods was conducted in Mongolia to identify the most influential social, economic, and environmental factors affecting farmers' decisions related to adoption of new technologies (case study: conservation farming technology); and

3. Agriculture extension—based on experiences and field studies, an extension model for the Mongolian agriculture system is proposed.

1.2. Methodologies[3]

A research project was designed and implemented focusing on the current agricultural research and extension system in Mongolia but keeping in the foreground the perceptions of farmers and the socio-economic and agronomic factors that influence farmer decision-making. The field research was carried out in several venues and was also diverse in terms of the research modalities and disciplinary and interdisciplinary information that was mobilized.

The case study on the most recent example of a technology transfer (introduction of conservation tillage farming practices) in Mongolia was used to better understand the real process of technology transfer and adoption in practice. This included participation in, and observation of, several projects designed to introduce conservation tillage practices in Mongolia. Farmer experiences with these technologies and, with the agencies and personnel that were promoting their introduction were further studied through a survey questionnaire and in-depth interviews. Additional perspectives on the technologies and on the efficacy of extension efforts were gathered through a survey of extension personnel.

A set of tillage and herbicide field trials was carried out in Saskatchewan, Canada, in a grassland region with soil and climate conditions broadly comparable to those of the

[3] Detailed methodologies for each disciplinary study are described in the beginning of each chapter discussing concerned research objectives.

cereal-producing regions of Mongolia. These field experiments were designed to familiarize the writer with weed-control problems and other potential issues in the use of conservation tillage systems and some ways that these challenges could be addressed through modification of the cropping/cultivation system.

2. KNOWLEDGE AND NEW TECHNOLOGY: CREATION, TRANSFER, AND ADOPTION

What is knowledge and where would we find it? Where and when did the first agriculture technology evolve and start to be used? Was something like science involved? Were there lessons learned by farmers? Was the growth of knowledge the result of purposeful activity or a complete accident? Often, doing something differently might have been just the result of practical reasoning. Likely, mistakes were made and positive improvements could have occurred by chance. Accidental discoveries in the process of doing something can make humans understand how and why things happen the way they do. Since humans are intelligent creatures, they try to find ways to improve their practices or to control a situation. Depth and breadth of knowledge have become greater through time. For instance, take the science and technology of the Inca peoples. Their interpretations and communication with nature, earth, sun and moon were amazingly complicated and now we know that many recognized scientific principles were involved. Many observations about nature were religiously interpreted rather than scientifically explained. Of course, in that time, nobody talked about codifying knowledge or cognitive knowledge. Terms like knowledge creation, organization, transfer, and adoption were likely unknown or unused. When knowledge is not codified and systematically organized, people frequently tend to be unaware of the depth of knowledge that is being used. Different types of knowledge and practices were found and used among different groups of people. Gradually, through time, their knowledge and practices were dispersed among different groups allowing the integration and development of new knowledge and practices. Nevertheless, this slow and subtle process of technology development and/or exchange of knowledge and practices was not formally noted and recorded. In our contemporary world, researchers try to organize and codify knowledge and its creation, transfer, and utilization (Hassanein, 1999; Nonaka, 1991).

This chapter will focus on issues around contemporary agricultural information, knowledge, technology, and its creation, organization, transfer, adaptation, and adoption. Let us think about agriculture in its earliest phases and what kinds of production systems were used. The stages of technological development and adoption that farmers undertook were many. Many questions surround the creation, diffusion, adoption, and application of new agriculture technologies, how those technologies were invented and implemented by agricultural producers, and how information was transferred to farmers. A little more than a century ago, farmers relied primarily on themselves and their neighbours for the transfer of important information. Today, the development of agricultural knowledge and technology is a primary objective of research, education, publicly supported transfer, and dissemination institutions. Institutionalization of agricultural knowledge and practices has been a necessary outcome of modern governance systems. The speed and depth of knowledge and technology generation, and development of new practices has been rapid and crucial in modern society. Nonetheless, it does not mean agricultural production per unit of land has always increased, even if the efficiency of the production system may have improved with advancement of agricultural technology. What this means to people and how this efficiency affects farmers' and rural people's lives are questions that need to be discussed.

2.1. Knowledge in Relation to Information

"Knowledge is information in action, information focused on results".

Peter F. Drucker

There are many ways of conceiving of the relationship between knowledge and information[4]. The concept of knowledge is often confused with concepts of information and data. Perhaps it is best to think of them as having a kind of symbiotic relationship.

Data are simply the result of empirical inquiry. Data itself make no sense and have no meaning unless the collected data are analyzed and interpreted.

[4]According to the *Oxford English Dictionary*, knowledge is expertise and skills acquired by a person through experience or education including the theoretical or practical understanding of a subject. There is however no single agreed definition of knowledge at present, nor any prospect of one, and there remain numerous competing theories. One of the well-known theories of Nonaka (1991)—Spiral of Knowledge—says that "Knowledge is a dynamic process of justifying personal belief toward the' truth".
Whereas information is "fact or circumstance of which one is told" and/or "Separated from, or without the implication of, reference to a person informed: that which inheres in one of two or more alternative sequences, arrangements, etc., that produce different responses in something, and which is capable of being stored in, transferred by, and communicated to inanimate things." (http://dictionary.oed.com).
Information is the result of processing, manipulating and organizing data in a way that builds the knowledge of the person receiving it.

Once interpreted using an understanding of relevant concepts, calculations, and background literature, data become "information". Both information and data are subject to analyses and interpretations. However, information can be misunderstood, or misinterpreted. This is why in science; research trials are replicated in time and space to mitigate misrepresentation and misinterpretation.

In order for information to become knowledge, it must be understood, believed, and its truth tested/experienced to be true. Therefore, knowledge cannot be transferred or transmitted readily like information because understanding cannot be transmitted—at least not in the same way that information can be transmitted.

Box 1. Knowledge in Relation to Information

If I say "I know that X" (where "X" might be that a certain fertilizer will result in a two-fold increase in yield of a certain crop), I am saying that I believe that "X";

(1) *In what are known as strong cases of knowing, I would also be claiming that "X" is true;*

(2) *I have (sufficient) evidence for the belief that "X" is true.*

The farmer might claim to know "X" because, having used the fertilizer, he has experienced the increased yield two or three times. The scientist who claims to know that "X" might have experimented with the fertilizer many times in different conditions and, furthermore, she claims to know why the fertilizer works. Both the farmer and the scientist claim to know "X"; only the evidential basis is different.

To be informed that "X" is to say that someone else understands what the claim "X" means and, furthermore, believes that "X" is true. But to receive information does not imply necessarily that the recipient had any evidence to believe that "X". These looser conditions allow us to say that perhaps in this case she has been misinformed. The farmer might just take that claim on faith or accept the authority of the scientist who is passing along the information, or perhaps she is urging the farmer to use the fertilizer in the next crop season. That is, sometimes, information is simply believed and in other cases, it is used as the basis for action.

To summarize, as illustrated in the Box 1, an information proposition becomes a knowledge proposition when someone believes it, when it is true, and, in strong cases, when the person has the evidence to ground the belief.

People can use their knowledge to create new information, but information can also help to develop new knowledge. In other words, new information is produced based on existing knowledge (or new findings possessed by an individual) and is codified in a form that can be understood and which can be stored and transferred. So the question here is, "Can knowledge be stored, transferred, disseminated from one place to another?” According to Nonaka (1991), knowledge is person-oriented. Therefore, in order to transfer knowledge, it has to be converted to a form of information which can be stored, transferred, and delivered to another mind. Consequently, knowledge is developed in a person based on the received information and experience, after certain analyses, thinking, utilization, and the application of truth tests. Thus, once results from research projects are obtained, they become a source of information that can be accessible to others if appropriate. After the information is obtained and dispersed to others, it evolves into a component of knowledge of the user if it is understood and used in the right context. Therefore, in theory, a knowledge system can be distinguished from an information system, but they are intimately interconnected and interdependent.

As shown in Figure 1, when data are codified and interpreted in a certain way, information is produced; then, when information is applied in an action, it can be transformed into “practical knowledge”; and finally, Boisot (2002) claims, knowledge can become wisdom.

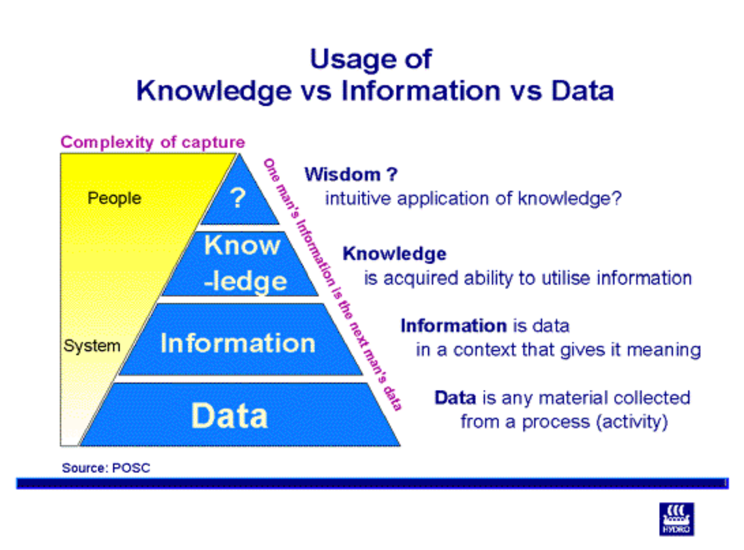

Figure 1: Illustration of knowledge vs. information (Biosot, 2002)

Not all information should be converted into knowledge. Only information that helps people understand and act in a certain way needs to become knowledge. Information that is put into use and context contributes to the creation of knowledge. However without a context, it is still information–-not knowledge. Information that is received is sorted by its relevance and only a portion of it is kept for use. In order to convert information into knowledge, an individual has to engage received information within a given social, economic, cultural, and environmental setting. Information is given to people to build knowledge in their own context. However, later this knowledge also becomes the foundation for generating new information.

Knowledge is accumulated through a process of analysing, testing, and conceptualizing, and it becomes personal property, whereas, information is a product which can be archived, transferred, and used (Hassanein and Kloppenburg, 1995). Many institutions—including research, educational, government, and non-government organizations—believe that they produce knowledge. Similarly, agriculture extension agencies talk about transferring knowledge, instead of transferring information that may help in building knowledge. One might argue that knowledge can be transferred provided that either they—the agencies—possess the evidence for the truth of the propositions or they pass along the evidence to the recipients. However, for the recipients, that knowledge is just information until evidential conditions are met.

Organizations produce information using their knowledge[5] resources and expertise. When that organizational information is transferred, and used to understand certain things, it becomes different types of knowledge depending on who receives it and for what it is used.

2.1.1. Types of knowledge

There are different types of knowledge. Classification of knowledge varies through its association and form. In terms of ownership or association, knowledge can be classified as individual knowledge, organizational or institutional knowledge, or community knowledge. In terms of form, knowledge can be informal or formal. Informal knowledge is mainly associated with local people and includes common knowledge, local knowledge, folk knowledge, indigenous knowledge, and tacit knowledge, whereas

[5] Organizational knowledge is the knowledge that is in the heads of people, processes, technology, and other sources within an organization. Organizations can have a rich knowledge in their expertise, but, to those outside of the organizations, they are only able to provide information based on their organizational knowledge and expertise.

formal knowledge often refers to scientific knowledge, technical knowledge, and academic knowledge which are often associated with formal institutions. Often, informal knowledge is based primarily on inherited beliefs, perspectives, habits, and experiences that are accumulated over generations. Also, it is habitually taken for granted (Nonaka, 1991; Pigg, 1992; Rhodes, 1989) and, most often, it is not recognized by formal communities such as researchers and academics. Some informal knowledge is based on knowing how and why certain things happen or occur in certain ways. Sometimes, people just know how and what to do even without complete understanding of the underlying assumptions and some of the practical consequences.

Formal knowledge comes as a result of institutional processes, technologies, and interaction between researchers. Hassanein (1999) said that the term “knowledge” refers to both technical information about specific topics and ideological assumptions that are built from practice. Informal and formal knowledge are not totally distinct. They have, rather, mutually inter-related elements: “They interact with, and change into, each other in the creative activities of human beings” (Nonaka et. al., 1996). Therefore, they should be seen as complementary rather than in opposition.

2.1.2. Agriculture knowledge: formal versus informal

Agricultural knowledge can be differentiated into two types: a) farm-based knowledge, and b) research-based knowledge (Rhodes, 1989). An agricultural knowledge system includes both types of knowledge, and the best form of an agricultural knowledge system occurs when the formal (research-based) knowledge and informal (farm-based) knowledge are integrated. Holistic integration of those two types of agricultural knowledge is considered a key requisite in sustainable agricultural development (Rhodes, 1989). There have been lengthy debates about the differences between these two types of knowledge systems. One position is that these systems are qualitatively different and, therefore, not compatible (Hassanien, 1999). Farmers’ knowledge is often not verbally and numerically codified, and is often inseparable from their behavior, while being affected by geography, culture, and society (Sutherland, 1999), whereas formal science tries to validate and codify knowledge systematically as well as quantitatively

(Rhodes, 1989; Sutherland, 1999). Another position argues that these two types of knowledge should not be seen as systems, yet should be used as an engagement space to explore commonalities (Scoones and Thompson, 1994). Others have argued that farmers approach research in a similar way to researchers and make conclusions in a similar manner (Okali et al., 1994). This may be one of the reasons that the gap between farmers and researchers has decreased in contemporary society. It includes positive changes that have been made in government programs, researchers' and farmers' attitudes and acceptance of each other, and farmers' perceptions of research and research institutions. As a result, differences between the farmer and researcher knowledge systems have faded, and integration between these two groups and their knowledge systems has increased. However, a seamless interface between farmers and researchers is often not easy to achieve (Sutherland, 1999) nor is it clear that this would be only a positive development.

The value of local and/or farmer knowledge is becoming more and more recognized and credited. Gerber (1992) suggested that farmers' understanding of how multiple variables affect each other and their observations of practical solutions produce more experiential knowledge and understanding. Subsequently, this knowledge and understanding derived from a farm-based experiment is much more powerful or effective than research institute-based knowledge in influencing farmers' decisions. Farm-based knowledge and information (local knowledge) is practical, personal, and developed in relation to distinctive yet active social and physical features of local areas. Therefore, it is crucial to emphasize local knowledge and information for sustainable rural development, and to allow farmers to play a key role in the strategic development of agricultural systems without replacing the involvement of scientific research and development. Indeed, science is necessary to maintain the generation of fundamental theories and enables validation of practical knowledge. In short, it is important to recognize and value the different knowledge systems that are available, and to embrace a variety of knowledge and information systems from a variety of sources.

2.1.3. Agricultural knowledge management

A little more than a century ago, farmers depended primarily on themselves and their neighbors for information. However, agricultural knowledge and information are now a focus of academic education and research with investigation and dissemination the responsibility of many organizations. From the 1960s to the 1970s, numerous studies were conducted on the process of knowledge generation, transfer, research innovation, form of knowledge, and decision-making. From the many studies on knowledge management, it becomes evident that:

- most rural producers or farmers are not aware of all existing information sources and research innovations;
- if they are aware, it may be physically, cognitively, and temporarily inaccessible to them;
- if research knowledge and information are accessible, it is often irrelevant to their needs and interests (Habermas, 1971; Bell, 1973; Weiss, 1977, 1979).

However, like everything else, there are exceptions and it might not hold true in some parts of the developed world where farmers may have had a university education, and the communication system is advanced. In such cases, many of the gaps between farmers and researchers have been removed, and most farmers have access to the internet and other databases.

This, however, it is not the case in many developing countries, such as Mongolia, where a hierarchy still exists between government and farmers. Research organizations lack resources, and extension services are not well established. Therefore, misunderstanding of technology, transferring of inappropriate techniques, and trying to force adoptions can be commonplace. In many cases, government agencies do not possess the information and technologies that are currently available from other areas and do not have access to them. Thus, in these cases, it is like the blind leading the blind. Obvious solutions to these issues would increase awareness and accessibility, and improve the relevance to producers.

In contemporary society, increasing communication is accomplished in many locations at the same time via the internet, video conferencing, multi-media, and various forms of distance education. However, in many developing countries, only a few or none of these dissemination pathways are available, and face-to-face methods such as in-person training sessions are still commonly used and are still the most effective. Unfortunately, many rural producers have limited accessibility to information for various reasons. These reasons or barriers to the new technologies and information can be personal, cultural, infrastructural, or governmental. Removing these barriers will require a significant amount of time and economic development. However, some of these barriers can be removed simply by making information and training materials available and easily understood. For instance, making training materials suitable for the trainees' background and circumstances sounds easy, but, in reality, strategies such as using plain language to explain research results, reducing volume or quantity by summarizing key points, and employing graphical illustration are not well utilized, in most developing countries. Finally, the relevance of the information and technology is a crucial issue.

Although sociologists identified knowledge and technology-related issues a long time ago and suggested some potential solutions for them, the level of knowledge management and utilization processes remains low. The knowledge system is the institutionalized system of roles, norms, values, and resources by which knowledge-related processes are carried out (Holzner and Marx, 1979). According to Holzner and Marx (1979), knowledge-related processes include production, organization, storage, retrieval, distribution, and application of knowledge. Even though these knowledge-related processes in knowledge-management systems could apply to most types of knowledge, they are primarily designed and used for scientific and/or institutionalized knowledge systems. Different institutions are specialized in different knowledge systems or different elements of a complete knowledge system. Therefore, overall, a knowledge system encompasses a range of institutions and organizations that fulfill different elements of a complete knowledge system such as creation, transfer, organization, storage, and application of knowledge.

2.1.3.1. Creation of new agricultural knowledge and technology

Throughout agricultural history, farmers have been generating knowledge and information necessary for their farming practices. In fact, knowledge and information that have evolved from the farm have influenced agricultural development in various ways (Rhodes, 1989; Hassanien, 1999; Buckland, 2004). However, knowledge generation mainly refers to scientific information generation and technology creation. In this perspective, universities and other academic institutions are the primary homes for the knowledge or information generating process. However, this process is closely linked to, and influenced by, social, legal, ethical, cultural, governmental, and infrastructural settings pertaining to farming societies. Knowledge production from research organizations increasingly tends to be protected and capitalized because it is understood to be "intellectual property" and is not always freely and publicly available. In this chapter, consideration will be given mostly to knowledge and technology generation at an institution–formal or scientific knowledge.

The drivers of technological change in agriculture are complex. Two main factors can influence technological changes in food production technology: first, supply-side or production side; and second, demand-side or consumption side (Buckland, 2004). Supply-side refers to the factors related to farming systems such as the availability of land, base cropping practices, equipment, water, seeds, fertilizers, pesticides, and farmer family characteristics. For example, soil erosion, new crop varieties or diversification, and the need for farm employment would be drivers on the supply side that contribute to new technology creation. Demand-side refers to the factors that influence agriculture indirectly via food consumption. It includes issues like food safety, taste, packaging, processing, and marketing. For example, the concept of organic food brought together its own production system as well as its own consumers and food markets. Specific organic farming technology is required to accommodate organic food production demand. These supply and demand sides have acted interdependently (Buckland, 2004).

Another cause of new technology generation is the market economy, private industries, and other agri-businesses (Hall, 2003; Agbamu, 2000). Just as the demand or consumer side influences new innovations, the private industry sector, agri-businesses, and agri-market influence technology development as well. They can have an influence through their products, services, and the investment opportunities provided. Furthermore, involvement of private sector is also political. Governments, especially in the developing world, have power to shape or influence agricultural production and technology development in any direction that they think is right. But, sometimes, political influences in technology transfer may not be very visible to some groups. For instance, agribusinesses are involved in research projects that will favor their production chain and product sale adoption. Likewise, governments can control the direction of research and technology development through their funding and subsidies. In the cases of farm input companies, they sponsor research projects that can positively influence the volume of sales and diversity of products offered. In direct seeding technology, herbicides are used for weed control without soil disturbance. It works and achieves the purpose. However, new issues have arisen as a result of direct seeding practices, such as new weed infestations like dandelion[6] and weed resistance to herbicides. Solutions that chemical companies suggest to control new problems include the development of herbicide tolerant crops and new herbicides (Duffy, 1999). Chemical companies are willing to provide funding for research projects that will support their new product development. It has been suggested that science has been unduly influenced by industries (Hassanien, 1999; Beyonon, et al., 1998).

Although this can hold true in some research communities, it can also be argued that, from personal observations and experiences of interaction with scientific communities, it is natural to find a contradiction in any technology or practice. Everything is likely to have both pros and cons. Funds are available to examine both the pros and cons of new technology and research projects are based on combinations of industry, producer, and government support. Thanks to the diversity in the industries, research programs,

[6] Dandelion is a perennial weed that has become a one of the major weeds in the North America where direct seeding technology is commonly practiced (Stevenson and Johnston, 1999).

and communities, a wide range of research projects exist to evaluate both positive and negative aspects of any technology.

2.1.3.2. Organization of new knowledge: storage and retrieval

Organization of knowledge refers to the structuring of existing knowledge into explicit, codified, and coherent bodies. Clearly, scientific knowledge is structured and codified by its subject matter and/or classification using, for example, a library system. Traditionally, libraries and archives are the main institutes of knowledge and information storage and retrieval. However, in contemporary society, computer databases with multi-media, digital storage, and retrievals are also included. Information and knowledge systems are becoming sophisticated and advancing quite rapidly with increasing ease of access. At the same time, an increased risk with respect to the security and the reliability of information sources is also becoming a concern (Nonaka, 1991).

2.2. Information and Technology Transfer in Agriculture

Technology transfer refers to a wide range of transfers from a piece of information related to a specific aspect of production such as weed control to the complete technology package for farm management or a farming system. However, information transfer must not be seen as a one-way process from researcher to farmers. Francis (1990) stated that farmers seek two types of information. First, farmers look for new ideas and/or new information to support decision-making about a new technology. Second, they look for more information to update their general knowledge and awareness about the farming community and agricultural system. Farmers also produce powerful and promising sources of new knowledge and technology from the grassroots, which can be very useful for the development of an alternative agriculture technology (Hassanien and Kloppenburg, 1995). Therefore, information transfer has to be a two-way process in order to fulfill each other’s needs appropriately and efficiently. As an example, the Indonesian government tried to promote the technology of bench terracing without any assessment and involvement from farmers or producer groups. However, this technology was not introduced successfully to Indonesian farmers as it was not well suited to their conditions. Later, the government began to understand the importance of grass-root level involvement and assessment. From the lesson learned, the government established on-farm experimentation to demonstrate conservation farming practices. It turned out to be a success story in the end because a) the technology was appropriate for the Indonesian farming systems; b) farmers were involved in the technology development and demonstration process; c) trials were carried out on farms, and d) farmers followed or learned from one another, not only from the government (Agus et al., 1998).

2.2.1. Agricultural extension

"Extension is a system of non-formal education." Boone, E. J. 1985.

Technology transfer activities and processes are referred to as "extension". Extension is a term that is used in agriculture and involves all actions that transfer any form of information from one place and person to another place and person. Agricultural extension plays an important role in national development throughout the world. Extension has been described as the largest institutional development effort the world has known (Anderson and Feder, 2003). Often, extension agents or departments are affiliated under an umbrella of governmental and non-governmental organizations. Agricultural extension is a key to agricultural and rural development. It also is a two-way bridge between research and adoption of effective farming practices. Extension passes information from researchers to farmers and from farmers to researchers. There are many definitions of extension, all having similarities. Most of them agree that extension is basically an educational process aimed at voluntary change, even though the immediate success of an extension activity is measured usually by the number of farmers adopting a new technology or making some kind of change in their farming practices (Anderson and Feder, 2003). In theory, extension is supposed to transfer information and technology from an unbiased view point, and it aims for voluntary changes. However, in reality, many extension agents filter or pick and choose what they promote. Often, this is due to their governance and funding systems. Therefore, it is important to have a variety of private and public organizations and agencies delivering information, and introducing different technologies and practices. The competition or variety in extension services will provide options for farmers to consider.

Extension services bring information and new practices that can be adopted to improve farm production as well as the living standard of rural communities (Hanyani-Mlambo, 2002). Productivity improvement can only occur if there is a gap between the actual productivity and potential productivity. Therefore, extension services aim to identify those gaps, and fill them by delivering appropriate information to help farmers with their production systems. However, extension should not only aim to reduce differences between actual and potential production; it should also play an important role in helping researchers understand agro-ecological and socio-economical conditions of farmers. In this sense, it should be a bridge between research and science knowledge oriented people, and practice and industry-oriented people (Blum et al., 1990).

The major goals of agricultural extension services are a) helping people identify their problems and identify their own solutions; b) assembling and transferring indigenous knowledge; c) bringing new ideas and innovations to farmers; d) providing technical advice and encouragement; e) inspiring farmers with community actions; and f) improving the two-way exchange of information between farmers and researchers (Mercado et al., 1998; Hanyani-Mlambo, 2002). Also, extension attempts to improve farmer/rural people's livelihood and living conditions. Extension efforts try to convince them of the value of scientific information and technology and expose them to different approaches for management of their farms. Transferring technology from a lab to the field has traditionally been a significant challenge for extension workers. Nowadays, many information sources are available for agricultural educators, facilitators, and farmers. In order to be effective and efficient, this vast supply of knowledge and information must be integrated, objectively evaluated, and systematically transferred to farmers (Barao, 1992). Unfortunately, in many places extension institutions—both government and non-government—compete with each other instead of collaborating. Their sources of funding, clients, and political lobbies are likely influential factors affecting competition versus collaboration. Besides, it would not be reasonable to expect one extension organization in an agricultural system—such as an extension department in a Ministry of Agriculture—to provide services that meet the needs for all producers. While there is considerable variation in agricultural practices due to the location of a farm, landscape, climate, and culture of the area, extension personnel should be able to select the appropriate technologies for specific areas, and be equipped with agricultural and environmental skills (Arnon, 1989; Agus et al., 1998). Consequently, in order to facilitate technology transfer successfully, and achieve the adoption of new practices effectively, extension agents need to understand the following: 1) processes and factors that are involved in the technology transfer and adoption of innovation; 2) how ideas and practices are communicated among farmers; and 3) how they decide to adopt or reject a new technology (Bentham, 2000).

2.2.2. Extension models

Many different methods have been used in the transfer of information and technology. Often, some combination of all available methods and approaches is more effective than just one. One of the approaches becoming popular is the participatory approach that involves farmers in the whole process, including information delivery to decision-making (Mercado et al., 1998). Some use the term "learning opportunity approach" for this as opposed to the "blue print approach" (Gross and Martin, 1952). Although a farmer participatory approach has been identified as the most appropriate and sustainable way of developing and transferring new technologies, other traditional extension methods have been continuously used, including the training and visit approach, farmer-to-farmer approach, and cooperative extension approach (Arnon, 1989). Indeed, there is no single extension model for technology transfer that works best worldwide. Extension systems or models vary depending on country, culture, and farming practices. Many classifications of extension systems or models are available as mentioned. However, the extension models and systems that are most commonly used can be grouped into the following four categories (Rivera, 2001; Anderson and Feder, 2003):

1. A typical developing country extension system;
2. Training and visit model;
3. Farming systems research and development model; and

4. United States Cooperative Extension System model.

Their goals can be similar or different: educational, regulatory and/or mixed (blend of research, education, and profit), and depend on affiliation, funding sources, and the country (Rivera, 2001). However, all of these models have some common ground and very similar purposes, which makes it possible for them to be integrated.

2.2.2.1. Typical Developing Country Extension Model

The typical Developing Country Extension Model differs from other extension models in several ways. Singh and Singh (1994) and Morris (1983) have identified some important characteristics of this model, one of which is that extension systems in developing countries tend to be top-down. In addition, extension systems in developing countries usually are established apart from research and academic institutions. Often, they are affiliated with government agencies—for example, a department or a ministry of agriculture (Roling, 1987). It automatically establishes bureaucratic connections and motive in facilitation and transfer of new information and technology. Also, this type of extension system is subject to fairly direct political control. According to Anderson and Feder (2003), there are about 800,000 official agricultural extension workers worldwide and 80 percent of them are publicly funded. This means they are directly dependent on, or employed by, a government, and the government controls their programs. In addition, more than 90 percent of the extension personnel in the world are located in developing countries (Umali and Schwartz, 1994) where the majority of farmers are located (Anderson and Feder, 2003). One of the common issues of extension systems in developing countries is that extension personnel are not involved in research and demonstration like scientists at research and academic institutions. Therefore, extension personnel often lack the most updated knowledge, information, and in-depth understanding of a new technology that is being transferred. Usually, there are great gaps between researchers and extension organizations in developing countries. As well, government extension agents tend to be disconnected from researchers and researchers at other institutions have limited funding or interest in disseminating their research results. Also, the sense of competition, unawareness, and ego among extension personnel and researchers can discourage communication and cooperation between them.

One of the very common forms of a typical developing country extension model is a form of the public extension system. Public extension services are normally publicly funded and often government-run (Anderson and Feder, 2003). They are often free and available to large numbers of farmers. Consequently, it is especially useful in the earlier stages of the technology transfer process–building awareness and dissemination of information. Over time, as farmers' awareness about specific technologies and techniques has increased, the impact of, and requirement for, extension services are diminished—especially preliminary public extension (Byerlee, 1998). For example, in Western Canada, there were extension agents in every county in the 1980s. But their numbers have been greatly reduced in most provinces and there may now be as few as three to six extension agents for an entire province (Janssen, personal communication, 2005).

While the public extension model has been remarkably successful, it also has demonstrated some weaknesses with regard to effectiveness (Anderson and Feder, 2003; Rivera et al., 2001; Ameur, 1994). The universal challenge is that public extension systems operate within the typical bureaucratic and political environment within which they are financed and managed (Water-Beyer, 1989; Feder et al., 2001). Therefore, they fall under top-down extension management, and do not usually employ participatory methods for delivering information and prioritizing research and extension. It means often there is very limited involvement from farmers and their voice is hardly heard by decision makers. Also, in most developing countries, research and extension departments are not structured under the same umbrella (Roling, 1987). They are established with separate structures and management systems, and they often compete with each other over budgets and programs (Mureithi and Anderson, 2002). Also, scientific research projects often do not include the cost of information dissemination in their budgets. Therefore, as there is no effective interaction between research and extension, information and technology generated by research institutions may not be targeted for solving problems on the farm directly. In many developed countries, research and extension are frequently covered by the same management, and research grants usually include budget for activities that help disseminate the research results (B. Harvey, personal communication). Especially in developing countries, the number of clients that need to be supported by extension services is large and mass media and other communication tools are limited. This creates a high cost for disseminating information via extension services as it limits the number of farmers that can access the services. This raises the question of who gains access to the extension services. The selection of farmers for extension programs usually favors large farmers who generally are more innovative and can promise better cooperation and more in-kind contributions. Those farmers who are selected for direct extension contact are often not typical farmers (Roling, 1987; Van den Ban, 1999). Another major challenge for public extension is cost recovery, self-sufficiency, and sustainability. Public funding is problematic because of a weak political commitment and lower budgets, yet a large number of clientele need to be served. Lowering the budget reduces not only the quantity of extension activities, but it also reduces their quality and diversity of services. It also potentially limits the type of information and technology that is being transferred by public extension (FAO, 2002).

2.2.2.2. Training and Visit Extension Model (T&V)

The Training and Visit (T&V) Model was first demonstrated in India in 1977 through a World Bank project (Pickering, 1983); then, it was used quite extensively in African countries. The aim of this system is to enhance the effectiveness of extension services via structured training sessions and then a delivery system (Feder et al., 2001; Hanson and Just, 2001). During 1975–1995, the World Bank promoted this model very intensively and successfully implemented it in more than seventy countries (Umali and Schwartz, 1994). This model is based on successive intensive training sessions with a hierarchy of supervisory staff (Feder et al., 2001). In other words, recommendations and information from national and international organizations are packaged to train extension agents and subject-matter specialists, who train village extension personnel. Then, they deliver that knowledge and information to farmers through frequent visits to farm fields. Those local extension agents work under direct supervision of their government agriculture extension department. However, unlike a typical developing country extension system, extension personnel in the T&V Model are not obligated to do any regulatory work (Kumuk and Crowder, 1996). Their main job is to train farmers by transmitting information, and revisit them to provide more guidance. The T&V Model takes action at the grass-roots level of the agriculture production system—training and visiting farmers. However, in this model, farmers are seen only as receivers of the information and technology that is provided.

Although this model is used worldwide and is recognized as one of the best approaches, there are some concerns: the flow of information, even distribution of information to all farmers—rich and poor (Hanyani-Mlambo, 2002), focuses only on passing information to farmers, instead of developing skills and techniques with, or from, farmers (Kumuk and Crowder, 1996) in a "learn-by-doing" setting. It also requires a higher number of staff and the cost is 25-40 percent higher than for most other extension systems (Feder and Slade, 1993). Also, being dependent on government budget allocation and resources makes T&V systems vulnerable and limited.

2.2.2.3. Research and Development Extension Model (R&D)

The Research and Development Extension Model began with the objective of supporting small-scale family farmers and improving their living conditions by increasing agricultural production. Shaner et al. (1982) identified five major components of the model including: 1) selecting a research site–selecting a farm, 2) identifying farm problems and assessing the research base, 3) planning and developing research demonstrations, 4) conducting and analyzing research projects, and 5) disseminating outcomes and delivery of extension activities. This model uses on-farm trials and diagnoses as a key to facilitating linkages among farmers, researchers, and extension personnel (Anderson and Feder, 2003). Farmer collaboration is the key to the success of this system. Also, understanding of farmers' culture, needs, perceptions, and socio-economic situation results in better cooperation and participation from parties that are involved. This approach not only increases farmers' participation in research, but it also helps to ensure that a multidisciplinary approach is maintained through the involvement of different parties. Nonetheless, this model has not yet been practiced in many parts of the world.

2.2.2.4. Cooperative Extension System Model

The U.S. Cooperative Extension Service system (USCES), a large extension system widely used in the United States, was established by Land Grant Institutions in the 1890s to deliver institutional knowledge in the areas of agriculture and home economics (Sander et al., 1966; Kerka, 1998). Thus, state and local governments share control and funding over the USCES (Sander et al., 1966). It requires a large organizational structure but allows reasonable flexibility in the selection of programs. In the U.S.A., the cooperative extension services are located in, or affiliated with, universities where most cognitive information generation takes place (Anderson and Feder, 2003). In contrast, in most developing countries, the extension service agencies are not affiliated with information/knowledge generating institutions. Since research and extension organizations are structured under separate systems and managements, extension priorities do not play a significant role in research in most developing countries (Anderson and Feder, 2003). Therefore, often new information and/or research results are not transferred to farmers, and there is little interaction between researchers and farmers.

2.2.3. Technology transfer and extension tools and approaches

Buckland (2004) defines technology as a "systematic application of collective human rationality to the solution of problems by asserting control over nature and over human process". Like knowledge, the nature and even the definitions of technology have long been debated. Some assume technology is an answer to social problems like hunger. In this respect, technology is expected to create momentum in agricultural production and, therefore, help fix both social and economic problems. Others suggest that, in general, technology creates short-term benefits to some, but causes long-term costs for most people and the environment (Buckland, 2004). For instance, in direct-seeding technology, chemicals might have positive effects on weed control, but eventually they might cause environmental and health problems due to their inherent characteristics, unforeseen agro-ecological interactions, and/or inappropriate use. Appropriate technology transfer can make improvements in agricultural production systems by positively influencing the social and economic well-being of the community and country. However, the need must be identified by society and applied with due consideration to human and environmental conditions and concerns. I agree to some extent with the short-term benefits and long-term cost perspective. In the end, there is no single complete solution (technology) for sustainable agricultural production. Often, new technology is introduced to solve problems. But, after a period (often a long period) of using the new practices, farmers often encounter an unforeseen problem as a result of the long-term use of the technology. Then, farmers start to look for another solution for their new problem. Like a treadmill, farmers constantly make changes, modifications, reconstructions, adaptations, and adoptions in their farming practices in order to be compatible with the growth of social and economic demand and technological movement. Only sometimes are some of those stages a long-term process. Figure 2 illustrates the continuous process or cycle of the knowledge and technology treadmill.

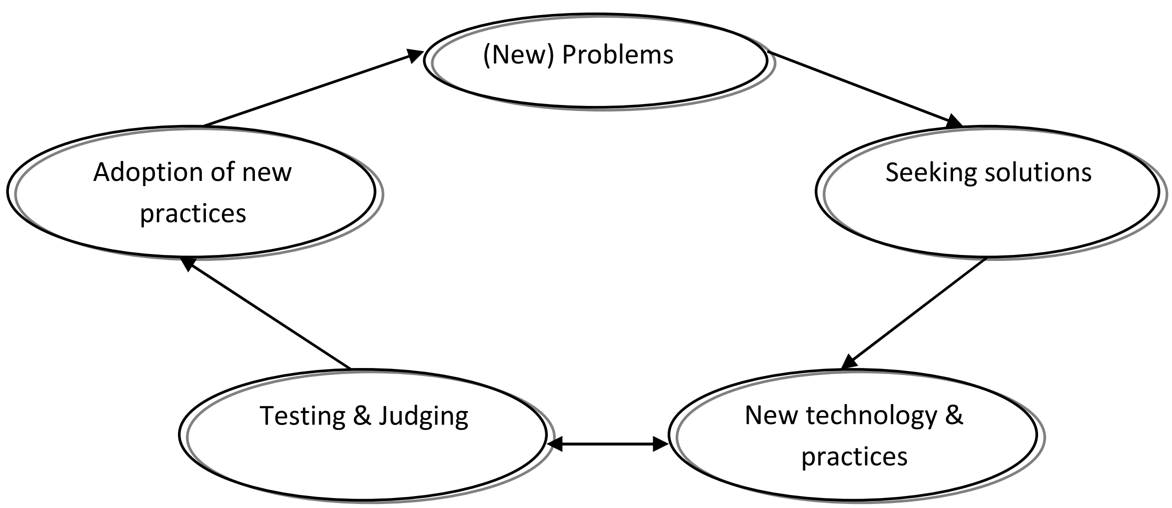

Figure 2. Technology treadmill for sustainable agriculture (Arnon, 1989).

The key message here is that adoption of new technology is not going to guarantee sustainable production. A sustainable agriculture production system requires a constant and continuous cycle of identification of new farm problems, seeking new solutions, developing and implementing new knowledge and practices, and finally monitoring to identify new problems. Some problems are predictable and farmers can anticipate them, but some are not predictable. Those problems that can be predicted can be avoided. For example, soil residual herbicides that persist beyond their intended time frame (Environment Canada, 2009) can possibly cause damage to the soil ecosystem. However, this potential problem can be predicted based on an understanding of how environmental and soil conditions influence persistence, and can be avoided with proper management.

Agriculture is a unique industry that cannot use the same technology uniformly across the world, or even across a province. Each individual location requires its own unique technologies because their application is governed heavily by environment, topography, as well as social and economic factors. Knowledge and technology that are recommended in one place may not be relevant to another. Therefore, it is important to involve farmers from local areas in the technology development processes in order to generate valid and appropriate knowledge and technology relevant to their circumstances. This will also build trust and mutual understanding between farmers and researchers. Finally, in all of these areas, it is crucial to work with decision makers and policy makers as they have power and opportunity to open doors to new information and technology to farmers.

The key to successful technology development and transfer is an ability to involve various agencies, especially extension, in the process of identifying alternative technologies that fit existing farming systems (Beynon et al., 1998; Agus et al., 1998). Appropriate technology development can only be enhanced if researchers understand the basic needs of farmers, farming communities, and other facets of the agricultural industry (Francis, 1990). Inappropriate technology development is a result of the lack of ability to understand farmers' social, economic, environmental, political, and cultural backgrounds and needs. Furthermore, such misunderstanding or lack of understanding about farming backgrounds may result in inappropriate policies and public promotions for inappropriate program funding and planning.

2.2.3.1. Tools for technology transfer and extension

Bentham (2000) and Rivera (2001) suggested the following four main tools and methods of information technology transfer: a) printed media—farm magazines, newspapers, technical publications; b) broadcast media—radio and television; c) personal contacts—other farmers, extension personnel, agribusinesses, and other expertise; d) the internet. Printed information is generally expensive. It requires the costs of publishing and delivery, plus time to deliver. However, printed documents are very beneficial with respect to referencing, storing, and rereading. Also, printed materials provide opportunities for readers to study, instead of just "listen and leave". While broadcast information does not offer all the advantages that printed materials have, it can be very timely. It can be broadcast on time over wide areas. Printed materials which have to be physically delivered cannot be as timely. One of the most effective methods is personal contacts—the face-to-face approach. It is widely and very effectively used for information technology transfer and communication. Personal contacts for agricultural technology transfer can be provided by extension people, farmers, private agents, seed sellers, and university professors (Bentham, 2000; Rivera, 2001). Personal contacts or interactions among all participants occur during farmer meetings, conferences, and field days, where agricultural industry players exchange ideas and information. However, the special duty of the extension agent is especially to convey information to farmers and consult with farmers about their needs and problems (Anderson and Feder, 2003). The internet is relatively new and is still a somewhat limited information source in developing countries. The number of farmers who have access to internet sources is increasing in developed countries while there still may be no access in developing countries. Ideally, it is preferable that one agent or organization employ all or most of these tools and techniques to transfer information and promote exchange of knowledge and technology.

2.2.3.2. Approaches to technology transfer and extension

Participatory extension approach

Many of the agricultural technology transfer approaches that were employed earlier did not consider farmer participation or what farmers think. Most of the approaches that were used in information transfer were top down. In other words, government or researchers would decide what information and technology should be transferred (Table 1). However, it was realized that many of the technologies that were developed and transferred without farmers' participation were inappropriate for farmers' agronomic, environmental, and social conditions (Beynon et al., 1998). In the late 1980s, participatory approaches emerged in Zimbabwe as a response to continued failure of traditional technology transfer (Hagmann, 1999; Anderson and Feder, 2003; Hanyani-Mlambo, 2002). The need for change in farmer training and educational approach was emphasized during this time. There was pressure to change from a top-down approach to a bottom-up or more participatory approach. Employment of this approach—involving farmers and communities more in the decision-making process—has increased rapidly in the last couple of decades (Wilson, 1991).

Hagmann (1999) compared "transfer of technology" and "participatory extension". Participatory extension approaches offer a flexible and holistic situation that can be applied to a variety of extension methods and can be integrated into multiple systems. In the farmers' participatory approach, farmers are involved in all stages of technology development and adoption: identifying problems, finding solutions, generating new information and technology, transferring new technology, and finally adopting the technology.

Table 1: “Transfer of technology” approach versus “Participatory extension” approach

	Transfer of technology	**Participatory extension**
Main objective	Transfer of technology	Empower farmers
Analysis of needs and priorities	Outsiders	Farmers facilitated by outsiders
Transferred by outsider to farmers	Precepts Messages Package of practices	Principles Methods Basket of choices
The “menu”	Fixed	According to choice
Farmers behaviour	Hear messages Act on precepts Adopt, adapt, or reject package	Use methods Apply principles Choose from basket and experiment
Outsiders’ desired outcome emphasized	Widespread adoption of package	Wider choices for farmers Farmers’ enhanced adaptability
Main mode of extension	Extension worker to farmer	Farmer to farmer
Role of extension agent	Teacher-trainer	Facilitator Searcher for & provider of choice
		Source: adapted from Chambers, 1993.

In this approach, extension personnel are not only teachers, but also listeners and learners. Therefore, building linkages, friendships, and interacting with researchers, extension personnel, and farmers is important.

Farmer-to-farmer extension approach

Historically as well as currently, one of the most effective technology-transfer approaches is farmer to farmer. It is well accepted as farmers tend to trust each other more than an external agent or organization. They are also the origins of new technologies and a rich resource of knowledge and information. Unfortunately, however farmers’ experience and knowledge are often ignored, and agricultural educators and researchers sometimes focus only on scientific knowledge and experiments (Compton, 1991).

Farmer-to-farmer training is about making the best use of farmers, researchers, consumers, and policy makers (Enshayan et al., 1992). Often in this system, selected farmers are trained to train one another. In this sense, farmers are replacing local or village extension personnel from the T&V Model. Training of trainer farmers is focused on helping decision-making as well as technical training (Anderson and Feder, 2003). In the past, most extension activities used to be top-down (that is,scientist to farmers). In other words, farmers were seen as passive recipients of information that was being generated at research and academic institutions (Enshayan et al., 1992). Nonetheless, this model allows information to go in multiple directions (farmer to university, farmer to farmer, and farmer to consumers), and creates healthy agriculture research, education, and extension services (Francis et al., 1990). However, the selection of farmers as trainers and the passage of information from farmer to farmer has to be evaluated and monitored on a regular basis.

Fee-for-service and private extension approach

Private firms or consulting-oriented institutions often charge a fee for their extension service, although public entities sometimes offer the service (Dinar and Keynan, 2001). This service reduces public extension demand. Also, with a fee-for-service system, it has been argued that accountability of extension services should be improved, even though identification of pure extension impact on production may remain just as much of a challenge (Hanson and Just, 2001). The quality and personalization of the service is relatively high in a fee-for-service system. The main drawbacks in such a system are exclusion of smaller and poorer farmers who might not be able to pay fees and who often farm in less favorable areas (Wilson, 1991; Dinar and Keynan, 2001). Therefore, this system might tend to favor wealthier and larger farmers. However, a fee-for-service system is often a market based system determined by demand from farmers and valued by the quality of information.

2.2.4. Factors for effective agricultural extension services

While environmental scientists have been investigating technical innovations that would prevent soil erosion, and economists have been calculating cost efficiency of those new practices, other more important aspects of adoption such as social and psychological impacts on a farming community have received little attention. Adoption of a sustainable farming system used to be seen as a technical problem. Technological or technical problems can be solved, but the real problem that is more difficult to address is the social issues that may accompany the technology (Salamon et al., 1997). Consequently, the practical importance of a new farming practice has drawn attention from many diverse disciplines to consider why some farmers are willing to adopt new practices, while others are not. Agricultural scientists have assessed all technical aspects of new practices, while economists have calculated long- and short-term financial consequences of different farming practices. Sociologists also have been studying the socio-psychological and socio-economic characteristics of adopters and non-adopters, and other social factors that influence farmers' decision making. All these studies have provided very useful information about both positive and negative consequences of adopting new farming systems, although there are always many questions to be answered. Adoption or acceptance of a new farming practice usually takes a whole series of "micro-decisions (Chibnik, 1987). Each micro-decision is influenced by its own circumstances. In other words, many small factors combine to influence adoption or non-adoption of new farming practices.

2.2.4.1. Organizational factors for technology transfer

Successful information dissemination and technology transfer are a result of the integration of multiple factors that occur at political, technical, and organizational interfaces (Garfield et al., 1996). Many organizations—including government agencies, non government organizations, private businesses, farmers' associations, universities and research institutions—offer extension services in their own ways. Therefore, identification of those individual organizations' perceptions, strategies, resources, and interactions are crucial to developing strategic extension approaches for a sustainable agriculture technology transfer system (Hanyani-Mlambo, 2002; Crowder and Anderson, 1996). Nevertheless, it is not very easy to develop those approaches as these organizations do not always share common goals. It has to be recognized that there can be many conflicts among the players within an agriculture system. Where organizational goals are similar, a group extension approach works well by sharing resources (Crowder and Anderson, 1996). However, many players are challenged to work together and, therefore, enormous amounts of time and resources can be wasted due to the lack of cooperation among those organizations. Often, the challenge is personal or institutional—for example, personal lack of willingness to work together, competitive attitudes, and insecurity. Sometimes, in some extension systems, there is also a lack of willingness to learn about individual farming environments, and their specific problems, which leads to the technical failure of technology transfer and limited adoption of new technology (Hanyani-Mlambo, 2002). Furthermore, all of these organizations have their own political backgrounds or lobbies. Especially in developing countries, political factors can result in issues like unbalanced funding, inappropriate technology promotions, and corruption within the agriculture system (Anderson and Feder, 2003). Potential political control over these organizations may affect the values, rewards, and collaboration among them. All these issues—including organizational structure, mandate, budget allocation, political control and communication among all participants—contribute to power struggles and individualism within organizations that lead to poor working relationships, corruption, and unsustainable linkages among those organizations. It ultimately creates poor extension services. Coordination of all of these factors and issues is not easy, nor does it necessarily lead to success, but it is important to have a system that supports and encourages it.

2.2.4.2. Financial factors for technology transfer

Funding is definitely the most powerful influence for technology transfer. In most countries, especially developing countries, agricultural extension services have long been provided by governments and funded by taxpayers (Van den Ban, 2000). In Mongolia, extension services are provided mainly through the Ministry of Agriculture and Food. However, in many developed countries, a variety of ways of financing extension services have emerged lately, mainly as the result of privatization and decentralization of extension systems (Garfield et al., 1996; Wilson, 1991). Regarding the services that are provided to farmers, the source of funding may have an effect on what kind of extension activities or services may be offered and which kind of information and technology is promoted. Unfortunately, the information-transfer process is expensive and very dependent on funding sources. Van den Ban (2000) suggests that financing mechanisms for extension can influence organizational decisions including their goals, target groups of farmers, methods/approaches to be employed, information to be delivered, and cooperation with other institutions. Therefore, some extension agents and organizations can be very political and narrowly focused on only technologies that are promoted from major funding or political support. Government funded extension systems usually offer public extension services from which everybody can benefit and it is often free of charge. Public good is not traceable and information can be freely passed (Wilson, 1991). In contrast, there are privately funded extension services, and their service can be accessible to the public as well as to the targeted audiences. Often, private extension services are not free. Nonetheless, privately funded extension services and information are focused on promotion of their private businesses and production lines (Van den Ban, 2000; Beynon et al., 1998). Generally, private businesses view their investment in agricultural extension services as a tool to reach their clients to achieve their business goals such as selling pesticides and machinery. In addition, government extension agencies try to achieve social and environmental development in agricultural practices that are promoted, whereas private firms usually focus on helping individual farmers to increase their productivity and income (Marsh and Pannell, 1998). Consequently, it is important to have public extension services through government agencies to service those who are not able to hire private consultants.

