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Farming without a recipe: Wisconsin graziers and new directions for agricultural science

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A B S T R A C T

From 2005 through 2008, we undertook a participatory research project involving graziers from 8 farms in Southern Wisconsin, all of whom practice management intensive grazing. We used semi-structured interviews and participant observation during research and field days to investigate graziers' engagement with university research. Grazing farms demonstrate rich variability and individuality as a result of their position within a number of biophysical and social contexts. Graziers emphasized the importance of finding ways to work with the variables of their specific context, rather than trying to control that variability. This effort entails the development and use of local knowledge, as graziers respond to the idiosyncrasies of their farms. It also leads graziers to reject mainstream agricultural research that has produced formulas for agricultural uniformity. The picture of grazing that emerged from our interviews leads us to propose the search for *agroecological principles* and *agroecological tools*, embedded in context, as an alternative to conventional research. We argue that this proposal speaks to the greater conundrum of how to relate the general knowledge of science to the place-specific, experience-based knowledge of grass-based farmers.

1. Introduction

Kurt and Renee have nothing against corn. They even grow some to feed their dairy cows in the winter. Their cows have eaten mainly grass since the farm became a grazing operation, but Kurt and Renee don't think they'll ever stop growing a few annual crops. It's good insurance, they say, for years like this one when they would be paying record-breaking prices to buy supplementary feed. So when Kurt says he can't stand Roundup Ready crops—corn, soybeans, and other plants genetically modified to pair with a neat package of herbicides—it's not the corn or the beans, specifically, that bother him. It's the mentality that he believes accompanies such farming methods.

> "Since Roundup Ready crops," he says, "all you gotta do is follow a recipe card and you would never have to look at the crop. You can write it all down on paper and as long as you pay somebody to do X, Y, and Z, it'll basically work."

From across the gravel driveway, a cow bellows emphatically. The herd has been turned into a paddock near the barn, in grass up to their knees.

> "For me," Kurt goes on, "a big factor in animal success is personal attention. And that takes a lot of time. But I think we're all pretty committed. My fifteen-year-old has gotten pretty good at assessing animal condition and knowing when something's right, when something's wrong. That's the reason I'm not interested in huge numbers of cows. Because I need to be able to take care of each on an individual basis. I think that's the best for them."

Kurt and Renee operate a small dairy farm in Southern Wisconsin, and like the seven other farm families in this study, they practice management intensive grazing. Much of their land is in permanent pasture, divided into a number of paddocks through which they rotate about 120 head of cattle. This paddock system compels the livestock to graze more evenly, and gives plants a resting period between grazing events, which seems to result in greater pasture productivity (Jackson et al., 2007; Paine et al., 1999). The frequency of the rotation and the size of the paddocks depend on a number of variables (such as how fast the grass is growing) which graziers continually observe and judge. In doing so, graziers come to understand their pastures in the same way that Kurt's son has learned to judge a cow's health—through experience. They also, out of practicality, learn to respond to variations, from the climatic conditions of a particular year to differences in soil type, that make one area of the farm drier than another.

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Over the course of three years, we worked with 8 Southern Wisconsin grazing farms, conducting experiments on their land while engaging with them through interviews and field days about the role of university research in the grazing movement. A reoccurring theme in these conversations was that there is no single best way to graze. The best way for any particular farm, these graziers emphasized, depends on a wealth of variables extending from biophysical conditions to a farmer's personal values. This requires graziers to learn the best way to farm largely through personal experimentation and observation, through the experience of neighbors and peers, and through careful reflection on their own goals. Departing from what Kurt called the "recipe card" method of conventional agriculture, graziers strive to "look at the crop," in the broadest sense.

In an earlier brief commentary piece (Bell et al., 2008), we sketched out how this attention to a farm's unique contexts contributes to both the productivity and sustainability of alternative agricultures such as grazing. We made a case that research can support such approaches to farming by providing *agroecological principles* rather than formulas for production—in other words, by providing a generalized understanding of agroecological processes and the contexts in which they operate. In this paper, we provide the data on which that commentary was based, and further our argument by discussing some of the tensions researchers and farmers face as they try to pursue such an approach to knowledge. One of those tensions is the practical need for routines of action in the face of the complexity and time demands of farming. Here we add the argument that researchers can also offer routines of action which we call *agroecological tools*, following the lead of one of the respondents. As we will describe, developing flexible agroecological tools can allow farmers to apply agroecological principles without resorting to a recipe approach.

Another tension is that researchers find it difficult to develop agroecological principles in the face of the contextual variability of the world. Here we suggest, also following the lead of a respondent, the value of *case knowledge* in the development of principles that help farmers understand the variability of their contexts, rather than attempt to reject it. We also argue that embedding agroecological knowledge in case studies keeps both tools and principles from becoming recipes, and thus helps them remain relevant to the ever-varying contexts of all farming.

In the last several decades, management intensive grazing has become increasingly important in Wisconsin, where the number of grazing dairy farms increased throughout the 1990's even as the total number of dairy farms fell (Taylor and Foltz, 2006). In the absence of comprehensive university research programs directed at management intensive grazing, and without the kind of private sector research which agribusiness might provide for more conventional farming systems, the grazing movement has relied largely on knowledge produced by graziers, for graziers. This has included knowledge from graziers' own experimentation (e.g. Reuchel, 2006; Logsdon, 2004; Salatin, 1995), knowledge developed and shared through grazing networks (Hassanein, 1999), and graziers' own interpretations of literature revived from an era when grazing was commonplace (e.g.Voisin, 1959; Murphy, 1987). Now, partly as a result of successful advocacy, more funding is available for research about alternative agricultures, and grazing has attracted the interest of researchers in a number of disciplines. As researchers, then, we are at a moment to critically review the role that science has played in producing knowledge about agriculture, and to ask what new role university research might play as we engage with the grazing community.

