/ECOLOGICAL PLANNING FOR KANSAS TALLGRASS PRAIRIE:/
BUILDING A RANGELAND KNOWLEDGE BASE TO SUPPORT DECISION-MAKING

by
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ABSTRACT

Tallgrass prairie has become a scarce resource and much of what remains is in Kansas. Societal values associated with tallgrass prairie include clean water, fresh air, biodiversity, recreational opportunities and open space. Since grazing and fire are essential components for protecting tallgrass prairie, private rangeland manager knowledge should be compiled with appropriate scientific information to support decision-making that is ecologically sustainable. Potential regulation of land use for water quality is expected to prompt increased dialogue among rangeland managers, scientists, policy makers and others. An system for knowledge management is adapted to illustrate how an exchange of scientific and local rangeland management information can enhance the existing knowledge base used for both private and public decision making. Geographic information system (GIS) models can be used to facilitate this exchange while simultaneously incorporating local biophysical and sociocultural knowledge into decision support tools. Existing Kansas organizations with rangeland management knowledge are in a strong position to use this approach to develop an extensive database of useful knowledge about tallgrass prairie.

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Introduction

It is estimated that seventy-five percent of the tallgrass prairie landscape in Kansas has undergone conversion to other cover types since European settlement (Lauver *et al.* 2001). Kansas has actually experienced less tallgrass prairie loss relative to other states because of the large expanse Flint Hills tallgrass prairie which is not conducive to crop production due to rocky soils (Briggs *et al.*, 1997). Land use that includes prescribed fire and grazing has helped prevent conversion of this and other remaining tallgrass prairie to woodlands. Long-term protection of remaining tallgrass prairie from conversion to cropland, woodland or urbanized area can be accomplished through ecological planning. Knapp and others have identified fire, drought and grazing as essential ecological variables for preserving tallgrass prairie (1998).

Steiner (2000, p. 9) defines ecological planning as "the use of biophysical and sociocultural information to suggest opportunities and constraints for decision making about the use of the landscape." A broad rangeland management knowledge base would help coordinate decision making among policymakers, scientists and land managers about the use of tallgrass prairie. This would support societal values including a reliable supply of clean water, fresh air, recreational opportunities, and open space. To help ensure that societal needs are achieved and sustained, biophysical and sociocultural variables influencing the management of private tallgrass prairie used for grazing (tallgrass rangeland) should be compiled to support decision making at different hierarchical levels. An approach is suggested that entails knowledge exchange among scientists, grazing managers and others familiar with tallgrass prairie; and subsequent cataloging of available knowledge considering its suitability for making decisions. Such knowledge can be used by public planning bodies developing land use controls, by agencies and organization developing natural resource conservation programs, and by rangeland managers planning grazing management strategies.

This report documents how a structured exchange of scientific and local information can be used to produce the improved knowledge base needed to support planning and management decisions that are socially acceptable and ecologically sustainable. An ongoing participatory approach is recommended for building the knowledge base and using it to develop plans, programs, and private land management strategies. Those developed should be adaptable to changing circumstances that could result from changing social values and our inability to reliably forecast the results interactive biophysical and sociocultural systems. To illustrate the process, development of a knowledge base built from scientific and local information about tallgrass rangeland and water quality is discussed. A similar approach could be applied by planners, agency personnel and land users researching a variety of other interactive biophysical and sociocultural systems

In the process of presenting a suggested approach for developing a rangeland knowledge base, the study also provides background information about tallgrass prairie which planners should find useful and helps demonstrate to private land managers the significance their involvement in participatory processes. It will conclude by identifying specific opportunities which could emerge to accomplish multiple goals for Kansas tallgrass prairie when institutions and individuals are provided easy access to decision support tools and a knowledge base of factors influencing management of the tallgrass prairie.

Building a Rangeland Knowledge Base

Water quality, biodiversity, open space, and other resource concerns are increasing public demand to improve planning and management associated with the use of private tallgrass prairie grasslands. Rangeland management decisions are subject to interacting biophysical, economic, and social systems. Collaboration among scientists (social and natural), private rangeland managers, local institutions, and citizens would facilitate mutual understanding and identify goals for sustainable rangeland use. Community-based ecological planning can be structured to tap the local knowledge necessary to successfully identify and implement plan objectives. The knowledge base development process presented would serve this purpose.

Opportunities for using the combined knowledge of scientists and rangeland managers to help develop and implement plans for sustainable use of Kansas tallgrass prairie are presented. Through collaborative learning, participants are expected to develop respect for others' knowledge and experience, which could lead to increased voluntary adoption of management practices needed to accomplish private and public objectives for tallgrass prairie rangeland. Mutual respect and understanding can also facilitate monitoring and research needed to adapt management and/or update plans as societal goals and system variables change over time.

Researching available knowledge through a participatory process (Figure 1) developed by Allen and Bosch (1996) has been used to promote collaboration and common understanding by helping scientists and stakeholders build mutual respect for other knowledge and by helping the various stakeholders understand different perspectives on rangeland issues. Geographic information system (GIS) technology and the integrated system for knowledge management (ISKM) framework are presented as tools to facilitate

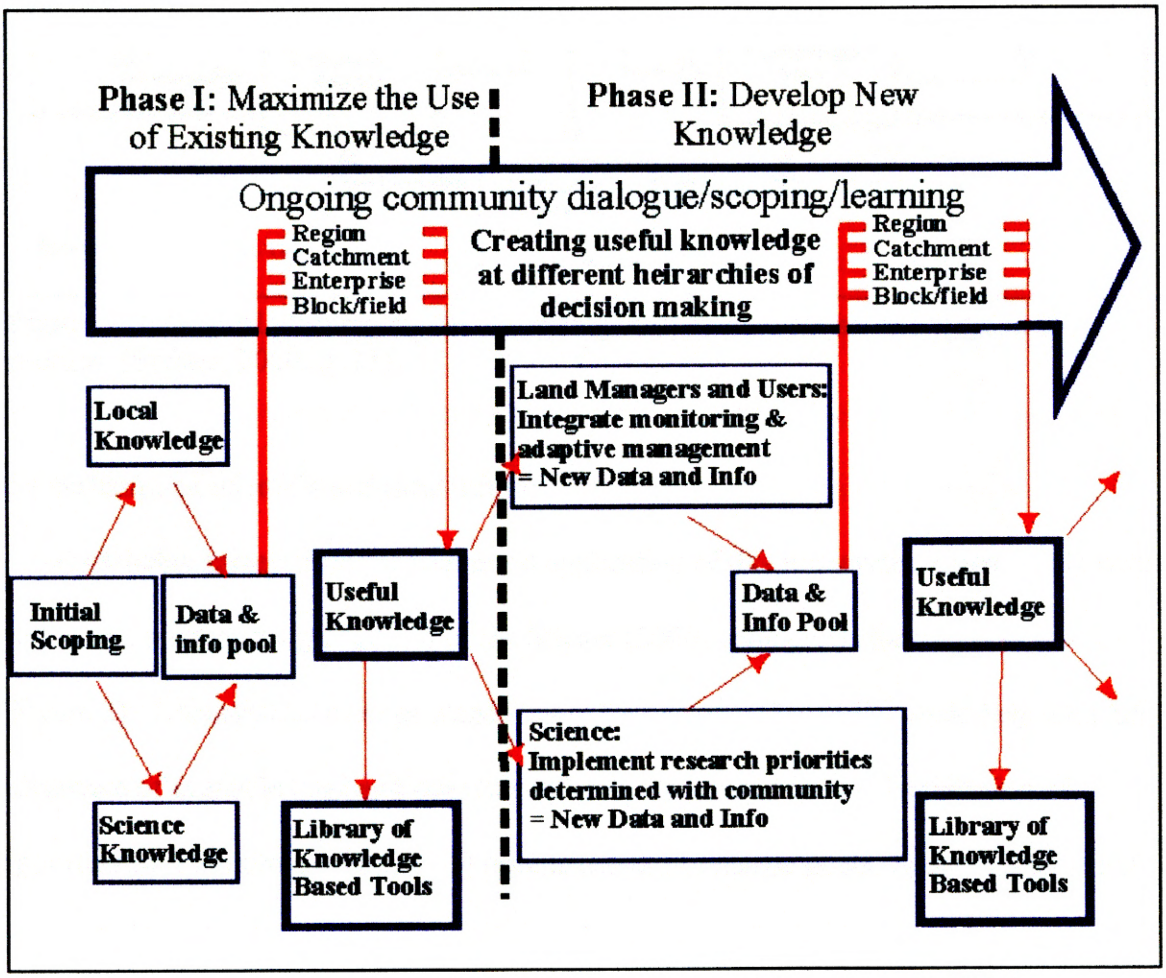

Figure 1. Participatory Integrated System for Knowledge Management (ISKM) framework illustrating the development of a knowledge base over time and community determination of the usefulness of knowledge at different levels of decision making (Allen and Bosch, 1996, p. 5)