2.2.4.3. Motivational factors for technology transfer

With incentives, the hope is that the transfer of technology will be enhanced and adoption will be sustained by providing some needed resources regardless of their source (Maglinao and Phommasack, 1998). Incentives should stimulate and encourage one to take action and work harder for something or someone. There are many forms of incentives. Government subsidies are one of the most common and effective incentives for technology transfer (Garfield et al., 1996). Generally, it has been observed that small farmers have inadequate resources and they are assumed to be incapable of implementing new technologies and making changes in their farming practices (Maglinao and Phommasack, 1998). Therefore, subsidies, particularly for farm inputs, have been provided as an incentive to effect wider farmer participation in new technology transfer activities (Haggman et al, 1999; Maglinao and Phommasack, 1998).

The success of transferring a new innovation or technology is evaluated by its acceptance and sustained adoption by the target clientele as mentioned earlier. Especially in a top-down approach, government subsidies or incentives can be very effective in increasing adoption. However, one of the main concerns of adoption through incentives is sustainability: will adoption and application of a new practice remain if the incentive is terminated? Often incentives, especially with government subsidies, result in rapid short-term adoption of new technology. Consequently, incentives must include consideration for a careful plan and assessment of their future sustainability.

2.2.4.4. Constraints to technology transfer

The problems related to improved technology transfer are numerous and well documented. Maglinao (1996) pointed out that success in technology transfer is possible when researchers, extension workers, and farmers work together, and interact well with each other. In addition, both researchers and extension workers need to understand the socio-economic dimensions of the farmers, as poor understanding of factors that influence farmers' decision has often caused the failure of the transfer and adoption of a new technology (Kaimovitz, 1991; Sutherland, 1999). Therefore, other factors affecting farmers' behavior cannot be neglected. In most countries, there is a large gap between farmers and researchers. Involving all parties and encouraging adoption equally in the extension program and the decision-making process can be helpful in filling these gaps and increasing adoption.

No technology can totally solve farm problems in the short-term (Kaimovitz, 1991). Technologies are created to solve specific problems that have occurred in farming, but that technology does not guarantee that it will not cause another problem. Often, as one issue is addressed by new technology, another problem arises as a result of implementing the new technology (Roling and Wagemakers, 1998). Indeed, there is no end to farm problems and the need for innovation and development of new technologies or practices. It leads to the endless process of adoption and modification. The recommended technologies should be technically feasible, economically profitable, and locally acceptable in their socio-economic domains (Sutherland, 1999). However, both farmers and researchers should be prepared for, or expect to see, a potential problem after using the same practice for a long period. Therefore, the lack of understanding among researchers and extension personnel about farmers' socio-economic and psycho-cultural circumstances results in a failure of new technology development, transfer, and adoption. Farmers' misinterpretation and incorrect perception also can cause failure of adoption.

There are many barriers to technology transfer and its adoption including cultural barriers, language differences, different scientific concepts, and different stakeholders in the system (Sutherland, 1999). They can either play against or in favor of a new technology. However, to overcome these constraints, a participatory approach can be used including dialogue and diagnosis among researchers, extension workers, and farmers to understand their problems, constraints, and socio-economic background (Kaimovitz, 1991; Sutherland 1999). It is hoped that the results obtained from on-farm research in which farmers participate in managing, evaluating, and developing a technology will help farmers and enhance the technology transfer and adoption process.

2.2.5. Linkages among researchers, farmers, and extension personnel for technology transfer

The term "linkage" implies an established communication and working relationship between two or more organizations pursuing commonly shared goals in order to achieve regular contact and improved productivity (Hagman et al., 1999). Arnon (1989) suggested that linkage be used to indicate that two systems are connected by messages to form a greater system. In this case, agricultural research and extension services are two systems which are linked by information flow and feedback. However, it is important to note that the flow of information has to occur in both directions.

In general, farmers are constantly looking for new information and technology that can improve their productivity as well as meet their other priorities in farming. For agricultural technology to be relevant to local needs, researchers, extension workers, and farmers must play equally important roles in identifying research problems, adapting the recommendations to local conditions, and providing feedback to researchers about new innovation technologies that have been introduced (Arnon, 1989; Francis et al., 1990). Unfortunately, it might not be too far from the truth to say that there is no place where linkages among all sectors of agriculture have established that level of collaboration and trust. Ideally however, such linkages enable development of new technologies and practices suitable to local conditions. Often, a new technology innovation does not meet with farmers' needs and requirements because they are based on ideas and results of research (Francis et al., 1990), and developed only under experimental conditions (Utomo et al., 1998). Certainly, this criticism is accepted. It has become commonly understood that on-farm assessment and demonstration of new technology is necessary before the mass technology transfer process can commence. Without successful on-farm demonstration in certain farming environments, it may fail to be accepted and adopted by farmers. Besides, on-farm research or demonstration is an excellent tool to introduce and display the pros and cons of a new technology. According to Henry (1994), this becomes an issue in top-down systems—where a lack of communication between farmers and researchers is lacking—more often than in bottom-up systems. Introduction and demonstration within controlled settings like university research farms and laboratories may not encourage farmers to adopt the technology for their farming practices (Barao, 1992; Arnon, 1989; Fujisaka, 1991). Therefore, in order to develop acceptable technologies, researchers should be concerned with farmers' perspectives and ensure involvement of farmers in research projects.

Another important group that needs to be involved in a research project group is extension personnel as this helps them become familiar with the technologies that they are expected to promote. One of the roles of extension personnel is to help identify social dimensions of the local community in relation to new technology development and transfer. In this perspective, involving extension personnel in research demonstration and development also helps ensure that the sociological dimensions of farming are not neglected. There is a need to recognize and address the psychosocial component of technology transfer as a part of the educational process. Generating knowledge is not the same as transferring and adopting knowledge (Barao, 1992). Therefore, strong linkages among researchers, extension workers, and farmers are needed for improved technology development, technology transfer, and adoption. The relationship between key stakeholders in the research–extension linkage system is illustrated in Figure 3 (Arnon, 1989).

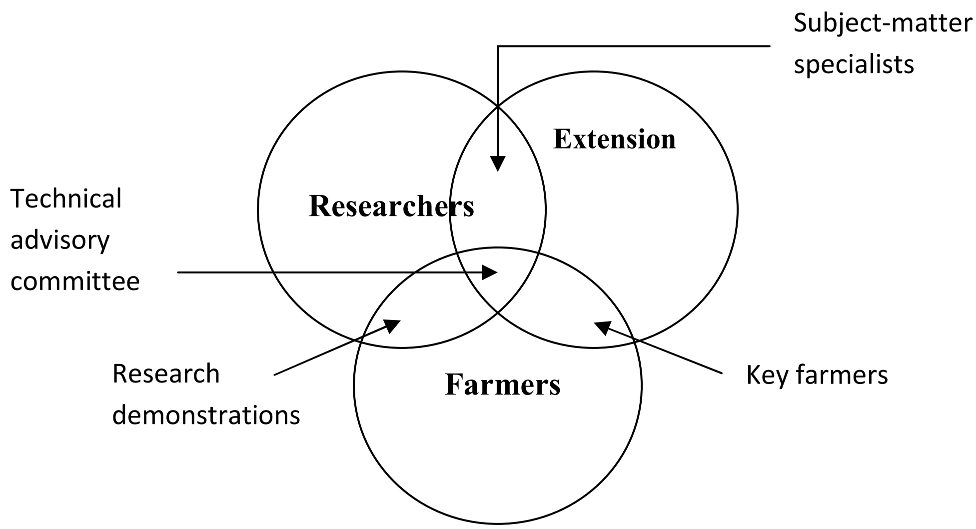

Figure3. Connection between the main actors in agricultural extension and research system

However, this model does not reveal informal linkages in commercial or profit-oriented research and extension systems. These informal linkage mechanisms are based on friendship and mutual interest of profit, which include the promotion of joint social activities and the use of existing personal ties (Arnon, 1989).

It is necessary for researchers and extension workers to understand the interrelationship between various problems on a farm and to address the complex issues of management and sustainable production (Francis et al., 1990). Agriculture development projects have a number of clients including farmers, researchers, extension workers, and policy-makers (Santoso and Dixin, 1998). One of the biggest misunderstandings is underestimation of rural community (farmers) importance in the development of agricultural research, policy, and production systems. Therefore, strong linkage and coordination mechanisms among those actors must be established to enhance appropriate technology development and widespread adoption of new technologies and to promote sustainable agricultural practices. Nevertheless, research and extension linkage enhancement requires policy changes, institutional reorganization, and the strengthening of organizations (Arnon, 1989; Haggman, 1999). According to Biggs's definition (1989), four modes of participation link farmers and researchers.

1. Contractual mode[7]: In this mode, researchers are in power and linkage is based on the exchange of materials. There is no participation of farmers in knowledge development and planning.

2. Consultative mode: In this mode, researchers still make all the key decisions, while farmers are involved in problem identification and priority setting.

3. Collaborative mode: Farmers and researchers are more equally involved in sharing the decision-making and exchange of knowledge. Farmers are involved in on-farm demonstrations and evaluation, the same as researchers.

4. Collegiate mode: Farmers are in power in this mode. Researchers respond to farmers' requests in a non-hierarchical way.

These four modes all assume a degree of linkage between researchers and farmers. However, what if there is no linkage between these two at all? Many countries have not established any linkage between researchers and farmers. They act as if they were in two different unrelated systems and it should be considered as a fifth mode, one with no linkage between farmers and researchers.

Most international projects operate on the interface between consultative and collaborative modes (Biggs, 1989). Nonetheless, this can create significant pressure on researchers to operate between complex sets of expectations from science, farmer, donor, and extension groups and agribusinesses. The array of expectations governs what researchers do and how they present and write up their results (Sutherland, 1999).

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[7] This is a mode that illustrates the Mongolian top-down agriculture extension system. In Mongolia, government officials have more power than researchers. But, the system, which governs agricultural technology development and transfer does not allow farmers` voices to be heard.

This could potentially create favors and/or biases toward one group over another, especially in relation to funding. Also, research areas that have more funding opportunities become priorities, and ones that do not have much funding lag behind.

2.2.5.1. Rural Participatory Appraisal (RPA)

Rural Participatory Appraisal (RPA) is an assessment or a baseline study that is conducted prior to the development of certain programs to identify specific needs of the beneficiaries. Often, the idea of technology transfer is concentrated around dissemination of technologies and information, and farmers' responses to the information that is delivered (Agus et al., 1998). Some significant issues have to be addressed prior to the dissemination of a new technology. Before making a decision to take a new technology to farmers, researchers and extension agents have to do their homework and study the suitability of the location for introduction in relation to the new technologies and practices. Selection of the location by which the technology is introduced, identification of existing socio-economic and political systems, and appraisal of supporting institutions and infrastructure are all equally crucial parts of the technology transfer process (Agus et al., 1998; Arnon, 1989; Anderson and Feder, 2003).

One of the major revolutions made towards establishing an interface between farmers and researchers was the rural participatory appraisals (RPA) (Wilson, 1991; Francis et al, 1990). Although some challenges still remain, this gives researchers a significant understanding of farmers' background and perceptions (Sutherland, 1999). Identification of research needs from the grassroots level is the most important part of the whole technology transfer process (Hassanein, 1999; Mercado et al., 1998). Identification of farm problems and assessment of farmers' constraints give guidance to agricultural technology transfer and research development. This assessment process should involve the active participation of farmers in order to increase the accuracy of the assessment. However, in many places, it does not happen that way. Especially in developing countries, farmers' opinions are very seldom heard among researchers, policy makers, and government officials. Increased farmer participation and involvement in research and extension requires systematic change in a structure or system and an attitude change among decision makers. It will require much training and convincing of decision-makers, researchers, and farmers for improved policy and research development to occur. Changing attitudes is a very difficult and time-consuming process. Convincing agricultural officials to listen to farmers, and convincing farmers that it is acceptable to say what they are thinking is a significant challenge. It is more difficult than convincing farmers to adopt a certain technology. Often, especially in developing countries, farmers are hesitant to bring their voices to the public for various reasons: 1) they are less confident about the richness of their knowledge; 2) they fear that speaking out causes judgment and conflict; and 3) in some traditions, farmers do not argue with researchers or higher authorities. Removing these psychological, emotional, and cultural attitude barriers is not easy.

Another farmer perception that should be mentioned here in relation to rural participatory appraisal is their attitude towards research results and researchers. Often, farmers are biased against the practicality of research results and researchers. Working together on pre- and post-research and demonstration appraisals will improve their attitude and respect towards each other and build mutual understanding between them.

2.2.5.2. Farmer Participatory Research (FPR)

Farmer Participatory Research (FPR) has been suggested as one of the most effective approaches for improving technology transfer processes and increasing farmers' adoption of new technologies (Henry, 1994; Fujisaka, 1991; Maglinao and Phommasack, 1998; Biggs, 1989; van den Ban, 2000; Wilson, 1991; Arnon, 1989). Sutherland (1999) offers this definition of the farmer-participatory research approach:

> *"In principle, FPR aims to operate at the interface between knowledge systems. It can be described as a people-centered process of purposeful and creative interplay between local individuals and communities."*

In this definition, Sutherland makes several different assumptions about an agriculture system. He assumes, first, that two sets of knowledge exist—research and farm knowledge; second, possible interactions occur between these knowledge systems involving discourse between the different groups; and third, this interaction will be put together into a “partnership”. Another factor Sutherland did not mention is an influence or interaction with community where there may be socio-economic pressures as well as benefits. The FPR approach refers to the effort of various projects and individuals to more fully involve farmers in all stages of technology and research development, as well as information and technology transfer processes (Hagmann, 1999; Sutherland, 1999; Utomo et al., 1998).

In the participatory approach, farmers decide which changes are desired and what kinds of support are needed from extension (Roling and de Jong, 1999). In addition, with the FPR approach, an extension organization becomes a learning organization with the ability to discover which changes are desired in each specific area (Van den Ban, 2000). Thus, extension personnel should be doing baseline studies and surveys among farming communities. Giving a clear understanding of FPR to farmers—why it is important to have farmers’ participation on all areas of research and technology development—might be helpful to break farmers’ hesitation and the barriers between researchers and farmers. In many cases, it is all about building trust and friendship with farmers, so that a two-way dialogue can be carried out comfortably between farmers and researchers. Farmer-led research seeks to identify a range of useful technology options to be shared with other interested farmers (Francis, 1990). In an example of FPR in Java (Sutherland, 1999), a team consisting of a soil scientist, agronomist, socio-economist, and an extension specialist carried out a Rapid Rural Appraisal (RRA) prior to a research project. Then, based on the results of the RRA study, research and demonstration designs were set. Technologies or practices that were tested came from farmers’ suggestions and references. Farmers themselves carried out on-farm demonstrations, and researchers acted as supervisors. Extension people organized training activities for information dissemination. These kinds of activities allowed farmers to learn by doing, and set realistic examples for fellow farmers.

Conducting such farm-applied research allows the development of appropriate and site-specific technologies that are suitable for areas of similar bioclimatic and socio-economic conditions (Mercado et al., 1998) in addition to educating farmers. Santoso and Dixin (1998) said that on-farm research is “a vehicle for displaying the recommended techniques”. Maglinao (1996) suggested a conceptual model for an integrated approach to facilitate technology transfer and adoption (Figure. 4).

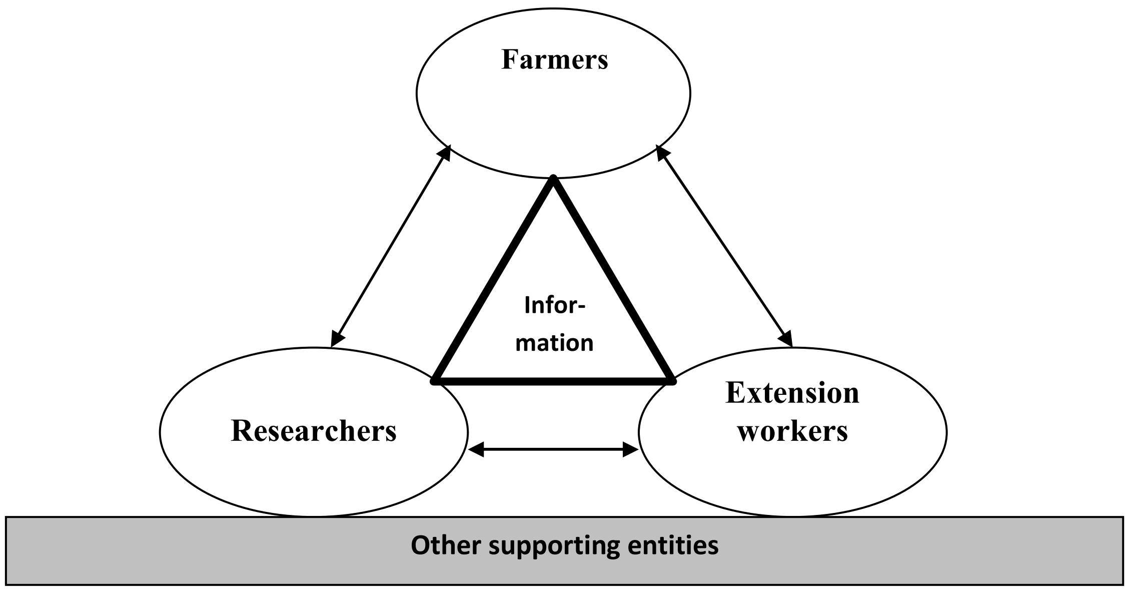


Figure 4. Conceptual model for an integrated approach to technology transfer in Indonesia (Maglinao, 1996)

The model illustrates the complementary nature of the relationships among research, extension, and farm groups. It has also been suggested that extension workers should no longer be considered as passive recipients of new technological knowledge to be transferred to farmers (Mercado et al., 1998).

Extension personnel should be active participants in farming communities and bring back knowledge and understanding about farming situations to researchers (Francis, 1990). Although researchers might not contact farmers directly or as often as extension workers, they are involved in the formulation of a research agenda that incorporates the inputs of farmers and extension workers (Arnon, 1989). Therefore, either directly or indirectly, researchers need to be aware of farming situations in order to be responsive to farm problems through their research and technology development activities. Very often, researchers are aware of the technical aspects of farm problems, but they are usually unaware of social and economic circumstances of the farm which very much influence farmers` choices of solutions to their farming issues. These may be a slow adoption or rejection of research information and technology, even if it works technically. Sharing knowledge and information among members of farming communities, researchers and extension workers makes any technology transfer system more sustainable and more economical (Maglinao and Phommasack, 1998). Also, Hagmann (1999) suggested that a participatory extension approach offers a flexible and holistic situation that can be applied to a variety of extension methods and can be integrated. Participatory approaches aim to provide opportunities for all members of a system to participate and voice their opinions, and to create an environment in which everybody feels equal and significant.

2.3. Knowledge and New Technology Utilization and Adoption

Human beings are very adaptable. People are always making decisions, and constantly altering them according to what is appropriate for the time and circumstance. That is, what they think is appropriate today may not be appropriate in the future. Therefore, sustainable development of a society requires judgment about today and being prepared to modify constantly through time and space. To understand human adoption behavior, we need to involve multidisciplinary perspectives. This is especially true in agriculture where technological change and adoption presents technological, ecological, demographic, economic, cultural, and social challenges that are a consequence of scientific innovations. Adoption is a slow and continuous process. Yet, it is adoption rather than innovation that ultimately determines the pace of economic growth and rate of change in productivity (Hall and Khan, 2003). One of the major revolutionary phases in agriculture history is innovation and adoption of conservation farming practices under the umbrella of the sustainable agricultural technology movement.

In short, the adoption process of new practices is complex, one that involves culture, economics, environment, technology, and more. Therefore, the adoption process has to be analyzed in an interdisciplinary perspective. Otherwise, it might be unbalanced and ineffective. The implementation of new technology is a result of interaction and evaluation of many factors. The reason for adoption or non-adoption of introduced technologies could, therefore, be related to technical, economical, social, cultural, and even political factors. These factors interact with each other in complex ways and vary from technology to technology, and from situation to situation. Consequently, developing sustainable agricultural production and agricultural technology transfer is not simply related to technical or agro-environmental problems, but it is also a socio-economic and political concern as well. There has also been significant progress in recognizing the changes in the sociology of agriculture and farmers' adoption behaviors through time (Arnon, 1989). Producers want socially, economically, and environmentally sound answers for their problems. However, economic issues are usually the most pressing of all. If new practices are not economically profitable and/or affordable, then there will be very little or no acceptance of the practice by producers. Many hidden but accountable forces influence farmers' decision to adopt new technology. Although it appears farmers have the option of adopting a new technology or not, in reality, farmers sometimes do not have an option at all. Global markets, not farmers, set prices of crops. Farmers are mostly trying to make a profit by controlling the amount of inputs they need to put into a farm. Sometimes, farmers cannot work profitably unless they adopt a new technology that they may prefer not to use. Therefore, in order to meet with farmers needs, farmers, private businesses, and other governmental and non-governmental organizations should be included in the process of constructing new farming practice recommendations.

Many social studies have been carried out to compare adopters versus non-adopters, and show the variety of social, economic, environmental, and technological characteristics and the relationships that are essential to shaping and making decisions. Although there were many mixed findings, a few strong relationships were identified. Many emphasized that economic variables were the most important to farmer's decisions. Environmental variables were the second most important to their farming practices (Brown et al, 1996; Carlson and Dillman, 1986; Seitz and Swanson, 1980).

2.3.1. Technology characteristics and adoption of new technologies

2.3.1.1. Economics of new technology adoption

Farmers need to consider other factors before making a decision to adopt or not adopt a technology. These include economic benefits, supporting institutions and organizations, compatibility with their socio-economic background, appropriateness and complexity of the technology, and the ability to maintain it (Agus et al., 1998). Although social, cultural, and political influences are very important, the direct benefit in economic returns is still one of the main criteria that farmers look for. Basically, if farmers do not see significant economic returns from the adoption of a new technology or a practice, they will not accept it (Agus et al., 1998; Utomo et al., 1998; Bentham, 2000; Sajjapongse and Maglinao, 1998; Pampel and van Es, 1977). Also, if a new technology does not meet with the farmers' preference, they usually do not adopt the recommended practices. Sometimes, researchers give more consideration to the environmental and technical aspects of a new technology and pay less attention to the on-farm benefits in which farmers are most interested (Agus et al., 1998; Sajjapongse and Maglinao, 1998; Pampel and van Es, 1977). However, not surprisingly, if innovative technology promises quick economic benefits or returns, farmers will likely adopt the new technology. In other words, farmers are more likely to reject technologies that do not have short-term economic benefits. One of the reasons why short-term benefits are more important to producers than long-term benefits might be annual cash return or survival strategy considering the challenges and limitations in the agricultural industry. Most farmers may not be willing to take a risk of making less or no money in the short-term, even for one year. Short-term benefits are more visible than long-term benefits. In this sense, farmers may easily see the short-term advantages of introducing recommended technologies or practices and may not be aware of long-term advantages. Pampel and van Es (1977) agreed that the economic benefit of a new technology is positively related to the adoption of any type of technology. They added that adoption of new practices is based on a farmer's orientation towards profit rather than orientation towards new ideas. This is understandable as the primary goal of farmers is to increase profit. Therefore, high labor requirements and high-cost practices will have a negative impact on adoption (Mercado et al., 1998). Some researchers have found that some farmers see their farm as a lifestyle, not a business enterprise. These farmers will be unlikely to accept a change in their farming style. Bentham (2000) observed that the economic benefits of technology transfer and adoption are the most significant factors for the farmers' decision to accept or reject a new technology. Nevertheless, the agro-market, politics, and government subsidies sometimes dictate farmers' attitudes and influence them to change their farming practices.

2.3.1.2. Appropriateness and inappropriateness of new technologies

The appropriateness of a technology relates to its suitability to the farmers' agro-environmental and socio-economical situations (Roling and Wagemakers, 1998). If a new technology is appropriate, it means that the technology is suitable for a certain farming situation. Therefore, the technology transfer process may proceed quickly, and the adoption rate of the technology might be high. However, if the technology is inappropriate, then the opposite is assumed unless there is long–term support or subsidies to promote its adoption (Arnon, 1989). Especially in the developing countries, where top-down systems exist, governments are closely involved in the development as well as the transfer of new technologies. Although there are many advantages to involving government in the technology transfer process, sometimes ill-suited technologies can be promoted through inappropriate government lobbies. The bench terracing technology transfer project in Indonesia is a political lobby involved in this process. Technology development and transfer without prior needs assessment at the ground level is not likely an appropriate or a desired change in the system. This is called a "blind recommendation" (Agus et al., 1998). Blind technologies are recommended without any consideration of their appropriateness and applicability to farming communities, socio-economic, and agro-environmental conditions. Technologies that are not based on site-specific biophysical and socio-economic circumstances cannot maintain agriculture production and sustain natural resources (Mercado et al., 1998).

2.3.1.3. Convenience and maintenance of new technologies

Convenience and maintenance requirements are very logical reasons why farmers will or will not accept new technologies. If a new technology is too complicated and requires special supervision or expertise and high maintenance, it may not be accepted by producers and the technology transfer process may not be successful (Barao, 1992). For instance, in many parts of the world, soil degradation is a serious problem. Many soil conservation practices have been developed and widely endorsed by scientists to overcome environmental problems. Yet the uptake of soil conservation practices has been slow and unsuccessful on farms in many parts of the world, while elsewhere they are using a "most advanced" version of no-tillage farming practices. Usually, researchers try to find common reasons among farmers to explain the lack of adoption of new technologies. Researchers think that the farmers' lack of understanding of soil erosion problems and proper soil management causes barriers to successful conservation farming technology transfer (Agus et al., 1998). However, Utomo et al. (1994) rejected this hypothesis and argued that farmers do not accept a new technology being transferred if the technology is too complicated, too costly, and/or requires high maintenance (Barao, 1992). On the other hand, although farmers are familiar with the concepts of these new technologies, they are not capable of adopting some critical parts of the recommended technology (Maglinao and Phommasack, 1998). In general, farmers look for simple and inexpensive solutions with high economic returns. Therefore, simplicity, visibility, usefulness, and feasibility are favorable characteristics that encourage technology transfer as well as adoption of new technologies.

2.3.1.4. Institutional support for new technologies

Having supporting institutions that provide a supply of technical guidance is very important for successful technology transfer. Often, institutions, especially those involved in international projects, introduce a new technology and/or agricultural inputs without a carefully designed supply and maintenance plan. In the case of Mongolia, a USAID project tried to introduce "No-Tillage" farming practice and imported some equipment and technology to Mongolia. However, there was no local institution or personnel prepared to provide technical guidance to those farmers who received the equipment or technology from the project. Following the project termination, the equipment was broken and parts were missing. Nobody was there to supply parts or do maintenance on this equipment. Inappropriate steps like this not only lead to mistrust between producers and technology transfer agents, they also build negative attitudes and resistance towards new ideas in the future. Therefore, plans for new technology transfer have to be carefully thought out, designed, and implemented (author's personal observation).

Some of the major factors affecting the sustainability of technology transfer are the lack of supporting institutions, farmers' ability to purchase and manage new technologies financially and intellectually (Huszar et al., 1994), plus maintenance and institutional support (Mercado et al., 1998). Education and technical assistance must be provided before the adoption process of any technology can begin. Some researchers refer to this as the "supply" side of the adoption process.

Brown (1981) stated that the "supply" side of the adoption process includes the ways that innovation information is made available to producers via preferred institutions. He has proposed three steps for the diffusion process: 1) establishment of diffusion agencies through which innovations will be dispersed to the population at large; 2) implementation of the agency strategies to induce adoption; and 3) adoption of the innovations. Mass media are well used for making innovations known to a large population, but interpersonal sources make it more believable (Clearfield and Osgood, 1986). However, Mason (1964) stated that the use of information sources change in different stages of the adoption process. He stated that possibly mass media plays an important role in the early stages of adoption, but fellow farmers might become more influential in making decisions in the later stages of adoption. Also, recent research has found that public programs—community meetings and conservation field days—can play a significant role in farmers' adoption of new practices (Buttel et al. 1990). Therefore, adoption of a new innovation is a result of one communicating with and learning from various sources (Clearfield and Osgood, 1986).

Being in contact with information sources (Buttel et al. 1990) and being a member of organizations such as farmers associations can have a positive impact on adoption of new innovations (Nowak and Korshing, 1983). It helps member farmers gain information about new innovations faster and more effectively. In fact, member farmers showed a greater tendency to adopt “extension-recommended” practices over other farmers who were non-members (Eponou, 1996).

2.3.2. Farmer and farm characteristics

Farmers’ personal characteristics are one of the most significant factors for their decision-making behavior, and they influence how the farmer would pursue new ideas. There are many ways of characterizing farmers in terms of their decision-making and adoption behaviors. Being aware of some of their personal characteristics helps to understand why farmers do what they do. Rural sociologists have carried out extensive studies regarding farmer characteristics in relation to adoption. To summarize, the most common characteristics of farmers who may adopt new technology are those: 1) with high education, 2) who operate large commercial farms, 3) who have active social participation, and 4) who own their land. However, many other variables have had mixed effects on farmers’ decision to adopt: spouses’ involvement, off-farm employment, age, and farmers’ beliefs and background. Korsching et al. (1983) proposed one of the most popular and classical categorizations of farmers. He grouped farmers into five categories depending on their adoption behaviors using classic adoption diffusion theory.

Adopters/Innovators—Approximately 2.5 percent of farmers belong to this category. Farmers in this category are considered risk takers. They have the resources (time, education, and finance) that allow them the opportunity to take risks. They are more willing to try new things and learn from new experiences. In general, they are relatively wealthy farmers with no or few debts. Farmers in this category are often key leader farmers who will likely demonstrate new practices on their farms and help to introduce them to other farmers. According to Korsching et al (1983), it is important to identify these farmers and work with them in the initial stages of the technology transfer process.

Early adopter—About 13.5 percent of farmers were counted in this category. Farmers in this category are information seekers and consistent decision makers. They are usually local community leaders and well respected in the community. Farmers in this group are also the key to technology transfer systems, says Korsching et al. (1983), and active involvement of these farmers will help speed the adoption process and outreach to other farmers. They are not as quick to adopt new technologies because they may not have the same level of resources as the adopter category.

Early majority adopter—About 34 percent of farmers are classified in this category. They are also decision makers, yet they need more time and evidence to make the final decision to adopt. They have fewer resources than early adopters, and they are less willing to take risks. These farmers are well connected to one another and well aware of what is happening in the community. They are excellent networkers. They watch and wait for adopter and early–adopter farmers to demonstrate new practices and to see some positive and profitable results.

Late majority adopters—In general, these groups also make up about 34percent of the farming population. They are not community leaders, and are not well connected to the community. They are risk adverse, skeptical, and can be under high social and economic pressure. These farmers have to be in totally comfortable conditions before they make the decision to adopt. They think long and carefully.

Laggards/non-adopters—They represent about 16 percent of farmers and are usually the last ones to adopt, if they ever adopt new ideas and make changes in their farming practices. They are more traditional farmers, and often they are closely tied with past experiences and techniques. Also, farmers in this group are very suspicious of innovations. They often lack resources, and so, they cannot afford to take risks.

One of the most important influences on innovation adoption is personal characteristics (Swanson et al., 1986; Clearfield and Osgood, 1986) and farmers' willingness to change

(Pampel and van Es, 1977). Personal characteristics are crucial, and many adoption behavior analyses are based on how much risk farmers are willing to take. Although, farmers are classified in different categories of adoption time-frames based on their personality, it is important to mention that farmers' behaviors are also governed by their economic wealth and other social pressures like family tradition. Often, late-majority-adopters and laggards cannot financially afford to take risk or invest in something that does not have evident benefit, whereas most early adopters are financially able to take risks. If those farmers invest and fail or if they change their mind, it may not hurt their farming operation as much. Farmers who are not financially sound may have to be relatively certain that introducing a new practice is more profitable and secure. In this sense, farmers' primary interest in a new technology is economic profit—how much more profit they can make by introducing this new practice. In addition, Swanson et al. (1986) pointed out that the level of education also influences farmers' perception toward new innovations. In relation to Korsching et al's (1983) classification, most farmers in the first three categories have a higher education.

Many more factors influence farmers' decision and attitude towards new technology transfer including family traditions, off-farm employment, social status, farm size, farm diversity, environmental and bio-ecological circumstance of the farm, and government subsidies.

2.3.2.1. Personal factors affecting adoption

It is crucial to look at characteristics of a farm household and farming community as influential variables in decision-making. Social researchers have found that many of these characteristics significantly affect adoption decisions regarding technologies such as reduced tillage practices, while some findings are very mixed. (The following categorizations of factors affecting adoption behavior are not placed in any particular order of importance.)

Household and family

In North America, individual families typically own farms. Therefore, discussions about adopting a new technology such as a reduced tillage system may include several members of a household. Usually, a male (head of the household) will be considered as "the principal farmer" and plays the main role of making-decisions, while opinions of other household members may be influential in this decision-making process (Chibnik, 1987). Wives or other family members can be barriers to adoption of this technology as well as supporters of new farming practices (Salamon et al., 1997). Salamon et al. (1997) found that, in a conventional tillage system, female spouses are more concerned about chemical effects on the environment more than their husbands, whereas male spouses are more interested in economic benefits and stability of this technology. Adoption of new farming technology is not a "sudden paradigm switch"; it is very much related to a family history such as what their fathers experienced and what their philosophy was (Salamon et al., 1997). However, Carlson and Dillman (1983) stated that when family members have common interests for the future of the farm, the use of technology like conservation farming practices is significantly higher. Salamon et al. (1997) concluded that "the entire farm family, its history, its kinship, network, and its community shape the social context for adoption".

Education

One of the most evident characteristics of adopters is level of education (Buttel, 1987; Carlson, et al. 1981; Ervin and Ervin, 1982; Pampel and van Es, 1977). Farmers with post-secondary education have a greater probability of accepting advanced or new agricultural technology than farmers who have less education. However, in some cases, even when a principal farmer did not have post-secondary education, if other members of the household have had some education, they can influence principal farmers to adopt new technologies such as a reduced tillage system (Chibnik, 1987). The level of education enables farmers to access many sources of information and to better conceptualize new innovations in the context of their own farming operation. Also, some researchers suggested that education is positively related to awareness and knowledge of government programs and positive attitudes towards government projects (Ervin and Ervin, 1982). It definitely reflects an acceptance of new farming practice like conservation tillage. Such results are found consistently in many studies (Clearfield and Osgood, 1986; Pampel and van Es, 1977). Also, Salamon et al. (1997) suggest that adopters are more open to trying new techniques, and perhaps because of a positive relationship with their career and experience with educational institutions prior to farming.

Local leadership

Some studies suggest that farmers who are initiators or leaders in their local community are likely to adopt new technologies earlier (Carlson and Dillman, 1986; Lovejoy and Parent, 1981). Perhaps this is related to the fact that better educated and bigger farmers are usually leaders in local communities because they often have resources to influence others. Thus, adoption researchers came to the conclusion that farmers are not restricted to relying on only formal information sources like extension activities or institutionalized sources to make their decision to accept new practices. Farmers' decisions are greatly affected by neighboring farmers' and informal community leaders' advice and opinion (Wilkening, 1952). Later, Lionberger and Francis (1969) confirmed previous findings about influential persons in the community having more effect on farmers' decisions to adopt new practices. He suggested that influential people in the community play a more important role than extension personnel because the extension personnel increase awareness about a new innovation, whereas trusted leaders in the community influence farmers to actually make a decision to adopt. In addition, Duncan and Kreitlow (1954) suggested that community background is also associated with adoption behavior. Among ethnically and religiously heterogeneous groups, adoption would more rapidly occur than in homogeneous groups.

Age

Age is one of the variables that results in inconsistent conclusions about its impact on adoption of a new technology. Results are also different among different technologies. Since the focus of this thesis is on adoption of conservation farming practices, only soil conservation technology adoption in relation to farmers' age was examined. Studies that considered the relationship between the use of a new agricultural technology like soil conservation techniques and farmers' age reported inconsistent results (Chibnik. 1987; Buttel et al. 1981; Pampel and van Es. 1977; Clearfield and Osgood, 1986). Some studies found no significant relationship between the age of farmers and their adoption of soil conservation practices (Chibnik, 1987; Carlson, et al. 1981), while others suggest greater relationships between younger farmers and acceptance of this technology (Seitz and Swanson, 1980; Nowak and Korsching, 1983; Buttel and Swanson, 1986). They claimed that younger farmers would likely accept soil conservation practices (Seitz and Swanson, 1980). Other researchers have argued that older farmers adopt soil conservation technology more than younger ones (Lasley and Nolan, 1981) because they are more concerned about future generations and have a greater desire to preserve the land for their children (Chibnik 1987). It is a subjective area because it may be younger children who influence their fathers' farm decision-making or vice versa.

Also, some researchers suggested that because years of farming and the age of farmers would likely have a linear relationship, each of these should also have linear correlation with the use of a conservation tillage system. Surprisingly, they also found mixed results between years of farming and adoption of conservation farming practice and the same with the age of farmers (Clearfield and Osgood, 1986). Therefore, more research is required to determine the effect of both length of farming and age of farmers on the adoption of conservation farming practices.

Off-farm employment

Sometimes, farmers are obligated to look for other income sources if their farming businesses are not very profitable. The time saved by reducing fieldwork allowed farmers to be employed in off-farm jobs, although some farmers preferred to spend that time with their families and on other social activities (D'Souza. et al, 1993; Buck, 2001). This is believed to be one of the factors that influence farmers' decisions to adopt a reduced tillage system. Nevertheless, with regard to off-farm employment, studies showed mixed results. Some studies suggest the presence of off-farm employment has no effect on the use of a reduced tillage system (Chibnik, 1987). However, some found a negative relationship between off-farm employment and the adoption of conservation farming practices (Ervin and Ervin, 1982; Taylor and Miller, 1978). In addition, Clearfield and Osgood (1986) suggest that having an off-farm occupation could also affect conservation behavior: “professional part-timers might be more likely to adopt conservation practices, because of higher education levels and availability of cash income”. However, this area has not been examined in depth.

Beliefs and attitudes

Farmers’ beliefs and attitudes are two of the motivating factors that affect the adoption of farming methods. For example, some farmers dislike government programs and government representatives monitoring their fields (Chibnik, 1987), so they refuse to use technologies promoted by a government. Social studies on soil conservation adoption found mixed attitudes towards governments (Clearfield and Osgood, 1986). Some farmers believed that accepting soil conservation techniques is like contributing welfare to the future generations and it is a moral obligation to adopt conservation farming practices (Ervin and Ervin, 1982; Clearfield and Osgood, 1986). Some researchers, however, found the opposite results between belief and adoption of conservation practice. For example, a Saskatchewan farmer said that “the soil is a live organism like a human body, and use of chemicals on soil is the same as letting humans drink chemicals” (D. Tanner, 2007). Therefore, farmers may have very mixed beliefs about what a conservation practice is, and not enough studies have examined this complex area. Some farmers might have very strong conservation attitudes, yet might not be practicing conservation farming methods. Therefore, attitudes and beliefs may not always explain farmers’ adoption behavior better than lack of knowledge, financial support, and other variables (Clearfield and Osgood, 1986).

Besides belief, farmers’ risk-taking attitudes have a positive relationship with the use of conservation farming practices (Ervin, 1986; Nowak, 1985a; Carlson, et al. 1981; Buttel, et al. 1990). They found a much more consistent relationship between the tendency to take a risk and the adoption of conservation practices. Also, some farmers believe that by accepting the most current technology, they will receive some kind of recognition among their community and it will help them to appear successful. In Rogers' (1995) study, he suggested that farmers' status achievement was positively correlated with the adoption of new farm practices.

Farm characteristics

As described earlier, farmers in different areas cannot always use the same technology uniformly in the same manner. Therefore, farm characteristics such as farm size, income, number of implements, and environmental conditions like soil type and climate are very important factors affecting the adoption of those conservation practices. For instance, reduced tillage technology is better suited to areas with light (not heavy) soil texture, and topographies that are subject to soil erosion such as hilly areas (Chibnik, 1987).

Another factor that has a significant effect on adoption of new farming practices is the socio-economic profile such as farm size (Buttel and Swanson, 1986; Carlson and Dillman, 1986; Chibnik, 1987; Ervin, 1986; Pampel and van Es, 1977). Although farmers from farms of all sizes show a degree of interest in new farming technologies such as soil conservation practices, they may not all actually adopt them (Salamon et al., 1997). A large number of studies present clear evidence that larger or wealthier farmers practice conservation farming methods more than smaller farmers (Chibnik, 1987; Carlson, et al. 1981; Ervin and Ervin, 1982; Hall, 1998; Nowak and Korshing, 1985; Pampel and van Es, 1977). Clearfield and Osgood (1986) suggested that the larger the farm size and the more income produced by the farm enterprise, the greater the use of conservation practices. Consequently, it may also involve economic factors beyond the size of farm. Buttel et al. (1990) saw a clear relationship between farm socio-economic factors like farm size and income, and the adoption of commercial innovation. They stated that larger farmers tend to adopt conservation practices earlier and more extensively than smaller farmers who introduce the practice when public extension and cost-sharing programs are in effect.

One of the first in-depth studies on characterizing or identifying socio-economic and socio-psychological profiles of adopter farmers was Rogers' (1995). He developed a model to characterize farmers in various adoption categories: innovators, early adopters, early majority, late majority, late adopters, and laggards. Cancian (1967) also tried to show a relationship between adoption of a new farm practice and farmers' risk taking. He stated that the relationship between socioeconomic character and wealth of a farmer and willingness to take risk has a curvilinear pattern. In contrast, Cartrell et al. (1973) found a linear relationship between the economic characteristics of farmers and the adoption of new innovations. Morrison et al. (1976) supported the Cartrell et al. (1973) study. They argued that both adoption and rejection of the innovation involve risk; therefore, a farmer is taking risk with both decisions.

Land tenure

Land tenure is an important issue. Security of tenure may be as important as whether it is owned or rented. Some people with long-term leases from the state have at least as much security of tenure as owners—though there may still be psychological differences. Other studies have suggested that the presence or absence of an heir-apparent affects willingness to invest for the future and employment of new farming practices such as conservation tillage. Some studies show no relationship between land ownership and the decisions to adopt new farm practices, while some suggest owners of land are more willing than renters to use new practices (Carlson, et al. 1981; Pampel and van Es, 1977). Likely, owners of land might give more emphasis on the long-term benefits than a renter (Napier and Foster, 1982). In terms of conservation tillage, both Carlson and Dillman (1986) and Ervin (1986) suggest a positive relationship between owner-operated farms and the decision to adopt soil conservation technology. However, among renters, the decision to use conservation practices is varied (Ervin, 1985). Buttel, et al. (1990) also found very inconsistent results on the relationship between land tenure and the adoption of conservation practices. They also suggested that since land leasing is short-term, unstable, and uncertain, a tenant would have little interest in the long-term benefit to land owned by someone else. However, some of the causes for these mixed results could be that many farmers combine landownership and rental, and they use the same practice over all.

In Mongolia, land has traditionally not been privately owned but the creation of a new land law has made the private ownership of farm land possible. Security of tenure may be as important as whether it is owned or rented. Some people with long-term leases from the state have at least as much security of tenure as owners—though there may still be psychological differences.

2.3.3. Technology adoption processes

Technology adoption is a result of the accumulation of knowledge and information, and successive decisions about implementation of a new technology (Korsching et al., 1983; Bentham, 2000). In other words, a new technology is adopted in stages. The success or end result of technology transfer is the long-term adoption of a new technology by farmers. Thus, the adoption rate of a new technology by producers is one of the measurements of the success of technology transfer activities. Adoption of agricultural technology is well studied; however, the concept of agricultural technology transfer involves a huge variety of concerns and problems (Sajjapongse and Maglinao, 1998). Therefore, being sensitive and alert to farmers concerns and the factors that influence their decision to accept a new technology or not is very crucial to achieve widespread adoption. Some of these factors are personal and under farmers' control and some are independent and beyond their control. Often, scientists or researchers in different disciplines lack knowledge and understanding of other areas that might have significant influence on their work, both indirectly and directly. Hence, it becomes very important to develop an understanding of the whole system in relation to its technological, economical, social, cultural, and environmental aspects.

Achieving widespread adoption of new technology takes time and effort. It does not happen suddenly. Several models have been designed to describe the technology transfer process and adoption stages with the logic being similar in each process (Hall, 2003; Lamble, 1984; Rogers and Shoemaker, 1971; Bentham, 2000). Generally, they describe four steps or phases of the adoption process by farmers: 1) accumulating and gathering of information about a new technology, 2) attributing and persuasion of new technologies, 3) making initial decision to adopt the technology providing they can find necessary resources, and 4) finally, confirming their decision to adopt, and adopting the technology. The following are descriptions of these four steps taken by farmers.

Acquisition and gathering of information about a new technology—Farmers are first exposed to the existence of new practices and start to build some understanding about them. However, this acquisition process continues throughout all stages until adoption takes place. Lamble (1984) further breaks this stage into three steps. First, farmers just became aware of the new technology and its main features. Second, farmers develop knowledge and understanding about the proper application of the new technology within their farming systems. Finally, they become familiar with the underlying principles and theories about the new technology. This is a crucial step for extension agents who are promoting a new technology as it gives the first impression about the new technology or practices. Providing accurate, detailed, and targeted information at this stage may accelerate the process if it first creates an interest in the farmers.

Attribute and persuasion towards new technologies and practices—Accumulation of knowledge and information about the new technology helps farmers decide to adopt the technology if it creates a favorable attitude towards the new technology. Knowing the advantages and disadvantages of new technologies may not convince farmers to accept that technology. According to Lamble (1984), three main factors influence farmers' persuasion. They include an individual's personality, ability to comprehend the future impacts, and friends and neighbors. This stage involves considerable extension effort and activities. If the decision will ever be made to adopt the technology, it will begin at this stage.

Adoption decision—In this stage, individuals make many evaluations based on information they receive through extension activities. As a result of these evaluations, farmers make their choice to adopt or reject the innovation. Often, farmers will go through a trial stage where they try a new practice on a small area of land before they make their final decision about adoption. The level of satisfaction gained through a trial or demonstration stage influences farmers quite significantly towards accepting the new technology. On-farm demonstrations using smaller land areas help to build confidence or assurance in farmers to make the leap to adoption for their entire farming operation.

Confirmation of the decision—During this stage, farmers continue to seek more information to prove their decision is correct. However, if there is an issue or conflict, often farmers look for more information that will eliminate, solve, or at least explain the cause of the problem. In this stage, much thinking and rethinking is required. Sometimes, it leads to refinement of the technology, or potential rejection of the new practice. Normally, in this stage, farmers are quite unsure about their decision to adopt.

A model that was developed by Maglinao and Phommasack (1998) (Figure 5) has one additional stage to that described above—implementation. Implementation is similar to the trial stage that was mentioned previously, but on a larger scale. It should be noted that none of these models mentions rejection after the decision and/or confirmation. It is possible that farmers change their decision after using the technology for a little while due to cost, family issues, market, and so on.

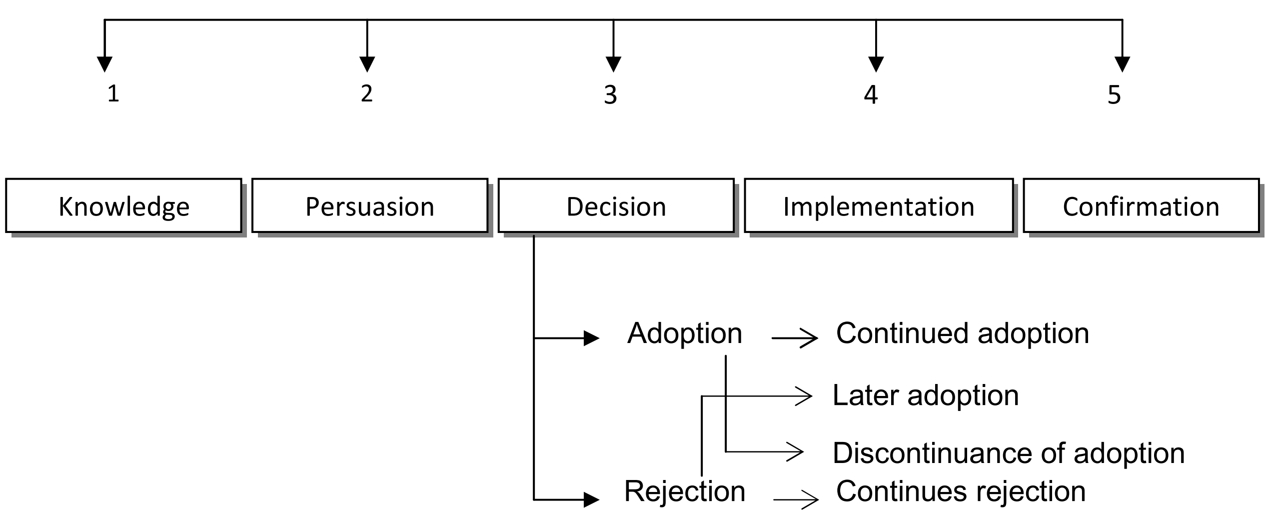


Figure 5. Stages of adoption and decision-making processes (Maglinao and Phommasack, 1998)

Maglinao and Phommasack (1998) stated that knowledge is gained when an individual first learns about an innovation and gathers information about how it functions. Through persuasion, a farmer forms a favorable or unfavorable attitude towards the innovation, and that leads to the decision to adopt or reject. If a farmer develops a positive attitude towards the new technology, then the idea of implementation or demonstration will follow. Implementation (trial) occurs when farmers put the innovation into use. However, as the previous model suggested, the decision for adoption and putting it to use may still be changed if a farmer's experience is not to his/her satisfaction (Maglinao and Phommasack, 1998). Hall (2003) stated that adoption of new technology is an ongoing process and it often leads to continuous modification in knowledge and farming practices.