To begin this task we will first lay out the ways in which graziers work with the many sources of variation on their farms. We will argue that working *with* variation, (rather than *against* it) entails the use of local knowledge and defies the kind of formulaic management practices offered by mainstream agricultural science. Secondly, we will ask how university research can best contribute to knowledge about grazing, given the disconnect between mainstream science's search for general knowledge which is independent of context and graziers' need for knowledge specific to individual places. While we do not pretend to offer a full resolution to this disconnect, we argue that agroecological tools and principles provide forms of general knowledge that can bring farmers and researchers together in a richer appreciation of context and that can enhance agriculture's ability to farm with variability.

2. Methods

From 2005 through 2008, we undertook a participatory research project involving graziers from eight farms in Southern Wisconsin, all of whom practice management intensive grazing. In doing so, these farmers diverge sharply from the conventional model of livestock farming in the United States, which is to keep animals in confinement for much of their lives, and feed them largely on silage produced from annual row crops such as corn, soybeans, and alfalfa. The reasons for practicing grazing instead of the confinement method involve economic, environmental, and social considerations, as we shall see. The farms in our study included beef, sheep, and dairy operations in four counties in Southern Wisconsin, and ranged in size from 30 to 250 head of animals, and from 80 to about 350 acres. Some farmers were recruited through existing research relationships with the university, while others volunteered for the project after a presentation at a conference put on by an organization that promotes grazing in Wisconsin. For practical purposes, participants were limited to farms within feasible driving distance of Madison, the site of our home institution, the University of Wisconsin–Madison, which lies in south-central Wisconsin.

We, the researchers, are an interdisciplinary research team of faculty and graduate students brought together as part of the Agroecology Cluster at Madison, and we were interested in examining questions about pasture ecology while also developing a participatory approach to research. We went about testing our natural science questions by collecting data from on-farm plots as well as plots on a university-owned research farm. As we did so, we engaged with farmers informally when we visited their farms, and held two field days where we discussed the progress of the project, the experimental design, results as they became available, and possible interpretations of those results. The field days also gave us a chance to talk about the broader role of university research in the grazing community.

In addition to field days and informal discussions, we conducted a series of interviews with the farmers and researchers throughout the course of the project. These interviews were semi-structured, using an interview guide but following up on unplanned topics that arose through conversation. Some of our questions were about farmers' and scientists' motives for working with each other and their constraints to doing so—which produced findings we have discussed elsewhere (Lyon et al., 2010). Other questions, which we address here, were about graziers' specific management practices, how they made decisions, and what kind of research they sought from the university. After identifying themes in a first round of interviews, we followed up on those themes in a second round, taking an iterative approach to our analysis.

3. Recurring themes in graziers' approach to farming

Graziers' accounts of the way they farm show how the productivity, resilience, and pleasure of management intensive grazing come from working with the variability of the land, a process which

creates and requires local knowledge. This philosophy calls for a new role for university research, as we will discuss. But first, let us examine some of these multiple sources of variability and the ways that farmers observe and creatively respond to them.

3.1. Responding to biophysical contexts

One way graziers respond to variation in biophysical conditions is by adjusting the size of their paddocks and the length of time animals spend in a paddock according to the availability of grass (Undersander et al., 1991). In our interviews, this responsiveness produced complicated answers to seemingly simple questions. When asked for an estimate of their stocking density, the number of animals per area of land at any time (Heitschmidt and Taylor, 1991, 161), many participants avoided naming a fixed number. Instead, they tended to give detailed descriptions of the variables that might influence that number. One couple, in response to such a question, emphasized how much their grazing management had varied over the course of the season:

> We had a very poor winter that killed quite a bit of our orchard grass, and our pastures were in very poor shape going into the spring. It was a very cool and dry spring, and [a state grazing specialist] suggested we should hold the cattle off the pastures for as long as possible. So we supplemented hay. Then, long about the first part of June when we turned the cattle out, we had a lot of heat and the pasture just exploded. So we ran them through fairly fast. In hindsight, we should have gotten them in earlier and ran them a little faster across the ground. We ended up following the cattle with the [mower], thinking that we would have the regrowth. And then we were dry for so long, we didn't get any regrowth whatsoever!

When this farmer says that the pasture "exploded," he refers to what graziers often call the "spring flush," a time of rapid grass growth brought on by the first warm weather of May and June. Sometimes, as in this case, grass grows too fast. If the graziers don't get animals into each paddock quickly enough, the grass becomes mature and woody, making bad feed. Furthermore, if this flush of grass is not grazed or harvested some other way, it will not produce the regrowth needed for later feedings (Undersander et al., 1991). But as the farmer points out, that regrowth also requires moisture, and in this case they had to feed their cows hay again because there was no rain, and no regrowth. This push and pull, first trying to keep up with the grass, and then scrambling when the grass falls behind, made it nearly impossible for graziers to identify a fixed number to describe the stocking density of their animals or the frequency of grazing. As another grazier put it: "We do not have a real guideline as to the number of animals per acre for a set time, because we do rotational grazing. So it depends on how much is there."

And how much grass is there depends on more than weather alone. Soil type and topography also influence the amount of moisture that will be available to plants, and for how long. In the very same county, a farm with sandy soil and a farm with heavier clay soil experienced the effects of weather very differently.

Sharon and Scott, who run one of these two farms, sat for an interview on an early spring day. The drive to their farm revealed fields half covered in water from the melting snow. On many farms, corn stalks protruded from large expanses of mud. But looking at their pastures through the kitchen window, Sharon pointed out that she and Scott had hardly any mud at all:

> On this farm one of the things we have to deal with is very sandy soil. That can be a terrible disadvantage in the dry times, but it's also an advantage. A lot of graziers will complain about mud in the spring—you get weeks of mud and you can't let the cows out because they'll destroy the grass. We don't have that here. Two days, even one, after a rain, and the soil's dried out. The cows don't make pugs when they walk. They don't hurt the sod at all. So, that's an advantage here, and we make the most of it. We never pull the cows off because it's too muddy.