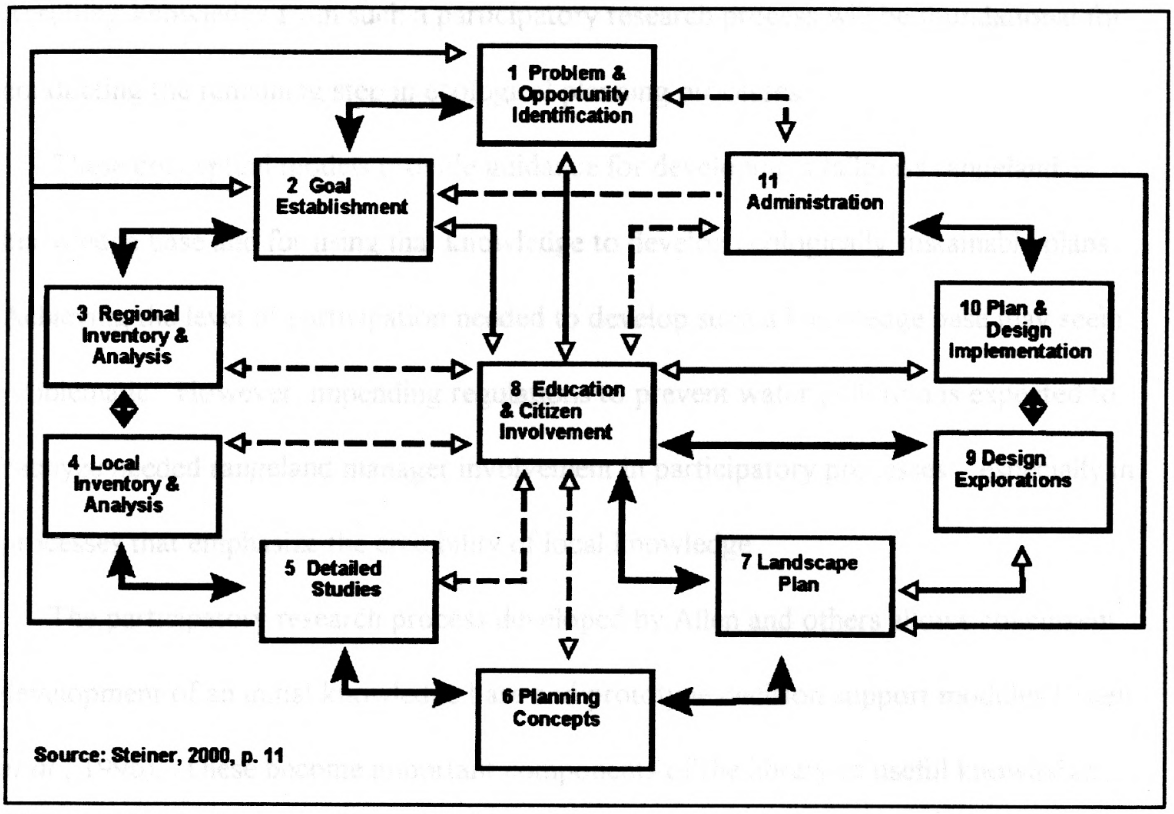

Figure 2 Ecological planning model illustrating citizen involvement as central to the process. (Steiner, 2000, p. 11)

the exchange of scientific and local information.

Knowledge gained from the suggested application of this framework corresponds with that need for conducting steps 1-4 of the Stiener (2000) ecological planning process (Figure 2). Using the knowledge management framework (Figure 1), would help take full advantage of available local and scientific information needed for 1) identification of opportunities to address problems, 2) establishment of realistic goals, 3) development and interpretation of regional-level biophysical and sociocultural knowledge, and 4) development and interpretation of local-level biophysical and sociocultural knowledge.

Resulting knowledge from such a participatory research process will be foundational for conducting the remaining step in ecological planning processes.

These conceptual models provide guidance for developing a tallgrass rangeland knowledge base and for using that knowledge to develop ecologically sustainable plans. Achieving the level of participation needed to develop such a knowledge base may seem problematic. However, impending regulations to prevent water pollution is expected to catalyze needed rangeland manager involvement in participatory processes – especially in processes that emphasize the credibility of local knowledge.

The participatory research process developed by Allen and others allows concurrent development of an initial knowledge base and prototype decision support modules (Allen *et al.*, 1996). These become important components of the library of useful knowledge based tools (see Figure 1) needed to support plan, program, and management strategy decision-making. In this research, a prototype module is presented which is designed to support selection of dormant pastures for use which supports both water quality and enterprise profitability. The prototype module will be used to help illustrate how a rangeland water quality knowledge base and decision support tools can be simultaneously assembled. Existing Kansas organizations with grazing management knowledge (Appendix A) are suited to use this approach to contribute useful knowledge to a rangeland knowledge base and apply the accumulative knowledge to environmental protection strategies.

It will be shown that knowledge exchange between scientists and stakeholders could be led and/or facilitated by personnel from Kansas State University Research and

Extension, Natural Resources Conservation Service, US Fish and Wildlife Service, and the Kansas Rural Center. Tapping information held by rangeland managers about the relationships between interactive biophysical and sociocultural systems will be crucial for developing the knowledge base. Members of organizations such as the Kansas Association of Conservation Districts' Grasslands Committee, the Tallgrass Legacy Alliance, the Kansas Grazing Land Coalition, and private grazing information sharing networks can contribute such information. Public access to the knowledge could then lead to achievement of multiple goals for tallgrass prairie via at least three avenues: 1) public bodies conducting ecological planning, 2) agencies and non-government organizations developing conservation programs and/or 3) private land managers employing conservation oriented management strategies.

Grazing Management and Water Quality

Since water quality is a major issue driving public planning and policy associated with agricultural land, grazing land water quality will be used to illustrate community-based knowledge exchange opportunities. This issue is expected to serve as a catalyst for development of an extensive rangeland management knowledge base. Kansas State University Research and Extension plans to deliver a newly developed Water Quality Financial Analysis and Resource Evaluation (WQFARE) Stewardship Program to natural resource professionals and agricultural producers across the state (Ohlenbusch and Jones, 2001). This includes conducting knowledge exchange in a format similar to that described by Allen and others (1996).

WQFARE is a grazing land water quality inventory and planning guide developed with support from U.S. EPA section 319 funding from Kansas Department of Health and Environment. Following five years of literature collection and study area analyses, the guide was produced based on Kansas data and review of select references. A participatory research framework developed by Allen and others (1996) will be used to encourage its implementation and be used to help refined educational materials. The history, current status and future directions of WQFARE knowledge development can be shown in an adaption of their knowledge management framework shown in Figure 1. This and the potential to produce useful knowledge relevant for decision making at different scales of water quality planning and management (basin, watershed, enterprise, and pasture) is shown in Figure 3.

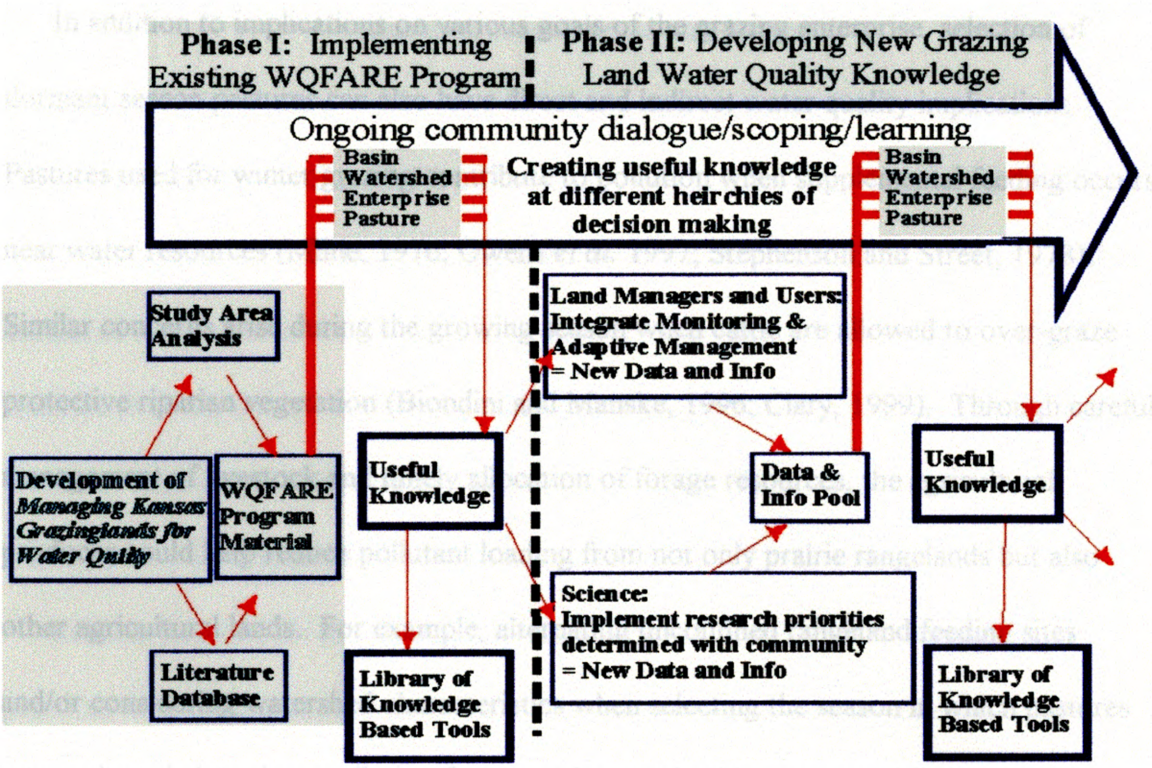

Figure 3. Areas in gray are adapted components of participatory research framework illustrating the status (Phase I) and direction (Phase II) of the WQFARE Stewardship Program. (Adapted from Allen and Bosch, 1996)

Efforts made on private rangeland to address water quality and other environmental concerns are for the most part voluntary. Successful promotion of voluntary management changes will likely require consideration of multiple factors influencing management decisions. For example, programs or recommended practices for enhancing water quality should take into consideration economic and physical limitations of the agricultural management system as well as preferences of the manager. A good example which will be used for illustrating the significance of these factors to management, and consequently program development, is the selection of pastures for dormant season grazing.