2.4. Case Study: A New Technology Transfer in Mongolia: soil conservation practices

A case study will be used to illustrate of the technology transfer process and adoption mechanisms in Mongolia using the most recent technology transfer process, namely conservation tillage as the example. Introduction of conservation tillage practices in Mongolia is a good example of the creation, transfer, and adoption of new technologies. Different aspects of this technology transfer process will be discussed at the end of each chapter where relevant. Therefore, only a brief background of the Mongolian farming systems, initial steps of the introduction of conservation tillage technology in Mongolia, and how it relates to the soil conservation revolution of North America, will be described in this chapter.

2.4.1. Mongolian crop farming system before transition to a market economy

Like their Western Canadian counterparts, Mongolian farmers used a tillage-summer fallow and wheat (50:50) rotation that involved extensive cultivation in the conventional farming system until quite recently. As a result of long-term use of conventional tillage practices, Mongolian farmers began to face problems like serious soil erosion, the reduction of soil nutrients, increased weed infestations, higher production cost, and lower yields. Consequently, farm production and economic return have declined and the rural economy of Mongolia has become very vulnerable to the harsh climate. It has become clear that crop farming will not succeed unless Mongolia introduces alternative tillage and cropping technologies to improve crop production and soil management, enabling a sustainable agricultural industry. As a result of the decline in agricultural productivity and the rural economy, over 40 percent of rural Mongolians now live in poverty (World Bank, 2007). In order to improve the social and living conditions of rural communities, the rural economy must become profitable and this will happen only if the agricultural industry becomes more profitable. However, successful farming does not come without adequate knowledge and appropriate technology. This requires an influential extension or information delivery system and a suitable social environment. Therefore, development of an influential and applicable extension model to successfully introduce new technology to rural producers has received the attention of political powers in Mongolia. There is also strong interest to import reduced tillage technology to the country.

This change in approach happened during the transition from a centrally-planned economy to a free-market economy which began in 1991. A positive impact of the transition was that it enabled international exchange not only in trade and marketing areas, but it also opened the doors to foreign technologies and expertise. It is believed that a technology such as minimum tillage is essential for the development of a sustainable agricultural industry and rural economy in Mongolia, since these technologies have had a major impact on rural Saskatchewan, which has a very similar environment to Mongolia.

2.4.2. Soil conservation revolution in North America: new technologies, new problems, and the demand for new information and technological solutions

One of the major revolutionary phases in the history of agriculture in North America was the adoption of conservation farming practices under the umbrella of sustainable agriculture. Especially in the 1930s, known as the “dirty 30s”, farmers in the western

Canadian and American grain belt witnessed the same problems of soil erosion and loss of topsoil that are currently being experienced in Mongolia. Farming practices, including very intensive tillage, have been identified as creating both harmful short-term effects and long-term problems. Especially in dry-land agricultural areas, soil erosion still remains the dominant threat to the long-term sustainability of agriculture. Erosion has an impact on long-term productivity through its effects on soil quality. Since then, there has been much discussion among farmers, agricultural scientists, agricultural organizations, businesses and government about the conceptualization and examination of those problems, and finding solutions that contribute to sustainable agricultural production. As a result, various conservation practices have emerged as solutions to many of those problems that arose in traditional tillage-based or conventional agriculture systems. The main objective of conservation farming practices is to protect soil from erosion and to reduce soil degradation. In other words, conservation farming technology attempts to control erosion by reducing tillage operations. This is why it is sometimes called a minimum tillage or reduced tillage system. By substituting tillage with chemicals to control weeds, reduced soil-disturbing operations will control soil erosion by leaving crop residue and stubble on the soil surface to protect the soil. It became evident that reduced or minimum tillage is an important soil conservation practice that protects soil from erosion, improves soil organic matter content, reduces the loss of soil moisture, and reduces production costs. Conservation farming practices are also identified as being more compatible with the goals of progressive industrialization and globalization, while addressing both environmental and socio-economic problems (Napier and Foster, 1982; Nowak, 1985b).

However, after using reduced tillage technology for several years, farmers in Canada have began to face new challenges that they did not have in a conventional farming system, such as new weed infestations and herbicide resistance (Beckie et al, 2004). One of the weeds that became a major problem in crop fields is dandelion (*Taraxacum officinale*). Dandelion has become an increasing concern in North America ever since direct seeding technology became widely practiced. Dandelion is a perennial weed and it is difficult to control in direct seeding systems.

Dandelion is a weed problem in over 20 countries (Mitich, 1989). Dandelion infestation in Canadian cropping systems appears as a direct result of the introduction of minimum tillage practices (Stevenson and Johnston, 1999). There are not many control options for perennial weeds in zero-till or low-disturbance farming systems. This limitation has caused a rapid increase of perennial weed dispersal such as dandelion in the North American prairies (Stevenson and Johnston, 1999). Dandelion plants are able to survive through a wide range of climatic conditions, especially in the mature growth stage (Stewart-Wade et al., 2002). Therefore, issues related to control of dandelion in a direct seeding system have raised a need to find a “new solution” to a “new problem”. It will require research concerning its competitive ability, biology, ecology, and demography of population in annual cropping systems. Finding dandelion control methods is crucial to reduce yield loss caused by dandelion plants. It leads to new research projects to generate new solutions to solve farm problems and create new information and technology. This on-farm concern for dandelion control methods is creating a demand from producers for solutions from scientists. Basically, the increase in dandelion is seen as a result of reduced tillage systems. Although there is a possibility of controlling it with tillage systems, there is also concern that a return to tillage may cause soil erosion, reduce soil quality, and the light fraction of the soil organic carbon (LFOC). Addressing this complex issue is not simple. Therefore, we examined both chemical and tillage control methods for dandelion as a part of the thesis research projects (see Appendices A and B for the specific field research results).

3 FIELD RESEARCH WITH MONGOLIAN FARMERS AND OTHER EXTENSION STAKEHOLDERS

3.1. Introduction

Sustainable rural development is a high priority for Mongolia. Agriculture is the main source of employment for rural people, and is central to the livelihoods and culture of rural families. As a result of declines in agricultural productivity and the rural economy, over 40 percent of rural Mongolians now live in poverty (World Bank, 2007). In order to improve the social and economic conditions of rural communities, the rural economy must become profitable, and this will happen only if agriculture becomes more profitable. However, if building sustainable agricultural systems is the goal, the social and economic implications of new agricultural practices and technologies must be carefully assessed.

Due to growing awareness and to deteriorating resources, environmental issues have received more attention in recent years. In agriculture, there has been growing concern about the impact of conventional farming practices with respect to soil erosion, fertility, and field productivity declines. Soil degradation is a term used to denote the range of processes that contribute to the loss of desired qualities in soils. Soil degradation and associated desertification are problems in Mongolia as they are in many other parts of the world (Pimentel et al, 1995). One of the responses to these issues is to implement more environmentally friendly farming systems.

An alternative approach that potentially reduces soil erosion, conserves soil moisture, and improves soil fertility is low-disturbance tillage. This set of practices and technologies is known globally by various names including zero-till, no-till, direct seeding, minimum tillage, conservation tillage, or conservation farming. This thesis focuses on conservation farming as a technological package and on its adoption in Mongolia. This chapter specifically deals with the results of a field survey in Mongolia that examines farmer and extension agent perceptions and attitudes towards conservation farming systems. There are many forms of conservation farming practices and systems. They have been known by different terms in different times and places. Here, the term “conservation farming technology” or “conservation technology” will be used to refer collectively to the various cropping systems that involve, at their core, reduced tillage or reduced soil disturbance approaches.

In Canada, agricultural technology is relatively advanced, and the adoption of conservation farming systems has progressed further than in many other countries. Proper introduction of this technology is seen by some observers to be essential for the development of a sustainable agricultural sector in Mongolia. Canada is a leader in the adoption of this technology, with conservation farming methods used on 74 percent of total seeded land in 2006 (Statistics Canada, 2006). Among Canadian provinces, Saskatchewan is the most advanced with respect to the adoption of conservation farming practices. About 60 percent of Canada’s conservation farmers are located in this province. Agriculture and Agri-Food Canada's Ontario Land Resources Unit reported that conservation farming methods have reduced soil erosion dramatically, in that the risk of wind erosion decreased by about 13 percent between 1981 and 1996 (Statistics Canada, 2002). Intensive tillage prior to seeding and tillage-based summer fallow are the main reasons for continued soil erosion. Until the late 1980s, the total area of crops under conservation technology was very small—probably less than one percent of seeded cropland. In 1990, a significant area of Canadian cropland was managed using some form of conservation tillage. Since 1996, conservation farming practices have been rapidly gaining farmer acceptance (Statistics Canada, 2006). However, in Canada and elsewhere, many farmers still have not adopted this kind of tillage and cropping system. Therefore, it is important to understand the reasons for non-adoption including the barriers to adopting such conservation farming technology.

Many very interesting questions can be raised regarding the adoption of this technology. For example, if it is such good technology, why are many farmers not adopting it, and what kind of barriers are they facing? What kind of social and economic factors affect adoption of this new technology? What kinds of information and information delivery system are best suited for the introduction of such technologies? Such questions are not only issues for agrologists. They are also multidisciplinary issues that need to be addressed in relation to social, economic, and environmental factors. Many scientists have come to realize that social and economic factors are as important to agriculture as the environmental and technological factors (Lovejoy and Napier, 1986). A socially, economically, and ecologically viable farming system needs to include the introduction and implementation of appropriate advanced technologies. Hence, knowledge about the factors that will likely affect producers' adoption of new technology will help in the development of introductory programs. Agriculture scientists have been involved with technical aspects of the agriculture system such as soil quality, plant protection, genetic studies, and other ways to increase crop production. Although they are all necessary for improving the world food supply, social influences on sustainability, which are equally important, tend to be ignored (Beckie, 2000). Therefore, it is necessary to look at agricultural technologies and practices in relation to social, economic, and environmental factors, particularly at the local level (IAASTD, 2009).

Since the early 1980s, there has been a growing emphasis on environmentally-friendly approaches to farming, and, as a result, competing models of sustainable agriculture have developed. The word "sustainable" refers usually to the interaction of complex factors. In reality, environmental, social, and economic factors are very closely related, and they influence each other under a large umbrella of sustainable rural agriculture (Hall, 1998; Saltiel et al, 1994). Sustainable development is a reflection of the social and economic interactions of human activities, and they are as crucial to sustainability as environmental and industrial activities (World Bank, 2007; National Statistical Office of Mongolia, 2007).

Another important consideration is how to introduce and implement new technology given a specific set of challenging social and economic circumstances. The particular issues and problems will often vary between geographical regions and cultures. Understanding the role of people and culture in relation to the adoption of a new technology is often more difficult than providing the technological solution (Boehm and Burton, 1997). The agriculture technology shift in the 1980s and 1990s not only changed agronomic practices, but also changed social dynamics and people's life styles. Therefore, it is important to gain a broader knowledge of the social, psychological, cultural, political and economic barriers that may inhibit individual farmers from adopting new technologies.

Developments in the agricultural sector have been centered on the creation and improvement of technologies which increase productivity and efficiency. This includes the development of agricultural inputs such as agricultural machinery, chemical products, plant and animal genetics, among others. However, the impact of adopting modern agricultural technology and farming practices on rural communities and economies, is generally not studied in an integrated, multidisciplinary way. Although technical issues must be addressed in order to increase production, the agricultural sector is likewise highly influenced by political, economic, cultural, and environmental forces. Because agricultural development dependents on multiple factors it important that it be studied in a multi-disciplinary fashion.

Most research on sustainable agriculture focuses on productivity, profitability, as well as the environmental dimensions of a cropping system. There are evident gaps between the insights and investigatory frameworks of agrologists, sociologists, economists, ecologists and others. The gaps in knowledge, communication, and coverage between the disciplines can reduce the sustainability of development. Farmers and agricultural scientists have discovered and demonstrated various advantages of alternative farming technologies. One of the biggest innovations in terms of beneficial effects on maintaining or improving soil quality has been the introduction of conservation farming technology (Hall, 1998). High-disturbance soil tillage or conventional tillage has been linked with soil erosion and degradation of soil resources in many agricultural regions. Although conservation farming has been identified as a key to “sustainable” farming both economically and environmentally, some farmers still have not adopted this technology and use conventional farming systems such as high-disturbance soil tillage (Boehm and Burton, 1997; Hall 1998). It is important to understand what the barriers are to the adoption of low-disturbance technology and why all farmers have not adopted this technology. Saltiel et al. (1994) suggested that for future adoption studies, scientists should study the measurement of environmental problems at the farm level, information resources available to farmers, and the effect of farmers' financial condition on their adoption of new technology.

In previous studies, most farmers were found to consider the economic benefits of conservation farming technology more than the environmental benifits when they answered questions on adoption (Hall 1998). For instance, new herbicides, such as glyphosate, can provide a cheaper alternative to tillage for weed control. The availability and comparatively lower cost of glyphosate has encouraged the adoption of conservation tillage cropping systems in Canada (Statistics Canada, 2002). Similarly, Saltiel et al. (1994) identified the financial position of farmers as one of the most important factors for the adoption of new methods. Another study by Boehm and Burton (1997) also found that the most influential factor affecting farmer attitudes towards conservation technology was the availability of financial resources. They also observed that a farmer's age correlated with the adoption of the conservation agricultural practices. In addition, Pampel and Van Es (1977) found that adoption also depends on a farmer`s attitude and beliefs about the role of farming more broadly. For example, some conservation-minded farmers hope that conservation technology will have a long-term benefit on the rural environment and adopt it for this reason. The same study also identified farm size as a determining factor of adoption. Bigger farms, and farmers who are striving to become bigger, are more likely to adopt the technology. Another researcher found that a farmer's level of education and knowledge about conservation technology were positively associated with their decision to adopt it, while the economic benefits remained a common incentive for all farmers (Barao, 1992).

From this illustration, while financial benefits remain an important driver in the adoption of a new technology, other factors such as age, education, and farming attitudes also play an important role, Therefore, any generalization about adoption behavior in different parts of the world would be a mistake. For this thesis, a small field research study was carried out in Mongolia to examine more closely the way farmers think about conservation tillage technologies—and, in particular, what may influence their decisions with respect to the adoption of conservation farming practices. This field study was intended to contribute to the discovery of the best methods for encouraging the adoption of conservation farming practices in Mongolia.

3.2. Objectives

In order to address the rural development challenges in Mongolia, appropriate research is needed to determine the most effective methods to provide training to people in rural areas, and to understand the social, cultural and economic factors that influence their farming activities and decisions. Achieving this complex goal presents interdisciplinary challenges. Agriculture is a key to rural development but it needs to be addressed in relation to social, economic, and environmental factors. For example, acceptance and adoption of conservation tillage technology is related to many social factors such as labor, age, financial status, gender, education, presence of an heir, and farm organization membership/affiliation. Recognition of the limitations of disciplinary research studies and the need for more integrated and interdisciplinary approaches is becoming widespread. Traditionally, there has not been much attention to dynamic interactions among the different components and dimensions of the whole agricultural system. A single disciplinary approach limits capacity to study such interactions, and to understand the interplay between technical, environmental, and social dimensions.

This study included three types of field research involving different methods, respondents, and foci. The field studies were intended to complement each other in fulfilling the following objectives:

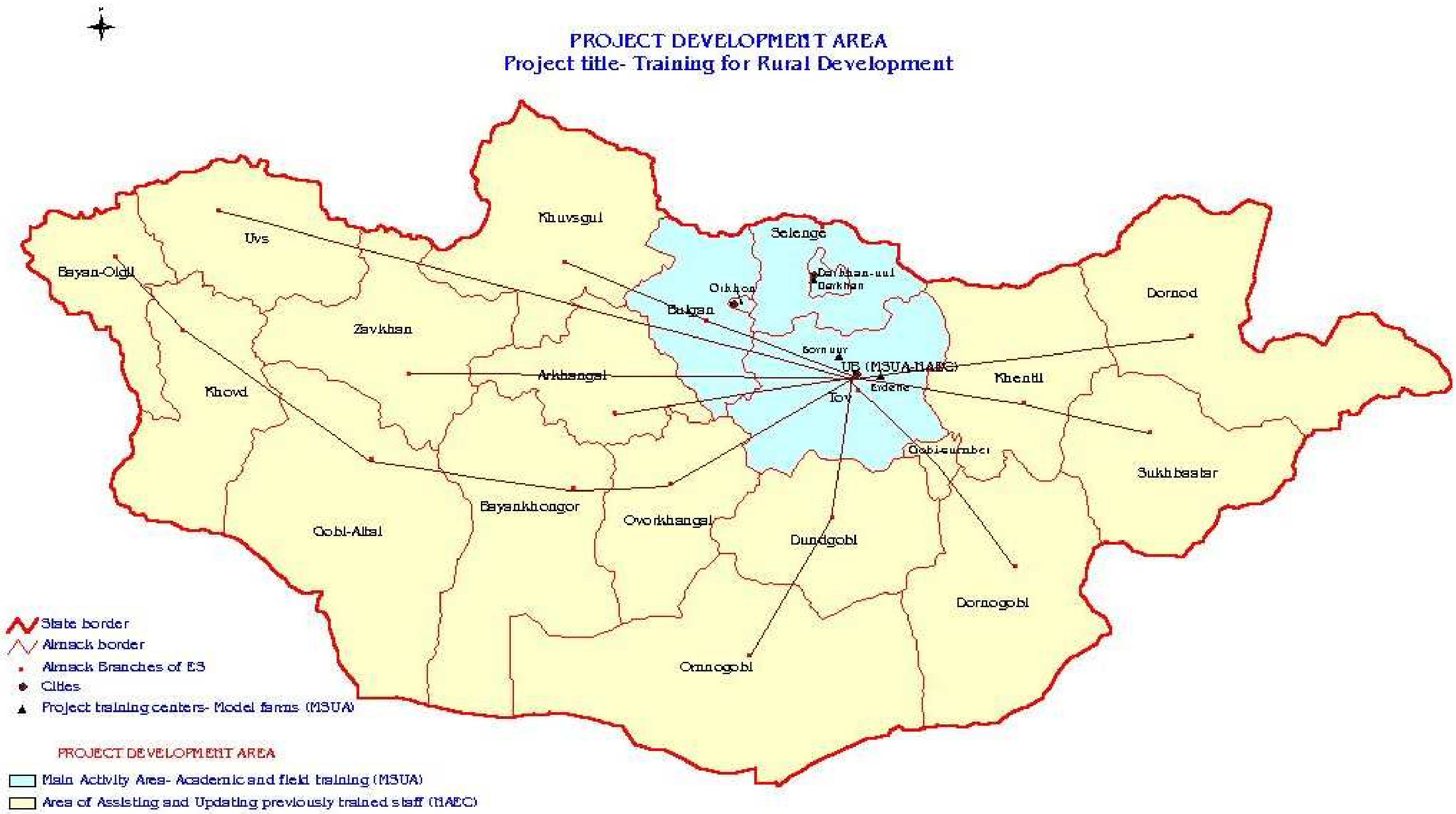
1. To identify and understand the most influential social, economic, and environmental factors affecting Mongolian farmers' adoption of conservation farming practices; and
2. To suggest an effective approach for agriculture extension systems in Mongolia by gaining a good understanding of the factors that affect farmers' decisions to accept or reject conservation farming technologies on their farms.

3.3. Materials and Methods

3.3.1. Site description

All of the farmers who participated in the surveys, interviews, and the case study are independent farmers from Selenge aimag of Mongolia which is similar to Saskatchewan in Canada in that it is the most important cereal crop production area in the country. Many other characteristics make Selenge aimag similar to Saskatchewan. Selenge, like most of Mongolia, is dry and warm during the summer and very cold in the winter. The average temperature of Selenge aimag is $+2^{o}$ C, and the average precipitation per year is about 310 mm. Climatic characteristics of Mongolia are similar to those in Saskatchewan where average annual daily temperature is $+2.5^{o}$C, and annual precipitation is 348.3 mm (Environment Canada, 2009). In Mongolia, the main crop is spring wheat, and the main crop rotation is wheat and summer fallow. Over 80 percent of farmers in Selenge aimag use conventional farming systems featuring conventional soil preparation practices including plowing (Terbishdavga, 2008).

Figure 6. Map of Mongolia: field research sites are highlighted in blue.


PROJECT DEVELOPMENT AREA
Project title- Training for Rural Development
Uvs
Bayan-Olgii
Khuvsgul
Selenge
Darkhan-uul
Darkhan
Orkhon
Bulgan
Zavkhan
Khovd
Arkhangai
Bornuur
UB (MSUA-NAEC)
Erdene
Tov
Khentii
Dornod
Sukhbaatar
Gobi-sumber
Bayankhongor
Gobi-Altai
Ovorkhangai
Dundgobi
Dornogobi
Omnogobi
State border
Aimack border
Aimack Branches of ES
Cities
Project training centers- Model farms (MSUA)
PROJECT DEVELOPMENT AREA
Main Activity Area- Academic and field training (MSUA)
Area of Assisting and Updating previously trained staff (NAEC)

3.3.2. Field research methods and tools

Since the objectives of this research cross multiple disciplines, the research methods employed were necessarily varied. Field research was conducted in Selenge aimag of Mongolia during the summers of 2004 and 2005. Data were collected in Mongolian and later translated into English. The overall research approach included three aspects: 1) field research including a survey questionnaire, interviews, and a case study; 2) field personal observations and experiences; and, 3) a review of secondary data and relevant literature.

An interdisciplinary approach was employed in order to integrate both social and technical dimensions of technology development, transfer, and adoption. This research also used an exploratory approach. The field research consisted of structured survey questionnaires administered to extension agents and to cereal farmers, semi-structured interviews with a subset of adopting farmers, a case study of a technology transfer project, and conversations, observations, and participation in various events such as conferences, workshops, and meetings. Analysis and interpretation of the field data were based on a review of relevant literature including selected works from the applied agricultural sciences, agricultural extension, rural sociology, and studies on knowledge and technology.

All field research and data collection were carried out in conjunction with Training for Rural Development (TRD) Project activities in Mongolia. The University of Saskatchewan (U of S) in partnership with the Mongolian State University of Agriculture (MSUA) received funding for this project from the Canadian International Development Agency (CIDA) and its University Partnership and Development Program (UPCD). Partnership in this case was between the University of Saskatchewan (U of S), the Mongolian State University of Agricultue (MSUA), the National Agriculture Extension Center (NAEC) in Mongolia, and Agriteam Canada, a consulting company based in Calgary, Alberta. The TRD Project provided the author with opportunities to conduct field research while also being involved in various project activities in Mongolia. To reduce costs and to increase access to farmers, the author took advantage of various project-related farmer gatherings such as workshops and field days to conduct field surveys and interviews with farmers. The farmers consist of a mixture of adopters and non-adopters of conservation tillage farming practices.

All of the farm surveys were conducted in 2004 during a trip to Mongolia to assist the TRD project with its baseline study in Selenge aimag. The project organized five farmers' participatory workshops across the aimag to conduct a baseline study and to get farmers' feedback on proposed project activities. The workshop locations were approximately 300-500km (a day drive by car) apart from each other. Each workshop was one day long. An extra day was spent at the location to have wrap-up discussions with local officials, for gathering of secondary data, and team reflection on the feedback that was received. A team of five people including the author facilitated the workshops. Other responsibilities of the author were to act as the team leader for the group and also deal with logistics and organization of the workshops in partnership with the local governments. The workshops were advertised in advance and local governments took the lead in publicizing the events and recruiting farmer participants. The workshops were often held in school classrooms or government building meeting rooms. They started at 9:30 am and ended around 5 p.m. with the completion of the survey questionnaire for this thesis. The workshops consisted of various participatory exercises such as Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis, and a problem tree analysis. On some occasions, surveys were distributed to the workshop participants at lunch time so as to allow them to be filled out during the afternoon, and handed back before they left the workshop.

3.3.2.1. Structured survey questionnaire for farmers

The aim of the survey or structured questionnaire was to obtain a better understanding of the technology transfer process and mechanism in Mongolia and farmers adoption decision-making based on their social economic factors. Since minimum tillage technology was the latest example of technology transfer in Mongolia, the structured survey questionnaire was developed in relation to the transfer and adoption of minimum tillage farming practices. The survey had two parts: 1) a structured-descriptive questionnaire to gather demographic information on farmers and extension personnel, and 2) a semi-structured and open-ended questionnaire to explore their perceptions about reduced tillage practices and decisions to adopt this technology.

Survey questionnaires were completed by two different groups of participants—farmers and extension agents. Extension personnel are locally called extension center managers. A total of 96 surveys were distributed to farmers and 30 to extension center managers. The field data were collected in conjunction with the “Training for Rural Development Project” (TRD) activities in Mongolia. The author’s involvement with the CIDA-funded project activities made it possible for her to travel to Mongolia and to visit rural areas where data could be appropriately collected for this thesis. Apart from funding the author’s travel and the workshops where the survey data was collected, CIDA did not have any direct role in this research. As such, there doctoral thesis research data were collected in parallel to the TRD project activities in rural Mongolia but without either project being significantly affected. Participants were informed that the two initiatives were separate, and that participation in the thesis survey was voluntary. Nevertheless, it is possible that conditions under which farmers participated in the CIDA workshops may somehow have affected their willingness to participate in the thesis survey. One could speculate that the effects on participation rates might have been both positive and negative and that any effects on responses might have been quite varied (if not random).

Farmer surveys were conducted at the end of needs assessment workshops for the Training for Rural Development Project. The TRP Project staff in Mongolia organized five needs assessment workshops, and was responsible for recruiting farmers for each of these regional events. Local government extension agents sent invitations to all farmers in the regions via local TV and radio programs. Also, towns in rural Mongolia are small and news spreads quite effectively through oral communication. The workshops were organized in five regions of Selenge aimag of Mongolia. The provincial center of Selenge is approximately 450km (7 hours by car) north from Ulaanbaatar, the capital of Mongolia, where the project office was located. Farmers who came to the workshops were asked to participate in an additional research survey on a voluntary basis to support this thesis research. At the end of the workshop, survey sheets were distributed to all participants who had consented to participate. The survey took about 30 minutes to fill out. When they finished, they handed the survey sheets to one of the workshop facilitators at the door. The survey was designed to collect information from grain farmers including adopters and non-adopters of conservation farming practices in Selenge. The questionnaire consisted of 70 questions including five open-ended questions. Most of the items were multiple-choices questions with possible responses indicated though many included space for comment and an “other” category with space for write-in answers (see appendices C and D).

There were two main variables - adopter and non-adopter of conservation farming practices. In addition to these two main variables, some key characteristics such as farm size were considered in the selection of farmers for the field survey. The names of farmers in Selenge aimag were obtained from the Ministry of Food and Agriculture and the Mongolian Farmers and Flour Producers Association. It was confirmed that the farmers who came to the workshops were representatives of both adopter and non-adopter farmers of reduced tillage practices in those regions. When uneven representation of adopters versus non-adopters occurred, additional arrangements were made to interview or survey farmers that were underrepresented. This meant driving from one farm house to another, and knocking their doors to get them to complete the survey. Unfortunately, most of the field surveys (53 out of 96 surveys) were returned incomplete and could not be used for this thesis[8]. Therefore, 43 surveys were used for the field research results and discussions.

The scale of the farms represented by the farmers who participated in these workshops varied. Some were relatively large and commercial, and some were small, household labour-based family farms. The survey gathered data on farmer background and knowledge through questions relating to age, education, farming experience, and so on (see Appendix C). Social and economic factors were further explored through questions

[8] Some surveys were returned with only demographic information on the farmer or the person who was filling out the survey, but did not provide any information on the agriculture production side. If more than 60 percent of information on production was not filled, the survey was considered incomplete and inadequate to be used.

on the availability of labor, family history, household, and enterprise financial status as well as role of government programs.

3.3.2.2. Structured survey questionnaire for extension agents

A modified version of the survey questionnaire was used to collect information from the extension personnel (see Appendix D). The “Training for Rural Development” (TRD) project organized a seminar session for extension personnel from agriculture extension centers across the country. The author acted as a translator and facilitator for the seminar. The 34 participants represented 17 of the 22 aimags in Mongolia. At the end of the seminar, the author introduced the purpose of this thesis research and extension personnel were encouraged to participate by filling out the survey questionnaires, which were distributed to all participants following the signing of a consent form. During the process of completing the questionnaire, six people withdrew their participation due to their lack of familiarity with reduced tillage (minimum tillage) crop-farming practices. It was expected that some extension managers would have no or little understanding of minimum tillage practices due to their background and specialized areas of expertise. However, many of the extension personnel were eager to share their opinions about new technology transfer and dissemination of information through their extension services. Upon completion of the surveys[9], the questionnaires were returned to the author. However, many extension personnel wanted to stay to discuss minimum tillage technology and expressed some frustration about the lack of information and educational resources available for new farming practices such as minimum tillage in Mongolia.

Both farmer and extension personnel survey data were entered into a Microsoft Excel® spread-sheet for easy storage and retrieval upon return to Canada. Both qualitative and quantitative methods were used to analyze data. Participant confidentiality and anonymity were taken into consideration during data processing, analysis, and

[9] Extension personnel surveys were returned much more fully completed than those from farmers. Especially, those extension workers who were involved in the transfer of minimum tillage technology seemed quite pleased to fill out the survey.

presentation. Prior to carrying out the research, appropriate ethical approval was granted by the U of S Research Ethics office.

3.3.2.3. Face-to-face interviews

Face-to-face interviews were used to gain more specific insights into the introduction of conservation farming practices in Mongolia. An interview outline was developed based on a review of the relevant literature using descriptive and explorative approaches to social study. Interviews were structured similarly to the survey outline but with much freedom and flexibility. Also, an in-person interview gave the author an opportunity to observe respondents' non-verbal communication.

Interviews were mainly intended to increase the representation of farmers. Another purpose of the face-to-face interview was to increase the response rate, complement results from questionnaires, and confirm the accuracy of results. Most in-person interviews were conducted with farmers who had accepted conservation farming technology and started practicing some version of a reduced tillage system on their farm. However, due to the recent introduction in 2000 of conservation farming practices in Mongolia, the level of implementation of reduced tillage practice varied. None of the farmers surveyed had completely adopted a reduced tillage system on their farms. The highest adoption level was about 60 percent of the farm converted to a form of reduced tillage practices which often meant using chemicals to control weeds instead of using a conventional plowing system in the summer fallow phase of the wheat-fallow rotation.

Seventeen in-person interviews were conducted. In July 2003, 10 people including farmers, professors, researchers, extension personnel, politicians, and an international project representative were interviewed. In these initial interviews, an attempt was made to sample different segments of the agriculture development sectors in Mongolia. Most of the interviews took place in the subjects' workplaces in Ulaanbaatar. In July 2004, seven more farmers who had adopted reduced tillage practices were interviewed. Most of the farmers were male heads of households, though their spouses were typically actively involved in the farming operation.

Interviews were conducted with individual farmers, often in their farmyards or in their farm offices. In all cases except two, men were the “principal operators” and managers of the farms surveyed. On three occasions, their wives accompanied them during the interviews. In most cases, these women act as accountants and bookkeepers, or they run small businesses such as restaurants, hotels, and/or stores along with the farm office. Unlike in Canada, many crop farms in Mongolia are considered commercial enterprises—limited companies—and have a farm office separate or distant from the family house/yard. Although this provided a good opportunity to observe their business environments and converse with farm workers, it limited the opportunity to see their families and where they live.

The farmers who were interviewed typically managed bigger and more established farms and were financially able to buy some inputs for reduced tillage technologies such as chemicals, sprayers, and other equipment. The names of the farmers who were interviewed were obtained from government extension agents, the Mongolian Farmers’ and Flour Producers’ Association staff, and other personal contacts. The farmers were called in advance and arrangements were made for an interview including the time and venue. Generally, only one or at most two interviews were conducted in a day since the distance between these farms is considerable. The interviews were semi-structured using outlines and open-ended questions from the survey questionnaire as a guide. Often, the interviewees were eager to talk about other farm issues which meant that it was sometimes difficult to keep them focused on the interview guide. Making personal contact and the face-to-face interviews gave the author a better understanding of deep feelings and emotions that would not be have been reflected as well in a survey questionnaire.

Most often, two or three farmers were interviewed in each local area or district (soum). Farmers within the same soum would be anywhere from a 30-minute to two-hour drive from each other. However, to travel to the next district (soum) took a day. To ensure that the farmers were home, they were often contacted a day in advance. Sometimes due to limited telephone communications in rural areas, the author had to arrive at the farmer’s door and ask them if they were available for an interview. Each interview took about two to three hours. When I was invited to stay for a meal, the interview could take up to 4-5 hours. A digital recorder was used during the interview; however, notes were also taken as much as possible. Note taking was a precaution in case the digital recorder failed for any reason or if the batteries died. It was noted that, in some instances, farmers would pause and make sure everything was written down before proceeding with the interview, while in other instances farmers were a little nervous and note taking was a distraction. None of the farmers interviewed appeared to mind being recorded.

In-person interviews were much more effective and revealing than the survey questionnaire. They allowed the author to meet the farmer on his/her farm, to see the farm context, and to gain a greater understanding of the farmer's circumstances. Also, having personal contact greatly reduced the risk of misinterpretation, allowed for clarification, and increased the accuracy of the information that was shared and recorded. Translations and summaries of the data were made during the winter of 2005 and 2006.

3.3.2.4. Personal experience and observations in Mongolia

The author was fortunate to have experienced a technology transfer process from the grassroots level through her previous work experiences as an extension worker, applied researcher, and national manager for the Introduction of Minimum Tillage Project in Mongolia. Through this initial stage of the introduction and experimentation with reduced tillage technology in Mongolia, the author gained a great deal of knowledge on technology transfer systems, process, mechanisms, and even politics in Mongolia. The first attempt to introduce minimum tillage practices to Mongolia started with a small research trial on testing glyphosate (product name, Roundup®[10]) for controlling perennial weeds such as quackgrass (*Elitrygia repens*), Canada thistle *(Cirsium arvense)*, and sow thistle (*Sonchus asper*) in grain fields. Instead of controlling weeds, the long-term use of a conventional summer fallow system (which involved frequent and deep cultivation) was creating a favorable environment for perennial weeds. This led to the

[10] "Roundup" is the brand name of systemic, broad-spectrum herbicide produced by the American company Monsanto and contains the active ingredient glyphosate. (Herbicide Handbook, 9th ed.)

development of uncontrollable weed problems, especially quackgrass. Much of the arable agricultural land started to be abandoned because of perennial weed populations. During 1996-2000, Mongolian researchers, politicians, and farmers were actively seeking new alternative weed control methods that would control perennial weeds, especially quackgrass. In 1996, a small amount of the first glyphosate product was imported to Mongolia. From 1997 to1998, the awareness of minimum tillage and zero tillage grew tremendously in Mongolian agriculture and eventually, a number of international programs were implemented to test minimum and zero tillage technologies.

In 2000, the author was hired as a local manager of one of those projects that was funded by CIDA, and this offered a great opportunity to be part of a technology transfer, extension, and research/experimentation team during the initial introduction period of conservation tillage and chem-fallow practices to Mongolian farmers. Through this project, a number of seminars in rural areas were organized, and on-farm demonstrations were conducted to test reduced tillage practices using new seeding equipment and herbicide to replace tillage, and to compare this with conventional tillage. Involvement in this project enabled the author to observe many activities and to interact with farmers, politicians, researchers, and other active players in the agriculture sector who were involved in diffusion and adoption of reduced tillage practices. Also, working for the TRD Project and making an annual trip back to Mongolia gave the author an opportunity to observe and analyze the outcome of the initial technology transfer work, and to continue the communication with farmers, politicians, and researchers in that regard. The thoughts and analysis of the author will be included throughout the thesis, and are reflected in the discussion of interviews and case studies. Having the personal experience of working closely with farmers in Mongolia and also a comprehensive understanding of the farming system in Mongolia has been a significant advantage in doing this field research.

3.3.3. Assessment of the field research data

The availability of factors including geographic coverage, financial support, and limitation on time did not allow an adequate sample size with random selection and representation to do an in-depth statistical analysis of this survey data. However, it is still appropriate to conduct some basic descriptive statistics and qualitative analysis. All of the field research data were collected in Mongolia. The distance between farmers and, therefore, the travel time needed to conduct the field research was a major constraint that limited sample size needed to randomly select participations. The farmer sample was not randomly selected; therefore, the results of this study cannot be used to generalize about all farmers in Mongolia. However, it does provide an indication of what Mongolian farmers think about conservation farming practices and what influences their decisions regarding the adoption of conservation farming practices. Conservation farming practices are not appropriate for all farmers in Mongolia; therefore, it was more important for this research to focus on farmers who had the potential to adopt this new technology and determine their reasons for adoption.

3.4. RESULTS AND DISCUSSION[11]

3.4.1. Stories from the field: farm and farmer characteristics

This section summarizes the survey questionnaire results and presents quantitative analysis of the surveyed farmers and their farming system characteristics.

About half of farmers who completed the survey were conventional farmers; seven percent identified themselves as conservation minimum tillage farmers; and thirty-eight percent identified themselves as mixed, using both conventional and conservation tillage practices (Figure 7).

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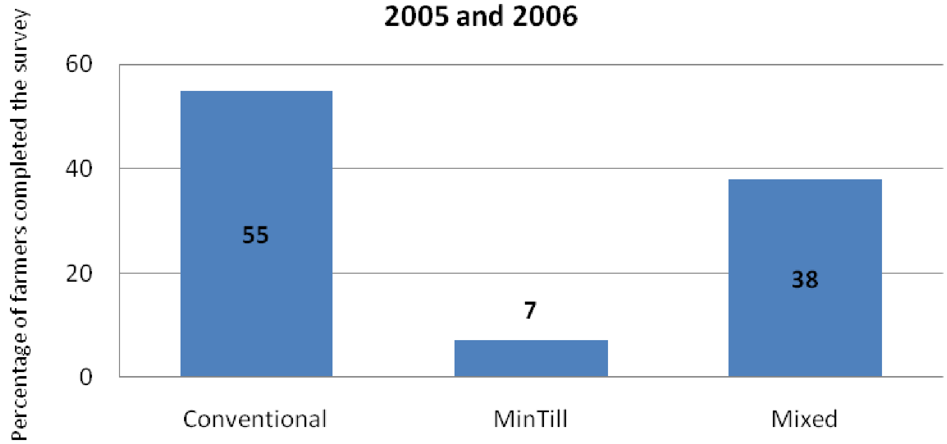
[11] **Limitations**

The research results should be interpreted carefully since sample size was small and not randomly selected. Data were not examined using in-depth statistical analysis due to insufficient number of samples. However, this study shows trends and possibilities that were expressed by the farmers and extension agents who participated in the survey. Language and translation was one of the challenging factors. The questionnaire was translated from English to Mongolian and answers were translated from Mongolian back to English. Sometimes both questions and answers felt ambiguous and difficult to interpret. It was difficult to translate literally, and the researcher had to make figurative translations based on personal understanding of the answer. Also, the author/translator had quite a bit of personal experience in the subject, therefore, the interpretation could be biased.

Figure 7. Number of surveyed farmers using conventional, conservation, and mixed farming practices in Mongolia, 2005 and 2006



From this, it was concluded that close to half of the farmers who completed the survey had some involvement with conservation farming practices such as minimum tillage, as they prefer to call it.

3.4.1.1. Demographic characteristics of the farmers

Gender

Sixty-three percent of the farmers who completed the survey were male and 37 percent were female (Figure 8). This should be considered a relatively good gender balance considering farming is a male-dominated industry in Mongolia. Three-quarters of the conservation tillage farmers in the survey sample turned out to be male.

Although the sample size was not adequate to allow for any advanced statistical analysis, there appeared to be a positive association between male gender and the adoption of conservation farming practices. Also, similarly, a positive association was noted between male farmers and farm size: the male farmers tended to have more cropland and larger herds than their female counterparts. The female farmers in this sample tended to operate smaller and more conventional farms, at least in terms of the cereal cropping systems that they used.

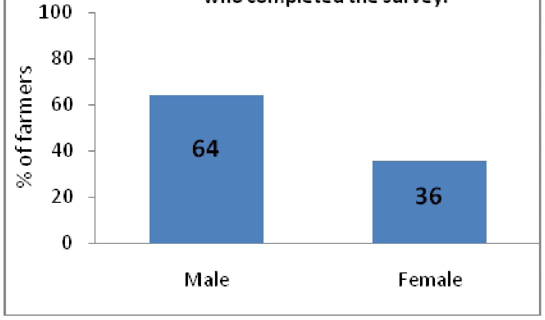


Figure 8. Numbers of male and female farmers who completed the survey.

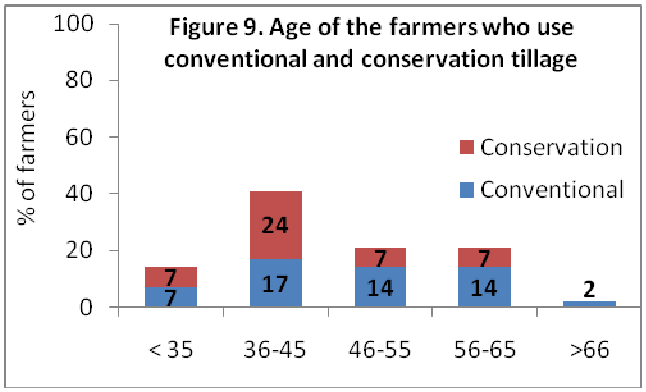
Although female farmers were less likely to be early adopters of conservation tillage practices, they were clearly interested in augmenting their knowledge of advanced farming techniques. On average, these women farmers attended more training sessions including workshops, field days, and other kinds of extension activities. However, based on my own observations, at such events, it appears that female farmers were more reluctant to speak up and to ask questions, whereas men would be more likely to ask questions and to seek clarification with respect to survey questions and workshop presentations.

There was a relatively balanced representation of male and female farmers in the study sample even though farming in Mongolia tends to be dominated by men. It is noteworthy that the farms that were managed and operated by women tended to be more diversified in terms of both crop and animal production. Often, they had land designated for vegetable and fruit production that contributed positively to their family's food supply and nutritional status by diversifying their diets.

Age and marital status

Most of the farmers who have introduced conservation practices were between 36 and 45 years of age (Figure 9). However, other (North American) studies (Knowler and Bradshaw, 2007) have reported no strong correlation between age and the adoption of conservation tillage systems. Although these results are based on a small "convenience sample" and are, therefore not extensive enough, they give some indication that in Mongolia at least, farmers in their early middle-aged years were more likely to try new technologies such as minimum tillage. Farmers older than 46 or younger than 35 years of age showed less propensity to adopt these technologies.

Whereas in the whole study sample the farmers were fairly evenly split between adopters and non-adopters of conservation tillage (Figure 9), farmers in the age groups 46-55 and 56-65 were twice as likely to be practicing only conventional tillage as opposed to conservation tillage. All the farmers in the age group 66 or older were using only conventional tillage. In addition to age, this may relate to a number of other factors, including economic circumstances, tolerance for risk, and access to information. There was a weak positive association between a farmer's age and concern about the cost of adopting new technology. If older farmers tend to be more concerned about the cost of introducing new technologies, they may delay or decline from adopting them. Conservation farming practice requires significant investment in the beginning and "payback" period can be long. Therefore, it might not be very attractive to older farmers.



In terms of marital status, 35 out of the total of 42 farmers who completed the survey were married. All of the married farmers reported at least one child[12].

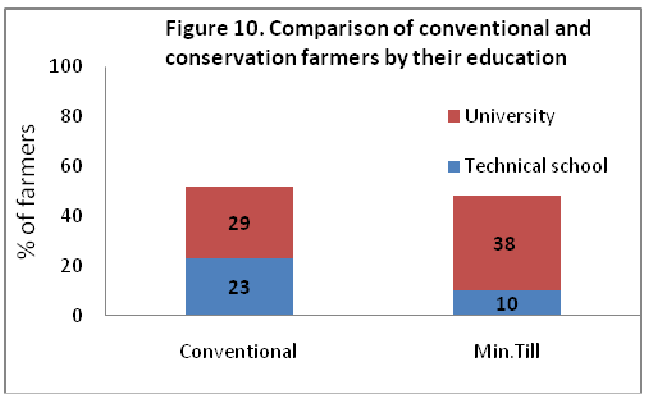
Education

The education system in Mongolia is very well established with a high literacy rate (97 percent) across the country (UNDP, 2009). Therefore, Mongolian farmers are generally well educated. All the farmers completing the survey were literate, and all had at least some post-secondary education if not an advanced university degree. Sixty-seven percent of all the farmers who filled out the survey had a university degree, with most being a bachelor's degree in agriculture. Those who graduated from colleges and

[12] Unlike family farms in North America, farms are run like an enterprise and there is very little involvement of the family members such as children in the farm activities. Farmer families also do not live on the farm site, and a farmer (a member of the family who works at the farm) would go to work (farm) in the morning and come home in the evening like any other job. Only during the busy periods such as seeding would farm workers stay (camp) at the farm for an extended period of time. Therefore, the family size and number of children do not have a significant association with farmers' adoption of conservation tillage practices in Mongolia.

technical schools were typically trained as agricultural technicians and agricultural machinery mechanics. Most of them grew up in a farming village with parent(s) who were farm labourers (for example, tractor drivers, herdsmen, dairymaids, field hands) on collective farms (in Mongolian, sangiin aj akhuy), and had taken a farm job after their formal education was complete.

Whereas education levels tended to be fairly high for all of the farmers in this study, there was a positive association between advanced study and propensity to adopt conservation tillage systems. Farmers with university degrees were over represented among the adopters of conservation tillage technologies. Farmers with a technical college or technical school[13] education were overrepresented among those who had stayed with conventional tillage technologies (Figure 10). Whereas 67 percent of the farmers in this study had at least a university education, fully 80 percent of the conservation tillage adopters had completed some university studies.



Many agricultural technology adoption studies in North America have shown broadly similar results. For example, Buttel, et al. (1990) stated that farmers with higher education tended to have better access to information and to be more likely to adopt soil conservation practices various kinds.

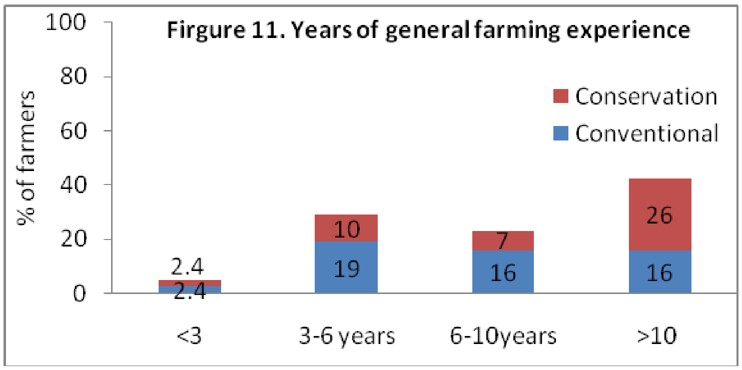
Years of experience in agriculture

The number of years of farming experience among this sample of farmers varied (Figure 11). Forty-two percent of farmers, who participated in the survey had more than 10 years of experience in farming. Twenty-three percent of farmers had 6-10 years of experience while 29 percent of them had three to six years of experience farming. Only

[13] In the past, a distinction was made between technical college and technical school, but after the economic and political transition, these institutions were effectively merged under the title of "technical school" (in Mongolian, technik mergejiliin surguuli).

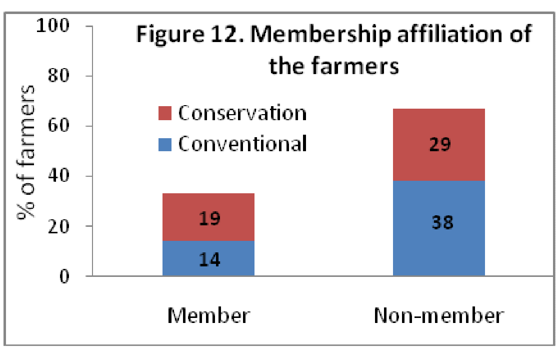
about five percent of the farmers who participated in this study had fewer than three years of farming experience.

The survey results indicate that, on average, farmers with more farming experience (more than 10 years) were more likely to adopt minimum tillage practices than farmers with less experience in agriculture. Among those with up to 10 years of experience, minimum tillage practitioners were a definite minority, however, among those with more than 10 years of experience, they were a definite majority. This perhaps relates most directly to the enterprise cycle, i.e. the stage they were at in terms of establishing a farm business, and, resulting from this, both their financial capacity and knowledge base for adopting new technologies.



