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IN THE FIELD

Farmer perspectives on cropping systems diversification in northwestern Minnesota

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Abstract. It is important to understand factors that influence management decisions that determine the level of diversification within cropping systems. Because of the wide variety of cropping systems within a region, our study focused on a single county (Marshall) in northwestern Minnesota. This county was selected because it is in an area where farmers were reevaluating their cropping practices during the 1990s in response to severe plant disease outbreaks and economic stresses. A survey (n = 153) and follow-up interviews (n = 9) of representative farmers in Marshall County showed that they were approaching their cropping systems management decisions under these conditions through a dominant conceptual framework (scientific) and two secondary conceptual frameworks (institutional and spiritual), which we termed "mental causal models." The study illustrates the ways farmers define and make decisions affecting their cropping systems diversity under conditions of agronomic and economic adversity. It also challenges agricultural professionals to expand their thinking about educational strategies that are sensitive to the varied perspectives of farmers beyond just the scientific mental causal model.

Key words: Crop diversity, Crop management, Decision-making, Mental causal model, Plant disease

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Introduction

Diversification within cropping systems is defined by the number of crop species (inter-specific diversity), as well as the genetic variability within those species (intra-specific diversity) (CAST, 1999). Increased specialization of farms over the past several decades has contributed to a decline in both inter- and intra-specific diversity (Allmaras et al., 1994; Cruse and Dinnes, 1995; Matson et al., 1997; DeVore, 1998; CAST, 1999; Tuxill, 1999). Agriculturists are concerned that such low levels of diversity within cropping systems are adversely affecting their ecological integrity, resulting in increased vulnerability to pests, soil degradation and, more reliance on pesticide and inorganic fertilizer inputs (Matson et al., 1997; CAST, 1999).

It is a farmer's decisions that determine the types of crops grown and the spatial configuration of those crops within a given cropping system. Thus it is important to understand the factors that affect such decisions. Past studies have considered cropping systems diversity from the perspective of documenting declines in diversity, as well as evaluating biological and agronomic risks associated with reduced diversity (Allmaras et al., 1994; Matson et al., 1997). Prior research has usually examined specific practices, such as rotations and multiple cropping, as strategies that enhance diversity (Cruse and Dines, 1995; Matson et al., 1997). Our study is somewhat unique in its consideration of crop disease as an element for assessing farmers' decision making as it affects cropping systems diversity.

For the purposes of this study, we use the terms "diversity" or "diversification" to refer to both temporal and spatial variability among crop species within a cropping system. Temporal diversity is affected by the crop rotations employed, which is a topic that agronomists have long recognized as an important management consideration (Karlen et al., 1994). Spatial diversity is defined by variation in species and genotypes within a species across the farm landscape at any point in time. Spatial diversity can be enhanced by varying the number of species among fields, by growing more than one crop in each field, and by adding shelterbelts or other non-crop vegetative species along field margins and across a farm landscape (Cruse and Dinnes, 1995).

Research that examines decisions affecting cropping systems diversification is somewhat limited (Bellon, 1996; Cutforth, 1999). Past studies have attempted to identify associations between the extent of crop diversity on farms and the properties and incomes of those farms (Pope and Prescott, 1980; Anosike and Coughenor, 1990; Ibery, 1991; Lyson and Welsh, 1993). Studies have also considered the complexity of factors influencing farmers' decisions bearing on cropping systems diversity (Halliday, 1989; Battershill and Gilg, 1997). For example, Halliday (1989) conducted a survey of 103 British dairy farmers and found that most of their rationales for reducing diversity on their farms were related to lack of time, family circumstances, and personal preferences rather than economics.

Some researchers have noted the importance of mental paradigms through which farmers make cropping systems management decisions (Beus and Dunlap, 1990, 1991, 1994; Allen and Bernhardt, 1995; Petrzelka et al., 1996; Raedeke and Rickoon, 1997; Chiappe and Flora, 1998; Abaidoo and Dickinson, 2002). Beus and Dunlap (1990, 1991, 1994) maintained that farmers make decisions from either an "alternative" or "conventional" paradigm. They further developed a scale, designated the "Alternative/Conventional Agricultural Paradigm" (ACAP), which described six categories by which alternative and conventional farmers differed. They also developed an attitudinal scale to evaluate the association between a farmer's paradigm and that person's management practices (Beus and Dunlap, 1991, 1994). In subsequent studies, the ACAP was used to predict agricultural behavior and an association was found between specific attitudes and practices (Allen and Bernhardt, 1995; Petrzelka et al., 1996). A study comparing the environmental views of farmers in Saskatchewan showed that the majority of farmers from both the conventional and alternative paradigm groupings held similar views including the need to "dominate nature," which challenges one of the categories of distinction in Beus and Dunlap's ACAP (1990) (Abaidoo and Dickinson, 2002). Chiappe and Flora (1998) showed that the sustainable paradigm itself is gendered in that women in sustainable agriculture have strong spiritual motivations that support utilizing sustainable agricultural practices. Such studies draw attention to the importance of examining paradigms when seeking to understand farmer decision-making.