In addition to implications on various goals of the grazing enterprise, selection of dormant season pastures can also have direct and indirect water quality implications. Pastures used for winter grazing contribute to pollution when supplemental feeding occurs near water resources (Milne, 1976; Owens *et al.* 1997; Stephenson and Street, 1978). Similar concerns arise during the growing season when cattle are allowed to over-graze protective riparian vegetation (Biondini and Manske, 1996; Clary, 1999). Through careful management of livestock and timely allocation of forage resources, the agricultural producer could help reduce pollutant loading from not only prairie rangelands but also other agricultural lands. For example, alternating unconfined rangeland feeding sites and/or considering watershed characteristics when selecting the season in which pastures are used can help reduce pollution from prairie rangeland pastures. Additionally, pollution risk associated confined (non-rangeland) livestock feeding could be reduced by increasing the distribution of livestock on rangeland during the dormant season.

Total Maximum Daily Load (TMDL) plans are currently being established to reduce the amount of pollutants entering Kansas surface water bodies. If voluntary efforts fail to achieve established non-point source water pollution standards within five years of establishment of basin-specific plans, implementation efforts could shift away from voluntary approaches (EPA, 2000; KDHE, 2002). Regulation, or the threat there of, is expected to be an impetus for increased planning and improved management associated with tallgrass rangeland.

Research Justification and Intent

Currently, compliance with non-point water pollution standards on private land in Kansas is voluntary. Water quality in Kansas is most frequently in violation of TMDL standards because of fecal coliform bacterial contamination (KDHE, 2000) which is often attributed to small livestock operations that are not required to have waste containment facilities (KDHE, 2002). If there is no significant progress toward meeting TMDL standards following a five years interim period, stronger, more effective management measures may be written into TMDL plans (EPA, 2000; KDHE, 2002).

Reliable methods for influencing voluntary adoption of agricultural management practices have evaded Extension practitioners and social scientists for decades. More recently, they have begun to focus on how interactive social, economic, and biophysical complexities influence natural resource management decisions (Duram, 1998). At the same time, public demand for environmental values provided by prairie grasslands is increasing. Meanwhile, human and financial resources allocated for knowledge acquisition and resource conservation seem static, declining or unable to meet increased demand.

In the face of these challenges, increased use of participatory processes and advances in information technology are paving the way for use of an innovative approach to knowledge acquisition, resource planning and management. Participatory research, which involves collaboration between scientist and mangers, is an effective means to improve the local knowledge base about rangeland and related systems (Allen and Bosch, 1996; Duram, 1998) The resulting knowledge base can then aid in the development and implementation of plans to accomplish current goals for prairie grasslands without sacrificing the ability of future generations to meet future goals. This study proposes and documents a method existing Kansas organizations could use to develop, manage, and use such a knowledge base for meeting both current and long-term societal and ecosystem needs.

The intent of this study is to describe, in a Kansas context, the participatory research and knowledge base development process developed by Allen and Bosch (1996) and to show that resulting knowledge can be applied to ecological planning, the development of effective conservation programs, and the implementation of sustainable management strategies. This report is presented as a means for encouraging stakeholders, scientists, and resource planners to share their knowledge and improve their understanding of interactive biophysical and sociocultural variables influencing sustainable management of complex systems – tallgrass prairie in particular. Additionally, this report provides background information about tallgrass prairie and rangeland management that planners should find useful and information grazing managers should know about participatory processes and societal values for tallgrass prairie.

Background

Regardless of how economic, social, and environmental priorities for tallgrass prairie grasslands unfold, their use and development should be ecologically sustainable to help ensure that a high quality of life is maintained. From an ecological perspective, sustainable use of the tallgrass prairie is best accomplished by simulating the major natural disturbances under which the system has evolved – particularly fire and grazing (Knapp *et al.*, 1998). Key players in ecologically sustainable land use have been and continue to be agricultural land managers and the citizens of rural communities (Bellamy and Johnson 2000; Kloppenburg, 1991; Rhoads *et al.,* 1999). Remaining tallgrass prairie – that fraction which has not been overtaken by development, forestation, or cultivation – is predominantly private land which has been managed for the past century with fire and grazing (Knapp *et al.*, 1998). The review that follows highlights the value of agricultural knowledge, participatory processes, and technology for developing a rangeland knowledge base to support ecological planning, program development and sustainable grazing management strategies. Since water quality associated with grazing management seems to be growing concern, it will serve to illustrate many of the concepts presented in this report.

Tallgrass Prairie Systems Knowledge

Basic sociocultural and biophysical science knowledge about tallgrass prairie is presented, followed by a description of societal goals for tallgrass prairie and how sustainable rangeland management can help achieve these goals. This is by no means a complete listing of relevant knowledge needed for a useful rangeland knowledge base. Rather it is a brief sample of existing information from which developers and users of a tallgrass rangeland knowledge base can use for developing ecologically sustainable plans and management strategies.

Sociocultural Knowledge of Kansas Tallgrass Prairie

Solutions to broad scale environmental concerns must ultimately be implemented at the land parcel scale where site-based local knowledge is used to make management decisions. Private land manager obviously do, and must continue to, base management decisions on enterprise profitability. However, other sociocultural factors influencing management decisions can also be influential

It has been shown that rangeland management decisions are also highly influenced by tradition and lifestyle preferences (Frank, 1997). Tradition can be a useful management guide at the local scale because it is developed from valuable site-based experience. However, over-emphasis on management tradition fails to account for changing external social factor including economic variables (such as interest rates, livestock price cycles and consumer preference) and public expectations (such as water quality, biodiversity, and recreation). In order for a private rangeland owner or managers to maintain their chosen lifestyle, management practices will need to account for changing external factors.

On the other hand, public expectations for socially responsible management of grasslands must be realistic and founded on information that is applicable to the region. For example, if public perception of pristine prairie conditions are contrary to historical accounts of pre-European settlement like Hart and Hart (1997) suggest, then establishing realistic goals for prairie management may be complicated. This challenge could be magnified if public perceptions about the tallgrass prairie ecosystems are be based on media accounts of controversial grazing issues on public lands in other regions. Other rangelands may be less adapted to grazing by large ungulates and are subject to different use regulations than private tallgrass prairie rangeland.

Knowledge about the history of the tallgrass prairie in eastern Kansas is important beginning for understanding cultural values of the prairie, for understanding the impact society has had on the landscape, and for developing realistic objectives for environmental improvements. Natural events (ie. drought and fire), indigenous grazers (ie. bison and deer) and native Americans were major forces interacting sustainably with the tallgrass prairie prior to European settlement.

The first distinguishable tribe in the tallgrass region of what is now Kansas was the Pawnee who, as early as 1,000 years ago, raised squash, corn, and beans, and hunted bison on the prairie. Approximately 500 years ago the Kansa Indians (from which Kansas and the Konza Prairie are named) entered the region from the east and/or northeast (Reichman, 1987). People in both of these tribes had/have a unique cultural connection to the tallgrass prairie. For example, several native plants unique to the tallgrass prairie are believed to have significant spiritual and/or medicinal values to these tribes (Kindscher, 1992).

With European settlement and industrialization came the rapid loss of tallgrass prairie due primarily to the conversion of prairie to cropland (Reichman, 1987). Land less suited for crop production has been more-or-less preserved as tallgrass prairie because of the continued influence of essential forces. Occasional drought continued to occur, roaming bison were replaced with grazing livestock, and spring burning which prevents forestation was employed by livestock producers (Knapp *et al.*, 1998). Today in Kansas 54% of the tallgrass prairie has been converted to cropland, 11% has been invaded by woody species as a result of fire suppression, and 10% is being used for urban or other purposes (Lauver *et al.*, 2001)

The current management culture for remaining tallgrass prairie typically focuses on conversion of grazeable forage to growing cattle prior to finishing in a feedlot and slaughter. Although this culture may tend to demonstrate independent qualities, there is significant intra-cultural exchange. Ranchers find knowledge exchanged from other ranchers to be most reliable (Seacrest, 2001) and they have establish information exchange networks in Kansas and elsewhere expressly for sharing useful knowledge (Hassanein and Kloppenburg, 1995; Kansas Rural Center, 2001). Information gained from such an exchange can be adapted to the unique combination of resources on an agricultural operation and can be used to supplement management decision that may otherwise be based on personal experience and tradition alone. These are important considerations when developing a rangeland knowledge base which is ultimately intended to influence management of private land controlled by ranchers.