Memberships and affiliations

Many adoption studies suggest that affiliation with organizations, institutions, and groups is an indication of farmer innovativeness and leadership attributes, as well as their access to information, markets, and technology (Phillips and Gray, 1995; Thompson and Scoones, 1994). Therefore, farmers who are affiliated with groups and institutions tend to be early adopters or innovators[14]. A minority of farmers who participated in this study belonged to any organizations or groups, and differences between conventional and conservation tillage farmers were fairly small in this regard (Figure 12). Only 33 percent of the farmers who



[14] Adopter or innovators are individuals who are highly motivated by personal values and goals. They are willing to deal with a high level of risk associated with new technologies or innovations. They are also often leaders in the community, and socially motivated and involved in various activities and organizations (Rogers, 1995).

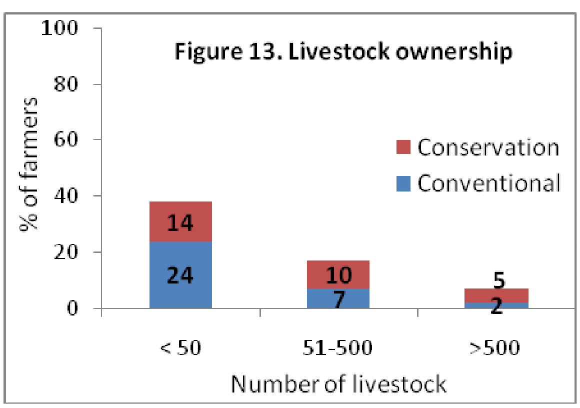
took part in this study reported any kind of membership in any farmer organizations or NGOs, while the majority (67 percent) did not have any such membership affiliations. However, farmers who had adopted conservation tillage practices were slightly more likely to report membership(s). Membership was also positively correlated with university education, and with being a male respondent.

In Mongolia, there are a number of farmers' organizations. Often they are attached to political parties or linked to a particular member of parliament. According to conversations with some farmers, there is little real benefit associated with being a member of such a farmer organization. Farmer organizations often serve as a lobbying group and disproportionately benefit a small number of farmers who already have relatively strong connections to those in power. In other words, according to these accounts, the activities of these organizations are focused on the needs and interests of a small minority of farmers who are already more closely networked with political power.

3.4.1.2. Wealth indicators

Livestock ownership

Livestock is a central part of Mongolian culture. Most rural people own some livestock including cattle, sheep, goats, and horses—but also sometimes yaks or camels. However, it is worth noting that although crop producers frequently own some livestock, cereal production in Mongolia tends to be quite separate from livestock production. These are not mixed farms in the North American sense of the term.



Among the farmers surveyed, 62 percent owned some livestock. A total of 61 percent of the conventional farmers, and about 63 percent of the conservation-tillage farmers in the sample owned livestock. It seems, at first glance, that there is no strong link between livestock ownership and the use of particular tillage practices. Figure 13 reveals more about the livestock holdings of conventional and conservation-tillage farmers in the study sample. These data show an association between conservation-tillage farming and the number of livestock owned. The conventional farmers who owned livestock tended to have smaller herds (<50). Correspondingly, a greater percentage of conservation-tillage farmers owned medium-sized (51-500) or truly large herds (>500). Among conventional farmers who had any livestock of the types mentioned above, the average herd size was 79 head. For conservation-tillage farmers with livestock, the average herd size was 314 head. Therefore, the herds of livestock-owning conservation-tillage farmers were, on average, nearly four times as large as those of their conventional counterparts.

These data are interesting because in Mongolia it is common to hear of conflicts between livestock herding and conservation-tillage cropping practices. With conservation farming practices, farmers aim to keep the straw and plant residue on the field, whereas in conventional cropping systems, plant residue is not necessarily kept on the soil surface. Sometimes, conventional farmers bale the straw for animal bedding or feed, and do not mind if animals graze their fields after the crops are harvested. In contrast, conservation-tillage farmers try to keep as much cover on the land as possible, and sometimes even build fences to keep livestock out of their fields[15]. Therefore, other things being equal, one would expect less livestock to be associated with conservation-tillage farming operations. However, these survey results show that farmers who have introduced minimum tillage practices tend, on average, to own more animals than conventional farmers.

For centuries, nomadic herding has been the traditional form of livestock production in Mongolia and, to this day, livestock is still the principal livelihood asset for many people who live in rural areas. Rather than putting money in a bank or buying equipment or buildings, livestock is preferred as an investment and as a form of savings. It is commonly understood that having large herds of livestock is an indication of wealth and

[15] Although livestock production has not been integrated into conservation-tillage crop production systems in Mongolia, there is nothing inherently or fundamentally incompatible between grazing and minimum soil disturbance tillage systems. There are some potential agronomic, economic, and ecological advantages of integrating animal and crop production.

status. Wealth was traditionally measured in terms of livestock holdings. But wealthier individuals also tend to buy more animals—as an investment, as a form of capital accumulation, and as a sign of social status. In the study sample, there was a direct correlation between the number of head of livestock owned and the number of hectares of cropland farmed. Since the conservation-tillage farmers tended to be bigger farmers both in terms of hectares cropped and livestock holdings, this suggests that farmers who have incorporated minimum tillage practices into their farms are typically financially stronger than those who are farming with conventional tillage farming systems[16].

As mentioned above, although many Mongolian crop farmers own livestock, these are not mixed farms in the North American or European sense. Crop farmers tend to keep their herds separate from their croplands. As discussed above as well, crop farms tend to be organized as commercial businesses, with owner-managers who are directors of the company, and hired farm workers to take care of cropping operations. If there are livestock present, there would also be hired herders to watch over them. A farming company with livestock and crops thus would have a crop production unit operated somewhat separately from the livestock sector. This kind of arrangement allows farming companies to avoid any conflicts between livestock and crop production systems—in terms of competition for labour but also in terms of livestock straying into crops. Wealthier farmers not only tend to have more animals, they also tend to have access both to more grazing land and to more cropland.

Farm size

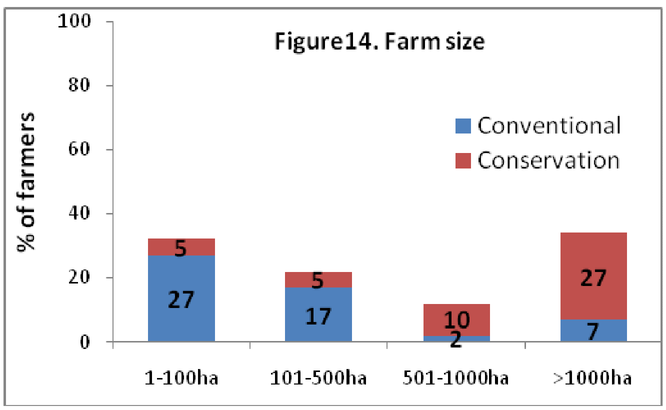
Land tenure and farm size are key aspects of most agricultural adoption studies. In the USA there has been a strong link between farm size and adoption of recommended conservation practices including minimum tillage (Buttel, et al., 1990; Pampel and van Es, 1977). Frequently, farm size reflects a farmer's economic situation, including his/her

[16] There was also a moderate positive correlation between numbers of livestock owned and membership in agricultural organizations. This might suggest a tendency for bigger and wealthier farmers to be more actively involved in farm organizations and other community activities.

ability to finance a larger scale operation. Moreover, conservation tillage practices often increase labour productivity and enable farmers to farm larger areas with fewer people and less hours of work. Farmers have a tendency to use any extra time and labor that becomes available to expand their farming operations.

There is generally a positive correlation between farm size and farm income (Buttel et al. 1990). Conservation tillage farming comes with a cost in that it requires a significant capital investment in new equipment and agrichemical inputs. Increasing the acreage cropped helps both to spread and to recover the capital costs of things such as direct seeding equipment and field sprayers.

The farm size of the farmers who completed the survey was quite varied, ranging from 17 to 3010[17] hectares. The large range in farm size made it difficult to group farmers into different farm size categories. With a small number of notable exceptions, conventional farmers in the study sample tended to have smaller farms, while conservation farmers tended to have bigger farms (Figure14). There was a significant overrepresentation of farmers who have adopted conservation tillage technology among those farmers who owned more than 1000 hectares of farmland. Similarly, conventional farmers were over-represented among those who owned less than 100 hectares land. Overall, bigger farmers appear to have a higher likelihood of adopting new conservation tillage technologies than smaller farmers.



The total amount of land farmed by the 42 farmers who completed the survey was 34,540 hectares. The mean farm size was 822 hectares. However, the average farm size for farmers who use conventional tillage was 416 hectares, while farmers who adopted conservation tillage practices owned farms that averaged 1,336 ha. Even

[17]According to the Mongolian Land Law (2006), maximum farm size allowed per farmer is 3000 hectares. Therefore, often in official documents, one does not see a farm size recorded exceeding 3000 hectares. However, one can easily come across a farm that is bigger than 3000 hectares. The extra land will be leased from other small farm holders.

though over half of the farmers (55 percent) who completed the survey were conventional farmers, they owned only 27 percent of the total farmland that was included in the survey. The remaining 73 percent of the total farmland was farmed by farmers who had introduced conservation tillage practices into their farming systems.

Note that this does not mean that all of the cultivated land owned by conservation tillage farmers was farmed using conservation tillage practices. Among the conservation-tillage using farmers, on average about 60 percent of their farmland was managed using conservation farming practices. From personal observation and field study, bigger farmers tend to be more concerned about soil erosion and economic benefit to their farming system, in terms of making decisions to adopt new technologies such as conservation tillage. In contrast, smaller farmers tend to show more interest in financial support and subsidies to enable them to adopt new technologies.

In conclusion, in this sample of Mongolian farmers, those who have adopted conservation tillage practices or those who have started implementing conservation tillage practices on their farms tend to have significantly more farmland than farmers who continued to use conventional farming systems. The results from this study appear to agree with previous studies (Knowler and Bradshaw, 2007) in that there is a strong link between farm size and adoption of conservation practices.

Farm equipment

Farm machinery is a major investment and capital outlay on a modern crop farm. Mongolian farmers have not had a real opportunity to renew their farm machinery since the transition to the free market economy in 1991 when most of the farms were privatized. Buying farm equipment is difficult as not much is available, and what is available is very expensive. Most farm machinery such as tractors, seeders, and combines are about 15-20 years old. Maintenance and purchase of new farm machinery is the biggest desire and challenge for farmers in Mongolia. Farmers in this study had, on average, two to three tractors and one to two combines, plus other tillage equipment such as harrows and discs. Surveyed farmers who have adopted conservation tillage practices have more farm machinery—tractors, combines, and sprayers—than farmers who are utilizing conventional farming systems.

On average, a typical conventional farmer had three pieces of equipment, while a conservation farmer had seven. A similar ratio applies to other farm equipment such as cultivators and discs, in that those farmers who adopted conservation practices own more pieces of equipment. However, it was difficult to find out some details of the equipment such as age. Therefore it is possible that some of the equipment may be old and back up pieces.

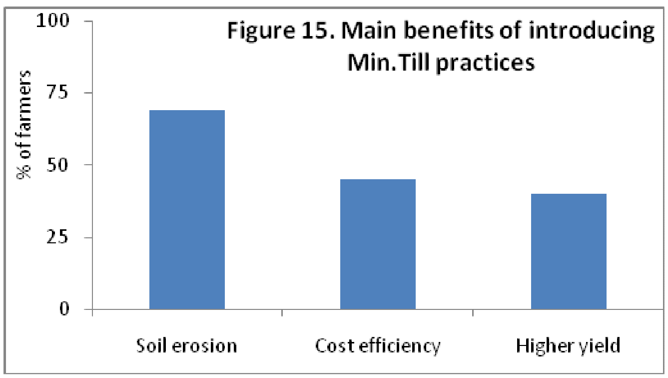
Conservation tillage machinery in North America is often big and efficient, such that equipment costs per hectare are reduced on large farms using this technology. Adoption of conservation tillage systems allows farmers to farm more land with less labour and less machinery. But in Mongolia, farmers still use modified conventional machinery in their conservation farming practices; therefore, there may be less difference in the efficiency of the machinery in conservation versus conventional farming systems in Mongolia. This may be is one reason why conservation tillage farmers have more machinery than conventional farmers. Another may be that these farmers are sometimes using both systems of tillage, so would need to have two sets of equipment. Of course the data presented here includes to tractors and combines and sprayers—items required for either type of cropping system.

3.4.2. Farmer Perspectives on Conservation Tillage Technologies

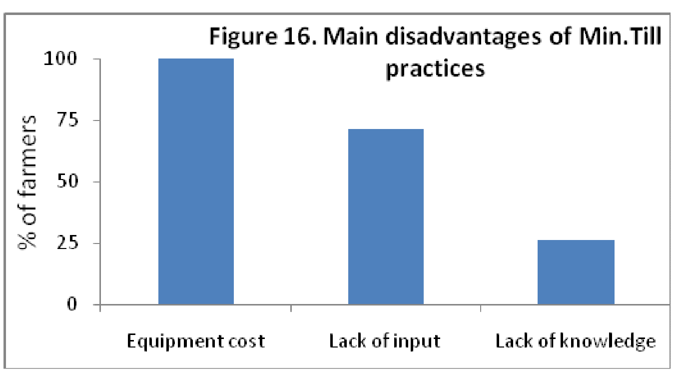
In addition to the descriptive and quantitative questions, the survey also included some questions concerning farmers' understandings and perceptions with respect to the adoption of conservation (minimum tillage) practices. This contributes to a more in-depth exploration of why farmers decide to adopt conservation tillage practices or not, and to a better understanding of the major factors they consider in making their decisions.

3.4.2.1. Perceived advantages and disadvantages of conservation tillage technology

Farmers' perceptions about the advantages and disadvantages of conservation tillage systems are complex and varied. Advantages of conservation tillage systems include reduced soil erosion, reduced costs for fuel and labor, increased soil and water conservation, better weed control, and more efficient use of equipment. In contrast, increased use of chemicals, some increase in pest and disease problems, and slow warming of the soil in the spring are disadvantages of conservation tillage systems that have been reported elsewhere (Phillips and Gray, 1995).



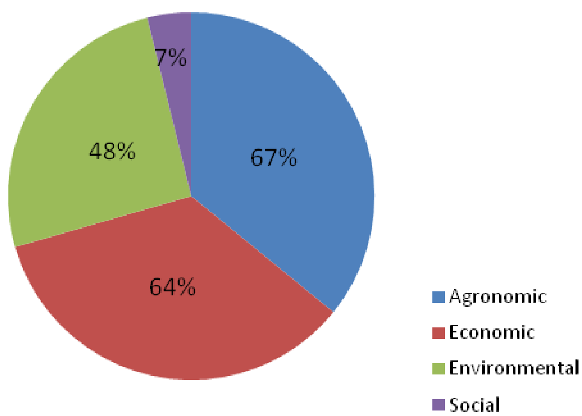
All of the farmers who participated in this field survey regardless of their current farm practice (both adopters and non-adopters) were asked to identify what they thought were the three main benefits of conservation tillage systems (Figure 15) based on their knowledge and information obtained. Close to seventy percent of the farmers who filled out the survey identified preventing soil erosion as one of the main benefits of minimum tillage systems. The cost efficiency of this technology was also seen as a major benefit, followed by increased yield. But cost efficiency and increased yield translate into higher return and increased profit. Cost efficiency will depend on the cost of inputs such as fuel, pesticides, fertilizers, labor, and price of seeds. Therefore, it may vary from year to year.



In contrast, the most frequently cited disadvantages of the conservation farming system were capital investment, lack of inputs, and lack of access to knowledge/information (Figure 16). Farmers in Mongolia feel that the conservation tillage system is expensive and requires significant initial investment. Another major challenge for those farmers is a lack of access to inputs. There are few agri-businesses that import agricultural goods and inputs. As demand for herbicides, fertilizers, and specialized agricultural machinery increases, the lack of a domestic supplier puts farmers in a challenging and dependent position. The third most frequently cited disadvantage or difficulty was lack of knowledge and information. As it is a fairly new technology in Mongolia, there is not much local information or field research data available. Farmers feel they are dependent on information from external parties such as international projects and experts.

In general, farmers feel most of the benefits of a conservation farming system are related to agronomic and economic dimensions rather than social and environmental (Figure 17).

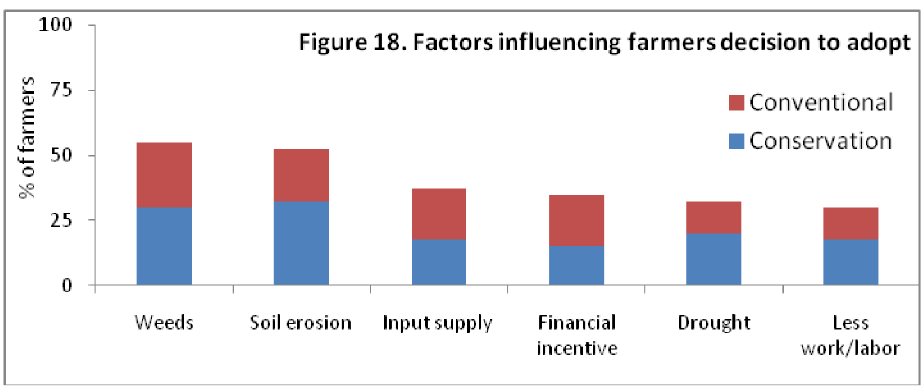
Figure 17. Farmer perception of the most important benefits of conservation farm practices



Among the farmers who participated in this survey, 67 percent said that most of the benefit of conservation tillage systems is agronomy related; 64 percent said it is economic related; 48 percent said it is environmental related; and only seven percent referred to social benefits. As previously mentioned, crop farms in Mongolia are set up as commercial enterprises. Therefore, the social values and philosophies of those farms who participated in this survey may be different from family farms, particularly those in North America, where farms have been passed between several generations. On the other hand, farmers everywhere must pay close attention to the agronomic and economic advantages of particular technologies, and environmental and social issues, while important, tend to come further down their list of priorities.

3.4.2.2. Factors influencing adoption of conservation tillage practices

Farmers were asked to indicate all of the factors that were influential in making them consider adopting minimum tillage practices on their farms. The specific question was "What are the most important farming concerns or issues that have made you consider introducing conservation tillage practices?" Ten factors were listed for the farmers to choose from and space was provided for adding other items. The results presented in Figure 18 are for the combined responses of both conventional and minimum tillage farmers. Conventional farmers responded to the question by indicating what factors would make them consider adopting minimum tillage practices. Of course, for farmers who had already adopted minimum tillage practices, the question was likely answered with greater certainty.



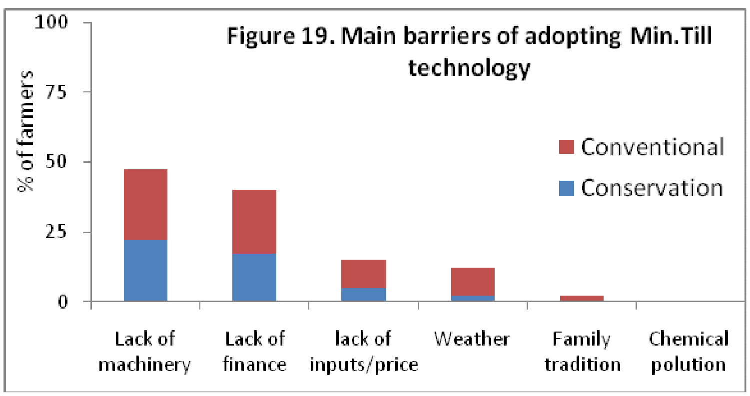
In Figure 18, the main factors that influence the farmers' decision to adopt minimum tillage practices are presented from the most influential to the least. Most farmers listed controlling weeds as the main factor. The impossibility of controlling certain perennial weeds in a conventional tillage system made them consider introducing a chemical fallow system where herbicides replace mechanical tillage to control weeds without soil disturbance. Replacing mechanical tillage with some chemical applications for weed control resulted in positive outcomes on the farm field in terms of getting rid of some weeds difficult to control with tillage. However, potential risk of using chemicals over the long-term and some safety measures were not mentioned.

Soil erosion was the second most frequently cited factor that has influenced decision-making with respect to conservation farming practices. It was the factor most commonly cited by adopters. Over 70 percent of the cultivated land in Mongolia is eroded to some degree (Terbishdavga, 2008). Extensive tillage combined with wheat and summer-fallow rotation is hard on the soil, eliminating cover and exposing the land to wind, water, and tillage erosion that leads to soil loss and reduces soil organic matter content and productivity. Therefore, it is not surprising that farmer concerns about long-term productivity and soil quality has influenced the adoption of minimum tillage practices. Reduction of tillage will lessen soil erosion, increase soil organic matter, and gradually improve other soil properties. Tillage also increases evaporation of soil moisture thus drying the soil. The dry climatic condition, with frequent droughts in the cropping areas of Mongolia, also encourages farmers to consider conservation tillage technology.

As expected, the availability of financial incentives was also frequently cited as a factor that influenced farmers' decisions with respect to adoption. As expected as well, this was cited more often by adopters. This suggests that subsidies or grants have been part of the equation for some adopters, and it points to possible sensitivity to the removal of any such supports. Labour-savings or reduced time requirements for field operations were somewhat less frequently cited as influencing the decision to adopt. It is noteworthy that this issue was cited more frequently by non-adopters. While difficult to interpret without additional corroborating data, this might indicate that labour-saving is not so important in a context where hired labour is used and wages are low. It may also indicate that farmers perceive little savings in field preparation time or labour costs at least in the initial phases of conservation tillage adoption.

Several other possible factors were listed but none of these was cited very frequently either by adopting or non-adopting farmers.

While surveyed farmers cited various factors as possible (positive) influences, it must also be acknowledged that the overall rate of adoption of conservation tillage practices has been, in some respects, both low and slow. There are many barriers to adoption and many reasons that a farmer might choose to not even try to adopt conservation tillage. Farmers were asked to identify barriers that prevent them from adopting conservation farming practices (Figure 19). The English version of the question that was translated into Mongolian was “What are the most important concerns or issues that made you decide not to introduce conservation tillage practices?”. The farmers who had already adopted the conservation tillage system were asked to reflect on the drawbacks or constraints they had during the period of their decision making. The gap between when the decision to adopt is made and when a new practice is implemented varies depending on the farmers’ financial and information acquisition capacity, input price and availability, and other contextual and environmental factors.



Farmers in Mongolia identified the lack of proper machinery and lack of capital and financial means to invest as the main barriers to adopting conservation tillage practices. These two factors are interrelated. Having sufficient financial capacity will help solve problems related to purchasing necessary machinery and other inputs.

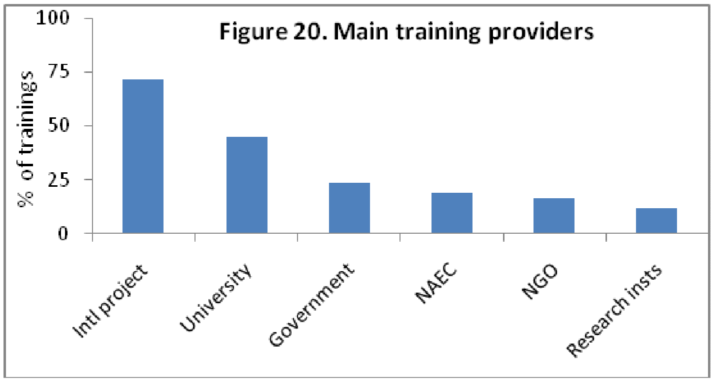
Herbicide and fertilizer availability and price influence the implementation of conservation practices as do environmental conditions. In a conservation tillage farming system, tillage is replaced by herbicide applications for weed control. Therefore, lack of herbicide availability and the high prices for chemicals will likely discourage farmers from adopting conservation tillage practices. The same holds true for fertilizers, as availability and price of fertilizers are important when a reduced tillage system is implemented. In comparison to conventional tillage systems, reduced mechanical cultivation or disturbance of soil in a conservation tillage system initially reduces the rate of soil nutrient mineralization (Bauer and Frederick, 2005). Therefore, fertilizer availability and price are crucial to maintaining and increasing crop yields in conservation farming systems. With adequate fertility, the additional soil water conserved when tillage is reduced or eliminated should make higher yields possible. Up to the period when this study was carried out, a reliable agricultural input supply (import) system had not been established. This was limiting the availability of inputs. Due to greater demand and low supply, chemical prices were relatively high at least in the years of conservation tillage introduction and adoption. For example, the price of Roundup™ was $8 USD per litre in 2002 (Rasmussen, 2003). Other things being equal, local prices of such chemicals will be reduced when the private sector establishes enterprises for importing agricultural inputs including pesticides and when more retail competition develops in the farm input supply sector.

Lastly, family traditions and concerns about chemical pollution do not seem to be seen as a barrier to adopting conservation tillage practices (Figure 19). While agrichemical availability was a concern with respect to the adoption of a conservation farming practices, farmers did not seem to be concerned about the chemical pollution or other environmental impacts of chemical use. Unlike most farmers in North America, farms in Mongolia are neither inherited nor family run. Most of them are commercial enterprises with hired workers. Therefore, they tend to be more profit oriented and less influenced by family members or family traditions with respect to farming systems.

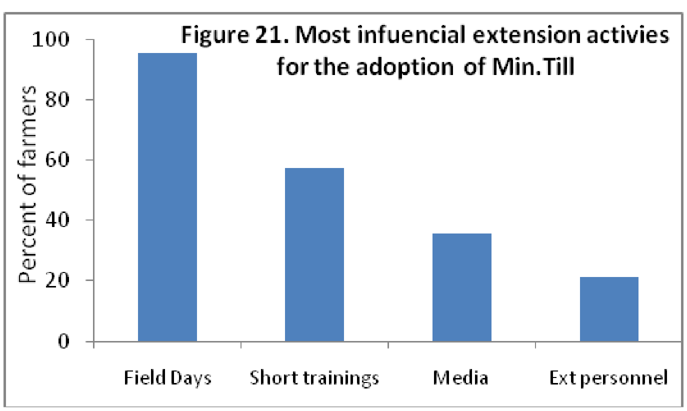
3.4.3. Farmer perceptions of the role of extension services in conservation farming technology transfer in Mongolia

In general, extension agents play a key role in the introduction of new technologies. In 1996, the Mongolian government created a National Agriculture Extension Center (NAEC) under the Ministry of Food and Agriculture (MoFA). Since then, NAEC has opened extension centers with extension agents in all aimags across the country. Through this field survey, a few questions were asked in hopes of gaining a better understanding the farmers’ perception of the role of extension services in technology transfer in Mongolia. This question was geared towards identifying the key institutions rather than key personnel/professions. Farmers seem to feel that the role of the national extension agency has not been very influential in helping Mongolian farmers decide to adopt conservation farming practices. Most of the extension activities/training that farmers have participated in was organized through international projects and organizations (Figure 20).

Farmers who participated in this survey indicated that the majority of the training sessions they attended were provided through international projects or organizations. Forty-five percent of the farmers indicated that they attended a training session(s) provided by universities (taught by university professors/researchers), 24 percent by government agencies, 19 percent by NAEC, 17 percent by NGOs, and 12 percent by research institutes (taught by researchers). International projects have played a leading role in the introduction of new technologies such as conservation tillage in Mongolia. Also, farmers felt that universities were also playing a key role in organizing and providing training to producers. However, farmers' perception of the level of support coming from NAEC did not seem to be very high. Also, extension activities provided or organized by various agricultural research institutions was low, less than 10 percent. This indicates that there is limited role and participation of research institutions in technology transfer activities to farmers.



In terms of types of extension activities that farmers perceived as important sources of information with respect to conservation tillage technologies, farmers found that field days and short training course and workshops were the most influential in helping them to consider adoption of the technology. In contrast, farmers did not feel that extension personnel influenced their decision to adopt. The public media such as radio, TV, and newspapers were also



identified to be somewhat influential in increasing general awareness of new technology (Figure 21) and therefore were perceived to be moderately important in the farmer's decision-making process.

3.5. Role of Extension

A total of 30 extension people who work for the Mongolian National Agricultural Extension Centers (NAEC) across the country were asked to fill out the survey questionnaire which included both multiple-choice and open-ended questions. The goal of the survey was to understand the perception of the extension agents about factors that influence farmers' decisions to adopt or not adopt new technologies.

In the North American context, Hall (1998) observed the importance of extension services to farmers' adoption of new technologies. Successful technology transfer does not occur without an effective and collaborative extension or information delivery system and a suitable social environment. Therefore it is important to evaluate the existing extension systems and information methods in relation to adoption of new technologies. Extension organizations such as farmers' associations and other local government and non-governmental organizations play a crucial role in the promotion of new technologies in farming communities. Pigg (1992) also stated that the methods which are used in transferring information and technology are important to the successful adoption of new technologies.

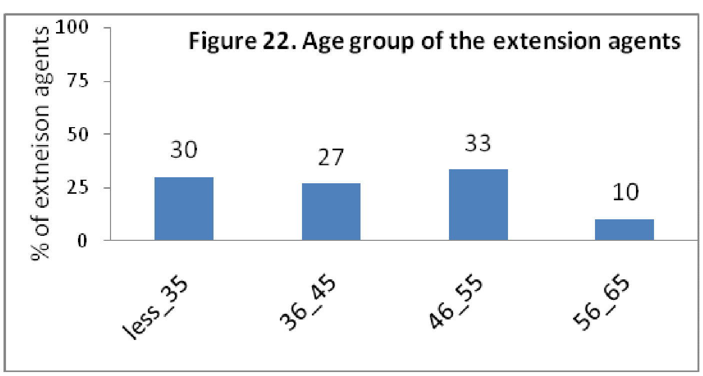
There are many ways to introduce or promote a new technology to producers. Some technologies or methods are promoted much more than others, through the media, through demonstration programs, and through subsidy programs targeting adopting farmers (Hall, 1998; Saltiel et al, 1994). Regardless of what tools are used to promote or introduce new technologies, a strong extension or information delivery system plays an important role in farmers' decisions to adopt a new technology (Hall, 1998). Suvedi et al. (2000) found that one of the reasons for difficulties in transferring agricultural technology in North America is that the number of part-time farmers is increasing and, for various reasons, these farmers participate less in extension programs. Similarly, some farm directors (owners) in Mongolia would have jobs in addition to their farming business. Thus, farm directors themselves would seldom attend technical training sessions but they would send a technical person or their executive directors.

The specific method used to promote and demonstrate new technologies will affect the rate of acceptance. In most cases, the approach of demonstrating a new technology using an extension agent and farmers' participation is effective. Usually, efforts to transfer information directly from research labs without involving practical farm trials does not lead to widespread adoption by farmers (Pigg, 1992). Farmers have been observed to more readily adopt new technologies even with limited assistance if they see that the technology is appropriate to their situation. Also, if the benefits of implementation can be gained in a short time, if the equipment for implementation is readily available, and if the risk of the new technology can be reduced, then adoption of the new technology will occur faster (Barao, 1992; Pigg, 1992). For many technologies, on-farm demonstrations have proven to be an effective way to transfer technology to farmers (Barao, 1992). Indeed, the "seeing is believing" approach has proved to be the best way to promote new technology to producers in Mongolia (Rasmussen, 2003). Also, in North America, the private sector is playing a significant role in the transfer of technologies to farmers. However, in Mongolia, private agribusiness has not yet evolved to the stage where it can play a significant role in extension and technology transfer.

3.5.1. Extension agent characteristics

Age

Thirty extension agents from NAEC representing all of the aimags across the country participated in the project. Thirty percent of the extension agents who took part in the survey questionnaire were less than 35 years old; 27 percent were between the ages of 36 and 45; and 33 percent were between 46 and 55 years old. Only three (10 percent) were between the ages of 56 and 65. The majority of the extension



agents in the sample were relatively young and this conforms with the general situation in Mongolia where the workforce tends to be young. According to the survey results, extension agents who come from a considerable distance from the capital city, Ulaanbaatar, tended to be more senior than those living and working closer to the major cities such as Ulaanbaatar and Darkhan. Also, from personal observation, those remote regions tend to use more traditional agricultural practices and farmers in the regions were the most unaware of new technologies. It could be due to the physical isolation from main information and technology hubs such as Ulaanbaatar, a lack of infrastructure and development, and the cost of disseminating information and technology.

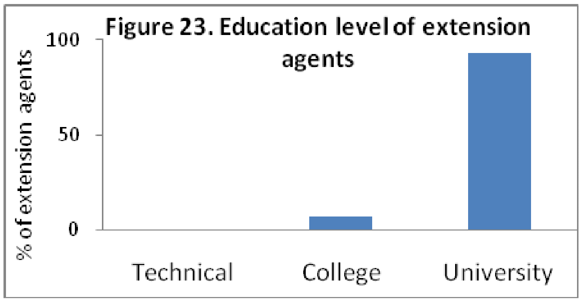
Gender

Extension agents in Mongolia are well balanced in terms of the ratio of males to females. Fifty-three percent of the extension agents surveyed were males and forty-seven percent of the agents were females. This is also an indication that Mongolian women tend to be quite highly educated, competitive, and equally as competent as men. In Mongolia, in professional environments, the balance between male and female professionals is generally fairly equal.

Agriculture is seen as a male dominated industry in general, and female professionals are not well received by farmers or their male counterparts in many parts of the world (FAO, 2001). But, Mongolia is one of the most gender equal countries (UNDP, 2009). For example, from the author's experience of working as an extension agent, there was no issue with male farmers taking advice from her as a young female. There was, however, a slight positive correlation between male agents and years of experience in agriculture. Male agents generally had many years of experience while females tended to have less than three years of experience. Perhaps, the preference of hiring men over women is diminishing.

Education

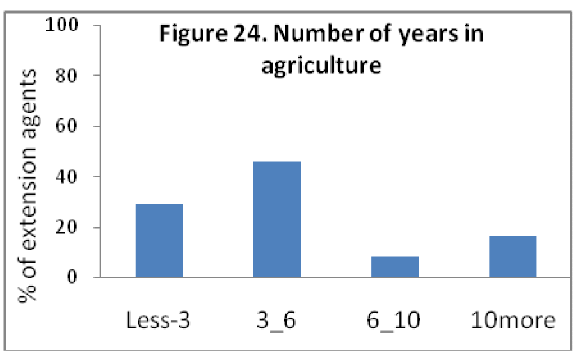
Almost all of the extension agents who participated in this survey had university degrees



(28 out of 30) (Figure 23). As reported earlier, the education level achieved is high in Mongolia and many of the young professionals have university degrees. Only 2 out of 30 agents did not have university degrees and none had a degree from a technical school or lower. Most of the agents had degrees from the Mongolian State University of Agriculture (MSUA) with a specialization in veterinary medicine, agronomy, animal husbandry, or agricultural engineering. A few extension agents had degrees in economics.

Field experience

The number of years of field experience is one of the common criteria used to judge people's knowledge and experience in their technical or skill areas. Forty-six percent of the agents had three to six years of experience in the field, and 29 percent had less than three years of experience in the field. This corresponds to the fact that the majority



of the agents were younger than age of 45. Only eight percent of the agents had six to ten years of experience, and 17 percent of them had more than 10 years of experience in the field. Extension personnel with more years of experience were most likely from remote aimags where traditional agricultural systems are practiced. Also, they are more likely to be unaware of the new technologies that have been introduced.

3.5.2. Extension agent perceptions on sources of information

National Agricultural Extension Centers (NAEC) in Mongolia are established to be the main information source for farmers. Therefore, in order to meet the needs of the many farmers and herders for up-to-date information, extension agents must be trained or provided with information on new technologies. Especially when introducing a new technology such as conservation tillage, which is not well known to many local agrologists, it is important to ensure that local researchers and extension agents are trained in how to successfully use the technology. Extension agents in Mongolia lack access to current information and technology sources, and lack the capacity to obtain up-to- date information on new technologies. Language is one barrier in that much of the current research is only available in English. A second barrier is the relatively low level of development of information and communication technologies and infrastructure in Mongolia. Most extension center offices that are not in major cities and have no access to the Internet or to other external sources for information and technologies. For these reasons, the majority of the training events for extension agents and for farmers relied on international projects and organizations that have expertise on the new technology and on language interpreters to translate the information to the local language.

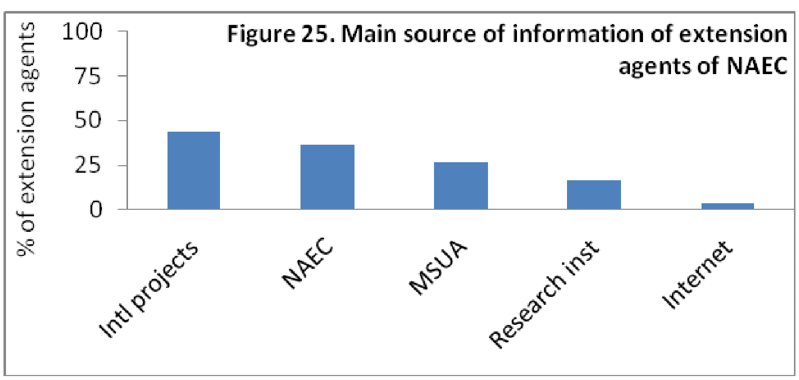
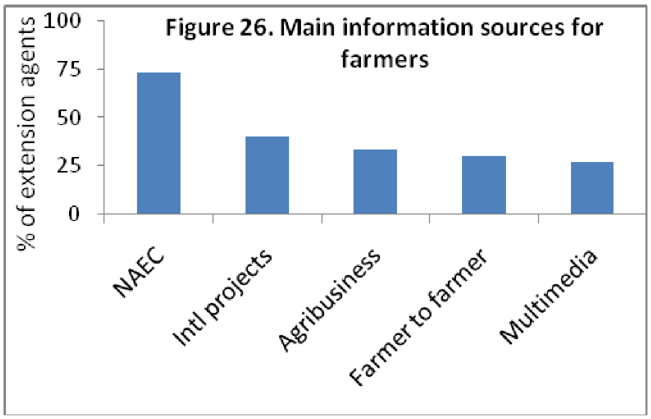


Figure 25. Main source of information of extension agents of NAEC

When extension agents were asked what was their main source of information close to half answered international organizations. Over 40 percent (Figure 25) said NAEC was their main source of information. It is interesting to see that extension agents identify the NAEC to be their main source of information, while the majority of the farmers (90 percent) who completed the survey did not think of NAEC as a main information and training provider. Another 30 percent of the agents said MSUA was their main source of information. Less than five percent of extension agents use the Internet for information. This indicates that the majority of them rely on international programs and their own NAEC for information and training. Very few extension agents use the internet for updating their knowledge on new technologies. Since many extension agents are graduates from the MSUA, many of them (about 30 percent) look back to their university for more information and training on new technologies. Younger extension agents are recent graduates of the MSUA, and they tend to use MSUA as a main information source, and relying on their professors for advice.

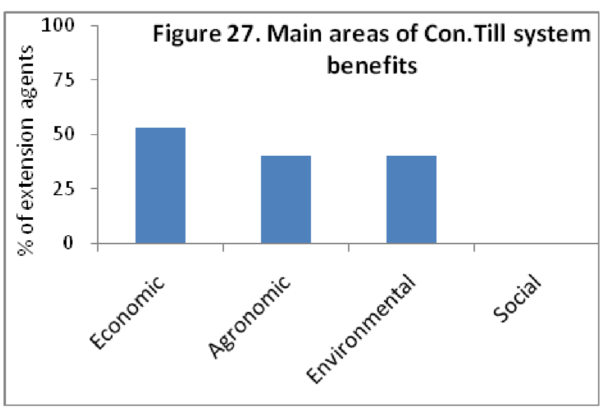


Extension agents were also asked what they think is the main information source for farmers (Figure 26). Contrary to the farmers' response (Figure 20), 73 percent of the extension agents who filled out this survey identified the NAEC as the main information source for farmers, while about 40 percent thought that farmers also tend to rely on international projects for information on new technologies. About 20 percent of them said that farmers obtain information from agribusinesses, fellow farmers, and various forms of media. Extension agents' responses imply that they would like to see themselves as the main information and technology center, although farmers' perception about the main source of information is not quite the same. This gap between farmers' and extension agents' perception regarding the main source of agricultural information and technology indicates that information provided by the NEAC is not necessarily fulfilling farmers' needs. There is a need for extension agents to: a) work closely with farmers by assessing their demand for information and technology transfer, b) provide necessary information and technologies that would help farmers solve their problems, c) obtain up-to-date information and technologies that are required by the farmers, and d) evaluate and identify most effective and collaborative ways of transferring information and technology to their clients (farmers) in Mongolia.

3.5.3. Extension agent perceptions on conservation tillage systems

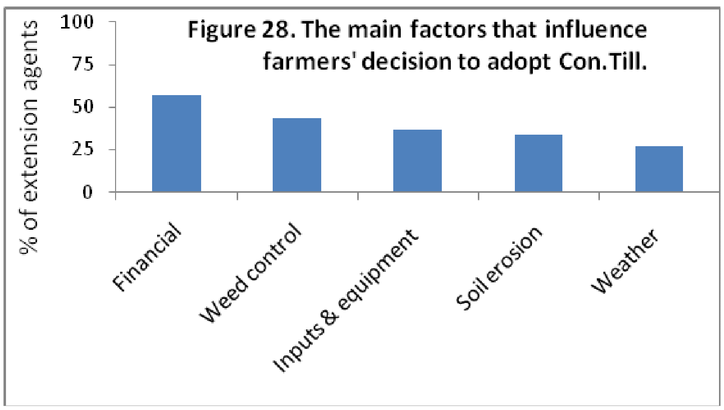
Although the concept of soil conservation has been known in Mongolia for a long time, it is only within the last decade that conservation farming practices have been re-introduced to Mongolian farmers, extension agents, and researchers. Many extension agents, especially those with many years of experience, were not taught conservation tillage practices at university. However, 26 of the 30 extension agents responded that they know about conservation tillage farming systems. About 40 percent of the agents indicated that the main source of their information and knowledge on such systems was from international projects and organizations that were working on the introduction of direct seeding technologies, including the CIDA, the USAID, and the EU. Also, about 30 percent of the agents obtain their knowledge about this technology from various training events that were offered through the NAEC. Only one percent used the internet for information. Most of the extension agents believe that conservation tillage systems are useful, and there should be more training on this technology for farmers, extension agents, and researchers in Mongolia.

Among the extension agents who participated in the survey, there was a tendency that younger, male agents were more aware of conservation farming practices than were female agents.



Extension agents believe that conservation tillage practices are beneficial economically, agronomically, and environmentally. Fifty three percent of extension agents felt that the main benefit derived from conservation tillage technology was economic (Figure 27). One agent said that "…in the end, it is all about money". Close to 50 percent of the agents chose agronomic and environmental areas as the main areas of benefit (Figure 27). None of the agents who completed the survey thought that conservation tillage practices provide social benefits. It is assumed that extension agents are perhaps unaware of possible social benefits of conservation agriculture practices, based on their strong statements focusing on economic benefits. On the other hand, the questionnaire may not have been sufficiently clear. Specifically, reduced soil erosion, reduced cost, and increased yield were identified as the three main benefits of conservation tillage systems.

During the informal discussion following the survey, female agents tended to recognize some social benefits such as saving time and labor, while male agents tended to focus on the technical aspects of the conservation tillage systems[18]. Also, the male agents indicated some concern related to the lack of equipment, lack of knowledge of delivery programs, and lack of input supply. Although conservation tillage systems have many benefits, adoption of the technology is slow in Mongolia. Extension personnel consider many factors that influence the adoption of this technology and farmers' decisions to adopt (Figure 28). The main factor influencing farmers' decisions to adopt according to extension agents is financial support (Figure 28). In contrast, farmers identified the fact that farmers can have better weed control as is the most influential factor. However, farmers agree with extension agents in identifying lack of financial capacity as an important barrier to the adoption of new technology such as conservation tillage. About 50 percent of extension agents who participated in this survey also pointed out that issues related to weed-control, fertilizers, herbicides, and soil erosion are very important factors. Replacing cultivation with herbicides gives farmers an advantage in the control of difficult weeds such as quackgrass. However, lack of availability and the high price of the herbicides and sprayers make it challenging for



[18] What gets defined as a social benefit is somewhat arbitrary and complicated. Reduced labour requirements may be seen as a social, economic, or agronomic advantage—or all three. On the other hand, from the perspective of hired workers, reduced labour requirements may not be viewed as a clear advantage. Extension agents may also be sensitive to longer-term structural impacts. Many technologies that save labour also frequently have been associated with accelerated farm consolidation and the emergence of large farms as dominant players in agricultural production.

farmers to adopt this technology. Extension agents also feel that in order to protect soil from erosion, partly caused by continuous droughts, farmers are driven to consider adopting conservation farming practices.

3.6. Summary of farmer and extension agent survey

In conclusion, both farmers and extension agents identified three main barriers for the adoption of conservation tillage systems in Mongolia; 1) lack of capital and investment, 2) lack of knowledge and information, and 3) lack of inputs and equipment. Moreover, they said that, if financial resources were available, then many of the other factors identified above could be taken care of. Knowledge is connected to money but cannot necessarily be solved with money. Secondly, both farmers and extension agents agree that lack of knowledge is a barrier to adopting the technology. They indicated there are insufficient sources of information and technology transfer activities such as farmer training events. Farmers, researchers, and extension agents rely heavily on international organizations and programs for information and training on this new technology, and perhaps more hands-on and locally-delivered grassroots training is needed as more specific regional questions and issues regarding the technology arise. Thirdly, lack of inputs and equipment is a major issue for the adoption of new technologies such as conservation agriculture. After the breakdown of the centrally-planned economy, collective agricultural input supply centers also collapsed in Mongolia. There are now very few reliable local sources of inputs and equipment. This creates a great challenge to farmers, forcing them to find other sources of inputs and equipment that are needed for their crop production system. A better distribution system than currently exists is needed.

Therefore, in order to increase the adoption of conservation tillage farming systems, much work needs to be done in building the capacity of farmers, researchers, and extension agents in Mongolia. Technology transfer activities including the establishment of demonstration farms, organization of field days, short training sessions, and extension activities are crucial for the successful adoption of the new technology. Also, training of local researchers and developing their research capacity to conduct local research on this new technology is also very important in generating local knowledge and information that is more suited for their local conditions. Also, extension agents need to be trained adequately to disseminate and transfer new information and technology to farmers. Lastly, some source of financial support will likely fast-forward the adoption of this new technology.

3.7. Introduction of Conservation Tillage Farming: Farmer Perception and Transition

3.7.1. Introduction

In addition to the field survey, the author interviewed 10 adopter-farmers to obtain a deeper understanding of the adoption process and their views on the experience of working with the new technology. Face-to-face interviews gave opportunities to explore details about their adoption process and to better understand issues that cannot be fully expressed through structured, written surveys. Being there in-person allowed the author to observe their farm offices, farm settings, workers, and sometimes their families and homes. Most of the farmer interviews took place at the farm[19], instead of at their home. From personal experience with NAEC and the Mongolian Farmers` Association, when working with Mongolian farmers one seldom has a chance to visit farm families. The only possibility of visiting a farmer family would arise when a close relationship was developed with them and, therefore, the researcher would be considered as a friend.

All of the interviews were conducted by the author who is Mongolian and whose first language is Mongolian. There were several advantages of the author conducting the interviews and they included: a) not having a language barrier, b) being very familiar with the context, and c) having an already established relationship of trust with most of

[19] Farms in Mongolia are set up like commercial enterprises. Farmers would have farm yards and offices separate from where they would have their homes. Their homes can even be in a separate city or aimag. Especially in the case of big farm owners, their families often live in the capital city, Ulaanbaatar, and the farm owner would be traveling or living in both places according to the season and work demands. Smaller farms tend to be owned by local farmers whose homes would be in the same town as their farm offices, yet still not in the same yard or location. Sometimes spouses are also involved in farming if she/he lives in as the same town as the farm.

the farmers in the study. For these reasons, it was easier to open discussions and to have the participants feel comfortable asking questions. There were also limitations associated with the author conducting the interviews: a) more time was spent socializing as they had not seen the author for some time; b) the farmers would sometimes skip some of their points or stories because they expected that the author knew the rest of the story; and, c) follow up or clarification was difficult or impossible because the author left Mongolia immediately after the initial field research was conducted.

3.7.2. The transition to conservation tillage farming systems

The concept of conservation farming has been known for a long time in Mongolia, although practical applications and the technology transfer to farmers started in 1999 when Mongolia had its first international project on No-Till systems coordinated through USAID. Following this project, Mongolia hosted a number of other international projects and programs on conservation agriculture and started providing training and demonstration activities to farmers. Through those projects, five farms were selected where the implementation of field demonstrations and field training events were carried out. By default, these five farmers became the early adopters of the minimum tillage technology. Also, these five farmers were selected because they were viewed as innovative, well established, and leading farmers. They also had sufficient financial resources to purchase the technology. However, the training and demonstration activities were carried out including the farmers in the community, policy makers, researchers, and some extension agents.

3.7.2.1. Process and factors influencing the farmers' decision

Conservation farming practices were introduced to Mongolian farmers to offer better soil protection, better weed control, the possibility of higher yields, and more profitable farming. The outline for the interview with early adopter farmers was similar to the farmer survey, but was much more open-ended and exploratory. The farmers' comments were similar, yet different factors had influenced their decisions to adopt minimum tillage practices. But three main categories of factors influenced their decisions to adopt minimum tillage practices: climate issues, agronomic issues and goals, and extension. It was important to understand the context of their farm and family in relation to their farming practice.

Table. 2. Factors and concerns that influenced farmers' decision to adopt conservation agriculture.