Jackson-Smith and Buttel (1998) concluded that the connection between farmer paradigm and practice was weak and that farmers could not be characterized by merely two paradigms. Similar critiques of the ACAP have argued that by simply examining the paradigmatic orientations of two groups of farmers, the diversity of perspectives in the ways that farms are actually managed was ignored (Raedeke and Rickoon 1997; Duram 1998). Raedeke and Rickoon (1997) noted that examining these two paradigms ignored the context in which such attitudes were formed, thereby not fully exploring the decision making process. Thus we decided that our study needed to include both quantitative and qualitative elements to assess decision-making as it relates to cropping systems diversification and management.

Cooperative Extension, historically a key information source for farmers, has also explored the role of paradigms and perceptions in information transfer and farmer decision-making in the United States (Jimmerson, 1989; Patterson, 1993; Alston and Reding, 1998). Jimmerson (1989) theorized that individuals make decisions under either the dominant social paradigm or an alternative environmental paradigm. He suggested that Extension educators tend to promote information that enforces the values and beliefs of the dominant paradigm. Alston and Reding (1998) found that farmers' perceptions of pest problems, among other factors, impacted their interpretation and the use of Extension-based integrated pest management information.

Miller (1984) defined the term "paradigm" as a "coherent set of beliefs and values that provide a frame of reference within which actions and events are interpreted and made meaningful." He described the concept of paradigm as not only being about one's beliefs and values, but also one's approach to thinking and reasoning. Miller further stated that it is "crucial that individuals attain greater insight into the influence of paradigms on their own and other's behavior." Within this paper, we chose to use the term "mental causal model" instead of "paradigm," but intend consistency with the meaning described by Miller. The term "paradigm" is cliché in contemporary culture. "Mental causal model" comes from the political science literature (Sabatier and Jenkins-Smith, 1993) and represents an individual's belief system and their perceptions of causal relationships. It acknowledges that relational, cultural, and socio-economic forces exist and that they influence how individuals act. We feel that by using the term "mental causal model" we help avoid mixed meanings while emphasizing the importance of thinking and reasoning in decision-making.

The goal of our study was to evaluate how farmers in northwestern Minnesota made management decisions within the context of cropping systems diversification. One interest was to determine how farmers' decisions were associated with mental causal models, as well as other influences that go beyond the factor of economics. We used a problem framing approach in which a crop disease epidemic and the farmers' responses to it served to focus both our survey instrument and our interviews with the farmers (Miller, 1984; Swaffield, 1998). The disease, termed "Fusarium Head Blight" or "Scab" (*Fusarium graminearum*), became a widespread issue in 1992 when it caused high losses in spring wheat and barley crops of the region. Between 1992 and 1998 scab was estimated to have been responsible for a $4.2 billion loss in income for small grains producers (DeVore, 1998). By 1997, one-fifth of the farmers in the Red River Valley had left farming (DeVore, 1998). In addition to higher incidences of crop disease, crop prices in the region also declined during the 1990s to levels lower than they had been in a decade. Furthermore the Federal Agriculture Improvement and Reform Act, which was passed by the US Congress in 1996, initiated a seven-year phase out of government subsidies for important commodities in the region such as wheat (Sternberg, 1999) and created additional uncertainties. The area also continued to experience a declining and aging population during the period (US Census Bureau, 2000).

Because of such problems and issues, many farmers in the region were making changes in the management of their cropping systems, and especially in ways that affected the diversity. In light of this, we saw a good opportunity to research the factors that affect such management decisions.

Methods

Our research was conducted in two phases – a survey of approximately half of the farms within Marshall County, Minnesota, followed by interviews with the managers of nine farms selected from the survey population. The survey evaluated farmers' attitudes about crop diversification in the context of the disease epidemics during the 1990s. The interviews enabled further assessment of the decisions that the farmers were making to alter their cropping systems, as well as the factors behind those decisions.

Agriculture is the principal industry in Marshall County, and it typically ranks second in the state for wheat production (USDA, 1997). Approximately 10,000 residents lived in the county at the time of our study. The county covers 1,772 square miles (US Census, 2000) and contains no metropolitan areas. The average farm size at the time was 677 acres, compared to a state average of 354 acres (USDA, 1997). A 1997 agricultural census of Marshall County showed that the number of farms with full-time operators had decreased from 70% in 1992 to 60% in 1997, reflecting a trend towards greater reliance on off-farm employment that was also occurring in other regions of the state and nation (USDA, 1997). The median household income in the county was $30,975 (US Census, 2000).

Description of Marshall County

Within its 97 km east-west breadth, Marshall County contains a wide variety of soil types. The western half of the county was formerly the bed of Glacial Lake Agassiz and contains soils with high proportions of silt and clay. The eastern portion of the county consists primarily of glacial lakeshore deposits of sand, gravel, and peat. The western part of the county produces sugarbeets (*Beta vulgaris* L.), potatoes (*Solanum tuberosum* L.), sunflowers (*Helianthus annuus* L.) and dry beans (*Phaselous vulgaris* L.). The eastern side favors livestock and grass seed, alfalfa (*Medicago sativa* L.), canola (*Brassicus campestris* L.) and flax (*Linum usitatissimum* L.) production. Throughout the county, spring wheat and spring barley have been mainstays within crop rotations for decades. During the 1990s the area sown to soybean (*Glycine max* L.) quadrupled and corn (*Zea mays* L.) acreage doubled (USDA, 1997).