The final, and probably most influential, sociocultural knowledge relevant to tallgrass prairie planning and management is rangeland economics. Cattle prices generally follow a ten year cycle and it is not uncommon for an individual enterprise to be unprofitable for one or more of those years but to sustain its existence on earnings from one or two highly profitable years. Factors such as market instability, rising cost of production and increased demand for societal values associated with rangeland has prompted many ranchers to pursue alternative income sources such as hunting leases and off-farm employment. Many operations may also find earning potential from improved record keeping and business management. Interestingly, tradition rather than detailed profitability analysis guides the management decisions of many grazing enterprises.

Biophysical Science Knowledge of Kansas Tallgrass Prairie

The most useful and reliable biophysical science information for a knowledge base designed for developing plans and management strategies should be long term and specific to the region. The Konza Prairie is one of only 20 Long-Term Ecological Research stations sponsored by the National Science Foundation. Research conducted at this station indicates that drought, grazing by large ungulates, and fire are essential to the biodiversity and resilience of the tallgrass prairie ecosystem (Knapp *et al.*, 1998). There are many case studies in the scientific literature identifying specific negative influences that grazing livestock have on the environment, and indeed it would be useful to know if and when such finding hold true for Kansas tallgrass prairie. However, basic facts supported by long-term data are most appropriate for the foundational information of a tallgrass rangeland knowledge base designed to support sustainable land use decisions.

Abundant rainfall and productive soils make tallgrass prairie highly susceptible to invasion by forests in the absence of fire (Knapp *et al.*, 1998). It is the physiological adaptations of grasses which allow them to best withstand stress from not only fire, but also grazing, and extended periods of drought. This gives grasses a long-term competitive advantage over other prairie plant species which fill smaller but still important niches in the prairie ecosystem. For example, an area which is temporarily denuded by a grazing or burrowing animals will be quickly stabilized by seedlings of short-lived forbes. Subsequently, surrounding grasses will gradually revegetate the site, usually through asexual propagation by subsurface rhizomes. Figure 4 shows a more extensive conceptualization of different biotic and abiotic components affecting plant populations in the tallgrass prairie (Knapp *et al.*, 1998).

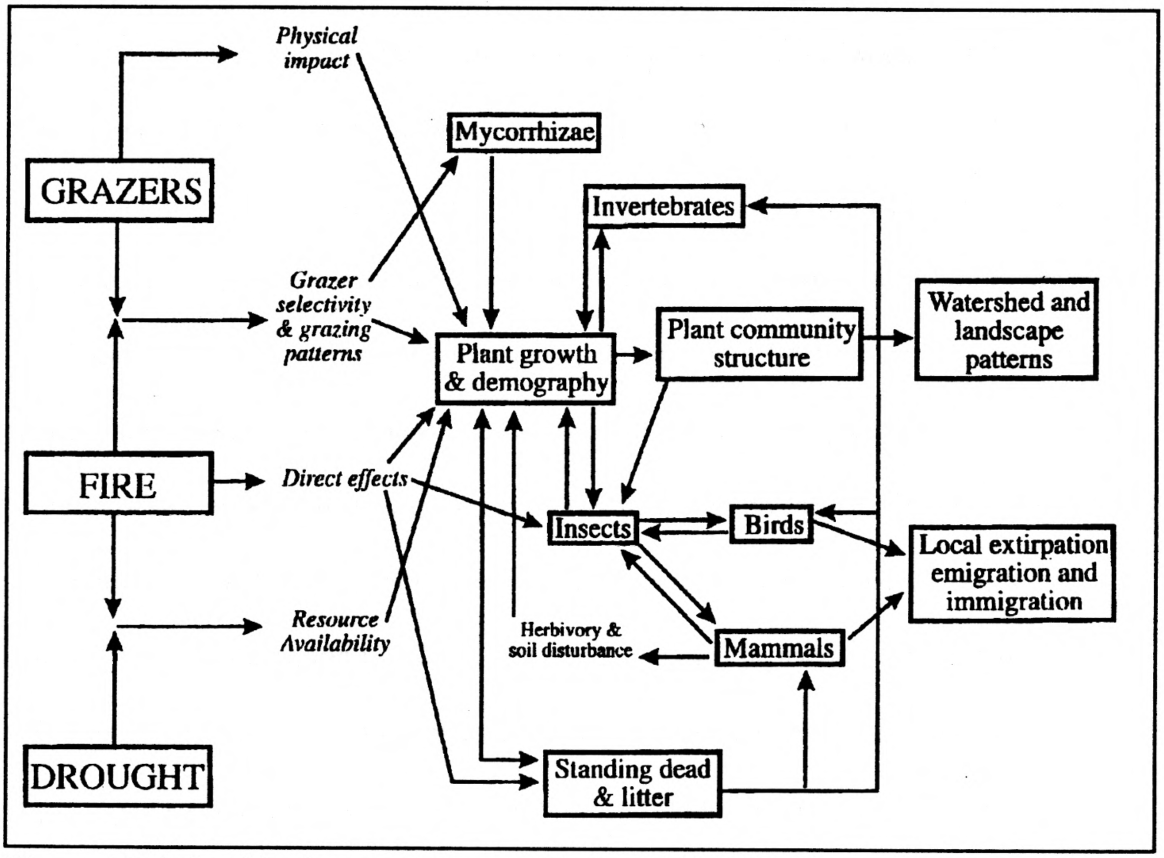

Figure 4 Relationships between the core abiotic and biotic components affecting plant populations in tallgrass prairie. (Knapp *et al.* 1998, p. 82)

Societal Goals Associated with Kansas Tallgrass Prairie

Societal goals that follow can be considered public goals based on collective public values. Water resource protection is a high priority environmental objective for Kansas (KDHE, 2001). The Kansas Water Office, Kansas Department of Agriculture, and public water supply providers are responsible for ensuring that a reliable supply of water is available in sufficient quantity to meet public needs for drinking, recreation and industry. The reliability of this supply is, to some extent, dependant upon infiltration of rain into well vegetated prairie soils and the gradual discharge of relatively clean water from springs that steadily fill streams (Sawin *et al.*, 1999) and downstream reservoirs.

Water providers are also obligated to ensure that the supply of water is safe for drinking as specified by drinking water standards administered under state authorities granted in the U.S. Safe Drinking Water Act (Dissmeyer, 2000). When a public water supply becomes polluted, costs associated with reporting and treating the water are significant. Recently, local governments were directed by EPA through state agencies to conduct source water assessments and consider establishing programs that prevent contamination. A watershed assessments is essentially an inventory of potential water supply pollution and an attempt to prioritize actions to be taken to reduce or prevent contamination. Information from the assessment can then be used to establish watershed and/or wellhead protection programs that could include land use restrictions, general and targeted public education, and management incentives for landowners and water users.

Although private wells are not subject to the same monitoring and treatment requirement the same health risks are present. Extension Councils and Conservation Districts can encourage basic private well testing to help prevent health problems caused by such constituents as nitrates and fecal coliform bacteria.

The societal goal of water quality is also regulated under the U.S. Clean Water Act. Under this law, states have been delegated authority to regulated both point source discharges into surface water and indiscrete non-point source (NPS) pollution which is usually delivered to water carried in runoff. Over the past 25 years surface water pollution originating from point sources has, for the most part, been lowered to acceptable levels (KDHE, 1997). More recently, the focus of Clean Water Act implementation has shifted to control of NPS pollution through the Total Maximum Daily Load (TMDL) program described earlier. In Kansas NPS standards for safe recreation and aquatic habitat are those which are most frequently violated (KDHE, 2000). Consequently, opportunities should exist for entities responsible for and interested in recreation, wildlife and biodiversity to work with managers of private rangeland to help achieve these standards. Beyond water recreation and aquatic ecosystem goals, tallgrass prairie grasslands provide remarkable terrestrial biodiversity and recreation opportunities.

The tallgrass prairie harbors exceptional biological diversity. Of the portion that remains undisturbed by cultivation, the greatest extent is in the Flint Hills region located predominantly in Kansas (Briggs *et al.*, 1997). Societal goals for tallgrass prairie biodiversity are both broad and specific. From a broad view, biodiversity is considered a crucial measure of the integrity and resilience of an ecosystem (Knapp *et al.*, 1998). At some point as biodiversity declines and/or disturbances (natural or anthropogenic) increase, a threshold is past – to which the ecosystem species mix may never return (Krebs, 1985). This could compromise the existence of rare or endemic species having more specific societal values. For example, the relatively diverse tallgrass prairie grasslands are home to plant species important to the social culture of native Americans (Kindscher, 1992). Many of these are medicinal plants that may becomposed of substances that could also be of even greater significance to society as a whole. Additionally, grasses are considered the most important source of food in the world (Simpson and Ogorazaly, 1986). If grassland genetics are not preserved in a natural evolving state, world food supplies could eventually be devastated by disease or pests due to lost intraspecies diversity.

Recreational opportunities on tallgrass prairie consist of a variety of outdoor sports such as hunting, hiking, biking, bird watching, and other activities of aesthetic enjoyment. Societal value place on rangeland recreational opportunities has been demonstrated in the lease of hunting privileges and in public/quasi-public support for game and non-game habitat development.

Controlled growth of urban or suburban boundaries is another societal goal associated with grasslands and their management. Since the agricultural value of remaining tallgrass prairie is low compared to other undeveloped land, it can be highly impacted by sprawling development of rural residences. It is to the advantage of city and county governments to control this growth in order to contain costs associated with providing widely dispersed public services. From the perspective of established residents, sprawling development compromises the open space and viewscapes of which they are accustom.