Climatic	Drought—five to six years of continuous droughts resulted in loss of yield, a vulnerable economic situation, and loss of faith in farming. As a consequence, farmers started looking for a solution: • Irrigation—very expensive and physically impossible as most of Mongolia is dryland agriculture without access to water. • soil moisture conservation—adoption of conservation tillage system is definitely an advantage.
Agronomic	Two main agronomic factors affected their decision to replace tillage with herbicides: • for the long-term, protecting soil from erosion • for the short-term, better weed control options especially for perennials such as quackgrass.
Extension/Training	• short training sessions are effective in increasing awareness and overall understanding of the technology. • field days—"*Seeing is believing*"—are effective in seeing what works and what does not. It helps them to confirm their decisions to try a new cropping system. • hands-on technical training is very useful in the early phases of adoption.

Pre-introduction of Minimum Tillage

Large-scale crop production in Mongolia began in the 1960s and Mongolian farmers had been slowly moving toward adoption of conservation farming systems. Most of the original knowledge and technologies came from the former Soviet Union. At the time, the cropping system involved heavy/deep cultivation and plowing. After 15 to 20 years of continuous intensive cultivation, farmers started to experience severe soil erosion problems. Soil erosion is defined as the loss of soil quality, fertility, and texture resulting in low productivity (Henry, 1994). Today, about 80 percent of Mongolia`s cultivated land is eroded to some degree. Recently, heavy plowing has been discouraged, and shallow cultivation using a Noble® blade has been promoted. Unfortunately, the amount of soil disturbance was not significantly reduced and little or no soil protection was achieved even using the Noble-blade. Switching from the plow to the Noble-blade did not stop the soil erosion and agricultural fields were continually getting more and more eroded.

Over time, weed infestations also had grown substantially and were becoming very difficult to control. Farming was not easy in Mongolia and farmers were struggling with poor soil fertility, major soil erosion, and low productivity and were also faced with controlling infestations of quackgrass, Canada thistle, and other perennial weeds. These issues are not separate, but are intertwined and influenced by multiple factors. For example, weed infestations arise because: a) there are limited numbers of control options; b) weeds adapted to cultivation and cultivation can spread weeds more; and c) a lack of timely finances can limit the efficacy of the weed control applications. Often, farmers can only afford to cultivate their fields once or twice a year and at this rate they cannot control perennial weeds. Many of these factors have resulted in increased weed infestations and reduced crop yield. Quackgrass in particular, was slowly taking over many fields with crop yield losses of up to 100 percent in some areas. Farmers had started realizing that tillage was not going to control quackgrass and several other perennial weeds so they began looking for better weed control options. Thus, the principle of replacing tillage with herbicides was the biggest selling point for the introduction of minimum tillage practices as a weed control option. Some farmers introduced minimum tillage practices solely for weed control purposes.

> *We used Roundup two years ago to control quackgrass. It works well and we got rid of quackgrasses. Then, this year, quackgrass is coming back again, so we are thinking about re-using herbicide on the summer fallow again.*

Farming in Mongolia had become a challenge, and farmers needed to examine alternatives to their cropping practices. Many farmers reduced the total number of hectares they were seeding, and thus, they abandoned many cultivated fields. However, one farmer said:

> *Farmers never run out of hope. We always hope that next year will be better. We have to have a faith in mother-nature. But this continuous drought for many years is taking away the faith of many farmers. In the spring, I was not sure if I should seed or not, because I was afraid. If I lose the crop this year, I will not be able to farm again.*

Drought has become a serious problem for much of Mongolia. Irrigation is a possible solution; however, in the cropping areas of Mongolia, there are not many water sources such as rivers, lakes, and wells. Also, establishing an irrigation system and irrigating large fields can be very expensive. One of the female farmers said that:

> *… I was lost. Then I decided to talk with professors at the Mongolian State University of Agriculture and asked their advice. They said the only limiting factor for the successful crop production in Mongolia is soil moisture. If you can preserve enough moisture in the soil, everything else is manageable.*

Thus, farmers were very interested in the moisture conservation potential associated with reduced tillage agriculture systems.

Most of the farmers in Mongolia produce wheat in a two-year wheat-fallow rotation, which translates to a bi-annual income on any given field. One must plan to defray two years of costs with a one-time profit. Serious financial instability has resulted from several years of continuous droughts and substantial yield losses. Not many farmers made money during those dry years and many fell into greater debt. In the spring, it is common for farmers to seek a bank loan to cover the seeding and summer fallow costs. Often, it would be an annual loan, and farmers would have to pay it back in the autumn. However, during those drought years, some farmers were not able to make enough to pay back their loans.

Farming is becoming a hobby (laughed). We have not made any profit for the last few years. But every spring, we take a bank loan to sow and hope for a better year.

This risk and their financially vulnerable position were significant influences that pushed farmers to look into ways to reduce their operational cost such as salaries, fuel, equipment maintenance, and inputs. The ability to reduce costs in conservation farming encouraged many farmers to try this new system. Farmers participating in the interviews said that minimum tillage technology reduces the cost of fuel, equipment, and salary quite significantly.

…Instead spending 15 days with 3 guys and 3 tractors to cultivate 400 ha, I can spend only 3 days with 2 guys to spray 400 hectares. Especially when fuel/diesel price is high, this new technology saves me a significant amount of money. *I am very happy with it. It is a win-win situation for me. I spend less, get better control of my weeds, and preserve more moisture*.

At the same time, the government was also investigating ways to help farmers and import conservation farming technologies. Unfortunately, several successive years of unprofitable farming resulted in much reduced financial capacity of farmers to buy new technologies. The Mongolian government and farmer organizations then started looking for solutions outside of Mongolia, which included a number of project proposals to international donors and agricultural development agencies.

The introduction of minimum tillage technology

Active introduction of minimum tillage technology officially began in 2000 when the first no-till project through the USAID/ACDIVOCA[20] was implemented in Mongolia. This was followed by a number of conservation agriculture projects funded through the European Union (EU), Canadian International Development Agency (CIDA), and the Food and Agricultural Organization (FAO). Within two to three years, four internationally-funded

[20] ACDIVOCA - is a private, nonprofit organization that promotes broad-based economic growth and the development of civil society in emerging democracies and developing countries. ACDIVOCA is based in Washington DC.

projects were organizing activities that would: a) increase awareness of conservation agriculture, b) demonstrate the practice of conservation agriculture on selected demo-farms, c) provide training to farmers, and d) begin the importation of inputs and equipment. Most of the demonstration sites were located in Selenge aimag, but also quite frequently the same demonstration farms were selected by two or three projects for a various reasons: a) Selenge is the main crop production aimag in Mongolia; b) it is close to the city, Ulaanbaatar, so administrative and transportation costs are, therefore, lower; and c) it has the ability to share the implementation cost and resources among international projects.

These projects all focused on similar, though distinct, activities. For instance, the EU project focused on irrigation and importing sprayer kits to modify old Russian sprayers found on Mongolian farms. The FAO focused on chemical fallow demonstrations and modifications to add straw spreaders to old Russian combines. The USAID focused on importing John Deere air seeders to demonstration farms and on demonstrating no-till and direct seeding practices. CIDA's minimum tillage project was focused on capacity building—offering technical training sessions to farmers, demonstrating various minimum tillage practices versus conventional farming practices, and organizing technical field days.

Field demonstrations and experiments: Field demonstrations of different minimum tillage practices were set up at different scales on the selected farms. One project chose whole summer fallow fields (200ha) and replaced all tillage operations with herbicides on a hill-side site. Field days were subsequently organized at the site. Most of the projects tended to choose a whole field to apply direct seeding technologies on the entire field, whether it was chemical fallow, herbicide application, or seeding. A few other projects chose to use replicated small trial plots to try various methods next to each other for easy observation of differences and comparisons. Having those demonstration and experimental plots on a commercial farm field had a significant influence on other farmers who were carefully watching the results.

Having my neighbor selected as one of the demonstration farms for those international projects enabled me to see minimum tillage trials in their field trials on a frequent basis. I had convenient access to see and to ask what was working and not working.

Training sessions and field days: In addition to the field demonstration, international projects organized many training sessions for farmers and combined these with field days. Training sessions were offered in various forms: short- and long-format, in-class and out-doors (hands-on), focus group discussions, and field days. Many farmers said that:

…Short trainings and field demonstrations introduced this technology to me.

As mentioned previously, farmers in Mongolia had already been looking for an alternative to their conventional farming systems. Thus, there were high rates of farmer attendance and participation in these training sessions. For many farmers, short training sessions were the gateway to the conservation tillage technology. It seemed that many of them obtained their initial understanding and information about conservation tillage farming practices from short training sessions organized through international projects. The field survey results lead to the same conclusion.

Short training sessions are effective for increasing awareness and overall understanding of the technology. However, farmers seemed to prefer field days more than in-class training opportunities.

Field days are more effective—Seeing is believing. But, once I have some experience with trying the new technology, in-class trainings are OK because I would be familiar with what is being taught. But, for first-time learners, field days are better to understand and see the differences.

Farmers said that field days are effective for seeing what works and what does not. It helps some of them to confirm their decision to try it out. Also, field days provide an opportunity to demonstrate technical aspects to farmers and to give them hands-on training with respect to techniques that they can apply on their farms. Farmers feel that field days are very useful especially in the early stages of technology assessment and adoption.

Many farmers felt that participatory and conversational training modes such as focus groups did not work so well. They felt that it was not comfortable to talk when many farmers had been put in a group especially when this included people that they did not know well. However, farmers tended to enjoy talking on a one-to-one basis or with a few fellow farmers who they knew quite well. Almost all of those interviewed said that they did not mind sharing their knowledge and experience with others. Indeed, they tend to visit and to talk with one another if they have a question.

Adopter farmers attended training courses quite actively. On average, an adopter farmer attended two to three training sessions per year. While farmers found short-format training programs to be useful, they would have preferred that some of the visual aids were more relevant to their particular farming context.

> *… Looking at Western pictures and videos was fun, but it was hard to convert that into our farming context in our mind*.

Some farmers found that the training session’s content did not always apply to their farming situation directly. However, they maintained that it was always good to hear what is new and what other people were doing:

> *If I feel training is very useful to my farming, I will pay my own cost to attend the training. Unfortunately, most training programs do not directly apply to our farming problems.*

Most of the farmers seemed to make their tentative decision to adopt conservation tillage practices on their farms based on these short training programs and field days. Then, often they seemed to confirm their decision with respect to introducing a new practice to their farms by consulting with local researchers or experts before they tried the new technology.

I thought a lot about it. It sounded all very positive and useful from those training sessions taught by international experts. But, I wanted to hear what our researchers and agrologists thought about it.

One farmer said that:

…even though our professors did not know very much about practical details involved with this technology at the time, they agreed with the principle and assured me that it was a good way to go.

This indicates that is important to build up the capacity of local research and educational institutions and experts. Unfortunately, not many of the international projects worked closely with local research and academic institutions with the goal of building capacity. Their main focus was on direct communication with farmers.

Upgrading and modification of farm equipment: Many farmers had understood that the aim of conservation tillage technology is to reduce tillage and to use herbicides instead of tillage to control weeds. Soil erosion is reduced and moisture is conserved due to reduced evaporation. Crop yields can be increased as well when the field surface is left covered with plant residue, weeds are controlled, and the crop is seeded without much soil disturbance. Later, farmers began to understand that straw or crop residue needs to be spread evenly on the surface of the soil instead of in piles which was what the old combines used to do. Therefore, conservation tillage is a system that starts at harvest with good residue management.

Another lesson learnt is that this technology has to be used in a complete manner in order to see the desired results. If any one step/aspect of seeding, harvesting, straw cover, and summer fallow is not taken proper care of, the results of the minimum tillage program are likely to be negative.

When I first started, people used to tell me that No-Till means just no disturbance of the soil. I did not know about other important parts of the system, such as maintaining straw cover, until more recently.

Through FAO funding, a number of farmers tried to modify their old Russian combines—in particular, to attach straw spreaders. Many of the trials did not work due to a lack of engine power. However, farmers came to understand the concept that the crop straw and residue needs to be spread in order to achieve a more even cover on the soil surface that will prevent soil from blowing and soil moisture from rapidly evaporating while also allowing seeding equipment to effectively pass through.

Another major modification involved the need for an appropriate sprayer. As herbicides are used to control weeds, effective sprayers become more important. The level of weed control achieved depends heavily on the condition of the sprayer that is used. Most of the farmers in Mongolia had old Russian sprayers that did not meet the technical level required. Through Tacis/EU (2002) the Ministry of Food and Agriculture imported sprayer kits (nozzles, pumps, and hoses) to upgrade the old sprayers, and sold the kits to farmers at a subsidized price. Many of the farmers bought the kits and upgraded their sprayers in order to be able to replace tillage on summer fallow with herbicides. Unfortunately, the size of the nozzles that were imported was larger than what is preferred to spray at low volume and fine drop applications. Large size nozzles require higher volumes of water to mix with herbicides, and the droplet size is larger, which is not well suited to the application of glyphosate. Lack of knowledge and expertise among people at the Ministry of Food and Agriculture as well as among farmers reduced the effectiveness of the technological change. One farmer said that:

> *Lack of knowledge is expensive. I made a lot of mistakes that I could not fix due to lack of knowledge and information.*

Nonetheless, the modified sprayers functioned better than the old-Russian sprayers though farmers had to use higher volumes and higher concentration of herbicides to assure control of weeds.

Government responses: From the beginning of the introduction of conservation tillage technology, the Mongolian government, in particular the MoFA, was involved. In addition to government support and effort in getting international donor funds, the MoFA was also looking for opportunities to support farmers during a critical period. One of the major programs the government launched was the summer fallow program in 2002 and 2003. Through this program, the government announced a tender among private agricultural businesses to import Roundup® and other herbicides that were needed for weed control in summer fallow fields. Imported herbicides were distributed through MoFA to those farmers who had received the approval of the Ministry. In 2002, herbicides were distributed free to farmers if they used them on summer fallow as a way of introducing minimum tillage practices. In 2003, herbicides were distributed at a 50 percent subsidized price. The government perceived that it had no choice but to help farmers by distributing the herbicides free, or at subsidized prices because otherwise there were not many farmers who would be able to afford to implement minimum tillage practices.

The program was perceived as helpful, both as a subsidy and as an inducement to persist in trying the new cropping system:

> *It saved us. If not for this summer fallow program and government loan to do summer fallow, there would not be as many farmers still in business today.*

Providing herbicides free or at a 50 percent subsidized price was a significant incentive for farmers to try herbicide on their summer fallow.

> *First, we started introducing chemical fallow to our farming systems because the government was providing herbicides free. We did not know a lot about chemical fallow and did not believe it was going to be better. But, then a year later, we realized that chemical fallow is actually better, and we have been continually doing it.*

Evidently, MoFA reached out to many farmers through their summer fallow program who otherwise would not have had a chance to try out this technology. This seemed to accelerate the adoption process quite rapidly, even though the specific subsidy lasted only two years. Through this program, the MoFA provided opportunities for farmers to: a) evaluate this technology on their own farms and to observe the costs and benefits, b) allow financial re-establishment with a break from bank loans, and c) achieve a quality summer fallow that leads to a good crop yield the following year.

On the other hand, providing herbicides to farmers who did not have enough knowledge of how to use them resulted in a lot of mistakes, and it negatively influenced some farmers' attitudes towards chemical fallow and conservation tillage systems.

> *I made a mistake and my field is a mess. Especially now, when we are not so strong financially, we cannot afford mistakes and to take chances.*

Perhaps, it will take some time to convince this farmer to try it again if he will ever reconsider. Sometimes, the first impression is very strong. Like another farmer said "Lack of knowledge is expensive". The government took a chance on rapidly increasing adoption on the one hand, but losing some potential adopters on the other. Perhaps, capacity building activities such as training of farmers prior to this program might have produced even more positive results.

After the initial introduction of conservation tillage technology—following the termination of international projects

> *Adoption is a learning process. It involves many years of trying. Nothing works perfectly the first time. I tried one way one year and another way the next year to see what works better for me and for my farm.*

The different international projects on conservation tillage came at about the same time, and ended at about the same time (between 2002 and 2004). By the end of the international projects, Mongolian farmers had become aware of the concept of soil and moisture conservation through conservation tillage farming systems. Also, a few farmers had started testing the technology on a portion of their farmland. In particular, demonstration farmers who were selected to work with these international donors had been applying the conservation farming practices on their farms, and some had received free equipment from these projects. Termination of the projects also ended many activities related to conservation agriculture such as farmer training programs, field days, and other research and demonstration activities. Just as mainstream farmers started to get interested in the technology, the key extension activities stopped, chemical importation was minimized, and everyone involved was left with little or no guidance.

Lack of knowledge and information: Most of the project activities were focused on farmers, and little attention was given to researchers, university professors, extension agents, and policy makers. Thus, local capacity to provide guidance to farmers with respect to conservation tillage systems remained low after the projects. Some local research institutions had started to experiment with some of the conservation tillage practices, but researchers' knowledge and information about this technology was too low to make the experiments comprehensive and relevant. In addition, lack of information available in their local language was one of the biggest limiting factors to developing their knowledge about conservation tillage.

Sometimes, a little knowledge can be more dangerous than no knowledge. Both researchers and policy makers developed some understanding of conservation tillage systems during the implementation of the international projects. Nevertheless, neither of them established a thorough understanding of this technology. Since the international experts have left the country, farmers have been looking to local researchers and experts for the information on minimum tillage systems. Farmers indicated some concern about the level of local expertise with respect to minimum tillage technology.

> *We (farmers) have nowhere to go. Sometime, it feels like our local researchers and extension agents are not any better than we are. We need training for all levels including us (farmers), researchers, academics, and policy makers. Those international projects ended too soon.*

Many of the farmers showed some frustration about being vulnerable as a result of not having enough knowledge. Lack of knowledge or misleading information has resulted in some costly mistakes.

> *I made so many mistakes that I cannot afford, especially during these financially difficult years. Minimum tillage is a good technology, but one has to know technical details of the application. Most of the mistakes are not fixable and it*

ruins the whole year of effort and investment. We really need more training or projects like CIDA's Minimum Tillage project.

Despite gaps in their technical knowledge, the farmers seemed to respect local experts and researchers and generally to have more faith in them. Many farmers indicated that they listened at the annual farmers' conference where local researchers, government officials, and climate forecasters speak about trends in climate, markets, technology, and agricultural policy. Farmers pay close attention to the technologies that are promoted by the local researchers and experts at that conference in addition to what international experts are saying. A couple of farmers said:

> *Minimum tillage technology was promoted at the farmers' conference this year. I am much more comfortable now to try this technology after our local researchers and experts tried it and have demonstrated that it works for our farming conditions.*

As it is more accepting or comforting to hear local researchers, it is very important to build local capacity of those involved in generating local knowledge on minimum tillage technology.

Lack of farm input supply: Farmers were also left frustrated by lack of availability of farm inputs. Most of the farmers interviewed believed that they had benefited from adoption of conservation tillage practices and would like to continue with the system. However, farmers struggle with lack of knowledge, lack of reliable supply of chemicals and equipment, and lack of financial support.

> *It has been two years since we introduced minimum tillage technology. It has been good so far. It saves cost,…better weed control. In this practice, everything has to be done on time. When you miss out the timing due to lack of supply of inputs, the consequences are great. There is no reliable input supply in the country. And nowhere to go for compensation.*

Herbicide and sprayer kit importation and other activities related to conservation farming practices went dormant when the government summer fallow program and international projects ended. Only one or two companies still import small amounts of herbicides. Therefore, the price of herbicides has gone up and quality has gone down. There is no option for farmers and no competition in the business.

> *It is my third year since I started chemical summer fallow and reduced tillage operations. The first two years were great, but this year is a mess. The herbicide we bought did not work at all. I just bought what was available. I did not know how to check the quality of the herbicide.*

Following the establishment of the government program promoting herbicide use, there was no system set up to regulate the standards for imported chemicals. As well, there was no monitoring and no evaluation system to control the quality of chemicals being sold to the farmers.

> *Inappropriate use of chemicals is creating distrust in the conservation farming technology. Many of my co-farmers stopped using chemical fallow because they cannot afford making mistakes and cannot trust those imported herbicides. I am also going to go back to conventional tillage but I will try minimum tillage again when our government puts together better conditions to address this mess.*

Many farmers complained that the herbicide they had bought did not work at all. Many of the farmers the author spoke with wanted to discuss how to check the quality of the herbicides and technical details of herbicide applications, as the author was previously involved in the minimum tillage demonstration and training activities in Mongolia. For some farmers who have seen this practice working, it was clear that herbicide quality for this year was not very good. But those who were trying it for the first time perceived that it was the reduced tillage technology that was not working for them. However, there could have been many factors that caused the failure such as poor water quality, poorly calibrated sprayer, and farmers' lack of knowledge and experience with the application of herbicides.

I tried it the first time this summer. It does not work for us. This Western technology is not suitable for Mongolia. I am not going to try again and waste my time and resources.

It seem clear to these farmers that the government needs to set up a regulatory system to control the quality of farm inputs that are being imported. Also, the timely supply of input requires some attention. Many farmers likely miss out the most optimum time to control weeds due to late distribution of herbicides. This affects a) the efficacy of the herbicide application, b) the final outcome of the reduced tillage systems, and c) the farmers' attitude towards new technology.

Some farmers invested in farm equipment and agricultural machinery during the introduction of minimum tillage technology. Others were given equipment as part of international projects. Unfortunately, however, supplies of parts, training, and other necessary services in Mongolia are not adequate. During the author's field visits and farm tours, it was sad to see John Deere air seeders, which were given to them through the ACDIVOCA project, covered up and not in use. When I inquired about the seeders, one farmer said:

…I have one of those very nice green seeders, but it does not work on my farm or I do not know how to make it work. That project ended a couple of years ago, and I am not sure whom to ask about this equipment. I guess if I keep it long enough, there will be people who are familiar with this kind of fancy stuff.

Another farmer says:

It is a beautiful thing. I have something missing and need to be replaced. But, there is no supplier in the country.

The John Deere seeders were donated. Perhaps, there would be more incentive to learn how to use them and use the equipment effectively if the farmer had to pay for it (though, either way, parts and service support could be an issue). One very innovative farmer, the earliest adopter of this technology in Mongolia, went out and bought a new airseeder and sprayer from Canada. He took a $450,000 USD bank loan to buy this equipment. Now he is concerned for various reasons.

> …*I really believe reducing tillage is only way to go. So, I bought an air seeder from Canada. But the openers wear out very quickly in Mongolian dry soil. To replace them, I have to order them from Canada. It costs me $25CAD per piece, plus shipping costs to Mongolia. That is a huge addition to my seeding cost. I cannot afford that. I decided to modify it with Mongolian openers and welded them on the shank.*

Although farmers are excited about the new equipment and technology, many were quite clearly frustrated about the lack of knowledge and reliable supply of parts and farm inputs. Many of those projects promoted importing equipment and machinery before building the capacity of farmers and the capacity of the country to establish sufficient knowledge base and suppliers to meet the farmers' needs.

> *When you try a new thing, many mistakes can be made. But, it scares our hearts to try it again.*

Lack of a regulatory system for timely and good quality input supply seemed like a significant barrier to a wide adoption of minimum tillage practices. Also, farmers' trust in agri-businesses and agricultural input suppliers seemed low.

3.7.2.2. Farmers' perceptions on environmental, economic, and social benefits of minimum tillage

Despite many problems in implementation, farmers' perceptions about the future of conservation tillage systems in Mongolia generally remains quite positive; many believe that this is the most sustainable way to farm. They see conservation agriculture as offering potential benefits in multiple dimensions: environmental, agronomic, economic, and social. Female farmers especially tend to place some emphasis on the social advantages that the conservation tillage system can provide. These include less time in the field, more time at home with their children, and more time for other part-time employment opportunities. Interestingly, farmers in Canada who have adopted minimum tillage practices tend to expand their farm land and use saved labor time on expanded farm field.

> *There are many advantages. It saves me a lot of money and time. I like the idea of spending more time on other things instead spending all day in a field in hot, sunny, summer weather.*

From a farmer's perspective, saving time and labor is a social benefit, and it also leads to an economic benefit by lowering the operating costs. Farmers expect more economic benefits in the long term. Nonetheless, they perceive direct benefits to their farmland, to the sustainability of the farm, and to their economic returns.

> *Minimum tillage is for the short-term, economically better. For the long term, environmentally better. It saves the soil for future generations.*

> *I hear people indicating some health concerns about using more chemicals than with conventional tillage. Let me say this: "It is better than importing unsafe food from China". But we must use chemicals safely and properly.*

Nevertheless, the primary reasons that farmers have for adopting minimum tillage practices are short-term. Many farmers' perceptions of minimum tillage are associated with weed control and soil protection, which are direct short-term as well as long-term benefits.

> *Soil erosion and weed control are the main reasons that I decided to replace tillage with chemicals.*

> *We decided to try this technology as it will help saving and protecting our soil. It is very windy here and wind takes the soil to the sky.*

> *Weed control was our main reason for trying minimum tillage—using herbicides during the summer fallow becomes the only option to control weeds like quackgrass. It has been three years since we have introduced chemical fallow.*

But we stopped this year because we got rid of quackgrass already. We will use herbicide in the fallow again if we see more quackgrass next year.

I tried introducing minimum-tillage to control some of the perennial weeds. I stopped this year because I financially cannot afford to buy herbicides. But, minimum tillage is good for soil erosion and protects soil, provides weed control, and conserves moisture. I had a good year when I planted on chemical fallow and had good moisture.

Even though they recognize other direct and indirect benefits of the technology, weed control figures strongly in farmer perceptions and acceptance of conservation farming practices. Farmer concern about soil quality and the effects of erosion is also a relatively significant influence on the decision to adopt a new technology offering potential to protect the soil from the negative consequences of continuous heavy tillage systems.

3.7.2.3. Farmers' commitment and continuation

Most of the farmers interviewed, especially those who have adopted minimum tillage practices, seem to have strong feelings and commitment for the technology.

For the very dry conditions in Mongolia with limited precipitation, we don't have many other choices but to introduce conservation farming technologies that will help us to protect our soil and conserve soil moisture. I am in it without going back.

We cannot chase only an annual yield and financial return. We have to protect our soil and introduce a technology that is good for the soil. If we go through the adoption process now and go through the trouble, it will be all set and ready for our children to carry on. We have to make a small sacrifice for our future and our children's future.

Most farmers seem to believe that conservation farming systems are good for the long term and that they will protect the soil. Until recently, Mongolian farmers could not own their farm land but leased it from the government on a long-term basis—up to sixty years with option to extend beyond that timeframe. In 2002, the Mongolian government approved a new land law that allows farmers to own their farmland. Since these changes were introduced, some farmers may feel greater identification with and concern for the land, due to ownership or the possibility of future ownership.

However, at the same time, farmers are also committed to trying something new and different to solve short-term issues and concerns that are directly related to their farming operations today, such as weed control.

> *I cannot keep my fields weed free without using herbicides and a chemical summer fallow system. I decided to replace most of my summer fallow cultivations with herbicide. My brother is an agronomist and he also confirmed with me that it is a better choice. So, between me and my brother, who is now hired as my company agronomist, I have tried many versions of chemical fallow on our farm. I am going to try different ways until I find the one that works for me.*

Some farmers have committed heavily already and cannot get out of it very easily. Therefore, they will likely persevere with this technology but not simply by choice, more by force of circumstances or as a consequence of their previous decisions.

> *The first two years have not been very profitable. I did not harvest enough yield at all. There were many days that I have wished to step back from this technology, but I have invested all I have into this. So, I have no choice but continue…*

Overall, most of the farmers I spoke with perceived many benefits associated with this technology and would like to adopt it. However, there are also factors that impede adoption:

> *For farmers in Mongolia, the biggest barrier to adopting this technology is financial capacity.*

Also, minimum tillage technology is heavily dependent on herbicides and other farm inputs such as fertilizers. Thus, a widespread adoption of this technology will happen only if there is a reliable supply of quality farm inputs. Right now, there is no entity to take responsibility for importing good quality inputs, including herbicides, in a timely manner.

3.7.2.4. Sustainability

> *Sustainable agricultural production will happen when farmers start to do well and harvest good yields. It will increase farm income, reduce flour and food prices, and also reduce the price of feed for livestock and livestock production like meat. Once we take care of the farming and start harvesting a good yield, it will take care of the economies and livelihood of people in Mongolia*.

In order to increase yield and prevent crop failure from severe droughts, sustainable soil moisture conservation and soil protection systems need to be in place. Most of the crop production area in Mongolia is located on dry plains where there are few water resources for irrigation. Soil and moisture conservation farming systems provide opportunities to farmers who do not have access to irrigation sources and also protect the soil from erosion and fertility loss.

> *Minimum tillage technology is economically better for the short term, and environmentally better for the long term. It saves the soil for future generations.*

> *We have no choice but adopt. I believe this minimum tillage technology is very important and needs to be considered where sustainability of our farming is concerned. I want to do the right thing for the land and our farming future.*

> *My son is studying in agriculture. I want him to inherit my farm. Therefore, I want to conserve the soil from erosion and degradation as much as possible.*

While short-term economic returns are likewise crucial, it is apparent that Mongolian farmers, in general, are concerned about the sustainability of their farming systems and the future of their farmland. Many of those who have decided to adopt minimum tillage technology seem to believe that the challenges of adopting a new technology today are going to pay off in the long term. Nevertheless, sense of uncertainty about future benefits and risks still exist.

> *It is disappointing when you make a mistake and lose big money. That is when I feel like going back to old system. But, no pain, no gain. I know it is good and, if we do it properly, there is big hope for this technology for the future.*

Conservation tillage systems are complex. In addition to many agronomic benefits, they carry some risks related to social and ecological issues[21]. In conservation tillage practices, pesticides are used for weed control and other plant protection measures. During the handling of the pesticides, mistakes such as over dose of chemicals, misuse of chemicals, and unsafe use of chemicals, are easier to be made and cost can be higher in the conservation tillage system than conventional farming practices both economically and environmentally.

While conservation tillage seems to offer some significant potential as a way to solve problems in cereal production, it may not be sufficient. Farm diversification may also be an important consideration in order to diversify income sources and thereby reduce risk. Many of the farmers in this study seem to be going for mixed farm systems, which include more diversified crop rotations, livestock and poultry, as well as small

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[21] Countries where conservation tillage is widely adopted such as Canada, are facing some social consequences of the wide adoption. Conservation tillage technologies have produced large equipment and machines that enable farmers to farm large areas with a little or no help. This resulted in increased farm size and reduced number of farms. Such technological changes in farming and the economies of scale have changed rural towns. For example, in the case of Saskatchewan province in Canada, between 1951 and the late 2006, the average size of a family farm grew from 550 acres to 1449 acres. During the same period the total number of farmsteads in Saskatchewan dropped from 112,000 to 44,329 (Government of Saskatchewan, 2005). Grain farming has become profitable only on a very large scale, as the cost of inputs has soared. Between 2001 and 2006, the percentage of farms with more than 2239 acres increased by 13 percent (Government of Saskatchewan, 2006).

Furthermore, such change in farming practices increased unemployment and population outflow from rural areas. The Saskatchewan population Report of 2006 records a steady rural outflow. Between 2001 and 2006, out of 283 villages, 232 recorded a decline in population. Out of 147 towns, 124 recorded population declines (Government of Saskatchewan, 2006). It contributed in disappearance of many rural towns as a consequence of reduced employment.

businesses in the service sector. Diversification in crop production such as crop rotation will also help reduce crop protection measures such as use of pesticides.

3.7.3. Summary

Conservation agriculture practices were introduced to Mongolian farmers, beginning in 1999 and 2000, by means of extensive training workshops, field demonstrations, and other technical activities funded by international projects. As a result, grain farmers in Mongolia have become aware of the technology and some have adopted at least some of these conservation farming practices on their farms. Many of the farmers are experimenting with and testing the concept—especially chemical summer fallow—to see which methods and practices will work best. Many farmers are determined to adopt this technology because they see it as being good for their farm enterprise and for their land. However, several farmers experienced major setbacks during their first try with the new technology, either because they made mistakes, or because appropriate equipment and inputs were unavailable. Some of these producers are reverting to more conventional methods of farming.

Factors that influence farmers' decision to adopt conservation tillage technologies in Mongolia include prolonged and repeated droughts, weed control problems, and the need to address soil erosion problems. The main barriers for the adoption of conservation farming practices are lack of knowledge and information, lack of inputs and equipment, and lack of financial support. Lack of consistent input supply and enforcement of quality standards is the main frustration of farmers who want to use chemical summer fallow and conservation farming practices. Also, there is a need for capacity building at all levels of the agriculture system including farmers, researchers, policy makers, and extension agents.

> *Farmers, agribusinesses, and the government should take responsibility for monitoring the quality of inputs and setting legal rules and regulations on the importation of chemicals and other farm inputs.*

Lack of quality control for chemicals, and missed timing of the operation results in very costly mistakes. Nonetheless, the introduction of conservation tillage systems appears to be important for a sustainable cropping system in Mongolia. Preventing soil erosion and conserving soil moisture will have a positive influence on sustainable crop production in the face of harsh weather and the threats of climate change. It may also contribute to the economic prosperity of successful adopters, provided that problems of reliable supply and input quality can be addressed. However, at the same time, potential social and environmental risks such as rural unemployment and chemical pollutions of natural resources should be considered and moderated if possible.

4. ANALYSIS OF CURRENT EXTENSION SYSTEM AND SUGGESTED MODEL FOR THE AGRICULTURAL RESEARCH AND EXTENSION SYSTEM IN MONGOLIA

4.1. Description of the Extension System and Lessons Learned from the Introduction of Minimum Tillage System in Mongolia

Investment in agricultural research and extension has been shown in many countries to result in large returns through improved agricultural productivity. A study by the Consultative Group on International Agricultural Research (CGIAR) claimed a benefit:cost ratio of 9:1 on their investments to date of $7.12 billion USD, and a ratio of 17.3:1 when program results were extrapolated out to 2011 (Raitzer and Norton, 2003). Various studies undertaken in the USA between 1949 and 1987 show a return of 30-60 percent overall where research and extension were combined in the program (Norton, 1991). It has been suggested that combining appropriate research and extension systems will enhance the adoption of new technologies leading to lower production costs, improved productivity, expanded markets, better food quality, safety, and nutrition. Synergy among research, extension, and teaching can lead to a more competent, effective, and innovative technology development and extension system (Agbamu, 2000).

Investors in agricultural research and extension should consider adopting a holistic approach that would help eliminate the constraints that inhibit technology adoption. A holistic package should include legal reform (resource tenure, pricing, and commercial law), public investments (irrigation, transport, market infrastructure) and institutional strengthening (policy, research, resource management, and finance). Also, Mongolian research institutions do not seem to have strong linkages with international research organizations so that they can benefit from such knowledge to solve local agricultural problems. Restricted research budgets and research agendas that are driven more by government philosophy and policy rather than the needs of the industry have resulted in a lack of trust and communication between farmers and researchers in Mongolia. A program of adaptive research (trials) to support appropriate and selective technology transfer is required to help Mongolian agriculture productivity to catch-up with the rest of the world, particularly in the areas of cereal crop production, extensive livestock/pasture management, and intensive livestock production.

Mongolia's agricultural producers include many owner-operators that have come to agriculture since 1990 as a means of economic survival after the transition to the free-market economy. Many of these operators lack technical background or training in farming. Although they hire farm employees to do the farming operations for them, to be successful they require access to market information, technical and business training, management skills development, and new technologies to improve their capacity to operate economically and environmentally sustainable enterprises. The existing research and extension system is constrained by a number of factors. For example, international research linkages based on the previous communist system have broken down. Strong links with global research and extension organizations have not been built, although such linkages have begun to develop. There is also a shortage of domestic resources to carry out broad-based research and extension programs.

The first part of this chapter describes circumstances and issues entrenched in the current research, extension, and technology transfer system in Mongolia. The second part will discuss the author's personal observations and experience based on the field studies of this thesis research as well as experiences gained while working in the Mongolian agriculture sector for seven years prior to undertaking graduate studies in Saskatchewan. An alternative extension model derived from analysis of experience, observation, and understanding of the current extension systems and a participatory field study on potential extension models for Mongolian agriculture will be presented.

4.1.1. Development of agricultural extension systems in Mongolia

Most of the agricultural extension organizations and entities in Mongolia belong to government bodies. Until 1990, the entire agricultural sector was operated by the government within a centrally planned economic system. There was a form of "extension" services at that time, although the term extension was not used. However, this capacity-building activity was imbedded in the "top down" government structure of the era. In this system, the government was very much in control and farmers' needs/opinions were little heard. In essence, it was a command or forced technology transfer system where the government decided what technology should be used.

Currently, the linkage between researchers and farmers is quite loose in Mongolia (NAEC, 2007). There is very little information and new technology dissemination from research institutions to producers. In addition, most of the research projects are not responsive to farmers' needs and problems. Therefore, a bridge to link researchers with farmers and farmers with researchers has become necessary. Especially since the breakdown of the centrally planned economy and privatization of state-owned collective farms, the agricultural production system in Mongolia has changed dramatically. The old top-down, capacity-building and technology transfer system has fallen apart. Free competition for information and technology and a demand for better production systems have risen. At the same time, the number of inexperienced and less knowledgeable farmers has increased. Therefore, many of the farmers need technical as well as farm managerial guidance to properly manage their farms and make a profit. In addition, old traditional farming technology has become environmentally, economically, and socially unsuitable. If all of those changes are related to global issues such as climate change and economic stability, then continuous and effective dissemination of up-to-date information and technology becomes crucial. These needs and changes have recently been recognized by those who are involved in Mongolian agricultural production, including the Ministry of Food and Agriculture, local research institutions, farmers, and international agencies. The government of Mongolia has acknowledged the importance of an extension organisation and supported it through establishment of the National Agricultural Extension Centre (NAEC) at the Ministry of Food and Agriculture.

4.1.1.1. The National Agricultural Extension Center

The National Agricultural Extension Center (NAEC) was established by the Mongolian government resolution number 286 on November 28, 1996. Based on a provision of the Food and Agriculture State Policy of the government and the loan policy document agreement between the Government of Mongolia and the Asian Development Bank

(ADB), a “mid-term development programme for agriculture extension services” was instituted (Sanjaatogtokh, 2007). The Food and Agriculture State Policy was approved by the Parliament in 2000 “to train rural personnel and workers to carry out profitable production under market conditions, introduce new production technologies and refine the system for information dissemination” (Buyandelger, 2004). In the loan policy document of the “Agriculture Sector Development Programme” financed by the Asian Development Bank in two successive projects, the mid-term development programme with all expenses assessed was discussed and approved. The programme is directed at strengthening and making the agriculture extension service accessible in local areas. The government of Mongolia agreed to finance a certain portion of the programme.

The NAEC is a government organization located in Ulaanbaatar. The legal status of the NAEC is defined in the Laws on Science and Technology. Simultaneously, a “mid-term development programme for agriculture extension services” was formulated by the NAEC together with local experts based on the provision of the Food and Agriculture State Policy of the government and the loan policy document agreed upon between the government of Mongolia and the ADB on December 31st, 2003. The mid-term extension development program has two phases. The first phase was implemented during 2004-2007 and the second phase was to be implemented during 2008-2010. The program indicates that by 2010 it will expand its scope of activities. All aimags and soums will be included in the extension service network, and will be provided with up-to-date equipment and materials necessary for training and information dissemination.

The mission of the NAEC is to improve human resources for sustainable agricultural development. More specifically, the NAEC will help develop a stable, intensified, and less risky agricultural sector with an efficient structure to extend advice, training, new knowledge and information, and support technology transfer in conformance with the needs of agricultural producers and herders. NAEC has established agro-parks across the country where training, field days, field trials, and demonstrations of new technologies and techniques are organized. Also, communication and training centers are established and equipped with office and training tools and equipment through the International Fund for Agricultural Development (IFAD). The centers are used for providing information and training services for agricultural producers. The main activities of the NAEC are: organizing training events; providing consulting services, information dissemination, and advocacy; being involved in technology development and transfer; and developing international relations with global agricultural partners.

The NAEC has branches in 16 aimags and 64 soums and aims to establish representative local offices in all aimags and soums throughout Mongolia. The NAEC has 12 full-time staff and over 60 part-time scientific advisers grouped in different agricultural disciplines. In aimags (provinces), there are over 120 part-time specialist advisers working in aimag agricultural extension centers.

The extension methodology currently used by the NAEC involves mostly a top-down approach for decision-making and other extension activities, but this system is slowly changing. The main objective of the NAEC is to provide agricultural producers with advice on modern technology. The NAEC also helps by providing advice on business management and the improvement of human resources (producer capacity and skills). This is done by contracting experts to provide training sessions to producers (farm employees and farm managers) or by organizing training events for international projects operating in Mongolia.

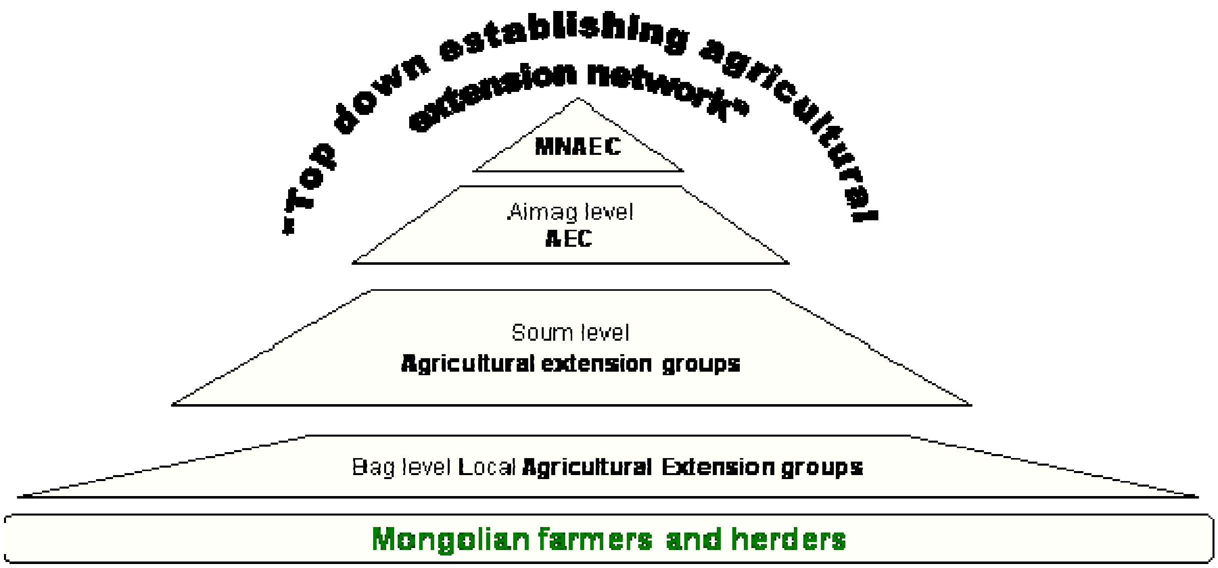

Figure 29: Concept and Structure of the NAEC in Mongolia (Source: Gungaadorj and Davaadorj, 2009)

Capacity of NAEC and extension workers

The NAEC hires researchers and other specialists from universities, research institutions, and NGOs to conduct extension training activities. The criteria for selection depend on their professional attitude, previous accomplishments, and work performance. Some specialists have teaching experience and professional experience in one or more of the six basic areas of research (agricultural engineering, agronomy, economy, veterinary medicine, animal husbandry, and food processing).

At the national administrative level, 90 percent of all extension workers have a Master of Science degree and 10 percent a Bachelor of Science degree. About 70 percent of the scientific advisers have a Doctor of Science degree; 30 percent of them have a Doctor of Philosophy (Ph.D.) degree. At the aimag level, 55 percent of all managers of extension centers have a Master of Science degree, 45 percent a bachelor's degree, 60 percent of extension advisers have a Master of Science degree, 30 percent a bachelor's degree, and 10 percent of them have a diploma. At the soum level, 35 percent of extension workers have a bachelor's degree and 65 percent have a diploma in agriculture (Gungaadorj and Davaadorj, 2009).

The scientific advisors come from government, NGOs, private science organizations, cooperatives, and universities. The scientific advisors are directly involved in extension work. They provide extension workers, farmers, and herders with production and marketing advice.

At the aimag level, the specialist advisers are volunteers. Ninety percent of the specialist advisors come from private organizations, cooperative organizations, NGOs, and the remaining 10 percent from government organizations. The specialist advisers provide farmers and herders with advice. NAEC and local extension centers are searching for soum-level extension specialists and farmer advisers. As of 2005, 64 extension groups have been established, made up of 250 farmers and specialist advisers. In recent years, the NAEC has organized many special training sessions for extension workers at all levels and has also sent extension workers to other countries including Japan, Egypt, China, Germany, and Canada to attend training courses (Bat-Erdene, 2006).

Extension as a subject of study has become popular in the last few years. Mongolian State University of Agriculture (MSUA) is now offering courses in extension, which should improve the capacity of participating extension workers to transmit vital information to farmers and herders. From 2004 to 2010, the Canadian International Development Agency's (CIDA) Training for Rural Development (TRD) project in Mongolia focused on building the capacity of the Mongolian extension system by training NAEC agents both in Canada and in Mongolia, and helping MSUA to develop courses on extension delivery methodologies (Stevens and Rasmussen, 2004).

Funding of agricultural extension centers and activities

Initially, the NAEC and the aimag extension centers (AEC) were financed by international projects including the Tacis program of the European Union and the International Fund for Agriculture and Development (IFAD) of United Nations. The project funding enabled them to buy office equipment, training materials, audio equipment, vehicles, and training materials, and to provide salaries for the extension staff. The idea was that extension centers would become self-sufficient through activities such as agro-park development and fees charged for services by the end of the three-year projects, 2002 to 2005. The objective of these externally funded initiatives was to develop extension services and expand their network. In addition to the investment made to support the NAEC and AEC activities, the projects put emphasis on improvement of AEC managers and extension agents' skills and know-how. During the last three years of the project, the AECs were able to increase the number of clients served in rural areas, and to gain a good reputation. As a result, AECs were able to organize various training activities directed at the rural population, herders, and crop farmers. Many of the activities were focused on the formulation of recommendations and business plans, and the provision of technical advice.

During those years NAEC slowly reduced its budget to support the operation of the AEC and handed the AECs to the provincial (aimag) governments. However, extension agents have been expected to sell their services and to find funding for their other activities. Since most farmers in Mongolia are not willing to start paying for extension services or for information, many of those extension centers currently struggle to survive. Nevertheless, some extension agents and centers have been very successful in marketing their services and in building and maintaining a network of clients. Other projects such as the CIDA-funded Training for Rural Development Project have supported NAEC's rural training activities, publication of training materials, and continuing education of NAEC staff.

Program of activities and focus of agricultural extension

NAEC services and activities are heavily focused on crop production technology transfer and crop-farm management. As a result, most of their clients are crop producers and training is the main extension activity of the NAEC and AECs. Training covers crop production, livestock production, veterinary medicine, farm mechanisation, economics, accounting, farm management, agriculture-related innovations, new technologies as well as improving household livelihoods. In addition, the AECs organise various field days, livestock fairs, and exhibitions. Figure 30 below shows the breakdown in terms of thematic focus of the training events provided during 2002-2006.

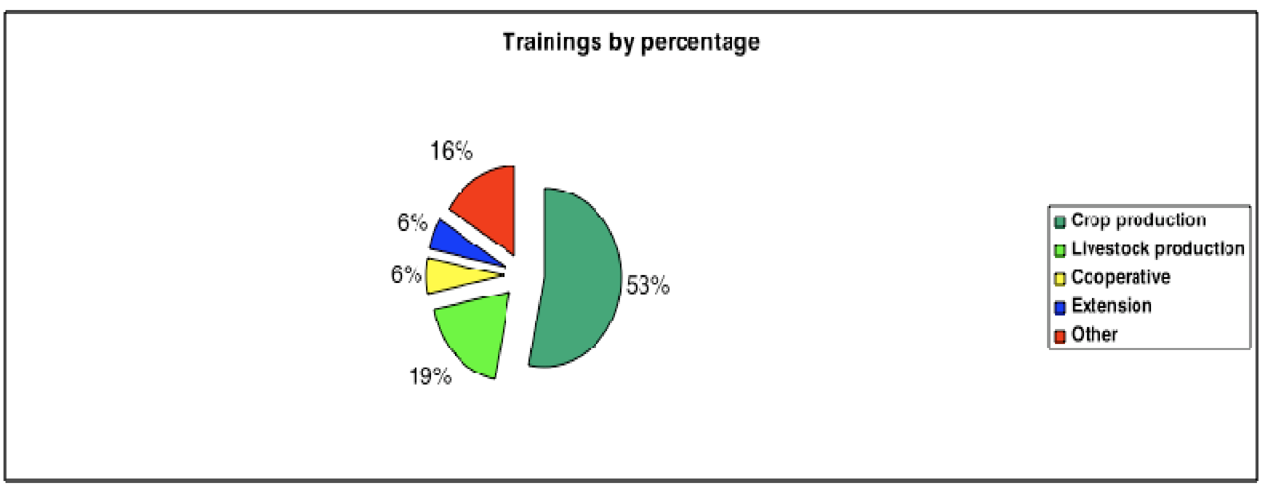

Figure 30. Different thematic areas of trainings offered through Mongolian Aimag Extension Centres between 2002 and 2006.