Meanwhile, on her farm not very far away, Debra described almost the opposite conditions:

> On our farm we've got that low ground, which we have to avoid. But even at the height of drought conditions in August those low pastures have a lot of forage in them, and it's usually pretty good quality. So that's a benefit to us. Of course, we can't always manage it quite the way we'd like to. Hay cutting is part of a management strategy and sometimes we can't get into a field to do that.

Despite very different conditions, both these graziers talked about finding ways to benefit from the unique conditions their land presented, and they did so by tailoring their management to the circumstances. Adjusting grazing patterns based on moisture, soil type, and topography were only a few of the ways that graziers' decision-making was shaped by the variations of their land. They also selected plant species and animal breeds based on the circumstances their farm presented, and made decisions about how to overwinter their animals based on the natural shelter their land provided. In this way, grazing strategies varied as much as the land itself.

3.2. Responding to social contexts

In fact, grazing strategies varied even more than the land. In addition to biophysical variation, graziers' placed great importance on the unique human contexts of their farms, such as social relationships, economic realities, and personal values. At Kurt and Renee's farm, for instance, the decision about which areas to put into pasture and which to plant with annual crops did not rest on considerations about soil type or topography. Instead, it all depended on the location of the milking parlor, which Kurt's father had built long before Kurt and Renee bought the farm from him and converted it to pasture. With the milking center located at one end of a long narrow property, they couldn't put pastures down at the other end because it would be too far for the cows to walk back to be milked.

> Kurt explained, "In our row crops or alfalfa production, there's one good flat piece. But there's some quite hilly and stony. You'd look at that and you'd say, 'Boy, that really belongs in pasture.' But that is a mile from home, one way."
> He laughed ruefully, looking at Renee. "If a tornado took the whole place down, I think I'd put the milking center in the very middle."

Other farms reflected similar legacies of decisions made by someone else, or infrastructure provided by neighbors and community. One couple fed their cattle sweet corn silage in the winter because it was available cheaply as a byproduct from a nearby canning plant. Others made management decisions based on the availability of hired help or borrowed machinery from neighbors.

There was also economic variation to confront. During the course of our project the prices of corn and gasoline rose steeply, and some graziers responded by changing their practices. For Kurt and Renee, the rising corn prices validated their decision to grow their own annual crops. For some graziers who had been applying commercial nitrogen fertilizer to their pastures, the rising prices of this petroleum-based input prompted them to change their practices:

> We didn't apply any commercial nitrogen this year. I did that last year because I was anticipating a hot dry summer. And that

worked out very well. But with these nitrogen prices, I chose to interseed a lot of clover this year. We seeded down about a third of the acres of pasture and crop ground with some extra clover, [and] some alfalfa. [I'm] trying to get as much free nitrogen from the atmosphere as I can, and [to] see if that's a viable alternative to the expense of purchased N inputs. Just trying to change our direction according to market prices.

On another farm, rather than spending money to fuel up the tractor to mow a field where the grass growth had gotten ahead of the cows, the graziers decided to let the cattle trample it down and leave it. They hoped that the trampling would stimulate regrowth in the same way that mowing would, but without the expense of purchased fuel. These responses of social surroundings and economic fluctuations show one more layer of variability that shapes grazing management.

The importance of multiple sources of variability became apparent during our first round of interviews, so in the second round we asked farmers if they would agree with such an analysis. Although they articulated the idea in many ways, they agreed. But several of them pointed out a variable that could not be left out of the picture: the goals of the farmers.

Goals and values, in many cases, formed the narrative that held a grazing farm together as a cohesive and workable entity within its many contexts, to borrow from Bland and Bell's (2007) framework of holon agroecology. Kurt and Renee valued self-sufficiency, and decisions such as growing their own annual crops reflected that value. Like several other graziers, they wanted the farm to support their children, and felt that with grazing it was easier and safer to involve young children in farm chores because of the lack of heavy machinery. Many graziers talked about being environmental stewards and making positive contributions to their communities as personal values which led them to grazing. These values echo the findings of a recent survey of dairy farmers' life satisfaction (Lloyd et al., 2007), which discovered similar qualities of life to be particularly important to graziers.

As we sat at their kitchen table on that early spring afternoon, Sharon and Scott were particularly passionate about this subject. Sharon spoke softly, but with conviction.

> "One thing that I think should be in there," she said, "is the people."
> "Oh yeah." Scott nodded.
> "When I think of a Wisconsin grazing farm, the people are a component of it. And they need to acknowledge what their goals are, and seek what they want for their life to look like. But then they have to somehow manage their farm to accommodate those goals. So often in agriculture we leave the people out of it."

For Scott and Sharon, considering goals and values was at least as important as understanding soil type and climate when deciding how to graze. Comments like these from several participating graziers portrayed an ongoing process of understanding how a farm was situated within a variety of interrelated and sometimes conflicting variables. To them, the challenge of grazing was to farm in a way that productively responded to those variables.

3.3. Working "with"

We have established that grazing farms experience a great deal of variability from biological, geological, and climatic sources well as economic and social ones. In this way they are perhaps not so different from other kinds of farms—that a crop's fate depends on the weather is nothing new, and surely farmers everywhere have various goals and economic constraints. The way that graziers perceived themselves as different, though, was in the way they approached that variability. Scott and Sharon described this approach when talking about the way they outwinter their cows, using the different hills on their property to protect the herd from the wind.

"That's one of the beauties of grazing," Sharon said. "We could build a building and shut them all up in it. But that's fighting the weather rather than using what you have and working with it." Later in the interview she explained again, emphasizing "with" each time she said it: "It's a much more integrated system. It's working *with* the cows, capitalizing on what the cows can do. And then working *with* the piece of property that you have, and capitalizing on it. And *with* your family, and your goals."

Sharon's emphasis on trying to "work *with*" the social and biophysical idiosyncrasies of a particular farm echoed throughout the graziers' descriptions of their approach to farming. This ethic showed in the way they fenced their pastures, separating wet bottomland from dry slopes so that they could be grazed at different intervals, taking advantage of the different rates of grass growth. It also influenced the way they selected their animals. They talked about looking for breeds that could withstand the conditions of the land, rather than building structures or changing their way of farming to accommodate higher-producing animals that required more care.