At both local and global scales, air quality is an additional societal goal for grasslands. Globally, there is excessive carbon in the atmosphere and grasslands have a potential to sequester much that carbon in the form of below-ground biomass (Conant, 2001). Locally, an air quality concern is odor from livestock feeding facilities. If greater reliance could be placed on using grasslands to feed livestock to maturity, then this problem would be reduced because of the wide distribution of livestock waste.

Grazing Management, Vegetative Cover, and Multiple Goals

Long-term ecological research conducted on the Konza Prairie indicates that periodic fire and grazing by large ungulates such as cattle or bison are essential variables for maintaining the ecological resilience and adaptability of tallgrass prairie (Knapp *et al.*, 1998). Sustainable grazing is guided by the management principles of stocking rate, uniform forage utilization, degree of utilization, season of use, kind and class of livestock, and systematic rests (Ohlenbusch *et al.*, 1995). The specific application of these principles will vary depending upon goals and the unique resources of each management unit.

A challenge for planners, resource management specialists, and private land managers is to satisfy multiple goals while minimizing trade-off when objectives for different goals conflict. Through collaboration and coordinated decision-making, practical means of applying prescribed burning and grazing management principles can be identified to meet goals. At times, concessions will be necessary in determining how to achieve the greatest net benefit may difficult.

A reasonable approach to address this challenge is collaboration to identify objectives for multiple goals based on vegetative cover. Vegetative cover is relatively easy to measure, one of a few important environmental variables easily controlled by management, and is already commonly used to guide prairie management decisions (Ohlenbusch *et al.*, 2001).

Local Knowledge for Participatory Research and Planning

Historically, natural resource management plans and programs devised to accomplish specific goals have been highly influenced by available scientific knowledge of biophysical systems. Incorporation of local knowledge into agricultural goal setting has increased significantly over the last few decades (Bellamy and Johnson, 2000; Duram and Brown 1999; Rhoads *et al.*, 1999).

Social involvement can continue to enhance the planning process by promoting use of local knowledge of biophysical and sociocultural aspects of agricultural system. In support of farmers involved in the social movement seeking more environmentally friendly agriculture, Kloppenburg (1991) presents a strong argument for placing greater emphasis on societal use of local agricultural knowledge. He argues that knowledge from positivist and reductionist science cannot precisely represent nature because of its focus on translocality rather than locality and its inability to account for system variability. Kloppenburg advised:

> The route to solutions to problems at the whole-farm level–at the local system level–runs not through agricultural scientists, but through those who think in terms of whole farms, . . . and whose knowledge has been developed by the integration of hand, brain, and heart in caring labor on whole farms–the farmer (Kloppenburg, 1991, p. 531)

Despite his concerns about the reliability of scientific knowledge, Kloppenburg (1991) ultimately saw the need for collaborative exchange of local and scientific knowledge and he presented sociology as an appropriate discipline to help reform agricultural science.

It can generally be accepted that people develop an understanding of their cultural and ecological surroundings can have unique insight that is unfamiliar to trained scientist (Blaikie, 1994; DeWalt, 1994). Much of the research reporting knowledge exchange between scientist and agricultural resource managers is focused on the study of developing countries (Blaikie *et al.*, 1997; DeWalt, 1994). Rhoads and others (1999) found that there was a poor understanding of the social mechanisms of community-based environmental decision-making in the United States because of the absence of detailed empirical studies. Their research found that concepts of nature, environmental quality, and sustainability are derived from social values and can not be derived strictly through scientific inquiry. Their mid-west U.S. case study concludes that "...because community based decision making is fundamentally a social process, scientists and technical experts must develop an understanding of the place-based social worlds of local communities." (Rhoads *et al.* 1999, p. 306).

Participatory Natural Resource Planning

Public participation and collaboration, as opposed to traditional top-down centralized decision making, is increasingly seen as a viable approach to addressing complex resource management issues (Bellamy and Johnson, 2000; Duram and Brown 1999; Rhoads *et al.*, 1999). Research by Duram and Brown (1999) evaluating participation in watershed planning across the United States found that if a collaborative approach is attained, success can be achieved even if it begins as a mandate. They also found that two-way communication methods were best for soliciting participation despite greater time and financial requirements. A separate review of U.S. watershed initiatives adds that effective watershed planning is typically led by agencies having extensive field experience and local credibility (Born and Genskow, 2000). Effective watershed planning also ". . . draws upon biophysical and social science, as well as local knowledge, to generate sound diagnosis of the problems and produce clear directions and feasible actions for resource management" (Born and Genskow, 2000, p. 20).

Bellamy and Johnson (2000) identified three major difficulties in implementing a community-based approach to ecologically sustainable land use: the complexity of the problems being undertaken, failure to recognize it as a continuous process rather than a goal, and failure to include all interests in the community. They promote an adaptive approach to ecosystem management which is responsive to changing circumstances and new knowledge rather than the traditional planning methodology applied within fixed time-frames. A shift toward adaptive ecosystem management is resulting, in part, due to the difficulty in achieving multiple-goals for natural resource through planning methodology relying exclusively on technical and scientific methods (Bellamy and Johnson 2000). Efforts to develop plans for use of Kansas grasslands should consider the previous points. The tallgrass prairie is a complex natural ecosystem important to multiple societal values including air quality, biodiversity, open space, and water quality.

Weber (2000) characterizes many such decentralized, collaborative and participatory efforts across the United States as part of a new environmental movement he labels grass-roots ecosystem management. He describes efforts of this movement as centered in rural communities and dependent on natural resources for at least 25% of their economy. In pursuit of sustainable land use, they adopt a holistic worldview seeking to meld ecology and economics with community needs. Its efforts, however, are unsuited for addressing environmental issues that occur on a regional, national, or global scale. Consequently, survival of grass-roots ecosystem management organizations may depend on their linkage to larger established institutions that have the resources and authority to support and coordinate local efforts which are addressing individual components of problems larger in scope (Weber, 2000).

Tapping Local Agricultural Knowledge of Grassland Systems

Because of their local insight and their direct involvement in resource management, active participation by agricultural producers is important to ecologically sustainable land use in rural areas. Experience of agricultural producers provides vital insight into system functioning at the local scale (DeWalt 1994, Duram 1998). Additionally, landholder acceptance of social responsibilities for managing the resources they use is increasingly seen as the underpinning of ecologically sustainable land use. However, for a wide variety of social, economic, cultural, perceptual, and situational reasons, known solutions to problems are not being adopted at the farm level (Bellamy and Johnson 2000, Dewalt 1994, Rhoads *et al.*, 1999). In recognition of this, there is an increasing need for integrated systems approach to resource management in agricultural environments (Bellamy and Johnson, 2000; Duram, 1998). This type of approach accounts for interacting biophysical and sociocultural variables, and is conducive to adaptation over time as values shift and/or knowledge about the system improves.

According to Duram (1998) understanding agricultural producer characteristics and attitudes associated with adoption of conservation methods will lead to appropriate policies for sustainable use of natural resources. Behavioral pragmatism is the philosophical basis for such environmental issues that focus on human behavior. A pragmatic behavioral approach can be particularly valuable at the grassroots level for encouraging change and new ideas because it ". . . does not seek judgment; rather, it seeks to learn what has occurred already, what is happening now and, what adjustments are possible" (Duram, 1998, p.92).

An explanation for conservation practices not being adopted is failure to integrate local knowledge and experience with scientific knowledge used for decision-making (DeWalt 1994, Duram 1998, Rhoads 1999). According to Duram (1998) agricultural lifestyles, more than most others, are based on integrated relations between humans and the environment. Consequently, agricultural producers are a logical source of the site-based environmental management information needed to ensure ecological plans are sustainable. This may be particularly true of knowledge about relatively diverse tallgrass prairie grasslands of eastern Kansas. According to DeWalt (1994) the value of local knowledge for resource management is greatest for biologically diverse systems.

Ikerd (1993) expands on the evolving role local agricultural knowledge plays in a systems approach to ecologically sustainable land use. An approach focusing on individual farming practices, methods, and enterprises may have been appropriate in the industrial era, but not so in the information age of today where knowledge drives economies and politics. An integrated systems approach which focuses on knowledge-base development of whole farms and communities is needed to address changing environmental, economic, and social conditions.

Bellamy and Johnson (2000) described barriers to sustainable resource management, including inadequate understanding of the long-term effects of agricultural activities on the environment, insufficient human, financial and knowledge base resources, and the short-term time frame of typical agriculture and government decision-making processes. They also identified bridges leading toward sustainable agriculture under an integrated resource management system. These opportunities included agriculture's strong culture of mutual support and information exchange, particularly at a time when new information technology is improving the capacity of communities to address resource management issues.

A knowledge sharing culture unique to grazing resource managers was examined by Hassanein and Kloppenburg (1995) and found be to useful in helping participants overcome limitations of personal experience. Networks such as those studied by Hassanein and Kloppenburg (1995), are a common means of disseminating local grazing management knowledge. At least eight such privately led organizations are active in Kansas (Kansas Rural Center, 2001). They are listed with a few additional similar organization is Appendix A. Extension and Natural Resource Conservation Service (NRCS) scientists in Missouri, challenged in meeting grazing management consultation demands, are beginning to develop similar organizations patterned after collective learning groups in New Zealand (Moore and Kennedy, 2001). If information exchange among managers can be expanded to included reciprocal exchange with natural and social scientists, and public representatives, the potential for developing a useful tallgrass prairie rangeland knowledge base is strong.