As seen in Figure 30, 53 percent of the training sessions offered during 2002-2006 were focused on crop production areas and 19 percent were about livestock. The need to include programs for herders in the extension service has become increasingly clear. Up to the time of this field research in 2006, training activities organized by the AECs had been free of charge, although establishing a financially self-sufficient and sustainable extension system is also a goal of the Mongolian government.

The AECs have worked on disseminating various innovations in agricultural production and new technologies using the following methods: a) leaflets and hand-outs which include materials produced by both AEC managers and local researchers, b) articles in local newspapers and journals, and books, and c) programming and announcements on local TV and FM radio broadcasting systems. Most of the hand-outs and extension materials are disseminated during the training sessions and immediately afterwards. In addition, studies and publications written by different researchers are purchased to be disseminated during sessions. Apart from training, farmers and herders can also come to the AECs during normal working days to get various kinds of information and educational materials.

Based on personal discussions and interviews with extension agents at AECs, agro-parks were established to: a) create favorable working conditions for the AEC managers, b) intensify and expand AEC activities, c) generate additional income through diverse agriculture services, and d) to be used for hands-on, practical training and demonstration activities.

Lessons learnt from the agricultural extension center activities

Agro-parks: Considerable investment was made to develop agro-parks. However, without adequate management and skilled labour to work in the agro-parks, it took much time from extension agents just to maintain the land with activities such as seeding, weeding, and watering. Rather than adding value to the extension centres, this work took extension agents away from their core activities and services,.

In establishing an agro-park or a demonstration site for training and education purposes, it is important to consider: a) the size of the park in relation to available capital and human resources, b) the type of demonstrations—commercial versus trial, and, c) the possibility of involving others including summer students, school children, and agri-producers. For example, demonstrations can be replicated on a commercial farm or in a producer's herd instead of trying to carry out everything at an agro-park. As a general principle, and in this particular case, there is a clear need for collaboration with other partners.

Smart investment in agricultural extension is necessary. Through international projects, much equipment and many inputs were provided to the AECs. While acknowledging the importance and usefulness of the investment, it is also worth mentioning that careful needs assessment should be made prior to investment to identify the most important needs and the most appropriate equipment, inputs, and supplies. For instance, as discussed above in Chapter 3, between 2002 and 2003, AECs distributed a sprayer kit with large-diameter nozzles imported from Europe. This happened about the same time that glyphosate (Roundup^{tm}) started to be used widely. However, glyphosate is most effective when it is applied with fine droplets. Increased communication and planning will be needed to more consistently support the acquisition of appropriate materials and equipment.

Farmers' participation in information dissemination and extension activities is crucial. Extension centers and extension agents are there to act as a two-way bridge between the producers of new information and technology (researchers, academics, international experts, and farmers), and the consumers of information and technology (producers/farmers). An effective extension system will exist only when information flows in both directions. Therefore, active participation of farmers in information and technology development as well as dissemination is necessary. Creating a consultative and collaborative extension model[22] requires farmers' involvement in identifying

[22] According to the Biggs's (1989) definition, there are four modes of participation through which farmers and researchers are linked: a) Contractual mode—where researchers are in power and there is no participation of farmers in knowledge development and planning, b) Consultative mode—where the researcher is still in the power, but farmers are involved, c) Collaborative mode—where researchers and

problems, setting priorities, sharing decisions, and exchanging information (Biggs, 1989). Attention needs to be given to inspiring and increasing farmers' participation in research and extension by involving farmer representatives in the decision-making and implementation processes.

Collaboration among the AECs and other extension service providers such as researchers, university professors, private businesses, and those who make policies and design programs needs to be established. There are 17 AECs and they are equipped with phone, fax, and e-mail connections. However, there is very little exchange of information and knowledge sharing among extension agents in different aimags. Mutual assistance and consulting are not widely practiced or well understood. While gathering data from the extension agents, an ethos of competition between AECs was noted. Also, collaboration between AECs/NAEC and research institutions is limited as the former work more closely with international projects than with local organizations. Therefore, focusing on local capacity building, strengthening local linkages and collaboration, and creating incentives to collaborate locally are important. One of the objectives of CIDA's Training for Rural Development Project has been to assist in the development of a co-ordinated extension system by strengthening the linkage between NAEC and universities.

4.1.1.2. Other extension players

NAEC and AECs are the main government units that are recognized as national agricultural extension providers. However, the overall Mongolian agriculture system engages many other groups who are involved in information and technology transfer activities directly and indirectly. These are grouped in the following categories for the purpose of this thesis (Figure 31).

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farmers are equally involved in the decision-making and information exchange, and d) Collegiate mode—where farmers are in power and researchers respond to farmers' requests.

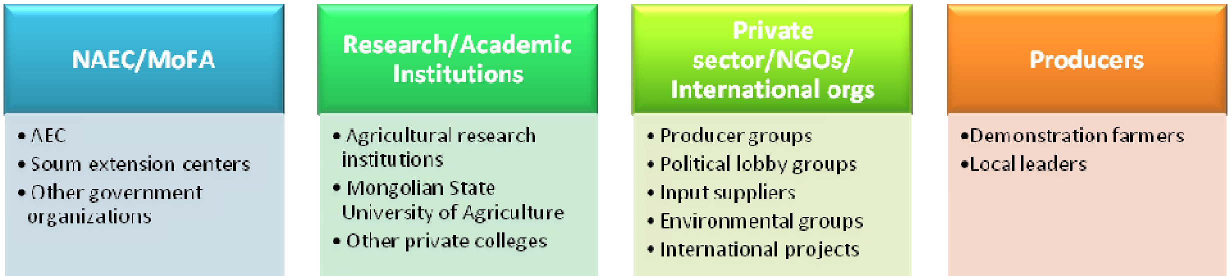

Figure 31: Main research and extension actors/pillars and their affiliations in Mongolia.

- Government agencies—Ministry of Agriculture (MofA), NAEC, AECs, National Science Committee, and Ministries;
- Academic and research institutions—Mongolian State University of Agriculture, Mongolian Farmer College, Plant Science and Agricultural Research and Technology Institution, Animal Husbandry Institutions, Research Institute of Veterinary Medicine, and others;
- Non-governmental and private sectors—Farmer organizations, producer associations, commodity association, agricultural development funds, international projects and organizations, private suppliers, and consulting companies;
- Producers—farmers, herders, and specialized agricultural producers such as vegetable producers.

The list of organizations involved in agricultural extension or related activities is long. However, these organizations tend to be very independent from each other and do not collaborate due, in part, to limited resources. There are few sources of funding for agricultural extension but many players would like to be involved. In the author’s opinion, this creates competition among them rather than collaboration.

National Science Committee

The National Science Committee (NSC) is a government unit chaired by the MoFA. The NSC was established to identify national research needs and to be involved in the selection of research projects that are needed to enhance the country's economic growth, agricultural production, and market access. The Mongolian government funds about 50 scientific research projects per annum in disciplines related to agriculture. The committee is hosted at the MoFA. Five to seven people would be invited to be members of the working group responsible for reviewing proposals during the research project selection process. Members are selected from various research and academic institutions such as agricultural universities, research institutions, and government ministries. Neither the selection process, nor the working group involves a farmer or producer representative.

At the beginning of the year, the Ministry of Food and Agriculture publishes the priority areas for research and announces the research project competition in a public newsletter. Researchers or research groups in various research and academic institutions develop their proposals according to the selected priority areas and submit them to the NSC at the MoFA. Following submission of the proposals, members of the NSC review the proposals, and select those that best fit the priorities. Once the selection is made, the Minister of Food and Agriculture has to make the final decision on which research projects will be funded through the Government Science and Technology Program. The funding of the projects includes the hard costs of the experiment such as seeds, fertilizers, other inputs, lab costs, and equipment rentals if necessary. However, the funding does not budget for any expenses related to disseminating the research results or extension training activities. The research projects are carried out by the respective researchers in their particular research institutions using their facilities and experimental fields. At the end of the research period, a report on the research results is written and submitted to the MoFA and its library.

Figure 32. Workflow of the National Science Committee and national research programs

Figure 32 illustrates the annual workflow and cycle of activities of the NSC at the MoFA and government agricultural research program in Mongolia (up to the time of writing this thesis). NSC makes a list of research priorities and publicizes the priorities based on their internal discussions at the MoFA. NSC selects some respected researchers and professors in each priority area for the NSC selection team who would review the projects and make decisions on funding the projects. From the priority setting stage to project approval stage would take about two to three months. Researchers at the MSUA and other agricultural research institutions are allowed to submit their research project proposal for funding. In the end the project/research results are submitted back to the NSC at the MoFA. There is neither direct producer (farmer) involvement/participation, nor any indication of extension dissemination activities in this national agricultural research development cycle.

It was a disappointment to find out that the wealth of information and knowledge produced through these research projects funded through the NSC for the most part simply sits on a bookshelf covered with dust and is never used. Thankfully, the authors retain ownership of the results and her/his knowledge has been advanced through the research projects. The question now becomes how can the researchers' wealth of knowledge be utilized and made available to farmers—the ultimate users of the agriculture knowledge. Some of it is theoretical research that does not necessarily serve farmers directly, but some is applied research that could be directly beneficial to farmers. Although 'knowledge is power' and some people like to hold it close to them, most researchers would like to share their knowledge and research results with others, especially with producers. Researchers should be encouraged to speak directly to farmers. However, they lack funding to do so because the cost of extension activities is not budgeted in the funding from the NSC. A systematic change is required to provide the financial support needed for researchers to communicate their research results to the producers. This does not imply that the only option is for the researchers themselves need to take the research data forward, only that provision should be made to fund the important step of research communication.

Agricultural universities

In Mongolia, the Mongolian State University of Agriculture (MSUA) is the main agricultural university that offers both under graduate and graduate degrees in agriculture sciences. MSUA is very interested in, and actively engaged in, agricultural extension, although independently. What is meant by "independently" is that each university has its own extension center that carries out its own extension programs without much collaboration with NAEC or other institutions.

The Extension Training Center at the MSUA was opened in 2006 through support from the CIDA-funded Training for Rural Development Project. The Extension Center is governed by the Council of Agricultural Sciences of the Mongolian State University of Agriculture (MSUA). The Center has its central office on the MSUA's main campus. Extension center staff members are able to use the equipment and facilities and gather information from eight MSUA-schools (School of Agrobiology, Engineering, Natural Sciences, Veterinary Medicine and Biotechnology, Ecology and Technology Development, Economics and Business, Biological Resources and Management, and the Graduate School), four research institutes (the Research Institute of Animal

Husbandry, the Research Institute of Veterinary Medicine, the Research and Training Institute of Plant Science and Agriculture, and the Research Institute of Plant Protection) and their regional branches.

As has been indicated to this author during various conversations with the extension center managers, the main activities of the extension center at the MSUA include training, consulting, brokering, transferring technology, applying research, organizing learning events, publishing training materials, and implementing projects. They organize training in the areas of crop farming, livestock farming, rural development, business administration, leadership development, and communication skill development for researchers. Training events are announced and promoted on a website and in the public media. The extension center also provides consulting services in three areas: a) agribusiness, b) policy advising, and c) consulting for development cooperation. Brokering services are provided in the following areas: a) linking farmers with domestic producers and importers of agricultural machinery, livestock, seeds and other production inputs, b) linking farmers to services such as artificial insemination, construction of barns, greenhouses, storage facilities and farm houses, repair of agricultural machinery, and c) importing machinery, livestock, seeds, and other production inputs from China, Russia, Korea, Japan, Israel, Turkey, and the EU. In addition, they offer assistance with the preparation of trade contracts to international standards as well as oral and written translation of agribusiness-related information into Mongolian from the languages of these countries, and vice versa. Technology transfer at Mongolian State University of Agriculture has usually been done independently by its research institutes and schools. The Extension Training Center, however, aims to become the central body of the university for technology transfer. Major activities in technology transfer include creating and publishing a catalogue of new technologies, organizing exhibitions and fairs for promoting new technologies, and helping the researchers in legal issues concerning intellectual property. They also organize agricultural tours for both Mongolians and international visitors.

A primary purpose of the extension center is to work with international projects, NGOs, and farmers directly in delivering technical training in required areas. The extension center organizes customized training based on requests from clients and hires MSUA professors to provide the training. The main clients of the MSUA extension center are international projects, NGOs, private companies, and the government. It is not common for a farmer or a group of farmers to put forward a request for training. Likewise, it is uncommon for an extension officer at the MSUA to go out to do participatory training needs assessment with farmers. Nevertheless, the CIDA funded TRD project has helped the MSUA extension center to organize training sessions on household gardening. On at least one occasion as well, the Mongolian Female Farmers' Association contracted the centre to organize training in vegetable gardening for female-headed households.

A positive aspect of the extension center at the MSUA is that it responds to the needs and requests of its various clients, who are perhaps more likely to represent grassroots needs instead of the priorities set by authorities. Also, as the center is a part of the MSUA, it has direct access to researchers and professors at the university. However, the linkage between the extension center at the MSUA and other research and extension service providers is limited. It tends to function independently and has been less interested in working with other research and extension service providers. It also appears that some of its leaders feel that, because it is based at the MSUA where most agricultural professionals are trained, it should be the main agricultural extension center and that the NAEC at the MoFA is redundant.

Research institutions

Along with researcher training, the establishment of research institutions and laboratories started in the 1970s. A total of 51 research institutions have been established in Mongolia and numerous research projects have been undertaken. Although these research institutions cover a wide variety of fields, 22 of them are focused on agricultural and natural science research and technology development (Altansukh et al., 1999). The transition to a free-market economy in 1990 resulted in insufficient financial resources for scientific research and technology development. In addition, the limited resources that were allocated were not targeted and managed carefully. In other words, funding for the research programs was not carefully planned to respond to producers' needs and the results were not disseminated to the producers. Only in recent years has investment been made in this vital activity. According to one study, following the transition, the number of researchers in research institutions dropped by 250 percent, the number of research centers decreased from 51 to 32, and support for and investment in research facilities stopped. From the 1970s to 1990, the national budget allocation for agricultural research and technology development increased by 760 percent. However, in 1990, the national budget for agricultural research declined significantly (Stevens and Rasmussen, 2004). Since 1997, reorganization of universities and research institutes has taken place, and the numbers of researchers and research funding have both increased (Purevjav, 2006).

Research institutions are affiliated under three categories:

1. Universities under the Ministry of Education and Culture—their main focus is education, although research is one of the main activities of the professors;
2. Research Institutes under the Academy of Sciences—their main focus is basic and theoretical research;
3. Research Institutes under the ministries—their main focus is applied research and technology development.

Most of the agricultural research institutions are affiliated with the MoFA, although they are administered by the MSUA. The MSUA is financed through the Ministry of Education, while research institutes are funded by the MoFA. A positive aspect of many agricultural research institutions is that they are often located in farming areas—closer to the producers and the field. Though up to 15 percent of the operational cost of these research institutions is self-funded, mostly through agricultural production, almost 75 percent of the research projects are funded by the government. Another way to look at this is to observe that research institutions in Mongolia are, at a maximum, 15 percent self-sufficient (Purevjav, 2006). They conduct long-term as well as short-term research projects. A long-term project can continue for more than 30 years.

In Mongolia, private sector involvement in research and development is limited. Fortunately, government funding for research and technology has been increasing. From 2000 until 2005, government investment in science and technology doubled. However, in terms of percentage share of the GDP, government funding remained stable during these five years (Gungaadorj and Davaadorj, 2009). As the central government is the main source of research and technology development, most of the research projects are carried out in public sector research institutes and universities.

Summing up the findings of this review and analysis of the contemporary status of agricultural research and extension in Mongolia, some main issues and concerns can be identified. The system is highly dependent on the government which is by far the most important source of funds. There is a corresponding lack of industry or private sector involvement. Another concern is that research priorities are not very clear and there is no formal mechanism for producer participation in the setting of research agendas. This results in weak linkage between research and the production systems. In terms of funding levels, despite rhetorical support and some more recent signs of growth, public and private investment in science and technology remains quite low. Finally, there are gaps and deficiencies in terms of government regulatory capacity and the legal environment with respect to the monitoring and supporting of research and technology development activities.

The private sector has limited involvement in agricultural research and extension activities. This stems in part from the fact that, beyond farming enterprises, there are not many agribusiness firms or agro-input industries in Mongolia. The private sector mainly plays a role in importing goods such as fertilizers, herbicides, and equipment. Typically, these agricultural imports are secondary to their core business activities. Their involvement in agricultural research and development is episodic and contingent as they respond to specific problems and commercial needs. Farmer organizations and NGOs frequently play a role in international project implementation and in political lobbying. Farmer organizations are often affiliated with, or led by, senior politicians in the government and thus tend to support their particular political agenda. However, it is important to note that there is no funding allocated to farmer organizations from the government. Also, unless there is external financial aid to carry out their activities, NGOs and farmer organizations are more or less inactive. This financial dependency tends to limit their capacity or political will to promote and defend the interests of farmers with respect to research and technology.

Capacity of research and extension personnel

A last important issue concerns the capacity of extension personnel and researchers to obtain and process (assess, adapt, and translate) information on new technologies. The current capacity of researchers and extension agents is low in Mongolia. This is a problem, especially given growing demands for increasingly sophisticated kinds of advice, and for solutions to complex and costly problems. To be up to date on technology development and transfer in a given system requires a long-term perspective. Most of the senior research scientists, university professors, and extension agents were educated under the old system where conventional farming systems were taught. Although local capacity in terms of research and teaching facilities and general education level of employees is high, knowledge of and experience with new technologies and access to external information sources is low. This slows and creates problems for the transfer and adoption of new technologies such as conservation tillage.

Under the centrally planned economic regime, the agricultural research and extension system was “top-down.” Farmers’ opinions were seldom sought or considered in any decision-making with respect to agricultural research extension programs. Even though some researchers and extension agents have taken training in participatory extension methodology, most of them still find it hard to conduct an extension session based on a dialogue between extension personnel and his/her counterpart partners (including farmers). Even when there are guidelines on how to use appreciative inquiry and participatory approaches, extension personnel tend to fall back onto their internalized rigid, top-down pattern of presenting material in a monologue and rushing through any exercise or topic.

Also, it is worth noting that while the MSUA offers extension courses, these courses are specific to agricultural topics—Agricultural Economics extension, Agricultural Biology extension, Agricultural Mechanization extension. The courses lightly cover methodologies and processes of delivering information and knowledge. The majority of the content is about economics, biology, and mechanization. As a result, newly graduated extension agents (agrologists) are not well trained in extension processes. There is a need for MSUA to develop curriculum for extension training and adult learning in order to enhance the capacity and skills of the next generation of extension agents. Topics could usefully include: program evaluation, program planning, adult education, communication and teaching methods, needs assessment, and working with farmers.

There is a need for prioritization and restructuring of roles and responsibilities in research and extension. Currently, extension activities are not included in the terms of reference for researchers and professors. This is unlike the situation found at Canadian agricultural universities and many research facilities. In Mongolia, extension services and activities provided by researchers and professors are carried out as side events—in spare moments, during holidays, and on weekends. In most cases, researchers and professors provide extension services on a voluntary basis or for a small fee. But the arrangements are made outside their full-time responsibilities. This situation may be unsustainable in the long run. The main issues are identified and described more systematically in Table 3.

Table 3. Issues: Agricultural Research, Education, and Extension Systems in Mongolia, 2009.

Level	Current Situation (Issues)	Desired Situation and Change Required	Solution - Role of		
			Government	Private Sector[23]	Projects
System Level	Role of government and private sector unclear in research and extension.	Collaborative systems and public-private partnerships for adaptive research and training well established and roles clearly defined.	MoFA: Overall coordination of programs targeted at the poor and vulnerable. MSUA: Lead role in adaptive research, curriculum development. Min of Education: Support middle-school curriculum and access to information networks. Aimag and soum governments: Operation of regional extension centers and outreach to soum level.	Demonstration farms and herds. Private training delivery by extension consultants. Training and support delivered by agri-business to their clients. Industry cost-shares research/training.	Projects/NGOs/Programs: For example: TRD project and Introduction of Minimum Tillage program.

- [23] In many countries agribusinesses are assuming a role as a conduit for the transfer of knowledge and technology as part of their service to customers (farmers). Agribusinesses often have more frequent contact with farmers than government or NGOs and are therefore in a good position to participate in the transfer of knowledge. In North America plant breeding companies, equipment dealerships and fertilizer and pesticide companies are all active participants in the training of farmers. However, businesses exist to make profit for their shareholders and there may be a tendency to promote technology associated with their own products rather than providing more generic training. Training may focus only on the advantages associated with the products (chemicals, equipment, nutrients etc) provided by that company. However, training involving specific products can also increase farmers' knowledge about general principles and improve their capacity to make choices about new methods, management practices or products.

Level	Current Situation (Issues)	Desired Situation and Change Required	Solution - Role of		
			Government	Private Sector[23]	Projects
	Memberships and linkages to international organizations are not established and information sources are limited.	Mongolian research and inspection organizations meet international standards and are active in related international organizations.	Provision of budgets required for membership and related requirements.	Private sector cooperates in establishing inspection standards and staff training	Facilitate linkage development. Support capacity building to meet membership standards.
	Inadequate budgetary support to carry out adaptive research, rural retraining and extension services.	Adequate resources for research and training have been found through public-private-project partnerships.	Establish both annual and long-term budgets for adaptive research and extension training.	Agri-business, farmer/commodity associations, and individual demo sites cost-share research and extension.	Project support to demonstration activities and training, especially for the poor.
	Inadequate amount of information sharing between government, institutions, private sector and projects	Readily accessible information system provides access to research, training, and upcoming events.	Provision of resources to ensure sustainability of the information and knowledge at the MoFA.	Provision of information through producer focus groups at cost sharing of information from ag-business sector. Payment of fees for specialized information	Project support to web site development, design, training.
	Linkages and awareness among research and extension activities in the country are not established.	Effective and efficient system that links all research and extension activities among all players.	Provision of sources to support coherent linkage between players. Ensure extension of results is required for all applied research projects and that funding are provided through their programs.	Participation in decision making, demonstrations, and trainings. Willingness and trust to work with public and private institutions.	Facilitation and organization of events to link independent activities by research and extension players in the country.

Level	Current Situation (Issues)	Desired Situation and Change Required	Solution - Role of		
			Government	Private Sector[23]	Projects
Institutional Level	Research organizations require upgrading and capacity building for new technologies and research methods	Research organizations have updated methodologies, membership to international groups, journals, equipment for research and teaching	Provision of funding to research and educational institutions to update their facilities as well as capacity building of researchers.	Help researchers to gain understanding of the practicalities of agricultural production systems by working closer with private sector.	Capacity building programs for facilities, standards, management, trace-back programs
	Curricula require updating	New curricula with greater emphasis on information and research result dissemination.	Led by research/training organizations with support from the Ministries.	Provide tours and internships to complement curricula	Provide information on new methods to upgrade curricula
	Inadequate capacity for market research and development	Market and policy analysis, & statistical branches established.	Include market research in the long-term adaptive research program.	Cooperate with institutions in conducting market research	Program design and exposure to best practice.
	Producer and industry associations not well developed for their role in a market economy, often operating as private consulting firms.	Producer and industry organizations operate as mature and democratic representatives of their members and take on lobbying, agricultural policy development, marketing development and service functions.	Include industry associations in decision-making and planning.	Join and support relevant industry and sector organizations through active membership and leadership and payment of member fees.	Study tours to see best practice internationally and training in Mongolia.

Level	Current Situation (Issues)	Desired Situation and Change Required	Solution - Role of		
			Government	Private Sector[23]	Projects
Individual Level	Extension agents, formal and non-formal, require new teaching methods, extension methodologies and updated technical skills. No formally trained extension professionals.	Skilled and competent extension agents able to deliver adult education training and technical support through various programs targeting different industry and social groups.	Policy and program support for extension evidenced in budgets for various Ministries and organizations involved in service delivery and support, such as MoFA/NAEC, MSUA, MFC, and others.	Developing working partnership with extension agents and researchers.	Capacity building for adaptive research and extension. Training in adult-learning methods and related skills.
	Rural people require retraining for agriculture production, processing and marketing in a market economy.	Rural people have technical and managerial skills needed to run profitable and environmentally sustainable agricultural enterprises in a market economy.	Provision of funding for long-term programs.	Training and services to association members, commercial enterprises and clients.	Financial support of programs targeted at the poor and the vulnerable.

(Adapted from Agriteam CoLtd report for ADB, 2009)

4.2. A proposed extension model for a sustainable agriculture system in Mongolia

From the analysis presented in earlier chapters and in the first part of this chapter, it is clear that organizing and coordinating those who are involved in agricultural research and extension is a key to creating a successful research and extension system. To review, the main players in the Mongolian research and extension system and their roles are:

- The government—developing agricultural production, extension, and research policy, funding and monitoring of agricultural research and extension activities, and partnership with external agricultural players/donors.
- The research institutions and agricultural universities—carrying out long- and short-term research projects, testing of different varieties and technologies, and offering both undergraduate and graduate degrees in agriculture. Both research institutions and universities have extension centers that offer some training sessions.
- National extension centers—delivering training and extension activities across the country through their aimag and soum branches.
- NGOs and private sector—implementing government and non-governmental programs, international projects, and bidding on tenders for input importation.
- International projects—providing funding for inputs and equipment, and providing expertise and support for technology transfer.
- Farmer associations and commodity groups—often formed by politicians for lobbying purposes, involved in implementing international and national projects (when funding is available).
- Farmers and agricultural producers—traditionally receiving the research and extension services (NAEC, 2007).

To summarize, it is understood that: a) the government allocates budget for research and development annually, b) research institutions have expertise with highly educated personnel, c) national and provincial governments have extension agents in place, and d) international projects continue to provide external resources and expertise with respect to technologies and inputs. International programs are typically implemented through the government, NGOs, or/and the private sector (Terbishdavga, 2008). Nonetheless, the main issue remains the coordination and organization of these actors.

Another concern is that the producers' participation and involvement in the planning and development of research and extension activities is weak and often ignored. However, farmers are beginning to understand that by working in cooperation with research and extension centers, they not only gain from increased productivity but also benefit from reduced risk (Badmaanyambuu, 2007). There is increasing interest among researchers, extension workers, and farmers in working together and building linkages at every level in the agricultural production system.

Most Mongolian farmers are literate and educated with at least a high-school diploma (Erdenebaatar, 2006). This means that they have the capacity to receive training and understand the information that is presented. Both herders and crop producers seem to understand the importance of new knowledge and the benefits of advanced technologies and development. This suggests that there is potential for increased benefit to the agricultural production system with improvements in the capacity and quality of extension services especially when these services are appropriately linked to other key players in the system such as farmers, agri-food processing factories, academics, researchers, and NGOs.

The purpose of this section is to present recommendations and to propose an alternative agricultural research and extension model based on the integration of learning from agronomic field studies, an extensive literature review, field research on the experiences of extension agents and farmers, knowledge obtained about the current agricultural extension system, as well as personal observations and experiences gained from working in various capacities in Mongolian agriculture for seven years prior to undertaking graduate studies. The discussion builds on an analysis of the strengths and limitations of the current extension system, and integrates various sources of knowledge with respect to potential extension models for Mongolian agriculture. The section concludes with a presentation of the proposed research and extension model (National

Agricultural Research and Extension Team - NARET[24]). The NARET model has been piloted in Mongolia through CIDA's TRD project. An objective of this model is to develop a responsive and collaborative research and extension system that can efficiently and effectively respond directly to the needs of farmers in an evolving agricultural industry characterized by changing market conditions and potentially changing climate conditions.

4.2.1. A conceptual analysis of the current situation and its consequences

Analyzing the current research and extension system in Mongolia and developing alternative models requires qualitative analyses of the system that considers history, culture, politics, and interaction with agricultural production systems. The main purpose is to develop an effective extension system for introducing new agricultural technologies, transferring knowledge and information, providing support and service to farmers, and also facilitating farmers and increasing their participation in research and extension. It can be done through fulfilling the following three objectives.

- circumvent an ineffective “top-down” extension system and decision-making structure;
- encourage better utilization of public-private partnerships; and
- promote increased participation of producer groups in decision-making processes.

The main national agricultural research and extension players/pillars tend to act as competitors rather than as complementary to each other (Davaadorj et al., 2006). Very little collaboration is involved, although some of their responsibilities clearly overlap. One key to success is to identify those areas where their responsibilities overlap and determine how they can share those responsibilities in ways that are mutually beneficial without disrupting each other's resources and competencies.

[24] NARET model has been proposed as an alternative agricultural research and extension model for Mongolia as a result of this thesis study and has been piloted in Mongolia through CIDA's TRD project in Mongolia. The author was an initiator of the model as well as a coordinator of the pilot in Mongolia.

The main national pillars of agricultural research and extension are the Ministry of Food and Agriculture (MoFA), research institutes, agricultural extension centers, and agricultural producers/farmers as the main clients (Bat-Erdene, 2006). Extension centers operate in partnership with the private sector, international projects, and NGOs. International projects play a major role in agricultural technology transfer activities. However, international projects often target transfer of a specific technology in a specific region rather than working in a broader concept of national agricultural technology development and transfer.

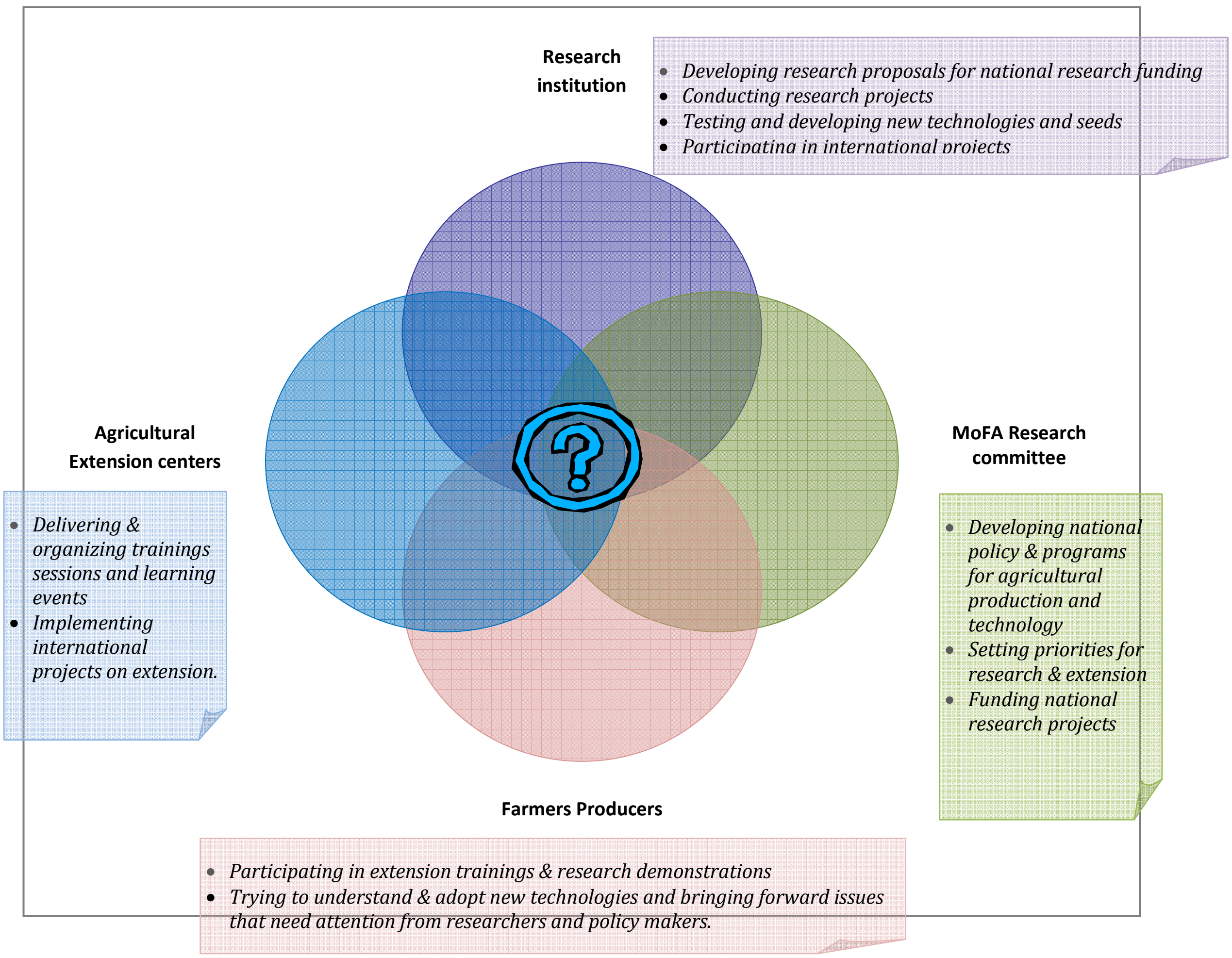

Figure 33, Main agriculture research and extension players in Mongolia and their responsibilities.

In order to have an efficient and effective agricultural research and extension system, coherent linkages between research and extension need to be established and the main pillars of the extension system need to collaborate with one another in areas where there is overlapping responsibility. Collaboration and linkage may be facilitated by international projects and other public and private sector partnerships. An agricultural research and extension system will become sustainably effective and efficient only when collaboration among core national pillars or players is well established.

Figure 33 describes a concept of the roles and responsibilities of the main actors in the agricultural research and extension system. Although there are some linkages between and among these stakeholders, there are clearly missing connections with respect to sharing information and coordinating their roles and responsibilities. For example, MoFA prioritizes national research and extension policies and programs but with very limited interaction with grassroots producers. Moreover, the affiliated research institutions involved do not take the steps required to disseminate the resulting research findings. Furthermore, agricultural extension centers are mainly liaising with and serving international projects in the organization of their training programs and other activities, rather than seeking to disseminate research results from national research institutions. Producers are typically viewed as recipients of extension events and activities rather than as actors capable of voicing their needs and preferences for training and research. Typically, an outside expert will come to the farming town with their pre-set training package, and ask local governments to call local farmers to attend a training session rather than asking farmers what they would prefer to learn. How can this major gap between the government research system and the other interested parties be addressed, how can these missing links be bridged and the necessary collaboration established? How can farmer participation be increased and their voices be heard at other decision-making levels? The responses forthcoming to these questions will have great bearing on the potential to create a more effective and efficient research and extension system.

There is a significant gap between government-based research and extension activities and service/implementation-based activities involving both private-public partnerships (see Figure 34).

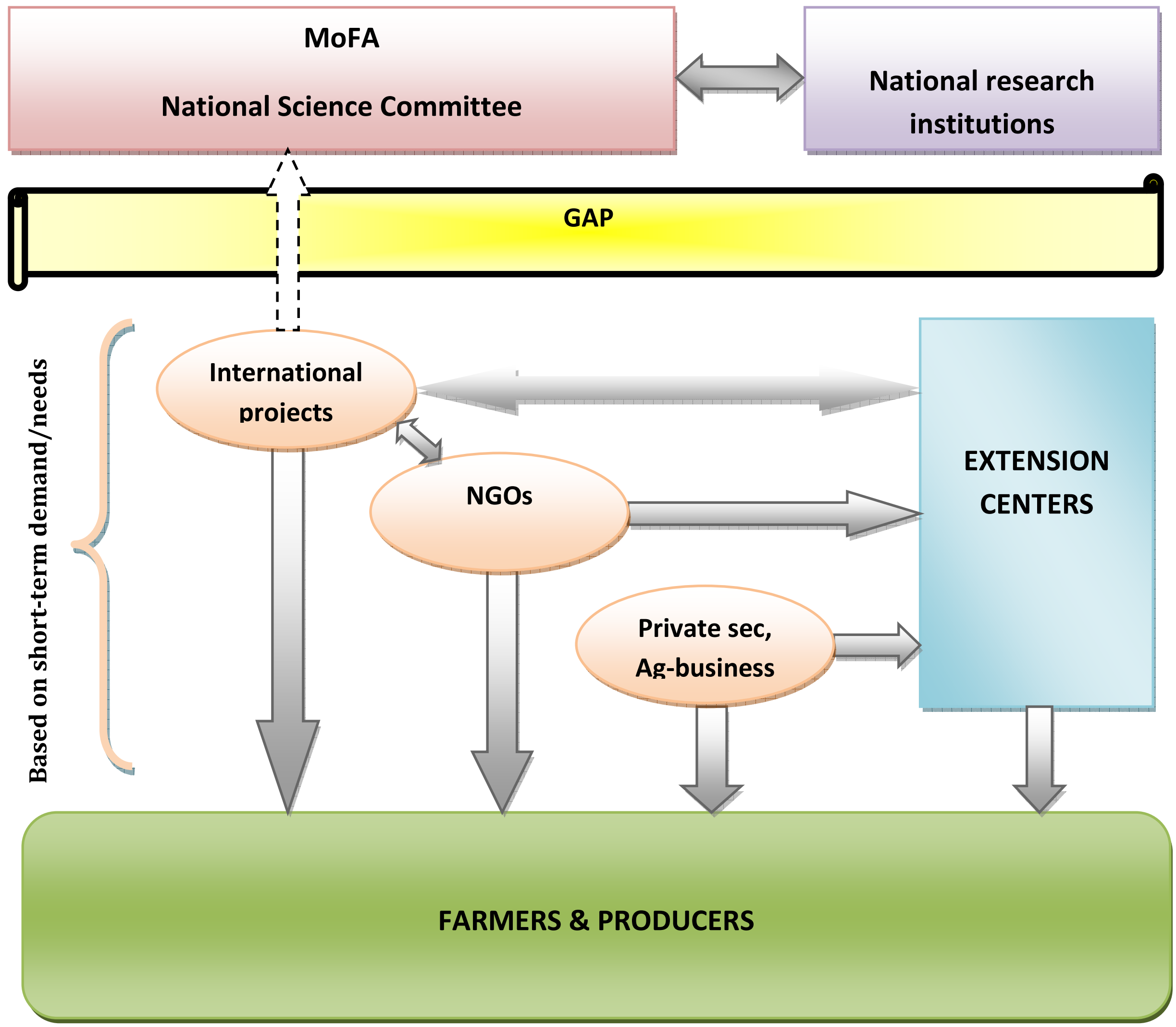

Figure 34. Working relationships, information flows, and gaps between pillars and partners in the Mongolian national agricultural research and extension system

Government-based activities are mainly research oriented, involving the MoFA and national research institutions. The national government funds about 50 research projects each year through MoFA and these are allocated to different research institutions after competitive bidding[25]. Unfortunately, however, dissemination and extension of the research results is not in the selection criteria and not included in the proposal for funding. Therefore, there is very little flow of information from the research

[25] NSC selection team will review and select the proposals for funding based on a list of criteria such as research priorities, feasibility, capacity of the research institution and researchers, and cost and benefit of the projects.

institutions to farmers, and from farmers to these institutes. This gap needs to be bridged in order to have farmers benefit from national research and development programs.

It seems that most of the linkages and interactions are happening between international projects, NGOs, and extension centers where service-oriented activities are concerned. International projects frequently utilize extension centers and NGOs in the implementation of project activities and training programs. However, as mentioned earlier, international projects are short-term. Often, they are funded only for two-to-five years. Many of them target grassroots producers and work directly with farmers, which has many benefits for farmers who are invited or able to participate. Even though some of these international projects invite research institutions to participate in their activities, more often they do not work directly with researchers and research institutions.

These short-term collaborations among international projects, NGOs, extension centers, and farmers in various forms result in a number of rather undesirable consequences.

- Unsustainable technical support and interruption of learning, because the completion of the project often means an end to the training and demonstration activities.
- Lack of capacity building and knowledge transfer at the national level, due to lack of involvement from national agricultural researchers and government officials in new technology transfer activities through international projects.
- Confused farmers with no guidance due to a lack of local capacity to support new technology transfer and removal of external experts who leave after short-term training activities.

The lack of longer-term support has a negative impact on the adoption and diffusion of new technologies. As documented and discussed in Chapter 3, this is substantiated through the identification by farmers and extension personnel of lack of knowledge and understanding as a persistent barrier to successful adoption of conservation tillage technology. The introduction of new technologies based on short-term interventions that do not fully integrate with the national agricultural system ends up being slow, ineffective, and inefficient.

Therefore, to achieve an effective and efficient agricultural extension system, all parties including government-based research institutions, service-based organizations, and farmers' groups need to be involved systematically and system-wide in all relevant processes including decision making about technological and agronomic approaches, priority setting, research and demonstration activities, and training and capacity building.

4.2.2. Proposed linkages for a collaborative research and extension system

In order to create an integrated and holistic national research and extension system, it will be important to have a coordinating or steering group/team that involves the core players in agricultural research and extension agencies including representatives from research institutions, government agencies, extension centers, and farmers. Figure 37 illustrates how a core team for national research and extension can be put together and how the main research and extension pillars can work together. There are some potential gains as well as some potential risks with this model. This proposed model is intended to be coordinated virtually by a team of members from key stakeholders involved in the research and extension system for agriculture production. It is not expected to change responsibilities and create an additional workload to those team members involved, since components of agricultural research and extension are already a part of their normal work and responsibilities. It should only require some adjustment and coordination of their activities with others, structurally. However, there is a potential risk that it could result in another bureaucratic layer in the system and centralization of decision-making power. Perhaps a more important but difficult factor for the successful implementation of this model is development of new perspectives to replace the prevailing mindset. It requires more open minds and a willingness to work with counterparts as well as acceptance of farmers participation in the decision making process. This will be a key to mitigating some of the associated risks and to increasing the benefits of this model.

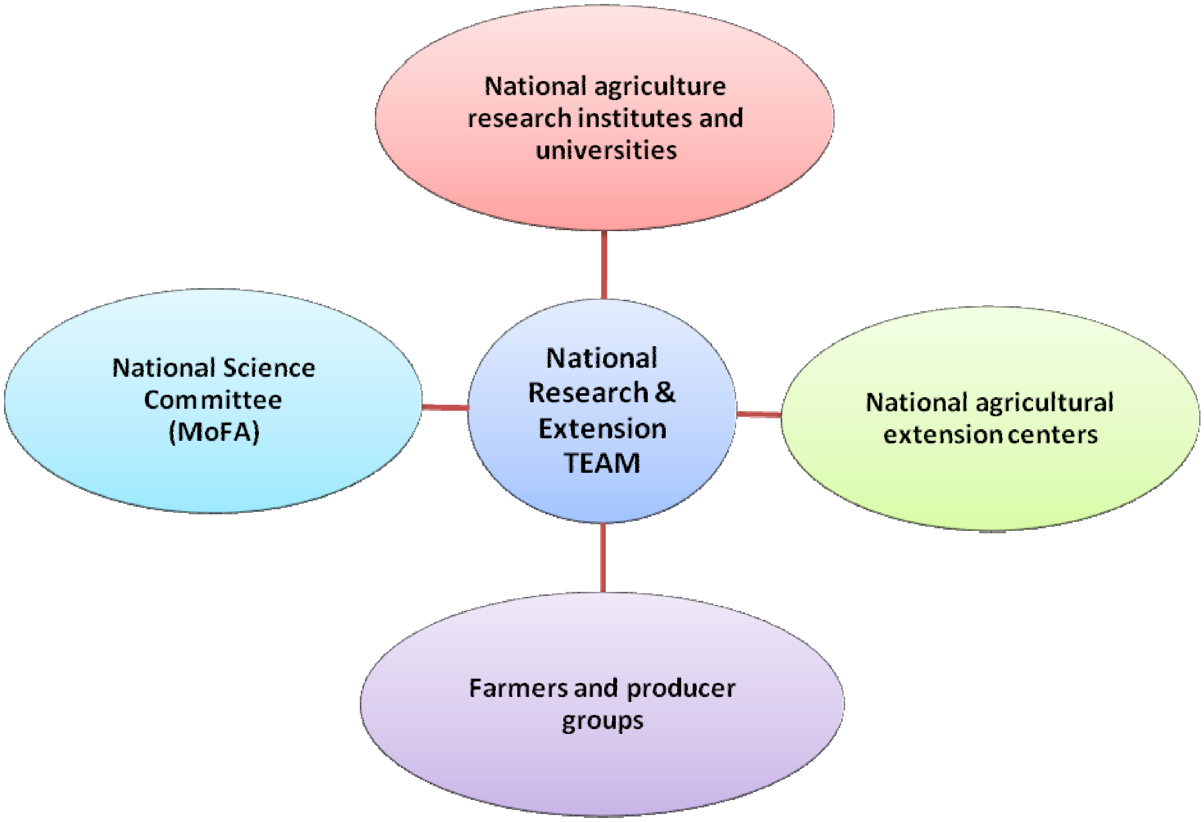

Figure 35. Proposed National Research and Extension Team for agricultural development in Mongolia

4.2.2.1. National Agricultural Research and Extension Team (NARET)

The proposed NARET team needs to be interdisciplinary and inclusive. The team would utilize its public and private partners to achieve both short- and long-term development goals and to act on the priorities and plans that had been negotiated and agreed to through the participation of representatives of all member groups. NARET could serve as a convenient resource for other public and private sector actors such as international projects and NGOs to gather information on key stakeholders (including farmers) needs, priorities, and actions on agricultural research and extension. NARET can also help to develop programs and projects based on their Annual Work Cycle (AWC). This approach will expand and strengthen the national core strategy and programs rather than spending resources on unplanned activities. Since the core NARET includes representatives from each level of the agriculture production system, recommendations from the team should benefit every level in the system, including crop producers and herders. For example, farmers would have an opportunity to voice their priorities, and the government would have a chance to hear grassroots needs and develop sound policy that has direct benefits to agricultural production.

It is important to ensure that the NARET does not become a formal decision-making unit. It should be a practical (applied) and informal group that aims to identify areas of need and areas of potential collaboration among all stakeholders of the research and extension system in Mongolia. Nevertheless, the team should be able to make recommendations to the government; it will have to be recognized by the government. The team should focus on assessing farmers' needs and developing a research and extension plan of activities based on farmers' needs and issues. Therefore, the NARET team should contain at least one person from the government—preferably someone from the National Science Committee, representatives from research and extension institutes, and farmers. The NARET should be organized under and report to the National Science Committee. In other words, the NSC should take a lead in coordinating key players of the system.

4.2.2.2. Annual work cycle for NARET

To accomplish these objectives, one could conceive of a working arrangement that would involve five stages where the NARET works together to implement their annual work plan (AWP) each year (Fig. 36):

1. Assessing farmers' needs;
2. Prioritizing research needs and call for projects;
3. Implementing research and demonstration;
4. Disseminating research results and capacity building;
5. Evaluating and recommending to the government and other stakeholders.

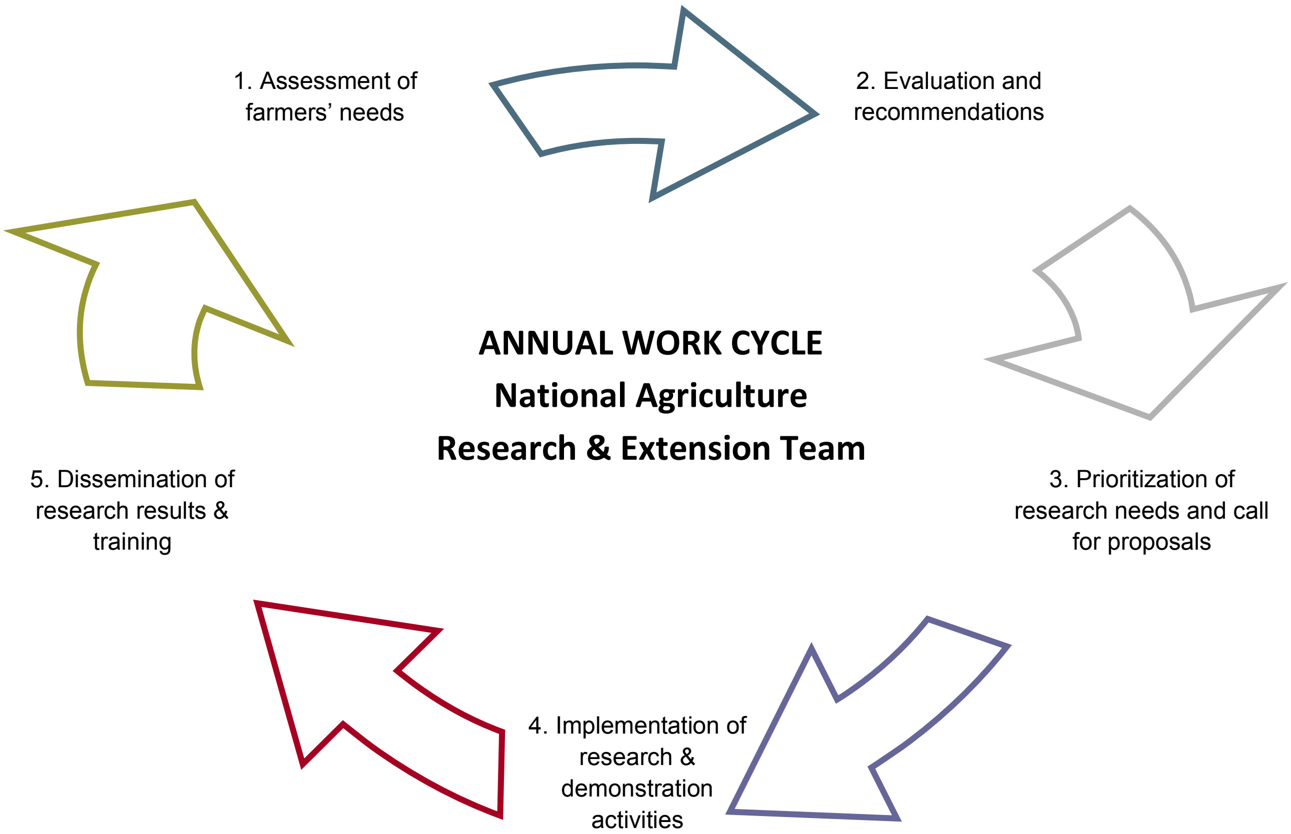

Figure 36. Annual work cycle for the National Research and Extension Team.