Climate and water drainage are important factors affecting the kinds of cropping systems in Marshall County. The short growing season and severe winters limit the kinds of crops that can be grown and the cultivars within each species. Beginning in 1992, higher than usual precipitation contributed to a greater incidence of crop disease. By the early 1990s, conservation tillage, which consists of practices to retard soil erosion by favoring maintenance of surface vegetative residues from the previous year's crop, had become common in the area. While the association between surface residues and disease were still being investigated (McMullen et al., 1997), many farmers had

Table 1. Characteristics of the study survey and interview farms, as well as of the farms reported in the Marshall County Agricultural Census of 1997.

Farmer/farm attributes	Survey farms (N = 158)	Interviewed farmers (N = 9)	1997 Agricultural Census of Marshall County
Average age of operator (years)	50	49	52
Sex of primary farm operator (percent)	100	100	100
Male	96	82	94
Female	4	18	6
Tenure as farm operator (years)	26	25	22
Level of education			
High school	82	100	Not available
College or university	52	100	Not available
Farmers working off-farm, part-time (percent)	63	33	54
Spouses working off-farm, part-time (percent)	65	65	Not available
Average farm land area – acres (hectares)	1,156 (468)	1,790 (725)	667 (270)
Range of farm land areas – acres (hectares)	11 – 8,000 (4 – 3,240)	500 – 5,200 (203 – 2,025)	Not available

discontinued or limited their use of conservation tillage assuming that it would help reduce their disease problems.

Our survey was developed to provide a countywide perspective and a context for the subsequent in-person interviews. The survey was mailed in June 1998 to a random sample of 450 farm owner/operators in Marshall County. This number represented approximately one-half of the total number of farms in the county at that time. Respondents were identified with the cooperation of the USDA Natural Resource Conservation Service. The surveys were mailed following a three-step process outlined in Dillman's Total Design Method (Dillman, 1978). Two hundred twenty-eight individuals responded to the survey (51% response rate). A total of 153 of those surveys were considered acceptable for analysis. The survey respondent population was compared to the 1997 agricultural census to determine how closely it paralleled that representation of the farm population of the county (Table 1).

The three-part survey was developed using questions adapted from a number of sources. The survey was reviewed for technical accuracy by several individuals, including a plant pathologist, agronomist, sociologist, and extension educator. A draft survey was then pre-tested with five Marshall County farmers in the presence of a researcher. Questions considered to be confusing or irrelevant were eliminated or revised prior to mailing the surveys. The first part of the survey asked the farmers to characterize their experiences with crop disease (particularly scab) during the 1990s, as well as to identify ways in which they had responded to disease in managing their cropping systems. A second section measured farmers' attitudes about agriculture in general, and crop diversity in particular, and was modeled after Beus and Dunlap's (1994) instrument for assessing the relationship between farmers' attitudes and practice. The third part of the survey documented biographical attributes of the farmers as well as farm sizes. This was included because prior research has shown the importance of correlation between farm diversity and such attributes (Pope and Prescott 1980; Anosike and Cougenhour, 1990; Ibery, 1991; Cutforth, 1999). We used descriptive statistics and cross tabulations to examine farm size, types of crops, farmer ages, and other quantifiable data.[1]

The survey gave respondents an opportunity to indicate whether they would be willing to participate in follow-up interviews regarding the research topic and 69 expressed such a willingness. Nine of these farms were chosen for the in-person interviews to obtain "information rich samples" (Merriam, 1998). The farmers chosen for the interviews represented a broad range of crop diversities and cropland areas, wide geographic distribution across the county (which represented a range of soil conditions), and different ages (Table 2). All of the farms had experienced scab disease during the 1990s, which meant that this could be a common point of reference during our interviews.

The interviews with the owner/operators were begun in the fall of 1998 and continued through the spring of 1999. The person(s) interviewed on each farm had indicated that they were the one(s) most knowledgeable about the cropping systems management decisions. On two of the farms, husband/wife teams made such decisions together. On the other farms, the man made these decisions. The interviews were conducted using a conversational approach and were designed, among other things, to document both cropping histories of the farms and the current factors influencing management decisions (with particular reference to cropping systems diversity). The interviews were conducted in two sessions, each approximately two hours in length. The first of these sessions focused on constructing a chronology of crops grown, as well as management practices and cropping systems used on the farms over time, and especially during the 1990s. How each farmer obtained agricultural information and established cropping goals for their farm were also ascertained during this session.

We had a special interest during this initial interview to identify specific cropping systems management decisions during the 1990s that could be further examined during the second interview. The second session explored how specific decisions had affected the spatial and temporal diversity of the cropping systems on the farms. The farmers were asked to explain their understanding of crop rotation, diseases, and cropping systems diversification. Through the interviews we attempted to ascertain how such understandings affected past and current management decisions, as well as how it might affect future ones.

Interviews were audio-tape recorded and later transcribed. The transcribed texts were coded for themes using a list of codes developed from pre-existing literature. Several of the interview transcripts were read to discover common topics within broader categories (Miles and Huberman, 1994). After the discovery phase, Nud*st software was used to help identify thematic associations within and across interviews.