Effective two-way knowledge exchange between rangeland scientists and individual private land managers occurs regularly across the United States. University Research and Extension and Natural Resources Conservation Service (NRCS) staff are the scientific participants in much of this exchange. Additional organizations having technical staff exchanging grazing management knowledge with private grassland managers include: U.S. Fish and Wildlife Service, private consulting firms, and rural development and sustainable agriculture organizations.

Bottom-up GIS and Decision Support Tools

Geographic information system (GIS) technology is increasingly used as a tool to incorporate local knowledge into public planning, a process Talen (2000) called bottom-up GIS. Use of GIS visualization and data storage capabilities would greatly enhance the ability of scientists and rangeland managers to communicate and analyze the interconnections between spatially oriented biophysical and sociocultural variables.

The integrated system for knowledge management framework shown on page 4 in Figure 1 and adaptions of it have been used in New Zealand to support ongoing dialogue between rangeland managers, scientists, policy-makers, and other interest groups (Allen *et al.*, 1996; Allen *et al.*, 2001;Gibson *et al.*, 1995). This framework has helped participants to share their experiences and observations; leading to construction of a knowledge base that supports more informed decision making. Use of the internet is now being explored as a means to enhance information sharing and decision support using this conceptual model (Allen *et al.*, 2001).

Various decision support tools can be used to facilitate desired communication among scientist and managers. Opportunities to use such tools for planning and management are increasing rapidly as information systems technologies such as telecommunications, the internet, Geographic Information Systems (GIS) and social and physical systems models are integrated and become more accessible and user-friendly. Integration of GIS visualization and analysis capabilities with decision support tools is increasingly being used for water quality planning and grazing management applicable to grassland systems in Kansas (Brock and Ownsby, 2000; Cochrane and Flanagan, 1999; Gillingham and Thorrold, 2000; Koelliker and Bhuyan, 2000; Mankin *et al.*,1999; Prato, 1999).

Increased local use of decision support tools at the watershed and field scales should be expected with increased use of GIS by staff of local institutions such as County Extension Offices, Soil and Water Conservation District, non-profit organizations, counties and cities. With their support this could even lead to widespread use of GIS and integrated decision tools by land users such as rangeland managers.

Coordinated use of decision support tools could be an important component of community-based knowledge exchange and ecologically sustainable use of Kansas tallgrass prairie rangeland. Kansas State University Research and Extension plans to deliver its Water Quality Financial Analysis and Resource Evaluation (WQFARE) Stewardship program to watershed communities in Kansas (Ohlenbusch and Jones, 2001). They will utilize the knowledge exchange format developed by Allen and others (1996). That adaption of the Integrated System for Knowledge Management (ISKM) participatory research framework, shown in Figure 5, helps illustrate how decision support system (DSS) module prototyping can be conducted simultaneously with the more encompassing knowledge base development process.

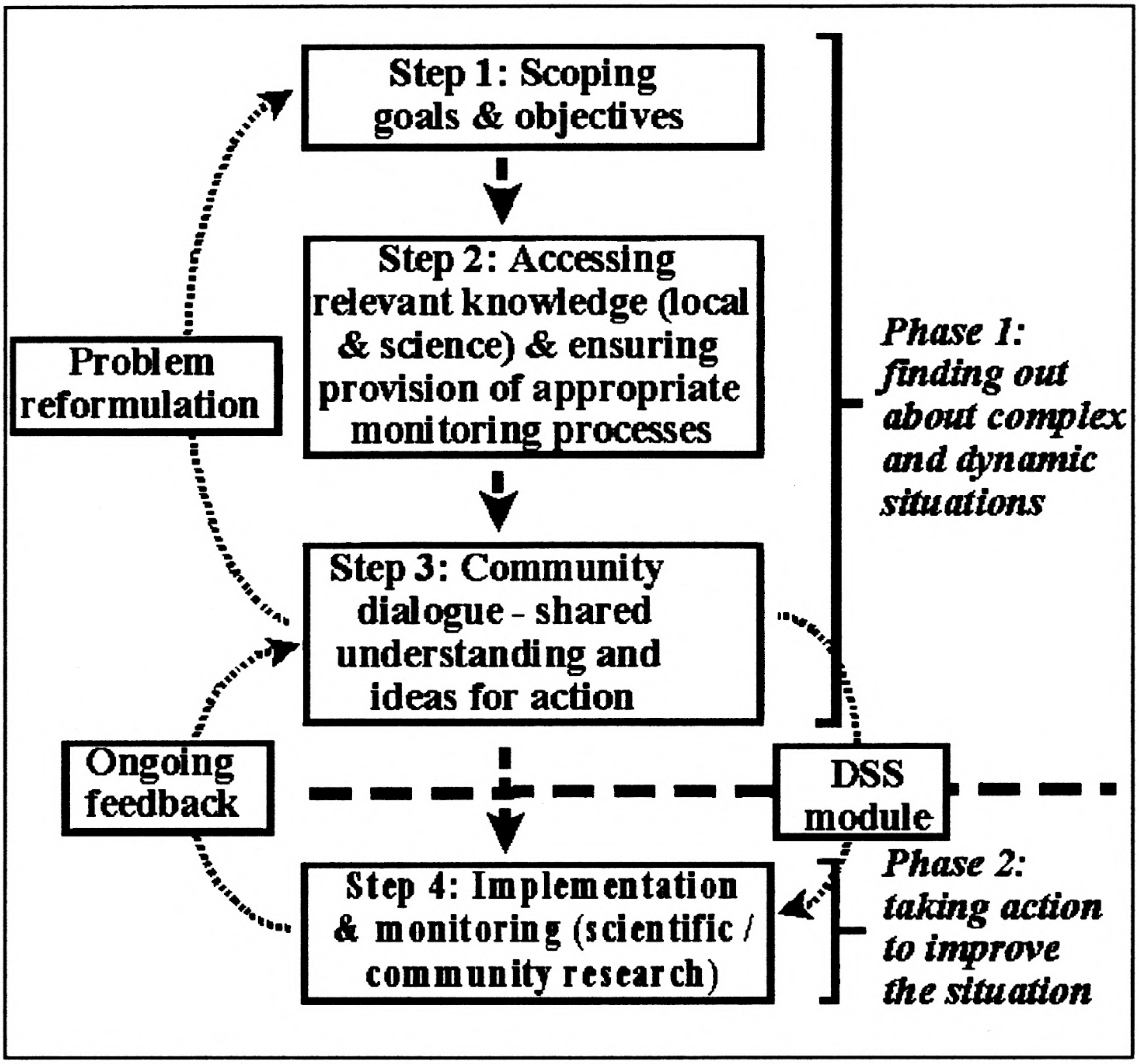

Figure 5 Knowledge management framework illustrating decision module development. (Allen *et al.*, 1996).

Background information in the review that follows introduces field research conducted for this report. It will be used later in an example explaining how local and scientific information can be combined to develop a prototype DSS modules for water quality protection on tallgrass rangeland during ISKM knowledge base development.

Kansas Rangeland Water Quality Example

Careful management of riparian vegetation has been identified as a principle component for water quality protection in Kansas (Brooks and Dienes 1993, Ohlenbusch *et al.* 1995). One approach to addressing concerns about riparian grazing is informed selection of pastures for increased dormant season grazing. Development of a prototype dormant season grazing decision support module is presented to illustrate how a library of knowledge-based tools similar to that described by Allen and others (1996) can be produced for Kansas tallgrass prairie rangeland.

The following is simply a sample of biophysical research applicable to rangeland management and water quality. This type of information would contribute to foundational knowledge for simultaneous development of a rangeland knowledge base and associated decision support tools. Relevant local knowledge about these and other biophysical variables, as well as important cultural and economic variables that influence management decisions would also be incorporated into a rangeland knowledge base and associated decision support tools.

<u>Biophysical Information for a Pasture Selection Module</u>

Finding solutions to water quality concerns associated with rangeland depends upon an understanding of livestock behavior (Ohlenbusch *et al.*, 2001). Slope and distance to water are primary influences on grazing distribution patterns (Senft *et al.*; 1987). Cattle generally avoid grazing slopes greater than 10% (Cook, 1966; Mueggler, 1965). A zone immediately surrounding a preferred watering point typically receives heavy use regardless of the season (Senft *et al.*; 1985b). Field observations by ranchers and grazing land water quality professionals in Kansas suggest that, when all other factors are equal, livestock prefer drinking from site types in the following order: 1) a trough watered from a spring or well, 2) pond, 3) pool in a stream, and 4) a flowing point on a stream (Ohlenbusch *et al.*, 2001). To help promote livestock distribution for improved water quality, Ohlenbusch (1995) recommends having watering points within one-half mile of any area within a pasture.

Additionally, thermal environments, and forage quality and quantity interact to influence cattle location during periods of both grazing and resting (Beaver and Olson 1997). Arnold (1985) explains that between periods of grazing, cattle usually spend from 5-9 hours per day ruminating, during which between 62% and 83% of their time is spent lying down. Since certain areas are preferred for resting, livestock waste becomes relatively concentrated there. He adds that when temperatures are less than 15° C little night grazing occurs. This suggests that locations cattle prefer for night time resting may be another potential water quality concern for rangelands during the colder winter months. The amount of waste concentrated at such sites and the abundance of vegetative cover separating the sites from water resources would determine the relative level of concern sites pose on water quality (Ohlenbusch *et al.*, 2001).