Assessment of farmers' needs: Farmers' participatory needs assessment should happen before the government prioritizes research areas to fund. The government should make a list of research areas it will provide funding for and makes a public announcement in January of each year. The farmers' needs assessment should take place in the late fall between October and November. If the team decides there was no need for a new assessment every year, assessment can be replaced by an evaluation of the demonstration projects of the past year and make recommendations for next year. Mongolia is geographically vast and varied. Thus, farming systems and farmers' needs differ in each aimag and soum. In order to have an assessment that reflects all farming areas, needs assessments have to be done in every area. At this stage, farmer representatives in NARET would play a significant role. A needs' assessment can be done using any of the following methodologies:

- The NARET selects a demonstration farmer in each farming community[26] and that farmer will be responsible for assessments, demonstrations, organization of farmers, and collection of information. A demonstration farmer would become a main bridge or a messenger between NARET and farmers in the area. In this case, a demonstration farmer has to ensure that other farmers in the area have genuine opportunities to participate and to contribute to decision-making and priority setting.

- The NARET organizes a farmers' participatory exercise to identify their needs for research and extension through workshops and consultative meetings in each area. This would give farmers an opportunity to interact and discuss their farming systems, although it might be more expensive to organize a meeting or workshop versus the demonstration-farmer approach.

- A third attractive option would be a combination of the above two methods. A demonstration-farmer would still act as a messenger and he/she would actually carry out some field demonstrations for training. NARET would organize an annual workshop or seminar for consultation and needs assessment as well as training events such as field days.

Evaluation and recommendations: Following the farmer needs assessment, the NARET would discuss and consolidate the assessment results, review the effectiveness of the work plan from the previous year, and make recommendations. The team would identify lessons learned, potential challenges, and opportunities by revisiting the previous work results and comparing these to newly identified and ongoing needs. The NARET could decide to continue some of the field demonstrations regardless of the approved timeframe of the research project, or could decide to modify them. Likewise, this stage is the time for the NARET to discuss all of the work cycle activities and to

[26] Administratively, Mongolia is divided into 21 aimags, although not every aimag produces crops. There are 5 main aimags that account for the majority of agricultural production, especially crop production in Mongolia: Selenge, Darkhan-Uul, Bulgan, Tov, and Arkhangai. The number of farmers and amount of crop and livestock production from each aimag is different. Selenge aimag is responsible for 40 percent of cereal production in Mongolia, while Khentii aimag produces about 10 percent (National Stats. 2007). Through the testing of NARET model, five demonstration farmers were chosen: 2 in Selenge, 1 in Bulgan, 1 in Tov, and 1 in Darkhan-Uul.

decide on ways to modify and enhance the activities for delivery in the upcoming year. All members on NARET have equally important roles and should participate in the review and discussion, as well as the preparation of recommendations for the next annual work plan and the report to the National Science Committee (NSC).

Prioritization of research needs and call for proposals: The government should take results from the participatory needs assessment into consideration in prioritizing research projects. It is important for farmer's views to be considered in prioritizing research. However, farmers cannot be expected to have adequate background knowledge in all areas relevant to sustainable rural development. The views and interests of farmers need to be combined with the insights of other players such as agronomic researchers, product development specialists, economists, marketing specialists, rural sociologists, ecologists, agribusiness leaders, and policy makers.

This stage is crucial not only in meeting farmers' needs but is also politically important for setting government strategies towards meeting grassroots demands. A representative from the National Science Committee at the MoFA in NARET plays a crucial role voicing and inserting the results from needs assessment into the national policy and research priorities. This is a crucial stage.

Findings from this stage of NARET intended to contribute (if not used directly) to the national agricultural research priorities for NSC's annual call for research proposals. Researchers from national research institutes and universities are invited to develop their project proposals and bid on the prioritized areas of research as it was mentioned earlier in the chapter. Also, NARET's interdisciplinary expertise could serve or be involved at the NSC's selection team to review the projects for funding. Extension of the research results should be included in the proposal criteria or requirements.

Implementation of research & demonstration: Based on the research priorities, those researchers who received funding would carry out the research projects much as they have done in the past. However, the new NARET model assumes that research priorities are set in response to an assessment of farmers' needs. Thus, along with conducting small plot research projects on research park experimental sites, the

NARET model suggests that some applied research projects be conducted on farms with demonstration sites. Researchers conducting research projects that directly address the expressed needs of producers would work with demonstration farmers to carry out trials on the farm site. Demonstration farmers are expected to provide a small area of land for the field experiment that can be tailored to the needs and interests of local farmers. Also, field demonstrations can illustrate and validate research findings from the previous year. The primary purpose of field demonstration is for training of farmers in the area but they will also serve as learning sites for research scientists and extension personnel.

Dissemination of research results and training: It is desirable that research results from both applied field research sites and experiments at research institutions would be disseminated in a manner that will inform farmer decision-making and help solve farming problems. Typically, on-farm demonstrations are used more for showing results to farmers through field days and less to generate scientific data. Agricultural extension centers would play a significant role in dissemination and training. Extension personnel would organize learning and sharing events among farmers, researchers, and policy makers to: a) share farming experiences, b) introduce and disseminate research findings with farmers and other interested parties, and c) help policy makers to understand how NARET is operating and how their decision to support such a model has contributed to addressing challenges in the agricultural production system. Through activities such as field days, publicity, and conferences, NARET will also help to empower researchers, demonstration farmers, and extension agents. Doing so will inspire others to be involved and to do more. Also, this kind of activity provides opportunities for all parties to meet in the same space with time to interact, discuss, assess, debate, and critique. Through these types of opportunities, NARET will have brokered stronger partnerships and strengthened linkages among all the parties involved.

The Annual Work Cycle for NARET is continuous. It does not stop at the end of the one-year cycle but starts all over again from stage one—farmers' needs assessment and continues through the stages again. At the end of stage five, the team would evaluate the farmers' participatory needs assessment again, and make recommendations to the government as well as to an APW for the following year.

4.2.3. Results from a pilot project demonstrating the NARET model

The University of Saskatchewan (U of S) has implemented a CIDA-funded project "Training for Rural Development" through a partnership with the Mongolian State University of Agriculture. The Training for Rural Development (TRD) Project focused on rural poverty reduction through increasing agricultural production and augmenting the skills and capacity of university professors, researchers, extension agents, and farmers (TRD, 2004). The project provided an opportunity to implement a pilot project "Farmers' Participatory Research and Extension" to test the feasibility of some components of the NARET model. The author worked as one of the main coordinators of the pilot study[27].

The purpose of the pilot study, which began in August 2006, was to demonstrate and evaluate the NARET model. The project was managed by a core research and extension team which consisted of the secretary of the National Science Committee (NSC), a livestock researcher from the Mongolian State University of Agriculture (MSUA), a crop production researcher from the Plant Science Agriculture Research and Training Institution (PSARTI), an extension manager from the National Agricultural Extension Center (NAEC), and five demonstration farmers located one-each in the five project areas (two herders and three grain farmers). The team members—researchers and farmers—were chosen based on their previous participation and contributions with the TRD. A representative from the NAEC was appointed by its Director. Similarly, a representative from the NSC was appointed by its chair.

The pilot has been running for four years and has been funded through CIDA's TRD Project. Implementation of the project has involved a sequence of steps starting as follows in Year 1 (2006):

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[27] Since the NARET model was developed through this thesis research, the author led and coordinated the pilot. It started with many meetings with the core players of agricultural research and extension in Mongolia, and putting together a team and recruiting the first NARET for the pilot. The author provided guidance and support to the team throughout the pilot with respect to principles and approaches of the NARET model.

- Selection of the demonstration farmers: Other team members were chosen before the selection of demonstration farmers. The team members went out to the project sites and gathered farmers in the area to talk about the pilot. During the discussion, the team invited the farming community to nominate one farmer whom they trusted and respected to be their representative and to be a demonstration farmer in the area. Often, farmers had an open discussion among them and agreed on one candidate for this role. Sometimes the farmers put forward more than one name and the final decision was made through a secret ballot.

- Training on participatory research and extension: All of the team members attended a full-day training session on a brief introduction of the main principles of the pilot program and the NARET model including a participatory approach, bottom-up grassroots systems, and the roles and responsibilities of each participant. Since Mongolian research and extension players have been structured in a top-down system, it was challenges to have the team members employ the farmers' participatory approaches, and to seek farmers' opinions rather than telling them what they should do.

- Agreement was reached between the farmers, researchers, and the NARET that demonstration and training activities would be carried out on selected farms. Researchers and extension managers would work closely with demonstration farmers, and demonstration farmers would be responsible for linking farming communities in their areas with NARET and with other available resources such as cellular phones[28], presenting the project at community gatherings, and updating farmers on the demonstrations activities.

- Farmers' needs assessment study: In October 2006, the team went to each project area, and organized a participatory workshop to do a research and

[28] Cellular phones are widely used in Mongolia. Almost every adult has a cellular phone if they live in a range of network coverage.

extension needs assessment of the area. The NARET team and the pilot were introduced and launched during this first needs assessment workshop.

- Demonstration proposals for the following year (2007) were developed by the researchers according to the results from the needs assessment studies. Unfortunately, results from the farmers' needs assessment study were not considered in the national research priorities set by the NSC in 2006 due to lack of recognition and reputation of the NARET model.

During the second, third, and fourth years—2007, 2008, 2009—the annual work cycle was repeated quite successfully, except step three, which was to influence the government in the establishment of research priorities. The government has not yet formally recognized the NARET and its recommendations. This issue will be addressed more successfully once NARET establishes greater visibility, a track record, and a positive reputation among farmers, researchers, extension workers, and policy makers, as well as other public and private stakeholders.

During the pilot phase, annual experiments and demonstrations were set up on each demonstration farm, and field days and training activities were organized on-site as well as at a central location using established research facilities. In addition to the annual training and demonstration events, on-going researcher support was provided to the demonstration farmers. Also, if farmers requested it, customized training sessions and workshops were conducted in some areas. Through those training sessions, field days, and on-farm demonstration activities, significant linkages and working relationships were established among stakeholders, particularly between researchers and farmers. Previously, there was very limited interaction between researchers and producers. Thus, the pilot has already succeeded in facilitating the establishment of important working relationships in the areas where the project was implemented. As one researcher reported with considerable excitement:

> *"I feel the relationship that is established between me and my demonstration farmers is more than a formal working relationship. Now, some of our demonstration farmers and their neighbors do not hesitate to call me up and*

discuss various things that are related to the field demonstration and other farming issues. Also, when I visit them, I am welcomed to their homes as if I am a part of their circle of family friends. I feel we are devoted to each other in a certain way."

It was expected that extension personnel would have the closest contact and establish the closest links with farmers. However, somewhat surprisingly, relationships between farmers and extension personnel are not as strong and close as the relationships that have developed between researchers and farmers[29]. Perhaps because extension workers were less involved than researchers in field experiments and demonstrations, they had less direct contact and interaction with farmers. Extension personnel play an organizing role by taking care of logistics and making arrangements for field days, workshops, and other public training events. They may seem a bit distant from the technical aspects of field research and demonstrations but they play vital roles and appear to be generally satisfied taking responsibility for publicity, organization, and various aspects of government relations.

The government representative from NSC acted as an observer most of the time. He would come along to all public events such as field days and participatory workshops. Also, he plays a major role in public presentations and dealings with local governments. His/her primary role on the team is to learn from the field and from farmers, and to take this information to the government when they plan and prioritize their agricultural research and extension activities for the following year. However, as noted, the NARET has not yet been able to formally insert the needs assessment results into government planning processes. One possible source of problems in this regard is the change of government and changes in the NSC. During the three years since implementation of the pilot project, the NSC representative has been replaced twice. While success in terms of winning government approval for the new approach is not guaranteed, there is

[29] The closer relationships with researchers parallels what has been observed in North America where well educated farmers have sometimes bypassed extension personnel to go directly to the source, i.e. the research scientists working on the particular issues of interest.

clearly a need to publicize NARET activities, increase its visibility, and present the outcomes to the government and to the public. Some key outcomes and challenges are summarized below.

Outcomes to 2009:

- Stronger linkage built between farmers and researchers;
- A team of highly motivated people has been put together for NARET, and a close working relationship has been established among them;
- A routine of activities has been established—the annual work cycle. All stakeholders including the demonstration farm farmers have become familiar with their role and their responsibilities in the AWC.
- A basis for an efficient and effective research and extension system has been established and demonstrated.

Challenges and lessons learned:

- Changing mindsets has been the greatest challenge. The farmers were very passive in the beginning. It was difficult to get their opinions, because their opinions had never been requested before, and they did not expect to be included in the discussions and decisions. Also, it was difficult to dissuade the government representative from talking to the farmers and other team members in an authoritative manner. All team members of the NARET have an equal role. Also, in the beginning, it was difficult to convince the team members to volunteer their time and effort for a good cause—a better system.
- Challenges related to the government are two-fold: a) changing the top-down attitude of the government officials, and b) the frequent turnover of government personnel especially following the elections. Convincing the government to accept grassroots ideas in their planning and policy-making is a long-term

process. With time, it is hoped this process will establish a sense of tradition and duty.

- Securing funding resources to carry out field activities and training sessions is not easy since extension and dissemination of research results are not imbedded in research project budgets. Resources include time, finances, human capacity, and equipment. Although the NARET model is cost-efficient and requires little in the way of external resources, funding will become a barrier to continuing and expanding NARET activities. Having the government realize the importance of on-farm research and extension activities is crucial to getting acceptance for the NARET model and getting the government to incorporate the NARET structure and approach into their annual work plan and budget.

- Up until now the NARET has been seen an ‘extracurricular’ activity for the team members, and they have been involved on a voluntary basis. Incorporating the NARET model into the national system will not only help to solve resource issues, it will also help researchers and extension personnel to become more involved in NARET activities as part of their official roles and responsibilities as stated in their job description and terms of reference. That will give the members more responsibility and a rationale to be more fully involved in research and extension activities.

Although the NARET model has many advantages in comparison to the current research and extension system in Mongolia, the author wish to acknowledge that the model was piloted only for 2 years in 4 provinces. For this model to be accepted by the government as a part of the national research and extension system and to be scaled-up across the country would take time and more resources. Meantime, NARET members need to be nourished and supported in order to keep their interest and ensure their willingness to carry out the AWC until such time as the NARET roles and responsibilities are recognized and included in their normal work plans.

5. SOME CONCLUSIONS

The thesis research was done as an interdisciplinary study using a number of research methodologies such as literature review, structured surveys, face-to-face interviews, and the personal observations of the author, to examine and assess technology transfer processes and the agricultural extension system in Mongolia. A framework was developed to analyze and better understand the characteristics and components of the current research and extension system from the perspective of Mongolian farmers. It was also used to understand the socio-economic factors that influence farmer decisions. The recent soil conservation technology transfer process in Mongolia was investigated in order to better understand the structure and functioning of a technology transfer system, including its successes and failures in Mongolia.

Addressing knowledge management systems in relation to Mongolia's current agricultural research and extension system, and obtaining a clear idea of the roles and responsibilities of all agriculture research and extension actors, were required steps to provide the background and understanding needed to propose a new extension model. The factors that influence farmer decision-making processes are complex and diverse. A better understanding of those factors, including the socio-economic, agro-environmental, and governmental factors, provided useful insights for developing a more effective and efficient extension model for Mongolia.

Farmers in Mongolia have been encountering various problems with conventional agricultural practices that involve intensive cultivation and soil disturbance. The main concerns were soil erosion, weed control, and soil and water conservation under dry land (rain-fed) farming systems. Therefore, the main reasons Mongolian farmers adopted reduced-tillage conservation farming technologies were better weed control, reduced soil erosion, and improved water conservation in the soil.

Approximately one-third of the grain farmers in Mongolia have started implementing soil conservation practices by minimizing tillage and employing a chemical fallow system.

Most farmers who have adopted these practices are between the ages of 36 and 45 and often have more than ten years of farming experience. Mongolian farmers, in general, are well educated and their ability to learn and apply information regarding new technology is high. Farmers who have adopted conservation farming practices tend to have more capital and visible signs of wealth than farmers using conventional farming practices—more animals, more crop-land, and more farm equipment.

Farmers' perceptions are important. Mongolian farmers believe the main advantages of conservation farming practices are reduced soil erosion, improved weed control, increased cost efficiency, and improved yield. In contrast, they see investment costs, lack of reliable input supply, and lack of knowledge as barriers to adopting conservation farming practices. According to the farmers who were canvassed as part of this study, most of the benefits of conservation farming technology were agronomic and economic. The main factors that influenced a farmer's decision to adopt conservation farming practices were problems with weed control, soil erosion, and drought. The decision was aided by financial incentives and subsidies from the government, and other economic and agronomic advantages associated with conservation technology. However, a lack of machinery and capital, followed by a lack of inputs, the high price of inputs, and a lack of knowledge and information on new technologies were the main disincentives for farmers implementing this technology.

Technology development, transfer, and adoption are complex processes. This thesis research emphasizes the importance of consistency and continuity of new technology development by researchers, information transfer through extension, and, finally, technology adoption by farmers. Farmers constantly make changes, modifications, adaptations, and adoptions in their farming practices. Therefore, the research and extension process is never complete and the exchange of information should be ongoing. A sustainable agriculture production system requires constantly identifying new farm problems, seeking new solutions, developing and implementing new knowledge and practices, and monitoring to assess results and to provide some advanced indication of emerging problems. Adopting new technology is not the last step for sustainable agriculture; it is an ongoing process (Hall, 2003), involving the cycle of problem identification, provision of solutions, monitoring, and back to problem identification. Therefore, to ensure sustainable agricultural development, all the players in the system, including researchers, extension agents, policy-makers, agribusinesses, and farmers, have to work hand-in-hand with shared roles and responsibilities, simultaneously moving toward the same goal.

At the time this study was conducted (2005-2008), both farmers and national extension agents agreed that their main information source for new technologies was international projects. The capacity of local institutes to demonstrate and transfer new technologies such as conservation farming systems was low. A hierarchy still exists between government and farmers in many developing countries including Mongolia. Research organizations lack resources, and extension services are not well established. In order to meet farmers' needs and to respond to the problems effectively and efficiently, restructuring of the current "top-down" agriculture research and extension system must be considered, especially the ways that would increase farmers' participation in appraisal, implementation, and decision making. The agricultural research and extension system in Mongolia has proven to be ineffective and inefficient; therefore a new model or approach is needed to encourage better collaboration and linkages among core players.

In this thesis, a pilot "National Agriculture Research and Extension Team" (NARET) model for the agriculture extension and research system in Mongolia has been presented. This model was developed using a systems approach to ensure all elements of the system were included. To eliminate major gaps and missing links between key actors in the agricultural research and extension system, a team approach was proposed that would involve all core stakeholders including farmers, researchers, extension agents, and government representatives. The annual work cycle of the NARET is designed to respond to farmer needs more effectively and efficiently by working in much closer collaboration with the farmers—assessment of farmer needs, evaluation and recommendation of previous demonstrations and training activities, prioritization of research, implementation and demonstration of research, dissemination of results, and training of farmers, and then back to the farmers' needs assessment.

What distinguishes the NARET model from others in Mongolia is that all stakeholders involved in the research and extension system have strong representation on the same steering team and thus have a better opportunity to collaborate and complement each other, rather than working independently and competing for resources. In particular, this model recognizes the importance of involving farmers in all stages of the decision-making process, and treating them as equals in their participation and voice.

Sustainable agricultural development is crucial for eliminating rural and urban poverty in Mongolia since agriculture is the economic foundation of the economy. Indeed, in order to improve the social and living conditions in rural communities, the rural economy must become viable and this will happen only if the agriculture sector becomes more profitable. Therefore, it is crucial to investigate sustainable agriculture technologies such as conservation farming practices[30] that have the potential to benefit farmers as well as the country as a whole, economically, environmentally, and socially.

For various reasons, including personal, cultural, infrastructural, and governmental, many rural producers in developing countries like Mongolia have limited access to information about new technologies. Removing those barriers for effective technology transfer will require a significant amount of time and resources. However, some of these barriers can be removed simply by making information and training available and by better coordinating the stakeholders involved in the technology development and transfer system. Also, there is a need for national institutional capacity development and training of key stakeholders in addition to farmers. National level initiatives, such as better quality control and regulation of imported goods/inputs such as herbicides, would improve productivity as well hasten and reinforce the adoption of new conservation tillage systems.

Technology development and transfer refers to a wide range of transfers from a piece of information related to a specific aspect of production such as weed control to the

[30] Although conservation tillage practices have many benefits for sustainable agriculture, wide-spread adoption of conservation tillage technology is likely to result in new issues and challenges of a technical and socio-environmental nature; some of these issues may be predictable and some not predictable. Therefore, conscious and continuous efforts need to be made before, during, and after the adoption new technologies. As suggested in the AWC of the NARET model, annual identification of new problems and solutions is therefore important.

complete technology package for a farming system. However, information transfer must not be seen as a one-way process from researchers to farmers (Francis, 1990). Farmers also provide powerful and promising sources of knowledge and technology at the grassroots level, which can be very useful for the development of an alternative agriculture technology (Hassanien and Kloppenburg, 1995). Information and technology development and transfer should be conceptualized as a two-way process. A collaborative approach is also indispensable in order to unleash the power of knowledge co-production, with its associated advantages of shortened feedback loops and mobilization and integration of local ecological knowledge. Farmer participation in the process is crucial and should be a central feature of any new technology transfer program that is proposed to revamp ineffective, “top-down” research and extension systems, such as what currently exists in Mongolia.

Appropriate technology development can only be enhanced if researchers understand the basic needs of farmers, farming communities, and other facets of the agricultural industry (Francis, 1990). The key to successful technology development and transfer is an ability to involve various actors and agencies, especially extension, in the process of identifying alternative technologies that fit existing farming systems (Beynon et al., 1998; Agus et al., 1998). Furthermore, a lack of understanding about the context of farmer decision-making, including the socio-economic and cultural characteristics of farmers, is likely to result in the failure of the transfer and adoption of new technologies, as well as the endorsement of inappropriate policies, funding programs, and development plans (Kaimovitz, 1991; Sutherland, 1999). The multiple factors affecting farmers’ behavior and decision-making processes cannot be neglected. Transfer of new technologies is an important driver for agricultural development, although outcomes are not easily predicted. Therefore, the most appropriate orientation is one that is flexible and responsive to new information and evolving situations.

Adopting a more effective and efficient research and extension model like NARET could result in a significant improvement in the economic well being of people in Mongolia, and could have a significant impact in terms of improving soil and water conservation for sustainable agriculture. However, the successful implementation of the NARET model will depend on the coordination mechanisms and administration incentives, such as shared responsibilities, exchanged knowledge and information, shared benefits among all players, and government agreement and participation.

There are many aspects that must be considered and included in agricultural systems if they are to be sustainable. Research must examine the economic and social implications as well as the environmental effects of using new methods or technologies. Even if a new technology is shown to be more efficient, it will not be long lasting if it does not also maintain the environment. Similarly new technology or methods designed to improve the environment will not be adopted by farmers if they are too expensive or difficult to implement due to a lack of knowledge or a lack of other inputs. Therefore the multidisciplinary implications of new methods need to be examined to ensure their suitability and sustainability.

This multi-disciplinary thesis[31] has brought forward many issues and questions that need further exploration and research. First, it is vital for Mongolia to explore alternative technologies for sustainable agriculture development that are better suited to the changing climate. Features such as greater use of alternative inputs (for example, using manure rather than chemical fertilizers), integrated weed control methods, and diversified agricultural production systems (for example, the integration of crop and livestock production using zero-waste approaches) are important to consider.

Second, institutional structures and policy are complex and variable. Understanding these institutional cultures and the different factors that drive them is crucial for developing effective linkages and collaboration for sustainable development. It is important to evaluate institutional interests, capacities, and responsibilities to promote collaboration based on shared values and goals.

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[31] This interdisciplinary thesis involved disciplines including agricultural science, agricultural extension and technology transfer, and rural development and sociology. Research methods and approaches that were used to collect field data and information for this thesis included personal observation, participation, qualitative and quantitative social research, agronomic field trials, and evaluation of a pilot-experiment on technology introduction and organizational innovation in extension and research.

Third, while privatization and deregulation have given rise to many new agricultural initiatives, there is also need for effective regulatory mechanisms that facilitate coordination and collaboration, reduce risk, and provide assurance, e.g. with respect to the quality and supply of farm inputs[32]. Also, further capacity-building activities at all levels of the agricultural production system are required and should be targeted both at individuals and organizations.

Finally, the interaction between human agricultural practices and the ecosystem is an aspect of interest to all of Mongolian society. Thus, there is a need to further investigate this subject using a more holistic and interdisciplinary approach based on the characteristics and resources of the country. This will require an interdisciplinary team of researchers to extend beyond technical issues and further explore the economic costs and benefits, social and cultural dimensions, and environmental impacts for both the short and long term.

This thesis research was a significant initiative and attempt to evaluate the current system and to propose an alternative NARET model for a more effective and collaborative research and extension system in Mongolia. However, the author wishes to acknowledge that further testing and evaluating of the model in greater depth is needed. That will require resources and coordination. An international project such as TRD from CIDA might be an option for funding and facilitation in the beginning until local institutions and government are convinced of the benefits of such a project, and take up both funding and facilitation/coordination roles.

[32] In western countries, such as Canada, agribusinesses play an instrumental role in agricultural research and extension and technology transfer of conservation agricultural practices. In North America, private businesses such as seed breeding companies, equipment dealers, and fertilizer companies have more frequent contact with farmers than the government or NGOs, and are therefore active players in the training of farmers. However, businesses exist to make profit and therefore may have a tendency to promote technologies associated with their own products (chemicals, equipments, etc.). Therefore, multiplayer and multi-stakeholder government-guided teams need to be identified in order to make appropriate judgments and decisions on the promotion of new technology and the sustainability of the new practices being introduced.

Some recommendations:

The agriculture sector is a significant player in Mongolia's national economy and for its food security. The way in which the Mongolian Government manages the agriculture sector, in relation to other factors that influence the sector, will have an impact on its natural resources, agricultural markets and the general populace, and will ultimately will determine the future sustainability of the agriculture sector in Mongolia. As a result of an external assessment of Mongolia's current array of agricultural research and extension system through this thesis, the following recommendations are suggested for further policy action. The policy recommendations below are not in any particular order.

- *Initiatives for a better quality control and effective regulatory system for imported goods/inputs such as herbicides*: this would reduce risks, provide assurance to both buyers and sellers, and improve productivity as well hasten and reinforce the adoption of new conservation tillage systems.
- *Coordination mechanisms and administration incentives among all players in the agricultural research and extension system towards collaboration*: shared responsibilities, exchanged knowledge and information, shared benefits among all players, and government agreement and participation will facilitate actions towards a more effective and efficient agricultural research and extension system.
- *Actions towards changing top-down culture to bottom-up culture of the government agriculture extension system structure (NAEC):* the successful implementation of sustainable agriculture research and extension system will depend on mutual attitudes and the participation of all levels of players of the agriculture system including the grassroots level – farmers.
- *Capacity-building activities at all levels of agricultural production and policy making are key for better technology development, transfer, and policy development:* both individuals and organizations should be targeted.
- *Consideration of the multi-disciplinarily nature of the agriculture sector*: an interdisciplinary approach should be taken in consideration of new technology transfer such as conservation agriculture for agro-environmental and socio-economic sustainability.
- *Institutionalization of extension services by agricultural researchers*: a core criteria embedded in the job description of researchers should include extension services, and their annual plan of work and budget should include activities related to the dissemination of their research results.
- *Inclusion of technology transfer and extension service activities in the NSC research proposals and budgets*: it will enable and incentivize researchers to work closely with farmers, using their research work to address problems at the grassroots level.

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APPENDICIES

APPENDIX A: WEED CONTROL CHALLENGES IN CONSERVATION TILLAGE SYSTEMS

INTRODUCTION

Regardless of the technology used, weed control is always a primary concern in any type of farming system. Therefore, weeds are still a problem in conservation farming systems, though less problematic and more manageable than in most other systems. Mongolia and Saskatchewan have similar weed populations. Traditional weeds have started to adapt and new weeds have been introduced to crop fields as a result of the implementation of new conservation farming technology. Direct seeding technology has been introduced in many parts of the world and it has been rapidly adopted throughout western Canada over the past 20 years. There are many advantages of this technology including improved soil quality and reduced soil erosion. However, related challenges include new weed infestations such as dandelion (*Taraxacum officinale)* which are difficult to control in direct seeding systems. As a result, this species is becoming an increasing issue in western Canada's cropping systems. For instance, in Manitoba, from 1997 to 2002, the relative abundance rank of dandelion increased from 22nd to 9th most abundant weed in annual cereal and oil crop fields (Beckie et al., 2004).

Dandelion is a problematic weed in over 20 countries (Mitich, 1989) including Mongolia. Dandelion infestation in Canadian cropping systems is a direct result of the introduction of minimum tillage practices (Stevenson and Johnston, 1999). Consequently, there is a high possibility that dandelion will become a problematic weed very soon after a conservation farming system is introduced in Mongolia. There are few options for control of this weed in zero-till or low-disturbance farming systems. As a result, perennial weed populations such as dandelion have increased rapidly in the North American prairies (Stevenson and Johnston, 1999). Dandelion plants are able to survive through a wide range of climatic conditions especially in the mature growth stage (Stewart-Wade et al., 2002). Therefore, management strategies for the control of dandelion will require research concerning its competitive ability, biology, ecology, and population demography in annual cropping systems. Although some studies have been done on dandelion and its growth habit, competitive ability, and control methods, this species is becoming a greater problem in western Canada as well as many other countries, especially where reduced tillage systems are introduced. Control methods for dandelion are still unclear and many questions need to be answered. Because of this uncertainty regarding the best control methods to control dandelions, producers are increasing the pressure on scientists to develop improved control measures.

Dandelion plants are perennial and start to grow and flower early in the spring. Food storage in the strong tap root allows for the plants to grow very rapidly early in the spring, and for them to compete effectively for moisture, nutrients, and sunlight before many other plant species begin their growth for the season (Stewart-Wade et al., 2002). Also, this advantage of early dandelion growth not only allows for early resource capture by taproots, it also helps dandelions to compete with other plant species (Vavrek et al., 1997). Therefore, early spring control, either by tillage or herbicides, may have a significant role in controlling dandelion growth and conserving resources for the developing crop. Thus, the determination of optimal treatment dates is crucial.

Dandelion seed is a major method of reproduction and dispersal. Dandelions produce large numbers of seeds, and can produce seeds more than one time during the growing season. In Britain, the highest seed production occurs in April, September, and October (Vavrek et al., 1997). In Canada, dandelion seed production occurs mainly in May and June but lesser amounts of seed are produced later in the growing season when moisture is adequate. Dandelion seeds do not necessarily go through a dormancy period, and they can germinate right after they fall onto moist ground. However, seeds can remain dormant for up to four years (Roberts and Neilson, 1981). Roberts and Neilson (1981) found that dandelion seed germination is high in both fall and spring, whereas, Vavrek found that dandelion emergence is higher in spring and lower in fall. According to these research results, early spring and fall control methods could potentially reduce dandelion infestations and prevent, or reduce, seed production. Although some researchers have suggested that dandelion control is better in the fall

(Dunn and Moyer, 1999), crop yield loss is most affected by spring infestations of dandelion. Therefore, finding alternative dandelion control methods for the spring is crucial to reduce yield loss caused by dandelion plants.

It is evident that an increase in dandelion infestation is associated with the increased adoption of low-disturbance and no-tillage cropping systems (Froese and Van Acker, 2003; Steward-Wade et al., 2002). From 2002 statistics, approximately 8.1 million ha of crop land across the Canadian prairies were seeded with reduced-tillage or no-tillage practices (Statistics Canada, 2002). For this reason, introducing tillage into long-term direct seeded fields may have a positive result for dandelion control. In terms of chemical control for dandelion, Dunn and Moyer (1999) suggest that fall treatments are better than spring treatments because of the direction of nutrient translocation between roots and shoots. However, in order to reduce yield loss due to dandelion, methods to control or suppress dandelions in spring when the crop is establishing itself must be developed. It could be possible to control dandelion right after resources are transferred from root to shoot for plant establishment at about the flowering stage. Since increased dandelion infestation is a result of adopting reduced-tillage systems, tillage can be an effective tool to control this weed. Although it is possible to control dandelion with tillage, there is also concern that tillage may cause soil erosion, reduce soil quality, and reduce the light fraction of the soil organic carbon (LFOC). However, Liang et al. (2003) concluded that tillage had a negligible effect on LFOC. Addressing this complex issue is not simple. Therefore, the objective was to examine both chemical- and tillage-control methods for dandelion.

As in Mongolia, fallow is utilized in the rotation in the semi-arid areas of the Canadian prairies (brown and dark brown soil zones) mainly as a moisture conservation and risk-management tool. As producers move towards soil-conserving direct seeding systems and reduce or eliminate tillage, the fallow phase of the rotation is accomplished with the use of herbicides (chemical fallow) rather than tillage for weed control. Elimination of tillage will increase surface residue cover which will conserve moisture and reduce soil erosion. Greater surface residue will lead to increases in soil organic matter over time, and will generally have a positive effect on soil quality. However, at some point, a light tillage operation may be desirable in a no-till field where there are few herbicide options for control of certain weed populations and where tillage is more cost-effective. Increases in weed populations that are difficult to control with herbicides have been reported in no-till fallow systems in southern Saskatchewan. These include grassy weeds like foxtail barley ((*Hordeum jubatum)* as well as broadleaf weeds like dandelion and Canada thistle (*Circium arvense*). The impact on the surface soil organic matter and weed populations when tillage is imposed on a no-till fallow system is unknown, yet is important to make an assessment in order to ascertain the sustainability of such management systems.

OBJECTIVES

A. To determine optimum timing and rates of spring herbicide application for dandelion in a direct-seeding crop production system;

B. To introduce a light tillage into a long-term, no-till field and to determine tillage effects on soil properties.

MATERIALS AND METHODS

Timing of Spring Herbicide Treatments for Dandelion Control

Site description:

In order to determine the susceptibility of dandelion to herbicide treatments at various growth stages, field research was initiated in 2003 at a site located 70 km east of Saskatoon, SK in the dark brown soil zone which was chosen for its well-established dandelion infestation. Dandelions were distributed quite evenly and heavily throughout the experimental site. The field had been cropped to oats in 2002 and no herbicides were applied to the oat crop that year. The field project continued for two years—2003 and 2004.

Table 4 shows the soil characteristics at the experimental site in October 2003 as determined by standard soil test methods[33].

Depth (cm)	Texture	pH	E.C. (mS/cm)	Salinity	Organic matter (percent)	NO_3	P	K	SO_4
0-15	Clay loam	8.0	0.9	Non	3.4	21	9	>540	16
15-60	Clay loam	8.2	0.9	Non	-	49			46

Table 4. Soil characteristics and nutrient levels at the dandelion test site near Colonsay, SK. October, 2003.

Weather conditions:

Moisture conditions at the site were relatively good in both 2003 and 2004 as illustrated in Table 5.

Year	May	June	July	August	September	October	Total (mm)
2003 (Colonsay)	36.1 82%	41.9 66%	64.8 105%	22.3 59%	46.5 150%	15.0 85%	257.2 95%
2004 (Humboldt) [34]	31 71%	97.2 152%	73 118%	77.5 206%	21.5 70%	31.5 177%	361.7 134%
1970-2000 normal (mm)[35].	43.7	63.7	61.5	37.5	30.9	17.7	270.8

Table 5. Monthly precipitation in mm during the growing season at the dandelion test site near Colonsay, SK in 2003 and 2004, and comparison with normal precipitation (percent).

However, average temperatures for 2003 and 2004 were quite different, especially at the beginning of the growing season. The weather during the 2003 growing season was closer to normal both in terms of moisture and temperature. The spring was slightly drier than normal and September was somewhat wetter than the normal. Overall, air

[33] Soil test was done in the Enviro-Test Laboratories Agricultural Services (ETL) in Saskatoon, SK.

[34] Rainfall for the growing season in 2003 was measured at the actual experimental site, and rainfall for 2004 was taken from a weather station in Humboldt due to the failure of on-site station.

[35]Rainfall for the growing season in 2003 and 2004 was compared with the 1970-2000 precipitation data collected by the Saskatchewan Research Council + Environment Canada (Kernen Crop Research Farm, Saskatoon, SK).

temperature was close to average with the exception of August which was +3.5 degree C warmer than normal.

Year	May	June	July	August	September	October
2003	12.1 (+0.7)	16 (-0.2)	18.9 (+0.3)	20.9 (+3.5)	11.4 (+0.2)	6.5 (+1.7)
2004	7.9 (-3.6)	13 (-3.2)	17.1 (-1.5)	13.9 (-3.5)	10.5 (-0.7)	2.8 (-2.0)
1961-1990 Normal[36].	11.5	16.2	18.6	17.4	11.2	4.8

Table 6. Average temperature in ^{0}C during the growing season at the dandelion test site near Colonsay, SK in 2003 and 2004[37], compared with the 30-year normal values

However, the warm August weather encouraged rapid crop maturity and allowed harvest to be completed before the rains started in September. During the 2004 growing season 34 percent more rainfall than normal was received but precipitation in May and September was about 70percent of the normal precipitation for those months. Although moisture conditions in 2004 were above the norm, average temperature during the growing season was lower than normal. From May until October, the average temperature for every month was lower than the normal; the monthly differences in temperature from the norm ranged from -3.6^{0}C in spring to -2^{0}C in the fall. The cooler and moister conditions played a significant role in determining plant growth and crop yield. It not only delayed crop seeding, seed germination, and plant establishment in the spring, but also resulted a significant reduction in the crop yield.

<u>Experimental protocol and design:</u>

Experimental plots were arranged in a 3 x 8 factorial, split block design. Herbicide application dates were the main plots and herbicide treatments were the subplots. Plot size was 2.25 X 6 meters. Three different dandelion stages were chosen for herbicide application dates in spring prior to seeding the crop: pre-flowering, flowering, and post-

[36] 1961-1990 temperature normals collected at the Saskatoon airport weather station. The research site was about 70 km east of Saskatoon.

[37] Air temperature data was taken from the Kernen Crop Research Farm, Saskatoon, SK weather data.

flowering stages. There were eight herbicide treatments including glyphosate, 2,4D, florasulam, and tribenuron methyl (Table 7).

Treatment: #	Glyphosate rate (g ai/ha)	Additional herbicide (g ai/ha)
1	UTC	Nil
2	0	2,4D - (1120)
3	900	Nil
4	900	2,4D – (1120)
5	450	Nil
6	450	2,4D – (1120)
7	450	florasulam – (5)
8	450	tribenuron methyl – (7.5)

Table 7. Herbicides and application rates used in the field experiment at the dandelion test site near Colonsay, SK in 2003 and 2004.

The herbicide, 2,4D, was applied to all the experimental plots at 420 g ai/ha in late October, 2002 to control winter annual weeds. No other treatment was applied on those plots in 2002. Hard red spring wheat was seeded 3 days after the spring applications at 85 kg/ha. Prior to the seeding date, 112 kg/ha urea (46-0-0) fertilizer were cross drilled into the trial area Wheat seed was directly drilled to 4 cm depth with 17.5 cm row spacing. Mono-ammonium phosphate (11-52-0) at 51 kg/ha was seed placed during the seeding operation. A commercial mixture of bromoxynil and MCPA ester (Buctril-M®) was applied for broadleaf weed control at a rate of 280 + 280 g ai/ha and clodinafop-propargyl (Horizon®) was used for grassy weed control at 56 gai/ha. They were applied at 100 l/ha water volume with ABJ100015 nozzles at operated 275 kPa. Crop yield was determined by harvesting a 1.3 m wide strip from the centre of each plot using a self-propelled experimental plot combine. The threshed grain was dried to standard moisture content in a forced air drier, cleaned, and weighed.

Data collection:

Dandelion plants were counted just before each treatment date in the spring—during pre-flowering, flowering, and post-flowering stages of dandelion. A quarter square meter frame was used and two permanent quadrants were established in each plot. The dandelion counts were conducted three times during the year—prior to the pre-seeding herbicide treatment, before in-crop herbicide application, and in the fall. Six dandelion plants were marked in each plot in each of three different size ranges (<5cm, 5-15 cm, >15cm) for visual rating in order to determine herbicide treatment effects on different dandelion sizes. . Treatments were rated visually using the Canadian Weed Science Society approved rating scale (0-100) where 0 = no control, 100 = complete control and 80 = the minimum commercially acceptable control. Visual evaluation was done seven, 14 and 30 days after the herbicide application. In fall, wheat grain was harvested to determine the herbicide treatment impact on crop yield.

control plot **Glyphosate 900 G + 2,4D 1120 G A/ha**

Figure. 37. Illustration of herbicide plot layout: untreated check against (L) and a plot treated with high rate of glyphosate and 2,4-D herbicide mix (R). Different colored flags represent different sizes of dandelion.

Statistical analysis:

In all cases except for grain yield, multiple samples and counts were taken from each plot. A sample mean was calculated for each plot and subjected to statistical analysis. Dandelion count and wheat yield data were analyzed using analysis of variance (ANOVA) using GLM Procedure, using SAS statistical software and means were separated using LSD test at the 0.05 level of significance (Schlotzhauer and Littell, 1997).

RESULTS and DISCUSSION

Herbicide Effect on Different Growth Stages of Dandelion

Dandelion is a perennial weed with a short life cycle. It resumes growth early in the spring, and produces mature seed early in the summer. The objective of this study was to determine at which growth stage herbicide treatments are most effective. The eight different treatments applied at three different dandelion growth stages, pre-flowering, flowering, and post-flowering, resulted in significantly different impacts on dandelion (Table 8).

Table 8. Percent control of dandelion (based on visual assessment) with different herbicide treatments applied at three different growth stages at the dandelion test site near Colonsay, SK in 2003 and 2004.

Treatment	Dosage	percent control 95 DAT			percent control 95 DAT		
	g ai/ha	Pre-flower*	Flower	Post-flowering	Pre-flower	Flower	Post-flowering
		Application date – 2003			Application date -2004		
Control	-	0	0	0	0	0	0
2,4 D	1120	86	49	64	63	77	38
Glyphosate	900	85	13	49	52	59	13
Glyphosate + 2,4 D	900 + 1120	85	75	74	71	89	47
Glyphosate	450	58	11	4	44	38	-40
Glyphosate + 2,4 D	450 + 1120	85	16	69	53	79	41

Glyphosate + Florasulam	450 + 5	93	13	24	69	57	4
Glyphosate + Tribenuron methyl	450 + 7.5	94	46	59	53	82	16

In 2003, all of the herbicide treatments resulted in significantly better control when applied at the pre-flowering stage than at either the flowering or post-flowering stages. There was no significant difference between treatments applied at the flowering and post-flowering stages. However, in 2004, the herbicide treatments that were applied at both the pre-flowering and flowering stages produced significantly better results than herbicide applications at the post-flowering stage. There were no significant differences between the pre-flowering and flowering stage application dates in 2004. However, weather had a significant influence on the effect of the treatments on dandelion control, particularly in 2004 (Table 6).

During the pre-flowering stage, early in the spring of 2003, the weather was warm with ample moisture. This allowed the dandelions to grow actively. The active growth may have allowed the herbicides to translocate from leaf to root faster than at the flowering and post-flowering stages when dandelion growth was not as active as at the pre-flowering stage. Therefore, herbicides like glyphosate had a better chance to move through the plant system and control the plant effectively.

Another possible factor which could have positively affected the results is small plant size. Earlier in the spring—shortly after the rejuvenation of dandelion, plants would be smaller than later in the season. Smaller plant size eliminates shading and allows for better herbicide coverage. During the flowering and post-flowering stages, dandelions were much larger and it was difficult to achieve uniform coverage of all plants with the herbicide treatments.

All seven herbicide treatments controlled dandelion relative to the untreated check plots (UTC) at all three application dates—pre-flowering, flowering, and post-flowering stages. All seven herbicide treatments performed better at the pre-flowering stage than at the flowering and post-flowering stages. In other words, treatments applied at the pre-flowering stage of dandelion provided significantly better control than at the other application dates. All herbicide treatments, except for the low rate of glyphosate at 450g ai/ha, resulted in significantly better control of dandelion in comparison to the untreated check at all three application dates. Averaged over all three application dates, a combination of glyphosate at 900 g ai/ha plus 2, 4-D at 1120 g ai/ha resulted in the best control of dandelion, and glyphosate at 450 g ai/ha resulted in the lowest level of control. This treatment was not significantly different from the untreated check according to the average results of all three application dates. However, this low rate of glyphosate treatment was significantly better when applied at the pre-flowering stage than at the flowering or post-flowering stages. In general, the combination of glyphosate and 2,4-D produced consistently better results at all three stages of herbicide application, whereas other treatments, 2,4-D and glyphosate alone or glyphosate with florasulam or tribenuron methyl, had a lower impact on dandelion control at the flowering and post-flowering stages in comparison to applications the pre-flowering stage.

Although all of the seven herbicide treatments applied at the pre-flowering stage produced significantly better results than the untreated check, the low rate of glyphosate at 450 g ai/ha resulted in poorest control. Among herbicide treatments applied at the pre-flowering stage, all treatments resulted in more than 85 percent control of dandelion except for the low rate of glyphosate (450 g ai/ha). Glyphosate at 450 g ai/ha combined with florasulam at 5 g ai/ha or tribenuron methyl at 7.5 g ai/ha, resulted in the best control of dandelion among the seven different herbicide treatments applied at the pre-flowering stage.

Among herbicide treatments applied at the flowering stage of dandelion, only the high rate of glyphosate (900 g ai/h) plus 2,4-D at 1120 g ai/ha, produced significantly better control compared to the untreated check plots. The rest of the treatments did not differ from the untreated check plots. The herbicide treatments applied at the flowering stage did not result in significantly different control from the treatments at the post-flowering stages. However, the treatments at the post-flowering stage resulted in more varied control than those applied at the flowering stage. The treatments, 2,4-D at 1120g ai/ha, glyphosate at 900g ai/ha, combination of glyphosate and 2,4-D at 900 plus 1120g ai/ha respectively, glyphosate and 2,4-D at 450 plus 1120g ai/ha respectively, and glyphosate and tribenuron methyl at 450 plus 7.5 g ai/ha respectively resulted in significantly better control of dandelion than the untreated check as well as glyphosate at 450g ai/ha and glyphosate at 450g ai/ha combined with florasulam at 5g ai/ha when applied at the flowering stage. Glyphosate at 450g ai/ha and glyphosate at 450g ai/ha combined with florasulam at 5g ai/ha did not produce a significantly different result compared to the untreated check.

The results in 2004 were similar but slightly different from 2003, mainly due to the weather factors (Table 8). Spring 2004 was very cold, although there was enough moisture in the soil. Unlike 2003, herbicide treatments resulted in significantly better control of dandelion when applied both at the pre-flowering and flowering stage than treatments applied at the post-flowering stage in 2004. Still earlier application of herbicide treatments produced better results than late application. During the pre-flowering and flowering stages of dandelion, especially during the pre-flowering, the air and soil temperature was very cold (Table 6), and plants were not actively growing. Plants remained dormant or in a very slow growing mode until June when the weather started to warm up. This slow growth of dandelion had a significant impact on the effectiveness of the herbicide control as it hinders the uptake of herbicides and their translocation from leaf to the roots. Therefore, slow and dormant plant growth due to the cold weather resulted in less effective herbicide control of dandelion in the spring, especially at the pre-flowering stage. Although there was no significant difference between herbicide treatments applied at the pre-flowering and flowering stages, herbicide applications at the flowering stage resulted in better control of dandelion than applications at the pre-flowering stage. The temperature factor during the spring of 2004 significantly influenced the result of the herbicide applications for dandelion control.

During the flowering stage, with warmer weather and active plant growth, the herbicides worked better. Herbicide treatments applied at the post-flowering stage resulted in significantly lower control of dandelion than applications at the pre-flowering and flowering stages. Perhaps this is also related to the fact that active plant growth slows down during this stage. Therefore, herbicides were not actively translocated to the root.

Furthermore, by the post-flowering stage, dandelion plants are often large and the leaves tend to cover one and another. This overlap of leaves could reduce the herbicide dose applied to individual dandelion plants.

Averaged over all herbicide treatments applied at three dandelion growth stages in 2004, the only treatment that resulted in significantly reduced dandelion compared to the untreated check was the combination of a high rate of glyphosate at 900g ai/ha and 2,4-D at 1120 g ai/ha. This treatment also produced significantly better results than the low rate of glyphosate at 450g ai/ha. The high rate of glyphosate and 2, 4-D combination resulted in the best control of dandelion at all application dates—pre-flowering, flowering, and post-flowering. The low rate of glyphosate at 450 g ai/ha had the least effect on dandelion.

Among treatments applied at the pre-flowering stage of dandelion in 2004, 2,4-D 1120 g ai/ha, glyphosate at 900g ai/ha combined with 2,4-D, and glyphosate at 450 g ai/h combined with florasulam at 5 g ai/ha resulted in significantly better control of dandelion than the untreated check. Treatment 4, the combination of the high rate of glyphosate and 2, 4-D, resulted in the best control of dandelion among treatments applied at the pre-flowering stage. The low rate of glyphosate resulted in the poorest control when applied at the pre-flowering stage.