Results and discussion

Overall characteristics of survey respondents and farms

The survey participants and interviewed farmers seemed to represent the overall county population reasonably well in terms of age and gender (Tables 1 and 2). A higher percentage of the interviewed farmers reported working on their farms full-time than was reported in the survey respondents or in the county average. The 153 farms surveyed ranged in cropland area from 11 acres (4 ha) to 8,000 acres (3,240 ha) (Table 1).

Some in Marshall County regard large amounts of cropland as a necessity for providing income for a reasonable standard of living. For example, when asked about the importance of farm size, one of the farmers we interviewed stated,

> You need 2,000 acres for survival – for a standard of living that should be comparable to what the average income is.

However, over half of the respondents had maintained their farms at about the same cropland area over the five years prior to the survey, while only 27% had increased the area on their farms. Eighteen percent reported that their cropland had declined in area over that period.

Forty-five percent of the respondents reported that they grew three or four crops in a given year, which is slightly higher than for farms in the "corn-soybean belt" of southern Minnesota and the Midwest USA (Burkhart et al., 1994). Twenty-four percent reported growing five to eight crops on their farms, while 28% grew only one or two. As a rule, larger farms reported growing a higher number of crops, which agrees with the findings of Pope and Prescott (1980) in California and Anosike and Cougenhour (1990) in Kentucky.

Survey respondent attitudes regarding disease management and diversification

Seventy-seven percent of the survey respondents reported being affected by the scab disease between 1992 and 1997. Of those, 54% indicated they had experienced a "great deal of scab" and almost a third (31%) indicated that the scab was so severe "that they might go out of business." Both groups of farmers reported that they were more likely to use crop diversification strategies, such as changing wheat and barley varieties, lengthening crop rotations, and adding more crops to their cropping systems to attempt to manage the disease.

Fifty-nine percent of the survey respondents indicated that it was important to not grow a crop species in a given field more than once every four to five years. Similarly, over half of the respondents agreed that farms should be "diversified."

Five of the survey questions assessed the respondents' perceptions of their "control" over crop diversity on their farms. The majority of farmers maintained that access to information about crop options and alternative crops was not a limitation in diversifying their cropping systems. The majority of farmers also indicated that availability of cropland did not hinder them from growing a larger number of crops.

Over half of the respondents identified climatic limitations as a principal reason for not further diversifying their cropping systems. Sixty-five percent of farmers also identified a lack of markets and limiting infrastructure/institutional factors (such as farm policies) as obstacles to increasing crop diversity on their farms. Our survey was conducted soon after the passage of the 1996 Federal Agriculture Improvement and Reform Act, and the implications of this legislation for cropping systems diversification were likely still not clear to many of the respondents.

To further examine the survey respondents' perceptions of the concept of cropping systems diversity, we asked them to choose among a series of alternative descriptors. Approximately three-fourths of the respondents agreed that higher levels of cropping system diversity was "preventing disease," "healthy," and "good stewardship." However, three-fourths of the respondents also noted that greater crop diversity meant "more work," and more than half described it as "hard." Based on these responses we conclude that the farmers at the time of our survey regarded diversified cropping systems as both ecologically and economically advantageous, but they also saw inadequate markets, uncertain government policies, unfavorable climate, and greater workload and difficulty as factors hindering further diversification. As one might expect, those farmers faced with extreme disease problems were more likely to favor crop diversification.

Interviewed farmers' disease and agroecological/ agronomic understanding

All of the farmers interviewed in our study displayed similar levels of agroecological and agronomic understanding. All believed that a high level of crop species diversity within cropping systems was a positive attribute. They also all demonstrated extensive knowledge of the ecological and agronomic properties of their farms. Despite these similarities, the cropping systems of these farmers were substantially different in their levels of cropping systems diversity, as indicated by the number of crops grown (Table 2).

All of the farmers interviewed agreed that crop rotation was a crucial aspect of management practice. However, prior to 1993 all but one of the farmers reported growing small grains, and particularly wheat and barley, in a monoculture (the same crop species in the same field over consecutive years) – sometimes for as many as ten or more years in a row. When asked to explain such monoculture practices, most focused on pragmatic considerations as well as concerns about profitability. A statement by William[2] was representative with respect to a rationale for practicing monoculture prior to the outbreak of the scab disease in 1993:

> . . . well it worked. Put it this way, there was nothing to say that there was any problem in doing that. And it sure made life a lot simpler.

According to another farmer, Karl, the primary "rule" for establishing a rotation plan for his cropping system was "no wheat on wheat ground" and "no wheat on barley ground." Despite this maxim, Karl further noted,

> You know, a guy knew this before [not to plant wheat on wheat]. But sometimes you've got to do what you've got to do. We're not going to start farming garbanzo beans! What do you do? Sometimes you put wheat on wheat. It used to be wheat on wheat was the best thing to grow as long as you didn't have too many years in a row.

Pete, like Karl, focused particularly on short-term productivity on his farm. Over the years he had experimented with different crops on his farm because of his concerns about short rotations involving few crops. But successive years of small grain disease and a recent change to full-time, off-farm employment had altered his approach to managing his rotations. His recent decisions became even more oriented towards concerns about profitability:

> In an "economic rotation," you want to grow as many canola and sunflowers [as possible] because it pays. And economics is coming to determine rotational plans more than agronomics. Under financial stress you see only to the end of the year, not to the end of the decade. I cheated a little bit. I planted canola and sunflowers on all my acres, kind of breaking away from a sensible rotation because it seemed to be the quickest payback.