The audio recordings with Frank stand out because in all of them his voice is nearly drowned out by birdsong. Frank stood outside for the second interview, and flocks of barn swallows occasionally stormed the telephone line above, chattering loudly. The hilly land he farms has been in the family for around forty years, and he can see a history of farming written across it.

"I can see scars in our own farm from years ago," he says, "when there was erosion, back probably in the 20s and 30s, because farmers didn't understand what the effects would be. I could show you some ditches that are really hard for me to look at, because I value the land so much. It's such an important resource—I just can't go out there and treat the land that way."

The damage caused by erosion clearly made an impression on Frank, and as a result he is deeply committed to avoiding tillage, even when it would be a fast way to introduce more productive plant species to his pastures.

"I want to promote the grasses and legumes that are native here, rather than introduce rye grass or other types of vegetation that people think may have more yield or better feed value. I want to accentuate what's naturally here. And that's what I've been able to do with some fertilizing programs and with manure—without tillage and without chemicals."

In other words, Frank's values and goals lead him to work *with* the existing forages rather than try to replace them with new ones, which he could only do by tilling his pastures or spraying herbicides. He chose instead to use inputs (some in the form of manure) of potassium, calcium, and phosphorous to help improve the productivity and shift the balance of the existing species. Frank's case and the previous examples demonstrate practical applications of graziers' values of working with, rather than against, their land. In managed grazing, working with the land means using an understanding of ecological processes to accomplish land management and production objectives. This approach is clear in the very premise of grazing: producing meat and milk by fostering the adaptive ecological relationship between ruminants and grasslands. The conventional alternative—which requires farmers to grow and harvest monocultures of corn, soy, and alfalfa, and feed them to animals in confinement—uses large amounts of pesticide, herbicide, and fuel inputs in place of cows' ability to fertilize, control weeds, promote bioactivity in the soil, and harvest on their own through grazing.

3.4. Privileging local knowledge

To farm in such a manner, to work with the variability of the land, requires knowledge to inform one's daily and long-term decisions. Knowledge about how to control variability—by tilling the soil, planting the right seed, and applying the right fertilizers and pesticides—is plentiful in mainstream agricultural research. The recommendations of this form of agricultural knowledge are fairly straightforward, because, as we have argued elsewhere, they have been tested to work in almost every situation (Bell et al., 2008), generally by overwhelming place-based variability with inputs of machines, chemicals, and the plant varieties that respond well to them. Farming in a way that takes into account all the myriad variables of a place, though, requires knowledge more specific to that place.

Jack Kloppenburg's phrase "mutable immobiles" aptly describes the farming with variability approach. His term is a reversal of "immutable mobiles," a term Bruno Latour used to describe the goal of most academic science: to produce knowledge that can be understood independently of the contexts from which it arose (Kloppenburg, 1991). To be sure, science does not always accomplish this universality, and some scientific research produces results which are limited to a particular place and time. But the goal is usually to be able to generalize beyond local context, and scientists often find it difficult to find funding for projects that do not share this goal (Lyon et al., 2010). Kloppenburg's and Latour's critique of immutable mobiles resonates with graziers' skepticism about research that fails to notice, or purposefully ignores, the unique variables of places and people. As Kloppenburg (1991: 530) describes,

> The application of immutable mobiles to particular geographic or social places may fail to respect the exigencies and needs of a specific locality. Because it is reductive, abstracting, and interested in immutable components of a phenomenon, science loses connection with the variability of local systems.

Mutable immobiles are the opposite; here, knowledge adapts and changes but place does not. The knowledge that graziers develop on their own farms cannot be uniformly extended to other places because each place is different, and is difficult to test more than once because conditions are constantly changing. Yet because it takes account of all the idiosyncrasies of their farms, this trial-and-error knowledge was often the most valued by graziers.

The importance of local knowledge was apparent in the sources farmers used for information about grazing. Graziers spoke often of the value of knowledge produced on their own farm or on the farms of other nearby graziers. Grazing networks were useful for such information, as the knowledge shared was mostly from other graziers, thus people who experienced farming in similar ways. Knowledge produced outside of their community did play a role: some referred to grazing publications such as *The Stockman Grass Farmer* and the newsletters published by the grazing organization Grassworks. In counties where extension agents were supportive of grazing, several farmers found the University of Wisconsin Cooperative Extension a useful source of information (though in other counties, graziers complained that their local Extension agents disapproved of growing pasture on "good corn land.") Others had relationships with university faculty whom they contacted with questions. Yet for most of the graziers, the knowledge gained from personal experience and from nearby peers trumped the recommendations from these outside sources. Debra explained why:

> A lot of the research has been done out west or in the south and it doesn't really apply up here [in Wisconsin]. So you go and ask your neighbor. I think that's kind of what the grazing movement has done: people just helping each other. That's what grazing networks are. If you don't know how to do something you just ask someone else who's already made all the mistakes and figured out how to do it.

But sometimes even the experience of a neighbor wasn't close enough to home:

> The problem with the anecdotal information that you get from your neighbor or the other person is that it works on their farm but that doesn't necessarily mean it's gonna work on yours. Or they may have done something just a tiny bit different. So you just have to learn from experience on a lot of this stuff.

This reliance on local, experiential knowledge was a practical matter. But it also challenged the exclusivity of scientists' claim to the truth by placing higher value on graziers' knowledge than on university researchers' knowledge. This became apparent in a conversation with Kurt and Renee, when Kurt had been talking about useful directions for researchers to pursue. When asked what she thought about it, Renee admitted that she just didn't like research, and didn't see the use for it. It was a bit of an awkward moment—after all, she was saying this to a university researcher. Renee was insistent though, even as she struggled for words.