Among treatments applied at the flowering stage in 2004, the combinations of glyphosate at 900g ai/ha and 2,4-D at 1120 g ai/ha, glyphosate at 450 g ai/ha and tribenuron methyl at 7.5 g ai/ha, glyphosate at 450 g ai/ha and 2,4-D at 1120g ai/ha, and 2,4-D at 1120g ai/ha alone resulted in significantly better control of dandelion than the untreated check. The rest of the treatments did not differ from the untreated check. The high rate of glyphosate and 2, 4-D combination produced the best, and the low rate of glyphosate produced the poorest results compared to the untreated check when applied at the flowering stage. The herbicide treatments resulted in a significantly lower effect when applied at the post-flowering stage than at the pre-flowering and flowering stages in 2004. None of the treatments applied at the post-flowering stage produced significantly different results compared to the untreated check. However, the treatments with the combinations of glyphosate and 2, 4-D resulted in significantly better control than the treatment with the low rate of glyphosate alone. Also the combinations of glyphosate and 2, 4-D resulted in the most effective control of dandelion when applied at the post-flowering stage.

Figure 38 illustrates the overall herbicide control effect when applied at the different dandelion stages, in 2003 and 2004. In conclusion, dandelions were most sensitive to the herbicide treatments at the pre-flowering stage in 2003, and both at the pre-flowering and flowering stages in 2004.

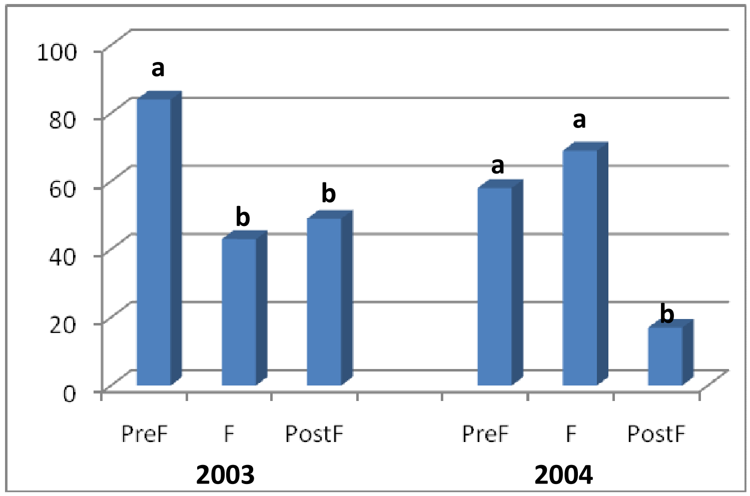

Figure 38. Average percent control (90 DAT) of dandelion for seven different herbicide treatments at three different application dates. (PreF - preflowering, F- flowering, PostF – post flowering stages of dandelion)

The best date for spring herbicide control of dandelion was at the pre-flowering stage in 2003 and at the flowering stage of dandelion in 2004, when dandelions were actively growing. In terms of the herbicide treatments, all seven herbicide applications resulted in significant reduction in total number of dandelion in relation to the untreated check. However, the high rate of glyphosate and 2, 4-D combination resulted in the best control of dandelion at all application dates in both years. In conclusion, herbicides are most effective if they are applied while plants are most actively growing.

Herbicide Effect on Different Sizes of Dandelion

Another objective of this experiment was to see if dandelion size influenced the effectiveness of herbicide applications. As mentioned in the methodology, three different size categories of dandelions were marked (<5 cm, 5-15 cm, >15cm diameter) prior to herbicide treatment. Following the herbicide applications, dandelions in different size categories were monitored visually and assessed 7, 14, and 20 days after the herbicide applications.

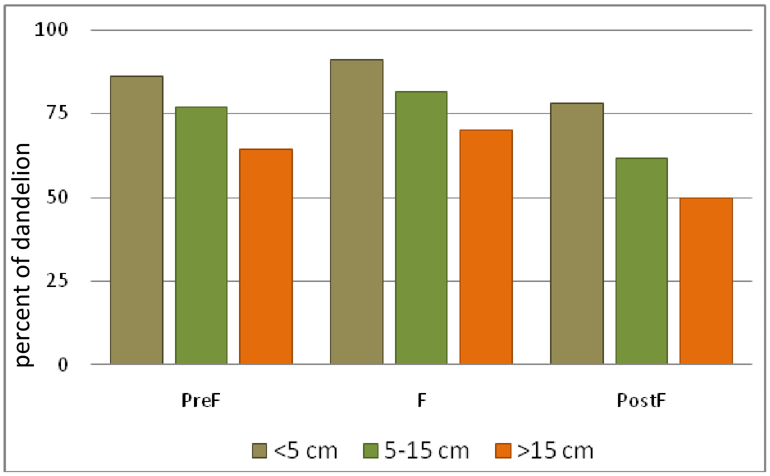

Figure 39. Effects of herbicide treatment timing and dandelion size on dandelion control in 2003 and 2004 at Colonsay, SK.
PreF-preflowering, F-flowering, PostF-Post flowering stages. (visual assessment by percent control—30 days after the

Figure 39 shows the herbicide effect on dandelion at three different growth stages. Results of the assessment (Figure 39) suggested that dandelions tended to be more sensitive to the herbicides when they are small (<5 cm) than both medium (5-15cm) and large (>15cm). Bigger dandelions tend to be less affected. This is perhaps related to the active growth of dandelion when it is smaller and at the earlier growth stages. This assessment also supports the conclusion from the previous section that herbicide treatments resulted better control of dandelion both at the pre-flowering and flowering stages than at the post-flowering stage. Also, success in controlling dandelion in the earlier stage could be associated with the size of dandelion. In the post-flowering stage, often dandelion size has already become bigger than 15 cm, and large plants tend to shade each other and limit the plant surfaces to be contacted by the herbicide.

Herbicide Effect on Dandelion Biomass

Dandelion biomass was measured to determine the final result of the herbicide treatments applied at the three different stages of dandelion. Above ground dandelion biomass response to the herbicide applications at the three dandelion stages followed a similar pattern to the herbicide effect on dandelion count. Dandelion biomass in the fall of 2003 was significantly less than in 2004. The herbicide effect on dandelion biomass in 2003 and 2004 differed significantly at each of the application dates—pre-flowering,

flowering, and post-flowering. Herbicide treatments applied at the pre-flowering stage resulted in the least dandelion biomass, whereas treatments applied at the post flowering stage resulted in the greatest dandelion biomass.

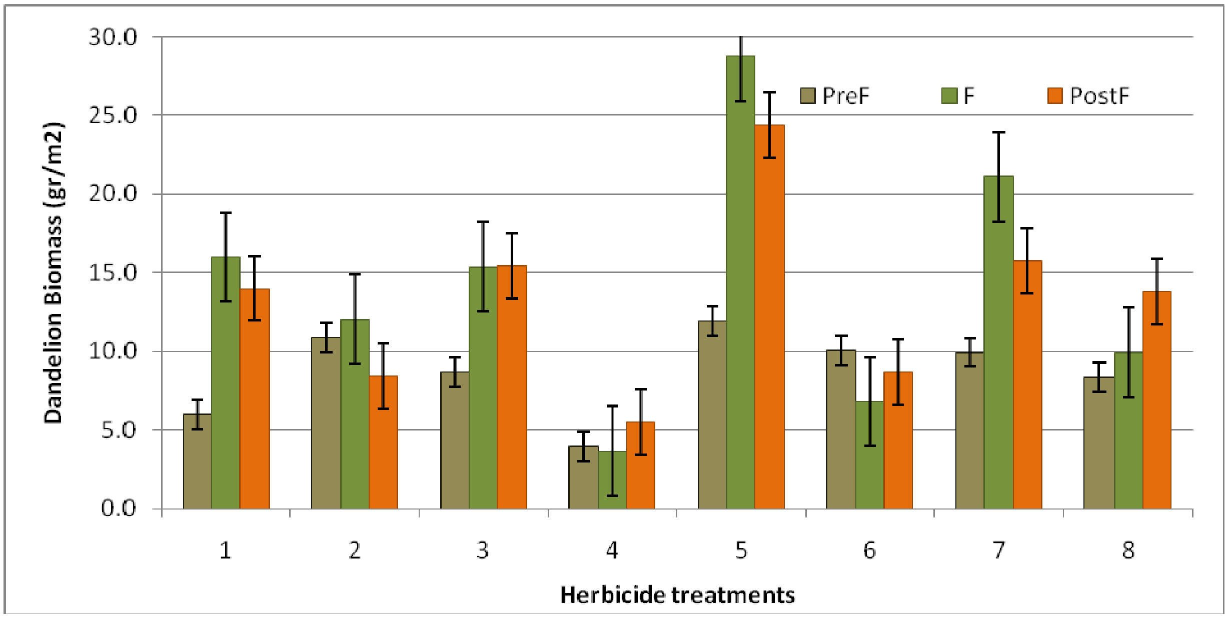

Figure 40. Comparison of dandelion biomass at three different application dates. (mean of 2003 and 2004) (1-Control; 2-2,4 D (1120 g ai/ha); 3-Glyphosate (900g ai/ha); 4-Glyphosate + 2,4 D (900 + 1120g ai/ha); 5-Glyphosate (450g ai/ha); 6-Glyphosate + 2,4 D(450 + 1120g ai/ha); 7-Glyphosate + Florasulam (450 + 5g ai/ha); 8-Glyphosate + Tribenuron methyl (450 + 7.5g ai/ha))
PreF-preflowering, F-flowering, PostF-Post flowering dandelion stages

Figure 40 shows the difference in the biomass measures among all herbicide treatments when applied at three difference application dates. All herbicide applications at the pre-flowering stage resulted in relatively even dandelion biomass. There were no significant differences among the herbicide treatments, but they were all significantly different from the untreated check. The herbicide treatments at the flowering and post-flowering stages resulted in varied biomass measures with some significant differences. The mean dandelion above ground biomass among all the treatments was 12.1 gr/m^2, and maximum dandelion biomass (28.8 gr/m^2) was found in plots treated with glyphosate at 450 g ai/ha at the flowering stage of dandelion. The high rate of glyphosate and 2, 4-D applied at each application date resulted in the greatest reduction in dandelion biomass in relation to the untreated check. The low rate of glyphosate and 2,4-D combination and the high rate of 2,4-D consistently resulted in high control of dandelion at each application date, resulting in less dandelion biomass in the fall. The low rate of glyphosate resulted in the least control of dandelion and the most biomass in the fall, except when the treatment was applied at the pre-flowering stage.

Herbicide Effect on Crop Yield

As expected, crop yields were better in those plots which underwent herbicide treatments; the dandelion infestation was such that the expectation of a significant crop yield without weed control was unrealistic.

Wheat yield response to herbicide application dates differed significantly (Figure 41). The herbicide treatments when applied at the pre-flowering stage produced the highest yields, while the treatments applied later at the post-flowering stage resulted in the lowest yields.

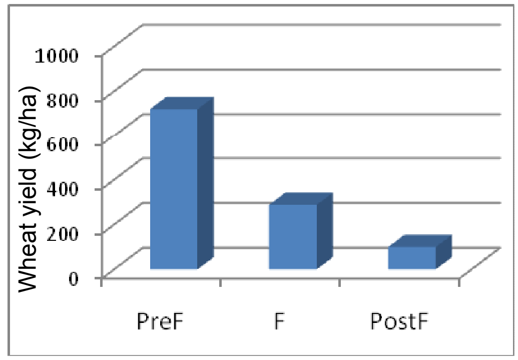

Figure 41. The effect of herbicide application date for dandelion control on the yield of wheat at Colonsay, SK in 2003 and 2004.

PreF-preflowering, F-flowering, PostF-Post flowering dandelion stages

All treatments at the pre-flowering stage resulted in significantly better crop yields than treatments applied at the flowering or post-flowering stages. The high rate of glyphosate and 2,4-D combination resulted in higher crop yield than all other treatments regardless of application date. This treatment also resulted in the greatest difference in yield compared to the untreated check. In contrast, the low rate of glyphosate consistently resulted in the lowest crop yield among the seven herbicide treatments at each application date.

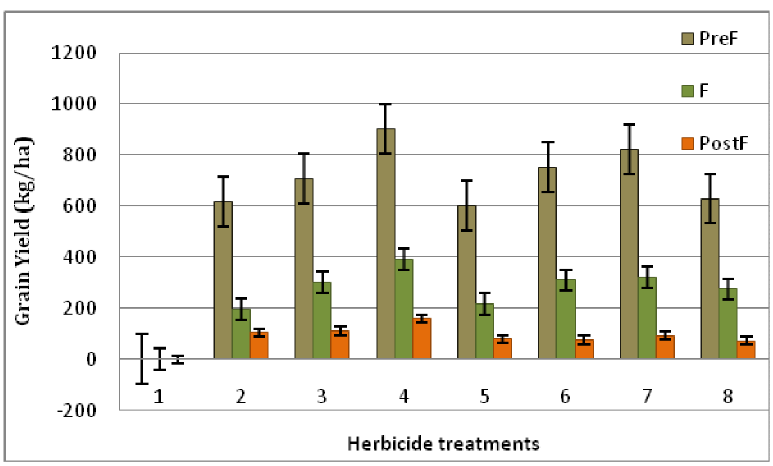

Figure 42. The effect of herbicide treatments at three different application dates for dandelion control on the yield of wheat at Colonsay, SK in 2003 and 2004. (LSD 106)

PreF-preflowering, F-flowering, PostF-Post flowering dandelion stages

From Figure 42, it is concluded that it is important to apply herbicide treatments as early as the pre-flowering stage in order to get the best results for dandelion control and crop yield. If herbicide application is made as early as the pre-flowering stage, it seems that any of these seven herbicide treatments can result in significant control of dandelion and increase crop yield. Early weed control is also related to an early seeding date. An earlier seeding date allows the crop to establish and take advantage of soil moisture in the spring. This translates into strong plant establishment and more crop competitiveness against weeds. The importance of the seeding date was also indicated by the wheat yield from the plots treated at the pre-flowering stage in 2004. In 2004, the treatments applied at the pre-flowering stage did not control the weeds as well as treatments at the flowering stage. However, crop yield was better from those plots treated at the pre-flowering stage than those at the flowering stage. This simply implies that an earlier seeding date gives crops an advanced start before dandelions and other weeds, and so, results in a better crop yield in the fall.

SUMMARY

Early dandelion growth allows dandelions to compete with other plant species including crops. Therefore, herbicide treatments in the early spring play a significant role in controlling dandelion and minimizing crop yield loss by reducing weed infestations. In these experiments, herbicide treatments were most effective in controlling dandelion when applied at the pre-flowering stage, when the dandelions were most actively growing. Although the combination of glyphosate and 2,4-D herbicides resulted in the best control of dandelions at all application dates in both years, all seven treatments produced significantly better control of dandelion in relation to the untreated check. In conclusion, herbicides are most effective when applied while the plants are most actively growing. But it is important to note that weather can also influence the effectiveness of the herbicide treatments.

Early application of herbicide treatments for dandelion control in the spring allows better control of weeds, less moisture and nutrient loss due to weeds, less competition for the crop, and allows better crop establishment and better crop yield.

Both dandelion biomass measurements and visual assessments of herbicide effects on three different sizes of dandelion support the conclusion that early herbicide application resulted in significantly better control of dandelion than later applications. Based on visual assessments, the herbicide applications were most effective on small dandelions. Also, the herbicide treatments applied at the pre-flowering stage resulted in the least amount of dandelion biomass in the fall. Among all herbicide applications, the treatment with high rate of glyphosate (900 g ai/ha) and 2, 4-D (1120 g ai/ha) combination provided the best control.

Finally, the herbicide treatments resulted in increased crop yields. The highest crop yields were harvested from the plots treated with herbicides at the pre-flowering stage of dandelion, while the lowest yields were harvested from those treated at the post-flowering stage. All treatments applied at the pre-flowering stage resulted in significantly better crop yields than treatments either at the flowering or post-flowering stages. All herbicide treatments, except the low rate of glyphosate, resulted in higher yields than the untreated check plots.

It is important to apply herbicide treatments as early as the pre-flowering stage in order to get the best results for dandelion control and higher crop yield. If a herbicide application is applied early, it seems any of the seven treatments would provide significant control of weeds and increased crop yield in the fall.

APPENDIX B. LIGHT TILLAGE EFFECTS ON WEED POPULATIONS, LIGHT FRACTION ORGANIC CARBON AND NUTRIENTS OF THE SOIL IN A LONG-TERM NO-TILL FIELD IN SOUTH-CENTRAL SASKATCHEWAN

Introduction

Dandelion infestations often result from the introduction of reduced tillage practices. The purpose of this experiment was to see the extent to which re-introduction of soil tillage for control of a perennial weed such as dandelion after long-term, no-till practices will affect weed infestation and selected surface soil properties in the field. The following research was conducted in order to determine the influence of light tillage (spring and fall) with a cultivator (sweeps) on the weed population, surface soil organic matter (thatch carbon, light fraction organic carbon), and nutrient supply in a ten-year, no-till field.

Site description

This experimental project was carried out on a farm at Central Butte in south-central Saskatchewan. This area is in the Brown soil zone, and the soil at the site is an Orthic Brown Chernozem of loam texture. The soil-climatic condition and crop rotation at the site are very similar to those of Mongolia with a semi-arid climate and brown, low organic matter soils. This large experimental plot is a long-term, no-till and tillage fallow landscape comparison. Jowkin and Schoenau (1998) described the environment and management practices in 1998. From 1993 to 2000, a wheat-fallow rotation using No-tillage practices was carried out on the no-till portion of the landscape. In 2001, canola was grown, followed by a fallow year in 2002. As noted elsewhere in the thesis, many no-till systems experience problems with infestations of dandelion, foxtail barley, and Canada thistle. Glyphosate was applied at 900 g ai/ha in the fall of 2002 in an attempt to control weed problems.

The rotation for the study years 2003-2005 was Hard Red Spring (HRS) Wheat (Var. Barrie) in 2003, summer fallow in 2004, and HRS wheat again in 2005. Seeding was done by direct seeding practices with a John Deere air seeder with 30 cm row spacing and 40 cm sweeps followed by harrows. Broadleaf weed control in the crop was accomplished with 2,4D herbicide, which is one of the most commonly used herbicides in Mongolia. During the fallow phase, glyphosate or glyphosate plus dicamba were applied.

<u>Experimental design</u>

The plots were set up to compare the impact of implementation of a light-tillage treatment with continued no-till treatment on weed population and surface soil properties in a long-term, no-till wheat-fallow rotation field. Plots were arranged in a completely randomized design with four replicates. Plot size was 5m by 10m. The main variable was implementation of ligh- tillage treatment compared with no-till treatment.

In the *tillage trial*, tillage treatments were applied in April and October with a chisel plow (5m) and with 30cm spacing and 40 cm sweeps without harrows.

Figure. 43. The implement that was used for the tillage treatments.

Figure. 44. Research plots with imposed light-tillage and continued no-till treatment

The imposed tillage treatments were applied in both the crop year (2003) and in the summer fallow year (2004) while the continued no-till treatment was sprayed with glyphosate and dicamba.

<u>Data collected</u>

Weed counts were taken in the spring before treatments in each of 2003, 2004, and 2005. Then, weed counts were repeated 2-3 weeks after the tillage treatments. Weed counts were done using a one meter square frame. Two quadrats each were counted in each treatment. Locations of the quadrats were determined randomly by throwing the quadrat. The dandelion counts were conducted three times during the year—prior to the treatment, before in-crop herbicide, and in the fall. Soil samples were taken after imposing the tillage treatments but before seeding in early May. Crop (wheat) yield was measured during the crop years 2003 and 2005 using one meter square frames. Also, two random quadrats each were sampled from each treatment.

Soil core samples (4 from each treatment) were taken from each plot using 15x10cm PVC cores. Cores (0-10cm) were removed intact from field; the visible surface thatch was removed, dried, and weighed. Soils were dried, ground, and analyzed for Light Fraction Organic Carbon using a Leco automated carbon analyzer (Wang and Anderson, 1997). The mass of carbon in light fraction (LFOC) was calculated. The bio-available NO_3, and P supply rates in the soil samples were measured using plant root simulator (PRS^{tm}) probes (Qian and Schoenau, 2002) in spring 2004 and spring 2005. Extractable nitrate, phosphate, and potassium contents were measured in spring 2003 and 2005.

Statistical analysis

The experiment was set up as a completely randomized design. Soil data were analyzed using Analysis of Variance (ANOVA) with least significant difference (LSD) at $\alpha=0.05$.

RESULTS AND DISCUSSION

Tillage effect on the weed population

As farmers introduce reduced tillage practices such as no-till, they start to encounter new problems including new weed infestations. One of the common concerns of introducing no-till practices is dandelion infestation in fields. As noted elsewhere in this thesis, increased dandelion populations result from reduced tillage farming practices in both Mongolia and Saskatchewan; therefore, one of the objectives of this experiment was to observe the effect of re-introducing light tillage on weed infestation on a long-term, no-till plot in the semi-arid Brown soil zone region of Southern Saskatchewan.

This experiment was carried out on a well-managed farm where there were not many weeds in the field. There were very few dandelions in the field. Most of the weeds in the experimental plots were kochia (*Kochia scoparia*), foxtail barley (*Horbeum jubatum*), and volunteer canola (*Brassica napus*). The average weed population per square meter was 27 weeds in the spring of 2003 prior to the first tillage treatment. The no-till control plots were treated with normal no-till practices—pre-seeding burn off herbicide treatment followed by seeding. Twenty days after the light tillage treatment or herbicide burn off, average weed populations were reduced to 0.5 weeds per square meter on lightly tilled plots, and 5.3 on continued no-till plots. In the fall, there were no weeds in either the tillage or no tillage plots.

Due to the limited size of the data set, no statistical analyses were done on the weed counts from this experiment. However, observations indicate that light tillage after a long period of no-till did reduce the number of weeds in the plots compared to no-till plots.

Tillage effect on soil organic carbon (SOC)

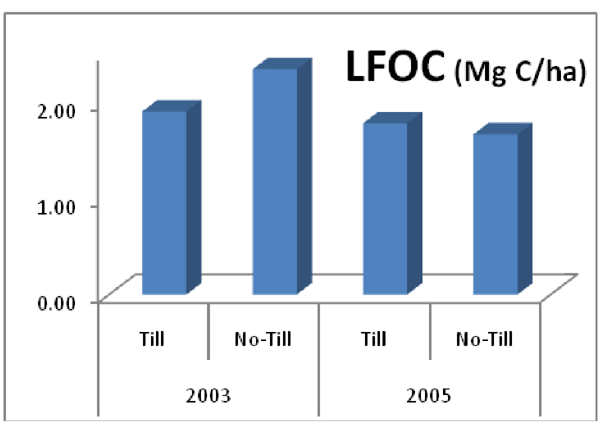

Figure 45. Light tillage effect on the LFOC content of the soil of a long term no-till field at Central Butte, SK.

Soil carbon is the most important soil property that affects soil productivity and is an important reservoir of carbon which is stored in different forms. This study examined the effect of the re-introduction of light tillage on the light fraction of the soil carbon (LFOC) of the long-term, no-till field (Figure 45). The LFOC is recently derived soil organic carbon originating from decomposition of recently produced crop residue (Baan, 2007). The LFOC fraction was selected for measurement since it is a dynamic fraction of soil carbon that is most sensitive to changes in soil management over a short time period.

Re-introducing light tillage did not have any significant ($p<0.05$) effect on the Light Fraction Organic Carbon (LFOC) amount compared to continued no-till treatment. However, there were some differences between the first sampling date (spring 2003) and the last sampling date (spring 2005) of LFOC of the soil, with lower content of LFOC in 2005 explained by the preceding 2004 fallow period in which decomposition takes place but no new crop residues are added. This agrees with work by Baan (2007) who found that imposing a cycle of tillage did not significantly reduce LFOC or TOC in similar prairie soils.

The LFOC is the most sensitive soil property in response to soil management practices such as tillage systems (Wu et al., 2006). In this experiment, light tillage treatment for two years did not significantly affect the LFOC of the soil in relation to the continued no-till treatments. Soil organic carbon is important for soil aggregation, nutrient, and soil water holding capacity—ultimately the main factors of soil productivity. Therefore, a single-tillage operation that is introduced to control weeds on a long-term conservation (no-till) managed field is not expected to result in a measurable decline in soil organic carbon through accelerated decomposition. However, it is also important to recognize that on a field scale, the removal of surface residue by tillage could result in reductions in soil organic carbon content if wind and water erosion were to occur, which was not the case in the plot study.

Lack of significant differences in soil carbon following light tillage on the no-till field is related to the fact that it takes a few years to produce significant differences in the soil properties, even LFOC (King, 2007). Perhaps, one light-tillage a year in a two-year period is not enough to make a significant difference in soil properties such as LFOC. Baan, et al., (2009) also suggested that one cycle of tillage is not enough to make an impact on soil properties.

Tillage effect on soil nutrients

Many soil nutrients can be affected by soil tillage. However, reintroduction of light tillage to a long-term, no-till field during this experimental period (2003-2005) did not result in a significant difference in supply rates of available phosphate and nitrate (Figures 46 and 47), or in amounts of extractable NO_3, K and P (data not shown) in comparison to the continuous no-till practices.

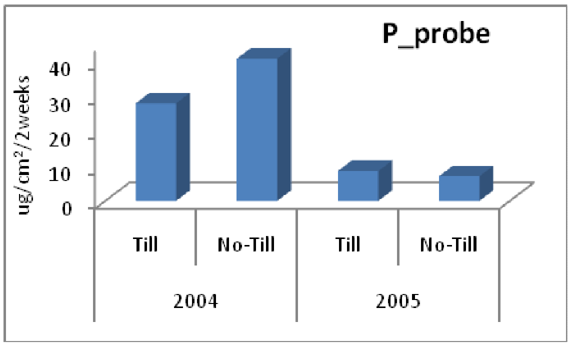

Figure 46. Light tillage effect on the soil available phosphorus (P) supply rate (ug/cm^2/2wks) at Central Butte, SK.

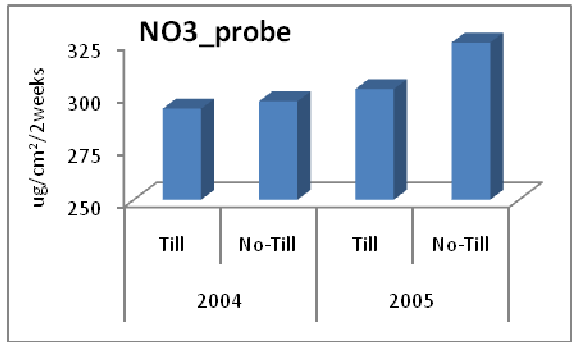

Figure 47. Light tillage effect on the soil available nitrate (NO_3) supply rate (ug/cm^2/2weeks) at Central Butte, SK.

Although the light tillage treatment did not affect soil properties significantly ($p<0.05$), there was a trend towards reduced supply rate of some soil nutrient ions. Both available phosphorus (P) and nitrate (NO_3) supply rate in 2004 were slightly less in plots treated with tillage than no-till. It could be due to tillage drying the soil that would reduce nutrient mobility, and tillage will incorporate straw that can result in microbial immobilization.

Tillage Effect on Crop Yield

Crop (Hard Red Spring Wheat) yield data were collected from the 2003 crop season. Prior to 2003, this field had been managed under no-till practices for over 10 years. Since 2003 was the first year, there was only one tillage

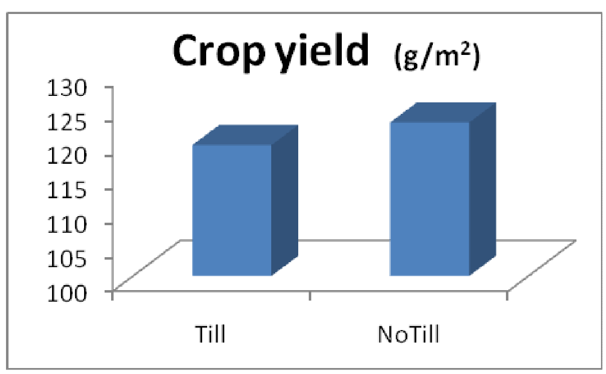

Figure 48. Light tillage effect on crop yield (g/m^2) at Central Butte, SK in 2003.

treatment that had been applied prior to the seeding.

One pass of light tillage did not result in any significant difference in wheat yield compared to the continued no-tillage treatments in 2003 (Figure. 48). The lack of a significant difference in the crop yield between light tillage and no-tillage treatments is consistent with lack of significant effects on soil carbon and available nutrients. These results also agree with the findings of Baan (2007).

Conclusion

In general, re-introduction of light tillage for two years does not appear to have a large influence on weed populations, soil properties, and crop yield on these and similar soils. It is important to note that the tillage implement (chisel plow with sweeps) was of the type that creates relatively little soil mixing and residue incorporation compared to other more severe operations like tandem disking or moldboard ploughing. Therefore, the effect of re-introduction of tillage will depend on the tillage implement and the frequency of operations conducted. As well, this was a small plot study where the effects of erosion by wind and water and tillage that may occur on a field scale would not be observed.

The results of this study provide information that would be of value to extend to Mongolian and Saskatchewan farmers, especially those who may be concerned about loss of accrued benefits from no-till (soil organic matter and fertility improvements) if they had to till the soil for some reason, such as to control a problem weed. Any technology transfer plan to introduce new technology and have it continue to be successfully utilized over time must include provision for updates and contingency to address new issues as they arise. Recognizing and anticipating new challenges is important in making farmers realize they will not be abandoned.

APPENDIX C. FARMER SURVEY

Date: Location:

Part A: Farmer Needs Assessment **Survey: Activity 320**

The purpose of this survey is to learn more about what you and your farm community need in terms of information about new technologies and farming practices. We are also interested in learning about the challenges you face, and the concerns you have, with respect to conservation farming practices. We will be grateful for your efforts to provide complete and accurate responses. The information you provide will be treated as confidential. Only the research team will have access to the completed surveys, and care will be taken to preserve your anonymity. Your participation is voluntary, and if you do not wish to answer a question or questions, please do not feel obligated to respond to all of the questions. We thank you for your time and effort.

I. BACKGROUND INFORMATION OF PARTICIPANTS:

The questions below ask demographic information about you. We are collecting this information in order to identify appropriate training approaches that are tailored to the needs of people with diverse personal and economic circumstances.

Farm location:

Aimag: ______________________________

Sum: ______________________________

Age: ☐ <35 ☐ 36-45 ☐ 46-55 ☐ 56-65 ☐ >65

Gender: F M

Highest level of formal education completed:

- ❑ Elementary
- ❑ Secondary School
- ❑ Technical School
- ❑ College
- ❑ University

Area of your specialty (e.g. animal husbandry, tractor driver)

____

Annual household income:

- ❑ < 300.000 T
- ❑ 300.001 –500.000 T
- ❑ 500.001 – 700.000 T
- ❑ 700.001 – 900.000 T
- ❑ 900.001 – 1.100.000 T
- ❑ 1.100.001 – 1.300.000 T

- ❑ 1.300.001 - 1.500.000 T
- ❑ > 1.500.001

Employment:

- ❑ Full time: (12 months per year)
- ❑ Seasonal: How many months per year are you employed? ____

2. **Marital status:**
   - ❑ Single
   - ❑ Married
   - ❑ Separated or divorced
   - ❑ Widowed

3. **Number of children living at home**:
   ☐ None ☐ 1-3 ☐ 4-6 ☐ > 6

4.Number of people in the household:
☐ 1-3 ☐ 4-6 ☐ 6-8 ☐ > 8

4. **How would rate your general health**: (please circle a number)
   (with serious problem) Poor 1 2 3 4 5 Excellent (no problem)

6. **On average, how many hours per day do you contribute to domestic chores** (such as going to market, food preparation, hauling water, cooking, cleaning, child care, washing clothes)
   ☐ <1 hour ☐ 1-2 hours ☐ 3-4 hours ☐ 5-6 hours ☐ > 6 hours

7. **How many years are you employed in agriculture**?
   ☐ <2 years ☐ 3-5 years ☐ 6-8 years ☐ 9-10 years ☐ >11 years

8. What is your role or job description in your farming enterprise? (e.g. farm manager, accountant)
I am ______________________

Specific responsibilities:– list FIVE main responsibilities (e.g. manage the farm, herd sheep, hire employees, set up salaries, milk cows, weeding, seeding, etc.) you have in your current employment.

1. ____________________________
2. ____________________________
3. ____________________________
4. ____________________________
5. _______________________________

FARM ENTERPRISE INFORMATION

Economic diversification of your farm enterprises (please, check every kind of diversification that you pursue on your farm.)

9. Livestock (What kinds of livestock?)

- ❑ Sheep number of head of sheep _______
- ❑ Goats number of head of goats _______
- ❑ Camels number of head of camels _______
- ❑ Horses number of head of horses _______
- ❑ Cattle number of head of cattle _______
- ❑ Yaks number of head of yaks _______

10. Field crops and summer fallow

- ❑ Wheat number of ha _______
- ❑ Barley number of ha _______
- ❑ Canola number of ha _______
- ❑ Other number of ha _______ Please identify by name: ______
- ❑ Summer fallow number of ha _______
- ❑ Total number of ha ___________

11. Vegetables (What kinds of vegetables ?)

- ❑ Potato number of ha _______
- ❑ Carrots number of ha _______
- ❑ Cabbage number of ha _______
- ❑ Turnip number of ha _______
- ❑ Other ____________number of ha _______

12. Do you make hay?

- ❑ No
- ❑ Yes

If yes, is it from:

Natural pasture grass number of ha _______

Hay or forage crop that you grew number of ha _______

13. Other economic activity (Do you do any income/business besides farming?)

- ❑ No
- ❑ Yes, Please describe:

____

14. Land tenure: (Do you own or rent farmland?)

- ❑ Own number of ha _______
- ❑ Rent number of ha _______
- ❑ Other number of ha _______ Please explain:___________________

15. What is your typical or standard crop rotation?

____

16. How would you describe your farm operation in terms of main activities /commodities produced?: (eg. beef production, dairy production, wheat production)

- ❑ Wheat production
- ❑ Other crops (except wheat)
- ❑ Meat production
- ❑ Dairy production
- ❑ Wool and cashmere production
- ❑ Potato production
- ❑ Special vegetable production (cabbage, carrots, etc)
- ❑ Mixed livestock and vegetable production
- ❑ Mixed livestock and grain production
- ❑ Other ________________________________

17. How many years has your farm enterprise been in operation?

☐ < 5 years ☐ 5-10 years ☐ 11-15 years ☐ >15 years

ACCESS TO TRAINING: Previous Training / Learning Opportunities:

18. In the past 2 years, how man formal learning/training opportunities have you participated in?

☐ 0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ > 10

19. Who conducted these training programs?

- ❑ Mongolian State University of Agriculture
- ❑ National Agriculture Extension Centre
- ❑ Private companies ________________
- ❑ NGOs _____________________
- ❑ International projects __________________
- ❑ Aid organizations _________________
- ❑ Farmers ____________________
- ❑ Local government _____________________
- ❑ Research institutions _____________________
- ❑ Other ____

20. **What were the topics of these training opportunities**? (e.g weed control, feeding management etc)

☐ ____

☐ ____

☐ ____

21. Were the topics and information relevant and useful?

☐ No

☐ Yes

Please explain the reasons for this answer:___________________________

22. **Were there any training program(s) available, and of interest to you, but you were not able to attend sessions?**
☐ NO
☐ YES
If yes, explain:____

TRAINING PROGRAM MODELS

We would like you to think about any training or learning opportunities you have had the past 10 years, and to answer some questions about these experiences.

23. Three types of learning opportunities from which you gained the most knowledge:

- ☐ In-class training
- ☐ Field days/demonstration days
- ☐ Field or herd tours
- ☐ Hands-on activities
- ☐ TV programs
- ☐ Radio programs
- ☐ Attending conferences and seminars
- ☐ Talking to other farmers
- ☐ Observing others
- ☐ Personal meetings with experts
- ☐ Other ____
- ☐ Suggestion? ____

24. **Location(s) of these opportunities**: (check as many boxes as apply to you)

- ☐ In local area
- ☐ In Ulaanbaatar
- ☐ Within 100 kms
- ☐ More than 100 kms

25. Venue(s): (check any that apply)

- ☐ In a school classroom
- ☐ In a field or pasture
- ☐ On a farm brigade or herder's pasture land
- ☐ In a factory or private company
- ☐ Tourist or vacation site
- ☐ Farmers' or herders' home/house
- ☐ In research institutes
- ☐ Other ____

☐ Suggestion? ____

27. Duration of the program(s): (check any that apply)

☐ < 1 day ☐ 1day ☐ 2 days ☐ 3 days ☐ 4-5 days
☐ 1 week ☐ 2 weeks ☐ 3 weeks ☐ 4 weeks ☐ > 4 weeks

28. Time of the day:

☐ morning ☐ noon ☐ afternoon ☐ evening ☐ weekend

29. Methods of delivering information: (check any that apply)

- ☐ Lecture
- ☐ Interactive workshop
- ☐ Working in groups
- ☐ Conversation
- ☐ Demonstration
- ☐ Combination of lecture and demonstration
- ☐ Other ____
- ☐ Suggestion? ____

30. **What did you like the most about this/these learning opportunity**?

____

TRAINING FACILITATORS

31. How many trainers provided the learning program? (think about the last one or two programs you participated in)

☐ 1 ☐ 2 ☐ 3 ☐ more than 3

32. What gender were they?

☐ Man or ☐ Most of them were men
☐ Woman or ☐ Most of them were women

33. Do you have a preference?

☐ Yes, men Why: ________________________________
☐ Yes, women Why: ________________________________
☐ No preference

TRAINING PROGRAM MATERIALS

34. Did you receive training materials from the program?

☐ No

☐ Yes, If yes: Describe the type of training materials from checklist bellow:
- ☐ Information sheet or leaflet
- ☐ Brochure or booklet
- ☐ Textbook
- ☐ Poster
- ☐ Other ____

35. Did the training materials help you to address challenges you encountered on your farm?
- ❑ No
- ❑ Yes

If yes, how and why did it help you? _________________________________

If no, why? ____

36. **Did the training material include examples?**
- ❑ No
- ❑ Yes

If yes: Did the examples include reference to both men and women?
- ❑ No
- ❑ Yes

37. What are the most important information needs in your farming region?
- ☐ Animal husbandry
- ☐ Pasture management
- ☐ Veterinary
- ☐ Agronomy
- ☐ Conservation farming practice (e.g. minimum tillage, chemical fallow)
- ☐ Vegetable production
- ☐ Financial management
- ☐ Cooperative farms of organizations
- ☐ Other: ____

38. In what specific areas do you require additional information?

1. ____
2. ____
3. ____
4. ____

39. Have you ever paid to get any such information in the past? (paid to attend seminars, buy brochures, hire extension people to give advice, etc)
- ❑ I have not
- ❑ I have, Please describe the events or circumstances:

____

40. Under what conditions and for what kinds of information or training would you be willing to pay? (Please check any of the following that apply to you)

- ☐ Help with soil conservation and environmental management
- ☐ Help to increase production
- ☐ Information on new programs and developments in agriculture
- ☐ Help to find out what other successful farmers are doing
- ☐ Help to make decisions re changes I am considering
- ☐ Opportunities to learn from other farmers
- ☐ Help to apply new technologies or techniques properly
- ☐ other ____

41. In what areas do you think that you have knowledge that you could share with other farmers?

1. ____
2. ____
3. ____

42. **Have you had any opportunity to share your knowledge with other farmers or agrologists**?

- ❑ I have not
- ❑ I have, Please describe the events or circumstances:

____

____

43. **Would you be willing to share your knowledge with other farmers if you had an opportunity**?

- ❑ No
- ❑ Yes

44. Do you have any other comments about farm issues, information needs, and training opportunities that you think would be useful for this study?

____

____

____

<u>SURVEY PART B: Only for grain producers—</u>Farming enterprise description

45. What farming method(s) or technology(ies) do you use in your grain production?

- ☐ Conventional (using tillage/plough)
- ☐ Conservation tillage (with chemical fallow)
- ☐ Mixture (use both traditional tillage fallow and chemical fallow with no tillage)

- ☐ Other ____

46. Describe your summer fallow operations:

- ☐ Number of ha treated only with herbicides ____________________
- ☐ Number of ha treated by plough __________________
- ☐ Number of ha treated with heavy cultivation ________________
- ☐ Number of ha treated with both herbicides and tillage ___________

Other ____

47. Are you involved in any research, agricultural or community organizations?
(e.g. Farmers Association, Agriculture Foundation, etc)

- ❑ No
- ❑ Yes

If Yes: identify the organizations by name: ____________________________

48. What is your farm enterprise labor situation:

- ☐ Number of family members who work directly on farm operations: _______
- ☐ Number of non-family hired employees _______________
- ☐ Number of people working on your farm: _________________

49. Please describe your farm machineries and equipment:

Farm machinery	Number	Horse power or size of the largest	Manufacture year of the newest one	Purchase year of the newest one
Tractor(s)				
Sprayer(s)				
Combine(s)				

50. Do you hire any custom machinery or equipment?

- ❑ No
- ❑ Yes, Please identify by name: ______________________________

51. What are the most important farming concerns or issues that have made you consider introducing conservation tillage practices? (check as many boxes as apply to you)

- ☐ Weed problems;
- ☐ High cost of production;
- ☐ Soil erosion
- ☐ Droughts
- ☐ Chemical cost and availability;
- ☐ Less work and less labour;
- ☐ Too much time in field;
- ☐ Equipment availability;
- ☐ Other: ____

52. What are the most important concerns or issues that made you decide NOT to introduce conservation tillage practices? (check as many boxes as apply to you)

- ☐ Weed problems;
- ☐ High cost of production;
- ☐ Weather conditions;
- ☐ Cost of chemicals
- ☐ Chemical availability;
- ☐ Chemical pollution to human and environment;
- ☐ Family traditions;
- ☐ Equipment availability;
- ☐ Cost of equipment
- ☐ Other: ____

53. What do you think are the three most important advantages of or motivations for using, or considering the use of conservation farming techniques on your farm enterprise?

1. ____
2. ____
3. ____

54. What are the three most important disadvantages or challenges with respect to adopting conservation farming techniques for your farm enterprise?

1. ____
2. ____
3. ____

55. What were the most important influences or sources of information that have made you consider adoption of this system? (check as many boxes as apply to you)

- ❑ Technical information supplied by extension personnel;
- ❑ Information supplied by personnel from agribusiness firms;
- ❑ Regulations affecting environmental impacts of farming;
- ❑ Educational opportunities through short training programs;
- ❑ Information via radio or TV
- ❑ Newspaper or magazines
- ❑ Farmers' networking (informal contacts with other producers);
- ❑ Government subsidies;

- ❑ Other ____

56. What do you think are the most significant advantages/benefits of conservation farming technologies (for farmers)? (check any that apply)

- ☐ Agronomic
- ☐ Economic
- ☐ Environmental
- ☐ Social
- ☐ Other: ____

57. What are the most important factors that have made you think about changing your tillage practices from conventional to conservation technologies? (check as many boxes as apply to you)

- ☐ Extension communications/training opportunities
- ☐ Weather conditions (drought, etc)
- ☐ Economic situation
- ☐ Neighbors (who have tried conservation tillage techniques)
- ☐ Government programs
- ☐ Current yield situation
- ☐ Agribusiness promotion of new technologies
- ☐ Availability of loans to purchase chemicals or equipments
- ☐ Other: ____

58. Have you implemented any conservation practices to protect the environment?

- ☐ Permanent windbreaks or field shelters
- ☐ Strip-cropping
- ☐ Terraces
- ☐ Contour cultivation (cross slope tillage and planting)
- ☐ Snow trapping
- ☐ Adding forage/green manure to crop rotation
- ☐ Avoiding certain chemicals (herbicides)
- ☐ Reduced/Minimum tillage
- ☐ Other: ____

59. If you use conservation tillage practices (including chemical fallow):

In what year did you first try these techniques (start using chemical fallow, etc)?

____

* (If you have never used conservation tillage practices on your farm, please skip to question # 63)

60. What was the economic situation of your farm when the decision was made to try conservation tillage?

- ☐ Quite good
- ☐ Medium/So so
- ☐ Poor (i.e. low income/profit)
- ☐ Quite poor with high financial stress (in terms of debt load and/or cash flow)
- ☐ Comment: ____

61. What was the recent environmental situation when the decision was made to try conservation tillage?

- ☐ Dry with poor crop
- ☐ Normal year
- ☐ Above average rainfall with fairly good crop
- ☐ Comment: ____

62. Please describe the social and economic situations on your farm at the time you decided to try conservation farming techniques. (Check any that apply).

- ☐ Labor situation changed due to retirement and/or children leaving the farm (for school, work or marriage)
- ☐ Son (or daughter) returned to the farm after studies or working off the farm
- ☐ Family financial needs rose making it important to find ways to increase farm income
- ☐ Amount of the cultivated land was expanded
- ☐ Had opportunities to meet other farmers to share information re conservation farming practices
- ☐ Comment: ____

63. Are weeds a big problem with your current farming system?

- ☐ Yes
- ☐ No

64. Which of the following methods do you use to control weeds:

- ❑ Tillage;
- ❑ Chemicals;
- ❑ Tillage + Chemicals;
- ❑ Don't use anything specifically for weeds, but rely on other operations like seeding to control them.
- ❑ Crop rotation;
- ❑ Other: ____

65. Have you noticed any changes in weed populations/conditions on your farm land in recent years?

- ☐ No
- ☐ Yes, Explain: ____

66. Do you associate these changes with the introduction of conservation tillage practices? (skip if it is not applicable to you)

- ☐ No
- ☐ Yes

67. In your own words, please describe how you came to adopt conservation tillage technologies? (skip if it is not applicable to you)

____

____

____

68. What do you consider to be the main problems or barriers to adoption of conservation tillage practices? (e.g. cost of equipment, lack of knowledge, lack of finance, etc)

____

____

69. What do you see as main challenges to the survival of your farming operation now and in the future?

____

____

70. What are your perceptions of sustainable agriculture?

____

____

Do you have any other comments that you think are important in terms of conservation tillage techniques and adoption of this technology by farmers?

____

____

End of the survey. Thank you for providing us with this important information.

APPENDIX D. EXTENSION AGENT SURVEY

Date: Location:

Age: ☐ <36 ☐ 36-45 ☐ 46-55 ☐ 56-65 ☐ >65

Gender: F M

Highest level of formal education completed:

- ❑ Elementary
- ❑ Secondary School
- ❑ Technical School
- ❑ College
- ❑ University

Employment:

- ❑ Full time: (12 months per year)
- ❑ Seasonal: How many months per year are you employed? ____

How many years are you employed in agriculture?

☐ <3 years ☐ 3-6 years ☐ 6-10 years ☐ >1O years

Have you heard about minimum tillage technology?

- ❑ Yes
- ❑ No

If yes, where did you hear from?

- ☐ Mongolian State University of Agriculture
- ☐ Internet
- ☐ International projects
- ☐ NAEC/MoFA
- ☐ Research institutions
- ☐ Other

Have you received any inquiries on minimum tillage? (Yes/No)

- ☐ weed control
- ☐ soil protection
- ☐ equipment/machinery
- ☐ chemical usage
- ☐ others

What do you think are the three most important benefits of conservation tillage farming practices?

1. ____
2. ____

3. ____

What do you think are the three main disadvantages of conservation tillage farming practices?

1. ____
2. ____
3. ____

What are main factors that influence farmers' decision making? (check as many boxes as apply to you)

- ☐ Financial issues
- ☐ Soil erosion
- ☐ Weather condition
- ☐ Chemical cost and availability;
- ☐ Employment;
- ☐ More time in the field;
- ☐ Equipment availability;
- ☐ Other: ____

What are three most main information sources for farmers to introduce new technology?

- ❑ Technical information supplied by extension personnel;
- ❑ Information supplied by personnel from agribusiness firms;
- ❑ Information on environmental impacts of farming;
- ❑ Educational opportunities through short training programs;
- ❑ Information via radio or TV – media;
- ❑ Newspaper or magazines;
- ❑ Farmers' networking (informal communication with other producers);
- ❑ International projects;
- ❑ Government programs;
- ❑ Other ____

What do you think are the most significant advantages/benefits of conservation farming technologies? (check any that apply)

- ☐ Agronomic
- ☐ Economic
- ☐ Environmental
- ☐ Social
- ☐ Other: ____

What are the main barriers for adoption of conservation tillage practices?

- ☐ Weather conditions (drought, etc)
- ☐ Economic situation
- ☐ Neighbors farmers
- ☐ Government programs

- ☐ Current yield situation
- ☐ Agribusiness and agri-organizations
- ☐ Availability chemicals
- ☐ Availability of equipment and price
- ☐ International projects
- ☐ Weed problems
- ☐ Soil erosion
- ☐ Time in the field
- ☐ Farmers' knowledge and education
- ☐ Other: ____

Have you organized any training on conservation tillage practices?

- ☐ Yes
- ☐ No

In your opinion what are the main obstacles/barriers that are stopping farmers to adopt conservation tillage practices?

____
____
____

What needs to be done in order to increase number of farmers adopt conservation tillage practices?

____
____
____

What kind of extension activities will more effective in introducing new technologies?

____
____

Do you have any other comments that you think are important in terms of conservation tillage techniques and adoption of this technology by farmers?

____
____

End of the survey. Thank you for providing us with this important information.