In northeastern Colorado, dormant season grazing is recommended for pastures that are almost exclusively riparian because trampling has less impact on relatively dry flood plains and because of forage supplementation by fallen cottonwood leaves reduces forage demand (Sedgwick and Knopf 1991). This approach may have additional water quality benefits since research conducted at the Konza Prairie suggests that tree leaves are a major contributor to nutrient loading in tallgrass prairie streams (Knapp *et al.*, 1998). Also, in northeastern Colorado dormant season grazing is desirable in pastures that include both riparian and upland vegetation. At the onset of the dormant season grazing, preference shifts from plant communities in intermittent drainage to uplands and ridgetops (Senft *et al.*, 1985b).

Similarly, Masters and others (1996) reports that winter grazing in Nevada can benefit riparian conditions because cattle congregate less in creek bottoms during colder winter months. Likewise, in a study of New Mexico rangeland having minimal riparian areas, pasture use shifted from riparian to upland vegetation in the dormant season. In each pasture, time spent grazing was lowest from November to February because the animals did not leave protection (wooded ridges) for long to graze. Their daily distance traveled was shorter and they spent more time grazing during midday taking advantage of warmer temperatures (Goodman *et al.* 1989). This seems to support research by others who found that to avoid cold stress in the winter cattle decrease their exposure to wind or increase their exposure to sun, and that the presence or absence of wind is an important factor that affects where animals both rest and graze (Senft et al., 1985a). Adams and others (1986) recommend selection of pastures that provide feeding and resting sites protected from the wind. During late fall and winter the prevailing wind direction in Kansas is from the North and Northwest (KDHE 2000). Further research by Adams et al. (1996) describes economic incentives that can be associated with dormant season grazing.

Sociocultural Information for a Pasture Selection Module

Sociocultural factors influencing the management of prairie rangeland include tradition, lifestyle preferences, and economics (Frank, 1997). In the tallgrass prairie region of Kansas these factors have, over time, resulted in a spectrum of rangeland management styles. They range from farmers who have livestock as a secondary enterprise primarily for managing crop byproducts and for grazing areas that are impractical for raising crops, to ranchers that exclusively manage native tallgrass prairie.

The resource balance of individual management units can limit the practicality of making management adjustments in response to changing lifestyle preferences or economic situations. However, in some cases management adjustment contrary to tradition can be identified to address these changing circumstances. A possible example is increasing reliance on dormant rangeland for wintering cows as opposed to reliance on confined or semi-confined feeding of harvested crops.

One of the most costly facets of a cow/calf agricultural enterprise is feeding cows after grazing forages enter dormancy. Rather than providing the cows with higher quality mechanically harvested forage, there can be significant advantages to relying on the cows to harvest (by grazing) their daily dry matter requirements and providing supplements to meet any nutrient deficiencies (Adams *et al.*, 1996).

Residue left after crop harvest is a common forage source for cows during the dormant season. When crop residues are not a readily available source of forage, dormant prairie rangeland is another economical alternative (Adams *et al.*, 1996). To this end, rangeland pastures can be left ungrazed or lightly grazed during the growing season for subsequent dormant season use. Intentionally leaving rangeland forage for dormant season grazing could also provide added benefits including cover for wildlife, drought mitigation, and water quality protection.

Agencies and organizations concerned with water quality protection may find it in their interest to promote dormant season grazing with funding for conservation education and incentives. An improved understand of factors that influence the selection of rangeland pastures for dormant season grazing would help advance such opportunities. Delivery of the Water Quality Financial Analysis and Resource Evaluation (WQFARE) Stewardship Program by Kansas State University Research and Extension begining in 2002 presents an opportunity to develop an improved understanding of these factors (Ohlenbusch and Jones, 2001).

Methodology

To test the application of these concepts, a demonstration project was consisting of: 1) conducting preliminary research for a prototype decision support module for selection of tallgrass rangeland pastures for dormant season grazing, 2) illustrating how decision support modules can facilitate knowledge exchange between stakeholders and scientists, how models can be improved by incorporation of local system knowledge, and how they can be used as a tool for bottom-up community-based decision making, and 3) demonstrating the capacity of existing organizations to contribute to the local knowledge base needed to help ensure ecologically sustainable use of Kansas tallgrass prairie.

Prototyping a Module for Dormant Pasture Selection

The purpose of this field research is to study rangeland pastures that are selected for grazing cows during the dormancy of tallgrass prairie grasses. The terrain of Northern Flint Hills rangeland pastures in Pottawottomie County study area (Figure 6) was analyzed to help test the hypothesis that aspect is an important factor influencing selection of pastures for dormant season grazing. On November 10, 2001 rural roads in Pottawatomie County Kansas were driven to identify Flint Hills tallgrass rangeland pastures used for dormant season grazing. Pasture locations were recorded using global positioning technology. This data was translated into a file format viewable in *ArcGIS* software. The geographic information system (GIS) was subsequently used to develop data needed to evaluate terrain characteristics of the pastures.

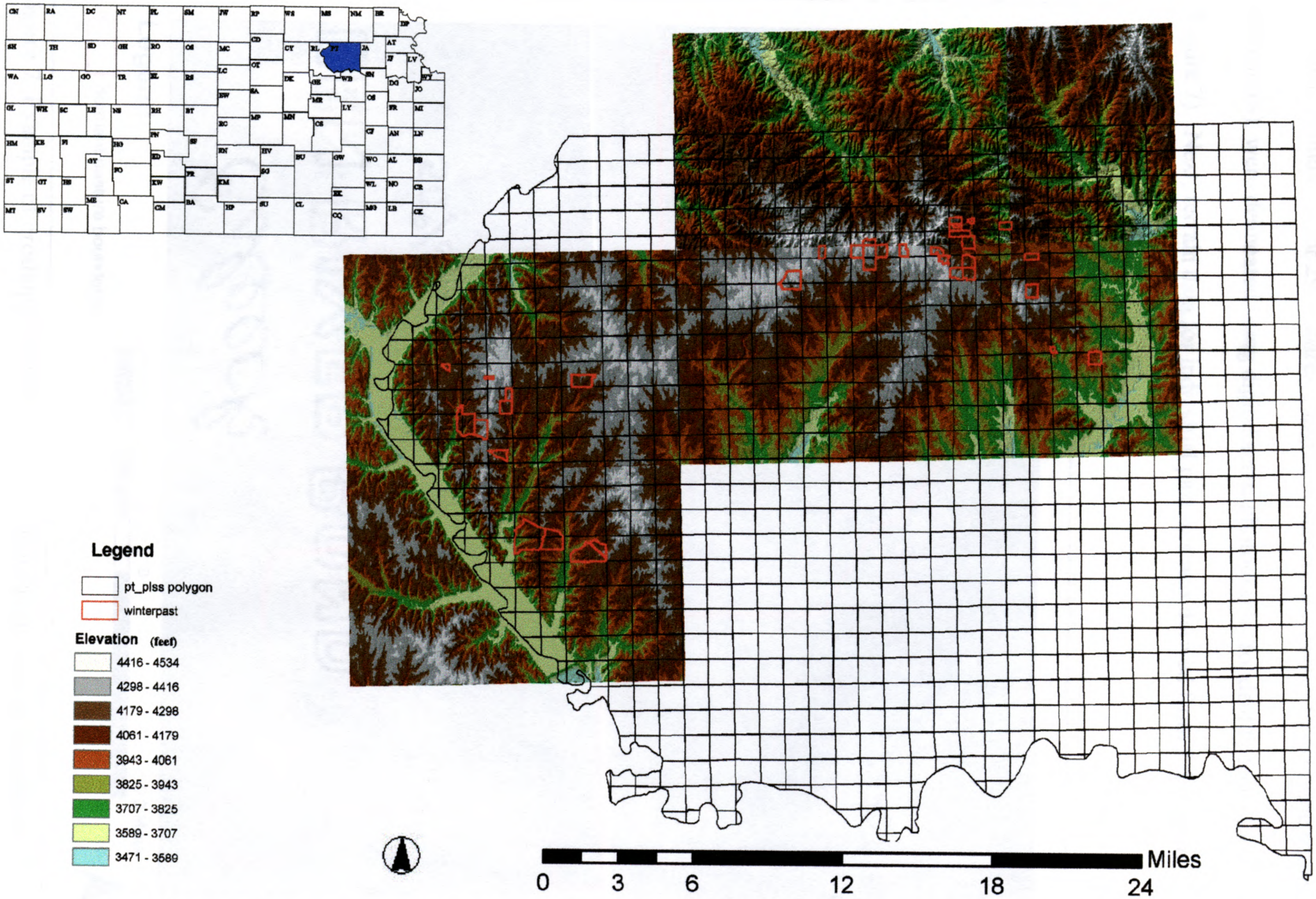

Figure 6. Study area pastures in fluvial influenced terrain of the Northern Flint Hills of Pottawatomie County, Kansas

First, boundaries for 29 pastures, ranging in size from 24 acres to over one square mile (640 acres), were delineated using digital aerial photography to identify fence locations (Figure 7). Next, terrain data for individual pastures was derived from 7.5 minute