> "I—I just don't see that the university's thoughts on it mean anything," she said.
>
> Kurt started to break in as if to soften what she was saying, but Renee continued. "Because it's not realistic. It's not life. You know, I value other graziers' opinions on how well or not well something worked, way more than anyone from the university's. Because they're living it. They're doing it, day in and day out."

Renee's privileging of local knowledge over university research echoes the "epistemic self-reliance" that Neva Hassanein (1997, 319) documented in Wisconsin grazing networks. Farmers participating in these knowledge networks, Hassanein writes, "challenged the power relations in agricultural knowledge production and distribution by relying on their own and members' experiential knowledge (ibid., 304)."

But even as they bring this challenge, graziers have not rejected university knowledge completely. In fact a common complaint we heard at grazing conferences, in casual conversation, and during interviews, was that the university is not involved *enough* with grazing research. In many graziers' view, too much university research is directed at the technologies of conventional agriculture, and more attention should be turned toward alternative agriculture like grazing. And as some pointed out, learning from experience was important, but there would always be questions that graziers didn't have the time or resources to address. Frank summed up what many of the graziers had said, again recalling his family's long history on the land he farms. The birdsong had finally dissipated in the background, now only the wind competed with his voice.

> We've researched [our farm] as long as we've been here. We're doing research every day. We have to determine what works and what doesn't. If you don't study your land, and study your operation, why, it deteriorates. But scientific research could come in to help. You know, I can do my own research. I can try out a certain grass or certain legume somehow. But we probably should have some guidance of some sort, somebody that knows a few more things about it than just going out there and trying it. Because it probably won't work and it will just be an expensive trip. So, even though you might know the land if you've lived on it a long time and worked with it, there's probably some science that should be applied too. And that's where researchers come in, I think.

Frank's avowal that "if you don't study your operation, it deteriorates" shows local knowledge as embedded in, and crucial to, any grazing farm. So much so, perhaps, that the production of local knowledge—studying one's land—must and will continue even as more university-produced knowledge becomes available. Nevertheless, he seems sure that science has something useful to offer.

4. Research for variability

We agree. The question of how university research can engage with grazing is, as we have framed it, a question of how science can work *with* local knowledge and not replace it, providing a useful contribution to agroecosystems that are variable and diverse. This question has been raised before (Bentley, 1994; Bruges and Smith, 2008; Gerber, 1992; Suppe, 1988), and requires more work than we will be able to accomplish here, but we will try to offer an entrance into the problem. We start by articulating the difference between recipes and principles for farming, two concepts described by the graziers and researchers involved in this project.

4.1. The problems with recipes

The graziers in this study came from a variety of backgrounds and had a variety of approaches to grazing. This made it particularly fascinating when during the first set of interviews each of them, without any prompting, talked about some variation on the theme of "recipes" when describing the differences between grazing and conventional agriculture. What their many definitions had in common was that recipes are formulas for production which farmers can follow without applying much of their own knowledge and without paying much attention to the idiosyncrasies of their land or farming operation. They saw recipes as the products of conventional agricultural science, and ill-fitted for grazing.

One farmer said there was "not a cookie cutter situation," in which each farm could be managed the same way. Another, who had converted from annual crops to pasture, said that unlike grazing, "growing corn and soybeans was pretty much a cookbook thing." He recalled what it was like to grow conventional row crops:

> If we had a problem, we'd just call the Extension [office], and they got the specialist out and they took a sample and sent it off. And then they'd say 'Well, it was herbicide damage,' or 'You were short a micronutrient.' You know, so it was fairly easy to get—we'd have all those people out there.

As this grazier describes it, farming by a "cookbook" involves a traditional relationship between farmers and agricultural scientists, reminiscent of innovation-diffusion models of extension—colleges of agricultural dispensing information and farmers consuming it (Gerber, 1992, 19). Other research about farmers' use of sustainable agricultural practices supports the idea that the innovation-diffusion model promotes industrially-oriented practices (Lacy, 1996, 33), and does not fit with the development of knowledge for alternative agriculture (Pretty, 1995, 28; Coughenour, 2003, 278).

Secondly, these recipes were for a particular kind of management style, one which often involved an extreme degree of intrusion in and domination of natural processes. Frank uses frequent soils tests and his own observation to determine how to manage the existing grasses on his farm for the most production. It would be easier, he said, to follow a recipe for pasture renovation:

> It's more difficult for me to do what I'm doing than just to take a twenty acre field and tear it all up and put in there what I want. But the whole thing with me is that I save my soil, instead of just going in there and ruining everything that nature has put there by tearing it up or spraying it, and then starting over. It's much easier to do that. You can write a recipe pretty good for that. Pretty close.

A third characteristic of recipe farming was that it could be done the same way in every place. A farmer who had once raised hogs pointed out how production agriculture had created a recipe for uniformity:

> Everybody had to raise these white hogs at a certain length and weight for the packers, so that when a consumer went to the store and bought that 'other white meat,' that pork chop would look the same in Madison as does in West Virginia. And then, you know what? The pork itself has no taste anymore. They totally destroyed what we were all about to begin with, which was good eating food. Sure, we can feed the world, but they're eating sameness.

In treating each farm as if it were the same, recipes treated farmers as if they were all the same as well. Sharon, who had just been talking about the importance of respecting farmers' individual goals, drew this connection:

> In the confinement model [of livestock production], anybody can take that formula, slap it on this piece of property, with this family, and you're done. But gosh! Maybe that family would rather not have their day made up with all the things that are necessary in that confinement model!
> In other words, formulas assume that every farmer has the same goals.

The problems with recipe knowledge, then, were threefold: first, it replaced epistemic self-reliance with dependence on outside sources of knowledge; second, it ignored the needs of a particular piece of land; and finally, it created sameness across agricultural and social landscapes. In all three areas, recipe farming conflicted with the philosophy of grazing those farmers articulated.