When asked what growing disease-susceptible crops meant for him in terms of his future rotations, Pete replied:

> There were a couple things going through my head. One point is we've become a year-to-year kind of people. Don't worry about the future because next year we might not even be farming another year. So I didn't care about the next year. I just wanted to get one good year.

Although five of the interviewed farmers had enhanced their level of species diversity within their cropping systems in response to the scab disease outbreak, most indicated that if the disease pressure lessened and commodity prices improved, they would likely return to rotation practices similar to those used before the crisis. For example, Gary stated,

> If there wasn't scab, I'd probably still be doing wheat on wheat because it has been good. Even now that the farm program has changed some with "Freedom to Farm" and being able to put different crops in, if wheat was still profitable, we would still be doing it because it's easy to grow. You put it in the ground, you spray the weeds and then you watch it grow for the rest of the year until harvest. That is pretty easy.

Jake shared his experience of growing up in the area and recalled that the practice of planting wheat after wheat was common. He described his impressions of the impact that government policies had on cropping systems diversity:

> For years we've been putting wheat on wheat, you know. Because the government program was so good, you're a fool if you didn't do it. Plant "fence row to fence row" and plant wheat because if you didn't, you'd lose your wheat base and we wouldn't get the government payment. And during the 1970s and early 80s, it was very profitable for my dad and my uncles. Following the farm program and planting wheat on wheat, that's what I grew up with and that's what I've known.

Farmer perceptions of crop disease

Scab began affecting both wheat and barley crops over large areas of Marshall County during the 1993 growing season. During the 1997 season, which immediately preceded the beginning of our study, farmers had experienced yet another year of serious disease incidence and loss while reliable approaches to controlling the disease were not available. In the fall of 1997, organizations such as the Minnesota Extension Service and the Minnesota Association of Wheat Growers had published information on methods to minimize losses due to scab during the 1998 growing season. In light of such educational efforts, it is not surprising that the farmers we interviewed all displayed good understanding of the causes of scab. All understood that the disease was favored by the wet, cool climatic conditions characteristic of the 1990s, as well as by the prevalence of disease-susceptible wheat and barley varieties at the time.

All of the interviewed farmers possessed a scientifically-based understanding of the disease and its causes. However, six of the farmers had additional perceptions that influenced their explanation of its causes. We reviewed the transcripts for thematic commonalties and found that such perceptions could be grouped into three categories, which we termed "mental causal models." We designated these as "scientific," "institutional," and "spiritual" (Figure 1). Each model reflects cultural influences that affected the farmers' understandings of the disease and its "source," as well as the level of control that they had over it. We fully recognize that how these particular farmers responded to the questions during our interviews represented perceptions at *that* particular time; however, we maintain that these perceptions would stay relatively consistent over longer periods of time as well. This premise, of course, should be evaluated through further study.

The farmers whom we classed as perceiving the scab disease through a scientific mental causal model (Table 2) tended to describe the disease almost entirely in biophysical and scientific terms. Their understanding of the disease was specific and their responses to the problem were based almost entirely on technological management options. For example, Ralph attributed the outbreak of the disease to wet, cool weather conditions that stemmed from the eruption of a volcano in the Philippines in 1990 and described the conditions favoring disease:

> The wetter our season is, the more dew we get at night. You get a heavy crop out there and you can go out there at four o'clock in the afternoon and it is still wet underneath – the leaves are still wet. That wetness promotes the fungus on your leaves and causes scab.

Ralph primarily used biological and technological approaches in attempting to control scab. He increased his fertilizer rates, because he had read that nutrient-stressed plants are more susceptible to scab. He applied fungicides and used moldboard plowing to bury the residue from a previous year's crop. He also added canola to his crop rotation based on the rationale that the same weather patterns that were conducive to scab would be good for growing canola. Other than "riding out scab" he thought that his only solution would be to apply technological measures (e.g., fungicides every year) to "just cover my bases" while waiting for the development of disease-resistant varieties of wheat and barley. Ralph, as well as the other farmers within the scientific mental causal model category, identified the university and agricultural experiment station as their primary source of information for managing scab.

The farmers from the four farms that were managed within an institutional mental causal model (Table 2) tended to attribute human or governmental institutions as the "cause" of the disease and its persistence, while still acknowledging its biological/climatic basis as well. While these farmers' control responses to scab were difficult to typify, they were similar to the scientific mental causal model farmers in their emphasis on biological and technological approaches. But they also maintained that there was a strong need for institutional changes within the agricultural industry and governmental systems. For example, Eddy believed that scab was a result of government intervention that began with the "conservation compliance" provision (government-directed conservation policies) of the 1985 Federal Farm Bill legislation. He argued that the government had coerced farmers to use practices

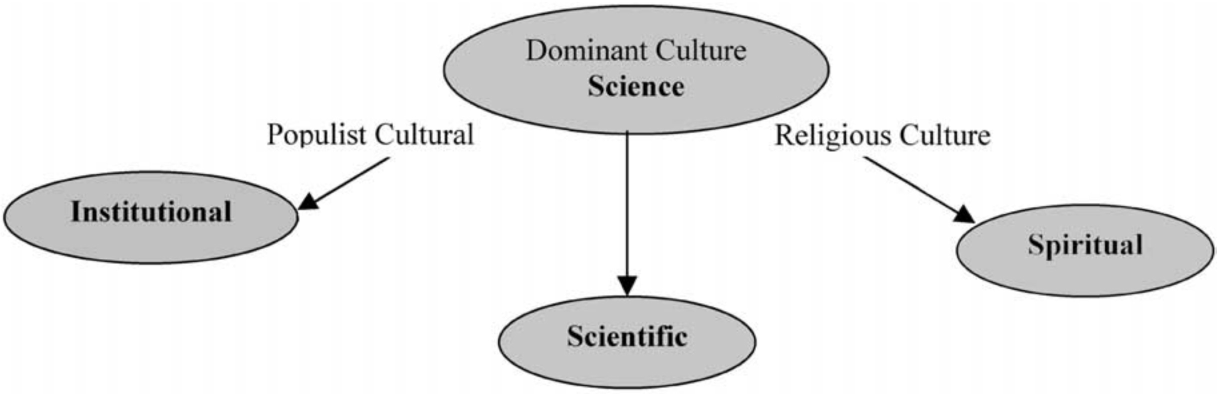

Figure 1. Mental causal model schema.

Table 2. Characteristics of interviewed farmers and their farms in Marshall County, Minnesota.

Farmer(s)[a]	Mental causal model	Operator age	Land area – acres (hectares)	Year began as farmer operator	Soil texture	No. of crops	Livestock on farm?
Josh	Scientific	58	5000 (2,025)	1965	Mixed	11	No
William	Scientific	61	3480 (1,409)	1961	Fine	6	No
Ralph/Lois	Scientific	59/59	1600 (648)	1970	Mixed	3	No
Karl	Institutional	26	2300 (932)	1996	Fine	3	No
Eddy	Institutional	49	700 (284)	1973	Mixed	8	No
Sally/Walt	Institutional	44/58	580 (235)	1958	Mixed	7	Yes
Pete	Institutional	47	500 (203)	1981	Mixed	2	Yes
Gary	Spiritual	44	1100 (446)	1975	Fine	3	No
Jake	Spiritual	35	850 (344)	1989	Fine	5	No

[a]Names have been changed to maintain confidentiality.

that were contradictory to those that the farmers knew were best:

> I guess on some of the places where you have a problem with erosion, maybe they should be farming forty-acre [fields] with shelterbelts around them, instead of farming in a wide-open section. The people that farmed constant wheat on wheat never farmed the ground right! That is where it started and, as far as I'm concerned, it is the USDA's fault. They forced you [to farm improperly] and you couldn't farm the land the way it was suppose to be [farmed].

Eddy responded to the increased incidence of scab on his farm by reducing the acreage grown to wheat and by adding flax to his rotation to eliminate growing consecutive years of small grain in the same fields. Eddy believed the best solution for the scab disease was to take legislative money allocated for scab research and instead allot it directly to farmers:

> The government . . . [keeps] spending money. They keep hiring people for research. Why? I think just get this crop burned or get it plowed down – or do something with it. I think it would be a lot simpler way to start. And then, $1.3 million for scab research, why not put the $1.3 million and raise the loan rate on the wheat that we've got. I mean, the heck with scab! Maybe people could quit raising wheat. But I think myself, I'd just as soon not see them spend the money in scab research. I'd just as soon see them put a higher loan rate in the wheat. Let us [the farmers] figure out a way to deal with scab.

Other farmers within the institutional mental causal model category attributed the scab epidemic to the government's emphasis on conservation tillage (also favored by the "conservation compliance" provision in the 1985 Farm Bill). They also felt that there had been inadequate emphasis by the universities in the past. Some farmers within this mental causal model proposed changing the Federal Crop Insurance programs so that they would be more equitable, as well as investing more in rural community infrastructures rather than research.

The two farmers categorized within the spiritual mental causal model also held a biological/climatic explanation for the scab disease. For example, Gary stated that prevalence of the disease inoculum coupled with favorable weather conditions were the primary cause:

> It's my understanding that scab will winter over in the grass and ditch banks, wherever there is another plant. So it's something you can do the best job for your field to prepare it, but if the conditions are right, the Fusarium is in the air or the spores are present, you can get hit hard as anything. Weather is to me the biggest factor, plus having the spores present for scab.

But the farmers within this category also added another level to their explanation when they attributed the disease to a broken relationship between humankind and a higher power. Gary explained that the scab outbreak was a "sign from God" in response to a lack of moral leadership. He stated,

> Scab has been around for thousands of years. But it makes you sit back and try to figure out a little bit why we're having such big degrees [of scab] in our country today. I personally believe that God can use different situations, different weather, different crop failures to get our attention.

Gary also maintained that scab might have been something brought into his life as a "trial or tribulation" that was intended to bring him closer to God. This perspective contrasts with the "spiritual" dimension that Chiappe and Flora described in their study of female farmers who reported feelings of spiritual wholeness connected to honoring and understanding nature through their agricultural work (1998). Significantly, these women did not use the spiritual as an explanation for agricultural problems or calamities. In response to the disease incidence, Gary planned to use tillage to bury crop residues, to wait for the development of improved fungicides and disease-tolerant cultivars, and to trust that he could "get a fair price" for his wheat.