Of course, it is quite possible that farmers growing conventional row crops, or raising livestock in the conventional confinement model, would also argue that recipes don't always work for them. They might argue as well that their farms experience multiple sources of variability, which they must consider in their management practices. In graziers' frequent comparisons of their farms with conventional dairying and annual row crops, graziers constructed an "other" with which to compare themselves, though that other was in some cases based on their own experience of conventional farming. Our argument, then, is not about how well these comparisons would hold up to non-graziers' experience. What we find interesting is how graziers used comparisons with conventional agriculture to describe the kind of research-based knowledge they did *not* find useful.

How does graziers' critique of recipe farming implicate university research programs? For them, recipes for farming were often the product of mainstream agricultural research, especially research agendas influenced by commercial interests. Kurt's example of Roundup Ready crops was used by other graziers to describe the kind of one-size-fits-all practices promoted by agribusiness and the research it funded. "It seems," said Renee, "that the new way to do things, with the new equipment and the new kinds of seed—that's what gets published." Meanwhile, more adaptable ways of farming were often ignored.

4.2. An alternative: agroecological principles and tools

How, then, can agricultural science productively move beyond the search for recipes of uniformity, and toward a research

philosophy that embraces the variability of place? After three years of work with graziers, we have only begun to answer this question. Its further consideration will doubtless play an important part in future efforts of university science to address the needs of graziers and other alternative agriculture communities. The trickiness lies in the apparent conflict between the values of science and the experience of people who respond directly to the variable landscape. A grazier might be interested in the performance of a particular species of grass on a particular slope at a particular time of year—specific knowledge limited temporally and spatially in application. The scientific community, on the other hand, tends to seek knowledge that can be generalized across time and space, in other words, knowledge that is both immutable and mobile, as Latour describes. And this value of the scientific community is reinforced through academic structures, making the search for general knowledge as crucial to the careers of scientists as the search for specific knowledge is to the workings of a grazing farm. So the knowledge priorities of scientists and graziers seem to be at odds, each community engaged in its separate contexts of work.

How can we bridge this gap? One pillar, we would like to suggest, is the development of *agroecological principles* as an alternative direction for research. Rather than attempting to develop recipes that would apply to every grazing farm, we suggest that scientists might do better to search for the principles that describe pasture agroecosystems. These principles would arise as scientists and farmers develop a more complete, interdisciplinary picture of the grazing farm. They would be agroecological in the sense of taking into account the agronomic as well as the ecological, social, and economic contexts of a farm. What are the most powerful sources of variability and how do they interact with each other and with the farm? What dimensions of variability respond to management, and which ones can a farmer do little about? What are the likely stabilities and fragilities that farmers face in the ecology of contexts in which, and by means of which, a farm must try to hold together? These kinds of questions, many of which are already being asked, might produce knowledge that is less *pre*scriptive and more *de*scriptive. Such principles would not necessarily tell farmers what they should do, but would describe key elements of the grazing agroecosystem in ways that would help inform farmers' decisions. Consider, for instance, the scientific contribution of a general understanding of the factors affecting the relative abundance of pasture grasses versus legumes. A farmer, using her own situated knowledge of her land and her animals, might adapt this general knowledge to develop a grazing strategy that moves her pastures toward the species composition she desires.

Agroecological principles, then, would still be a form of general knowledge. Principles would represent factors that seem to hold true across time and space, rising above situational variation, though they might interact with other intervening or over-riding factors in particular instances. But unlike recipes, farmers would need to interpret the meaning of principles for their particular farm, bringing in those intervening and over-riding factors that comprise their specific context, thus integrating their local knowledge with this general knowledge. This is one important way we envision university research working *with* local knowledge rather than in opposition to it.

4.3. Elaborating agroecological principles

The concept of agroecological principles still needs elaboration if it is to be a useful suggestion as a direction for research. Based on our experience from this project, we can propose a few qualities that a finding would need to possess to be considered an agroecological principle. These suggestions arise both from graziers' descriptions of the kinds of knowledge they seek when making decisions on their farms, as well as from scientists' responses to our earlier findings about graziers' frustration with recipes.

4.3.1. Describing an agroecosystem

The idea of agroecological principles occurred as we discussed the theme that was emerging from farmer interviews—that agricultural research promoting formulaic approaches to farming did not fit with the variability that graziers experienced on their farms. In response to this theme, the natural scientists on the research team suggested that looking for principles would represent a departure from developing formulas, and might also fit more easily with the capabilities of ecology.

Over the last several decades, elaborating conceptual models of rangelands has been an ongoing project for grassland ecologists (Briske et al., 2005; Burke et al., 1998). Heitschmidt and Taylor (1991) outline four principles governing the intensity of grazing: the number of animals, the type of animals, the spatial distribution of animals, and the temporal distribution of animals. In developing "general principles," the authors attempt to depict how changes in each of these four areas affect range condition.

Farmers in our project also advocated the importance of principles-based knowledge. One put it this way, describing principles as applying across a wide variety of situations, but requiring adaptation to any particular farm:

> There are principles of grazing, and that is across the board. I don't care if you're using pigs or you're using cows, or sheep, or whatever. The principles are basically the same. And you just have to adapt those to your land and your facilities. But other than that, it's pretty much ordained that you have to find what works for you…. So the principles are there, but all the adaptations are individual.

As an example, she praised a presentation she'd seen at a *Stockman Grass Farmer* conference, about the relationships between above-ground and below-ground plant growth. The presentation discussed the effect that grazing plants to different heights had on plants' root production. "As far as I was concerned, that was the most informative thing they could possibly come out with," she said. "But it wasn't a formula, it was really more of a principle. It's informing you, 'This is happening when you do this.'".

4.3.2. Incorporating farmers' knowledge

These depictions of principles suggest a role for research-based, general knowledge that can be integrated with place-specific farmer knowledge. They also provide a way to approach participatory research, which many have argued is key for sustainable agriculture (Cleveland and Soleri, 2002; Dlott et al., 1994; Pretty, 1995; Pretty and Chambers, 2000). Many have also pointed out the challenges of negotiating social power structures and divergent interests when doing such research (Arnstein, 1969; Cooke and Kothari, 2001; Hayward et al., 2004; Mosse, 2001,). We hope that agroecological principles show a path through some of these challenges by providing one way for scientist and farmer knowledge to be partnered. Scientists may have more time, resources, and interest for doing research about general principles, but farmers should be involved in this work as well. As our experience has shown, farmers' intimate knowledge of the on-the-ground reality of grazing can yield important insights that make scientific findings more robust and extendable to the world outside of the test plot. And as scientists build relationships with farmers through involving them in researching principles, perhaps scientists may also become involved in the farmers' work of interpreting principles for individual farms.

Jeff Bentley's work with Honduran farmers provides an example of how such an integration between traditional scientific research

and farmer experimentation can result in practical innovation (Bentley, 1994). Bentley points out how scientists' knowledge can be extremely useful in areas that are hard for farmers to observe, while farmers are often knowledgeable in areas that are difficult for scientists to observe (Bentley, 1992). In focusing grazing research on the search for agroecological principles and encouraging farmers' to use their own observations to adapt these principles into appropriate practices, we might allow both farmers and scientists to use their strengths in working with each other. By envisioning the development of agroecological principles this way, we wish to place such an endeavor between two prevailing visions of farmer–scientist relationships. On one hand, the application of principles breaks away from the innovation-diffusion model, (Rogers, 1962), by encouraging a two-directional flow of ideas and showing that both farmers and scientists have important knowledge to bring to the interaction. On the other hand, researching principles provides an alternative to models of participation which essentially envision scientists as consultants and organizers for farmer communities (David, 2002). In the adoption-diffusion framework, scientists' knowledge replaces local knowledge—working *instead of* farmers' experience, as argued by Lawrence Busch (1978). In the consultant framework, scientists' knowledge becomes subordinate to local knowledge—working *for,* as in serving, local people. We believe that an agricultural science based on developing adaptable agroecological principles provides the opportunity for partnership between farmers' and scientists' knowledge—working *with* each other rather than either working *for* the other.

4.3.3. Engaging multiple disciplines

As we have argued, the search for principles should attempt to create a picture of grazing as an agroecosystem. One grazier described how such a picture relies on many different areas of knowledge:

> I have to provide the opportunity for the soil, and the opportunity for the grass, and I need to provide the right environment and opportunity for the cattle. So, we're looking at it from so many different points of view that you can't be narrowly focused. You have to be very broad. You have to grasp everything, and make a decision.

University research, on the other hand, often looked at farms from one discipline alone. "The challenge with university folks," the same farmer added, was that "everyone that's got an advanced degree has specialized in something." This critique points out that the interdisciplinary challenges of agriculture require interdisciplinary knowledge. Our project involved entomology, rural sociology, and grassland ecology—but at the second field day one of the graziers asked why there wasn't an economist involved, since economic outcomes are as important as ecological and social processes in the viability of a grazing farm. This reminds us that as we develop principles for grazing we should include contributions from as many disciplines as we can.

4.4. Agroecological tools: a second role for research

While our conversations with farmers clearly revealed the importance of principles in grazing, our conversations with scientists suggested how complicated such a research direction might be. As ecologists, the researchers we interviewed understood graziers' perspective that farming sustainably meant treating each place individually, thus moving away from agronomic recipes. Yet the researchers also expressed hesitation about trying to provide principles as an alternative. One researcher pointed out that scientific principles, such as Heindschmidt and Taylor's four principles of grazing, were "difficult to come by." It could take many years for a scientific consensus to build around such principles, and still they would never hold true for every situation. Indeed, the contextual sensitivity of principles-based knowledge practically demands that a principle not always express itself everywhere, given the complexity of the agroecological endeavor. As a result, researchers hesitated to present farmers with general statements about pasture ecology, knowing that any particular grazier might experience results that contradicted the principle. To illustrate this, one researcher talked about the application of nitrogen fertilizer in Midwestern grasslands:

> I can say, in general, grasslands in this part of the world respond to nitrogen fertilization by losing the legumes. Or the legumes decline. That's a pretty safe generalization. But in any one site [and] time, that might not happen. If it's really dry, the nitrogen might not have that effect…And so the farmer's sort of like, "That's not really what I thought would happen."

Scientists weren't the only ones to point out the challenges that principles presented. While the graziers largely agreed that principles were important, they pointed out that some graziers might still be looking for direct recommendations. They saw a conflict between needing to learn from one's own experience and wanting the simplicity of routines for farming. Scott and Sharon explained:

> If you get a new grazer or someone who thinks they want to graze, first thing they're gonna ask is, 'Well, what grass should I plant?' 'What cow breed should I use?' 'How big should my paddocks be?' And they want a formula. But experienced grazers have learned that it's better if you don't try to use a formula, if you try to adapt to your farm. Farmers want this model, this cookie cutter. And yet I think it's important in grazing that we *don't* come up with that.

Though Scott and Sharon insisted that graziers must resist a formulaic approach to farming, they nonetheless admitted that some farmers, especially beginners, might need routines of action that they can follow in some situations. We see it as a bit like a beginning cook, who does indeed find solace and security in a recipe book. But the more experienced cook starts to take into account the realities of the context of his or her own kitchen set-up, what is at the market and in the refrigerator, and what the cook's own tastes are and what the tastes of the eaters are. Can one substitute lime for lemon here, or vinegar for lime, or wine for vinegar? Maybe yes. Or wine for lemon? Maybe not.

How does the experienced cook decide, then? By not seeing a recipe as a recipe, but rather as a routine of action that embodies principles. Understanding those principles allows the cook to adapt the routine to the context and still put a good dinner on the table. In fact, Nahum Waxman (1996) reminds us that cookbooks used to give much less detailed instructions, assuming more expertise on the cook's part than they do today. This understanding of recipes as mere guidelines—with results dependent on the cook's inclination, experience, and ingredients on hand—is similar to the role we see for agroecological principles and tools in grazing. Debra's view of principles helps explain this point:

> I feel like we need to give farmers an understanding of the ecological processes that they're observing and then help them be better decision makers, so they can interpret what they're seeing and then respond with a series of tools.