Associations of mental causal models with other aspects of cropping systems management

The direct influence of mental causal models on other aspects of the farmers' approaches to cropping systems management was difficult to ascertain. However, analysis of the interviews showed that the mental causal models did appear to be associated with some of their other decisions involving crop rotations and soil management.

Farmers categorized within the scientific mental causal model cited recommendations from the university and experiment stations in deciding how to manage their rotations and tillage practices. Ecological concerns were also frequently stated as a rationale for their decisions. All of these farmers judged that the soils on their farms had improved since their forebears had farmed the land. All of the farmers with a scientific mental causal model tended to be older and managed larger farms.

Josh, who we categorized within the scientific mental causal model, had been a long-time advocate of crop rotation. However in recent years he had practiced what he described as a "survival rotation" in an effort to manage multiple crop diseases within his cropping system. Josh described the changes he had made and highlighted the disease risks he saw as *most* threatening to his cropping system:

> Well, in the past when we were doing small grains, we would have 25% of the acreage in a white mold crop [crops that are susceptible to the fungus Sclerotinia], sunflowers and dry beans, and 75% in small grains. My objective there was to have at least three years to break control of white mold. Repeat incidences with scab changed that rotation to a decreased number of years of small grains. We're [now] going to grow a white-mold subject crop every other year and that's really playing with fire too.

In making the decision to switch to small grains every other year, the application of technology, along with his prior experience, helped inform Josh's decision:

> In 1996 we got a combine with a yield monitor on it. I could see some differences then, but I wasn't paying much attention to what I was looking at. Then I really watched. I could watch the fields where wheat was not following wheat or a small grain and I could see the yield differences and I decided at that point, this is asinine [not to rotate crops].

Josh felt that the soils on his farm had improved due to the adoption of new technologies that had improved the fertility balance of the soils:

> I'll agree whole-heartedly that our fertility levels are higher and better than the native soils. My soils are balanced quite well. Quite honestly the native plant growth wasn't all that nutritious because of the unbalance in the soil. High pH, salts – there were places that didn't really grow much of anything. . . . I think we see it in the wildlife. Depending on what they eat, like any animal, they are more productive.

The farmers grouped within the institutional mental causal model discussed their rotations primarily in terms of how they could maximize profitability of their crops. Although exhibiting some of the same characteristics and knowledge as the farmers within the scientific mental causal model category, these farmers tended to draw more heavily on personal experience or the experience of relatives and peers in making decisions. The farmers within the institutional mental causal model grouping tended to regard the properties of their soils as having remained much the same over time and that improvements were a result of physical modifications (such as from drainage) rather than chemical changes (such as from use of fertilizers). Although there are no clear trends in age within this category, these farmers generally operated farms with smaller crop acreages.

Pete, a representative of the farmers within the institutional category, focused on the short-term profitability of his farm. As previously noted, Pete justified his recent decisions on the basis of short-term economic viability and applied his own statistical rationale to explain why the risks of following such short rotations were justified:

> I pushed a two-year rotation. Again, doing the math, I had the peace that I only had sunflowers twice in the past 10 years. It just so happened that those two years were consecutive.

Pete believed that the soil on his farm had changed little since his forebears farmed the land. He based this judgement on the high level of organic matter in his soil:

> I looked at old soil tests and the organic matter was 4 to 5% and that's where it is now. I wonder if I raised it any because I did about 10 years of minimum till. I'm very conscientious about stubble. I saw no change. Maybe it's not realistic to expect a change in 10 years. Maybe holding even could be considered a victory. Some of the sandy soils have gone down 2%.

The farmers within the spiritual mental causal model category were more apt to base their decisions on personal experience and to make reference to religious rationales when describing their crop management approaches. Both of the farmers in this category limited their acreage of wheat in response to scab. Gary increased his acreage of sunflowers and soybeans to avoid continuously cropping wheat. As he discussed his crop rotations, he expressed his beliefs about crop rotations within a biblical context. But Gary also expressed frustration at not always being able to make management decisions consistent with his beliefs because of poor economic conditions:

> I believe in rotation, I think it's a good practice. I wish we could use summer fallow [leaving fields unplanted for one year during rotation]. That used to be part of a rotation but in this day and age it varies on the summer fallow. I'm still a believer in that but it is economically almost impossible – just the way it's gotten to be. When I was younger I would say my father was really a believer in summer fallow because he had grown up in the years when there were very little pesticides available for weed control. Give the ground a rest. It's a biblically sound concept, that every seven years would let the ground rest . . . but nowadays you have to justify all those practices and unfortunately not too many do it.

Regarding his perspectives on the soil, Gary once again referenced spiritual factors as his rationale for management:

> I guess you realize that land provided for you for that many years, you need to respect it and take care of it because you know they say, one inch of topsoil, how many years does it take to build that? If there is a way you can preserve it then why not. But here again, the soil is here to grow crops. It's here for our use. We try to be as good stewards as we can, with what we have to work with. I think we need to be respectful. God created it, you know. We need to be respectful of his creation, but he did create it for us.