This metaphor seems entirely apt to us, and we suggest the phrase *agroeoclogical tools* to refer to routines of action which embody ecological principles that the farmer understands and can therefore adapt to his or her context. An illustration of the

relationship between tools and principles can already be found on grazing farms: graziers use their understanding of the principles of pasture growth to inform their use of the tool of animal rotation. But in order to use the tool, they must also use their own situated knowledge and careful observation of their pastures. Similarly, some graziers employ multi-species grazing, such as following cows with chickens or sheep, as a tool to control livestock parasites by interrupting the parasite–host cycle (Ekarius, 1999, p. 39). Graziers' use of this tool is based on principles of parasite lifecycles and animal feeding habits, but to decide between integrating chickens, sheep, goats, or llamas, graziers must rely on their experience with their own land and customer base. Agroecological tools, then, are another form of general knowledge that neither demands nor expects uniformity while meeting the local conditions of the soil, season, and society. Farmers need routines, as we all do (Bell, 2004). But graziers seem to get much of their yield out of adapting their routines to their locality, making variability a productive advantage (Bell et al., 2008). Consequently, they need to understand the basis of why a routine works, so they can change it when it does not.

4.4.1. Using case-based research

We suspect that the idea of providing agroecological tools to farmers would make researchers more comfortable than providing naked principles alone. The practical routines that a tool suggests can more easily be connected to something restfully real. But there is still a danger of hazarding something as general that may not work out exactly that way in a given situation—and in fact, probably will not. Especially given the legacy of how agricultural scientists and farmers have understood what general knowledge means, even the agroecological researcher might yet have cause to be nervous.

But what has been lacking from general agricultural knowledge is a sense of context. Instead of trying to create recipes that can be applied on every farm, our advice is that researchers should embed both tools and the principles they embody within place. One way to do this is to embrace case-based knowledge, understanding tools and principles in the context where they work and trying to communicate that context alongside the final product of research. Once again, we get this idea in part from our respondents. Here is how one farmer made the case for a case-based approach for the knowledge the university produces:

> The best thing I can think of is to take people who've been relatively successful and use some real life examples. Say, "Farmer X, in a certain county, with this type of soil, with this type of soil test, has been able to do *this*. Now a farmer across the way four miles, he's got a different kind of land, different kind of soil, he's been able to do *this*." And so it's gonna be, I think, a lot of examples that have to be documented. In cooperation with the producer, of course. Have somebody do that documentation that will be fruitful to somebody else, maybe in the neighborhood. Or maybe in some other neighborhood with the same…land-type, you know.

With the approach this farmer suggests, scientists might indeed develop generalized claims about tools and principles, but they would be generalized claims embedded in the context. This would allow both the researcher and the user of the research to see tools and principles as place-specific, as general but not universal, as matters to adapt to the situation. Knowledge of the context of the general claim, then, is crucial for successfully extending it to another situation, which is inevitably different, at least to some degree, and sometimes to a large degree. We can imagine one day a kind of publically accessible database of such case studies of principles and tools embedded in context. OK, the farmer can then ask, what is different and what is similar about my context from that of my neighbor, from farmers on the other side of the county or the state or the globe, or from the university research farm, and how will that influence the outcome of a tool or a principle? Indeed, that is the question that graziers are always asking anyway.

5. Conclusion

The recommendations we have developed here for agroecological principles and tools are based solely on our work with graziers, so it is important to think about how and why our findings might extend to other types of agriculture. Undoubtedly, these farmers' experiences and opinions were uniquely shaped by the type of farming they practice, just as the scientists' approach to the project was shaped by their particular fields of expertise. Nonetheless, we have reason to believe that at least some of our observations might prove useful to other types of agriculture, and other fields of science. No matter what the crop, every farm must find ways to handle multiple sources of variability, either by trying to control them with recipes for production, or by seeking ways to work with them. For graziers, the sustainability—in multiple senses of the word—of their farms depends on working in a place-specific way, and yet researchers in many disciplines face an academic and scientific cultures that encourage them to look for general rather than place-specific knowledge. We suspect that in other types of farming where sustainability is prioritized, similar dilemmas might arise, and we hope our concepts of agroecological principles and tools allows for the integration of the general and the place-based. We have provided our findings contextualized in our own variables of place, with the hope that others, in different contexts, can continue to engage and develop them.

For the graziers themselves are always at work along these lines, experimenting, refining, extending, adapting. Innovations on the farms we visited were as unique as the farmers themselves. After a long, muddy spring left bare patches in their pastures, one couple was taking the opportunity to introduce chicory, a blue-flowered dandelion relative which, they had read, provided good nutritional value. Another couple, citing research which showed mixed-species pastures to be more productive than those with just one plant species, had ambitiously planted a paddock with twelve different species of plants.

Let's go in deeper with another example. Sitting on the farmhouse steps, Frank explained that whenever he could afford to, he put off cutting hay in order to give the birds nesting in his hayfields time for their young to fledge. Delaying harvest that long meant poorer quality hay, as the grass matured and lost some of its protein content. And it meant that recording an interview outside on his farm had special challenges, due to the singing of the birds. But several years back Frank had participated in a study about grassland birds, and he found great satisfaction in encouraging their population on his farm. Frank's understanding about the quality of the hay probably came in part from a formula developed by traditional forage research. Yet it was a broader principle about grasslands and diversity that guided Frank's application of that recipe for hay quality, transforming the recipe into a tool for bird song.

Such decisions reflect individual graziers' goals and values, their understanding of their own farms, and their adaptation of knowledge produced by others—whether scientists or fellow graziers. As we examine how university research can relate to such place-specific farming approaches as grazing, we should note these diverse ways in which graziers interpret and adapt others' knowledge to their own farms. Any successful and lasting science for sustainable agriculture will produce knowledge that lends itself to these creative adaptations.

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