Summary and conclusion

This research was based on the assumption that high levels of spatial and temporal diversity characterize sustainable cropping systems. People – farmers – are the ones who design and implement cropping systems through their management decisions. Thus it is important to identify and study how such decisions are made. Through this study, we expected to gain a better understanding of the perceptions and rationales that inform cropping systems management decisions, and especially those that influence crop diversification. Our study, consisting as it did of survey and interviews within a single county in northwestern Minnesota, has its limitations. But despite its relatively small sample size and limited geographical context, we feel that our study helps to construct a "first approximation" upon which to conduct further studies in other regions and with different cropping systems.

The survey results showed that farmers who experienced moderate to severe production stresses associated with crop disease were more inclined to employ practices that enhanced crop diversity, such as lengthening intervals between the same crop within rotations or adding different crops. This contrasts with the majority of survey respondents who, although they believed diverse cropping systems had beneficial characteristics, believed that institutional and personal barriers hindered their ability to increase cropping systems diversity on their farms. Interestingly, access to information about alternative crops was not considered to be a limitation by most of the farmers in this survey. Our results also highlight the limitations that attitudinal surveys can have in explaining the lack of correspondence between attitudes and action, as has been described in earlier studies (Raedeke and Rikoon, 1998; Jackson-Smith and Buttel, 1998).

Based on the interview phase of our study, we conclude that, although all of the farmers have similar scientific understandings of their cropping systems, other influences greatly affected their decisions as well. Some of these influences can be included within the three mental causal models that we chose to describe the farmers' differing views of causality when addressing a complex and "uncontrollable" situation such as the scab disease of the 1990s. Despite similarities in their understanding of the biological/climatic basis of the disease, the farmers drew quite different conclusions about the "source" and implications of their problem. As with the survey some farmers, and especially those in the institutional and spiritual mental causal models categories, displayed a lack of correspondence between their beliefs and the cropping systems decisions they made, and especially with respect to managing crop diversity. This appears to be, in part, due to the additional influences and interpretations contributing to decision making, and that extend beyond scientific understandings, such as government programs, relatives and peers, or spiritual beliefs. Swaffield (1998) has argued that understanding basic outlooks or "paradigms" is important for understanding how people approach problem solving. During our study, we found ourselves continually asking what role mental causal model differences play in influencing farmers' management of cropping systems in a broader sense than just diversification in response to disease. We believe that such questions are worthy of greater attention and consideration by agronomists and other agricultural scientists.

In 1998 and 1999, Congress provided funding for a multi-state task force to address scab research. Study areas funded included epidemiology and disease management, biotechnology, germplasm introduction and evaluation, and chemical and biological control of the disease. While all of these areas are important for addressing the scab disease crisis in the region, they all reinforce the scientific and technological view of and approach to the problem and they most directly satisfy the "needs" of farmers who view problems from a strong scientific mental causal model framework. Farmers within the institutional mental causal model also asked compelling questions during our interviews about governmental policy and its influences on farmers. They also expanded on perceived barriers to diversifying their crop systems listed by many of survey respondents. Similarly the farmers within the spiritual mental causal model, also raised perceptive questions about their own and their colleague farmers' motivations for using specific crop management practices. Jimmerson (1989) argues that paradigms play an important role in information exchange. He suggests that no information sharing is neutral and that extension educators, as well as other researchers, tend to share information or solve problems within the set of dominant values and beliefs of the Land Grant system. He suggested that educators and researchers look to the "fringes" of society (to the farmers within our institutional and spiritual mental causal model categories possibly?) to consider alternative values and beliefs from which to enhance the depth of thinking about problems and their solutions.

If federal and state institutions working with farmers are to effectively address problems from the multiple perspectives of their farm population constituencies, they might be well served to consider and more directly address the perspectives of farmers who are not so strongly committed to the scientific mental causal model. Our study and others show that knowledge is influenced by the farmers' perceptions of the institutions and individuals from which they get information (Alston and Reding, 1998). Enhancing the understanding of farmer networks outside of the predominant scientific mental causal model provides an opportunity for partnerships with nontraditional farm groups, such as non-governmental or religious organizations, to whom such farmers might be particularly receptive. Such partnerships might provide the means to better bridge the lack of congruence between knowledge and action, such as was observed in our study.

Determining whether other categories of mental causal models exist, how these models might be modified, and how broadly these results can be extrapolated geographically and agronomically are clearly areas ripe for future research. Whatever the proportion of farmers who operate within an institutional or spiritual framework turns out to be, it is clear that educators who assume that all farmers make decisions solely through a scientific mental causal model are likely not correct in that assumption. Patterson (1993) calls for new models of program planning in Extension that offer a more holistic way of examining problems, that amongst other things acknowledges that people do have different views of the *same* situation. To address the concerns of farmers within the institutional mental causal model, educational and research institutions could more directly consider influences of government conservation programs, as well as better define the infrastructure requirements needed to introduce and maintain diverse cropping systems. Although it is difficult to see how activities of secular universities and experiment stations can directly address concerns of farmers within the spiritual context, our cause is not well served by ignoring them.

Notes

1. For a copy of the survey instrument, readers may contact the principal author.
2. Case names have been changed to maintain confidentiality.

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