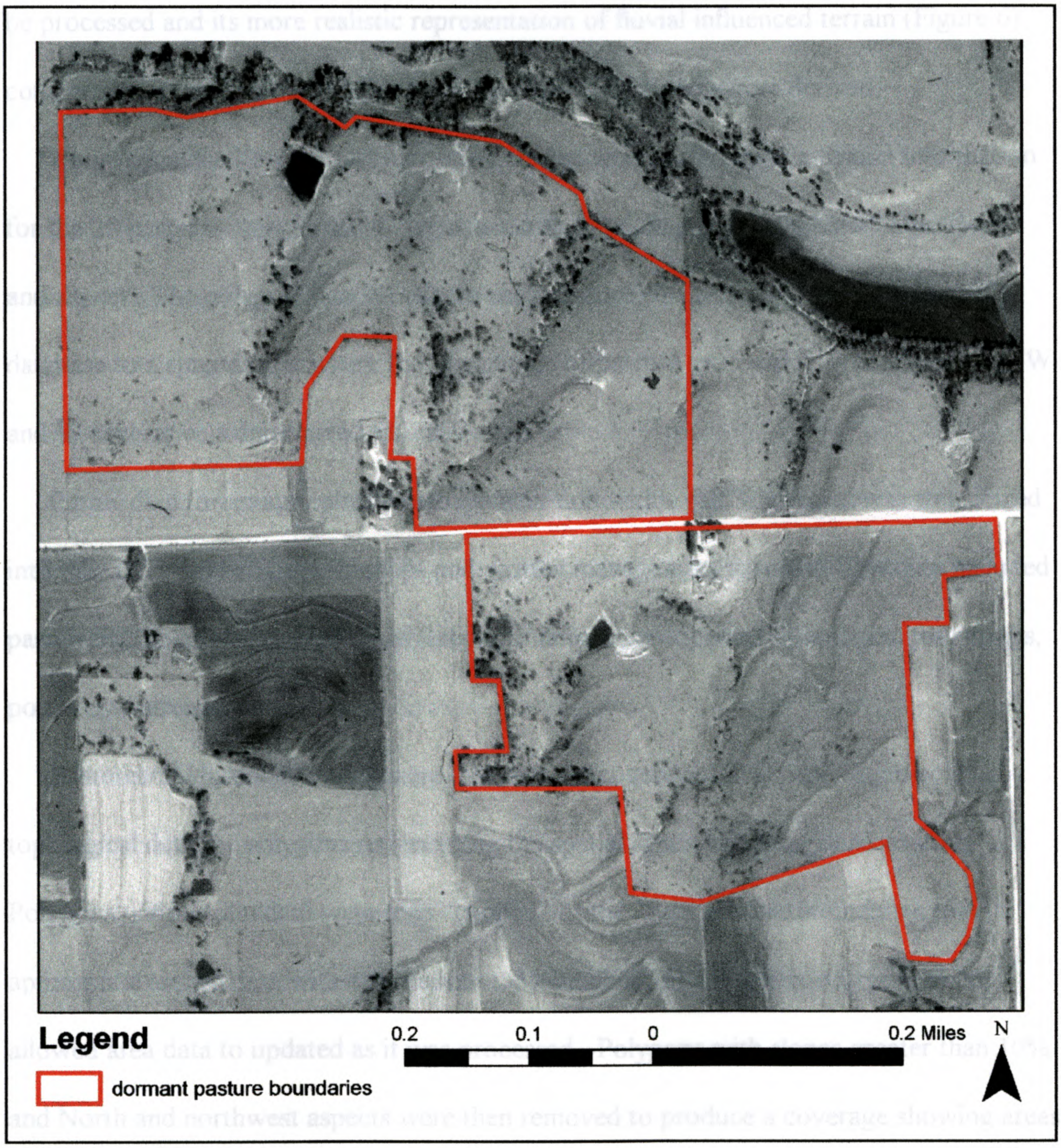

Figure 7. Example of orothophotography used for delineating pasture boundaries

quadrangle digital elevation grids which are readily accessible from U.S. Geological Survey Division of the Department of Interior. Data conversion tools in the GIS were used to derive terrain data from the elevation grids. The chosen format of the processed output was a triangulated irregular network (TIN) due to the speed at which the data can be processed and its more realistic representation of fluvial influenced terrain (Figure 6) compared to that of the grid based data type from which they were derived.

Approximately 12,600 triangular polygon that represented unique terrain information for the 29 pastures were isolated. Relevant data for each polygon included area, slope, and aspect. The polygon data specific to each pasture was transferred from the *ArcGIS* database to a spreadsheet where the percentage of pasture area with N, NE, E, SE, S, SW and W aspects was determined for each pasture.

Parcel data for an agricultural management unit within this study area was transferred into the GIS from hand-drawn maps and written management records. This data included pasture/field boundaries with cover/use information, and location information for springs, ponds, and streams.

Pastures/fields labeled range were isolated in a coverage file format which contain topological data for polygons representing the spatial area of the rangeland pastures . Polygons with terrain data were then "clipped" to the range pasture boundaries to appropriate terrain data with each pasture. Maintaining files in the coverage format allowed area data to updated as it was processed. Polygons with slopes greater than 10% and North and northwest aspects were then removed to produce a coverage showing areas predicted to be preferred by cows for grazing during cold weather.

Percentages of these areas within each pasture were calculated so that pastures could be ranked for dormant season grazing suitability based on terrain. It was assumed that a large percentage of desirable slope benefits both water quality and production because of improved livestock (and waste) distribution and decreased need for supplemental feeding.

Decision Support Modules and Knowledge Base Development

Initiating the development of a grazing management knowledge base and water quality decision support modules will be described using the participatory research framework developed by Allen and others (1996) and using existing resources developed by the Department of Agronomy at Kansas State University (KSU). Prototype decision support modules for the following purposes will be identified: 1) developing economically viable management strategies to protect water quality on grazing land, 2) determining pasture suitability for dormant season grazing, 3) predicting cattle behavior influence on vegetative cover during the growing season, and 4) balancing management practices with the forage resources of a grazing enterprise.

The first two have already been introduced. First, delivery of the Water Quality Financial Analysis and Resource Evaluation Stewardship Program by KSU Research and Extension personnel should serve as a catalyst for development of the knowledge base. The second is developed from the dormant pasture selection decision support module described earlier. The third would be derived from more detailed scientific study conducted by Brock and Owensby (2000), and the fourth will involve use of a KSU developed software by the Kansas Rural Center. A process of using the knowledge management framework and GIS technology to facilitated knowledge exchange will be introduced. Through this process additional variables would be added to the models following discussion between scientists, rangeland managers, and other stakeholders. New variables might include additional biophysical variables influencing livestock behavior or additional economic and cultural variables influencing management decisions. Similarly, the weighted value of variables in the decision support modules may need to be adjusted based on improved information provided through the knowledge exchange process.

The improved knowledge base would be managed in a manner similar to that illustrated in the framework in Figure 3 on page 9. This type of collaborative learning among scientists, stakeholders, and planners is presented as a foundation for effective community based ecological planning. It should first lead participants toward respect for other knowledge, then to understanding of different points of view, and finally to identification of common objectives for tallgrass prairie. Ultimately this form of community based planning should result in development and implementation of ecologically sustainable plans that can be adapted over time as priorities and system knowledge evolve.

Existing Organizational Capacity for Knowledge Base Development

Assembling a useful rangeland knowledge base using the knowledge management developed by Allen and Bosch (1996) will require input from qualified organizations. The ability of existing Kansas organizations to contribute to an improved local knowledge base will be discussed considering the needs for, and limitations to, ecologically sustainable land use which are identified in the literature. Three types of organizations will be discussed: a) organizations with a rangeland science staff, b) organizations that facilitate knowledge exchange between scientists and stakeholders and c) grass-roots organizations with local knowledge of rangeland systems.

Ideally, organizations with rangeland science staff should have extensive field experience and local credibility (Born and Genskow, 2000) as well as the ability to commit resources to a participatory natural resource management process (Bellamy and Johnson 2000). Facilitating organizations should be committed to two-way knowledge transfer and some level of one-on-one communications with land managers (Duram and Brown 1999). Finally, grass-roots organization should ideally have an established culture of rangeland resource information exchange (Bellamy and Johnson, 2000; Hassanein and Kloppenburg, 1995).

Findings and Observations

Findings and observations include results of dormant pasture selection research which includes result of terrain analysis in the northern Flint Hills study area plus hypothetical discussion and enterprise-scale analysis of additional pasture selection variables. This is followed by a discussion of available technical and human resources that can aid in the assembly of a rangeland knowledge base.

Dormant Pasture Selection Research

As could be expected, there were many unrecorded (non-tallgrass prairie rangeland) sites where cows were seen grazing either crop residues following corn harvest or non-rangeland cool season grass. The availability of other quality forages suggests that rangeland pastures being grazed at this time exhibit characteristics making them desirable for dormant season grazing.

Terrain data for the twenty-nine dormant season pastures is available in Appendix B. The study area pastures' median percent area for slopes facing different directions is represented in Figure 8. A relatively low percentage of the terrain in the pastures had north (median 6.66%) and northwest facing (median 6.08%) slopes. This could be related to slope exposure to prevailing cold-weather winds from these directions (KDHE, 2001).

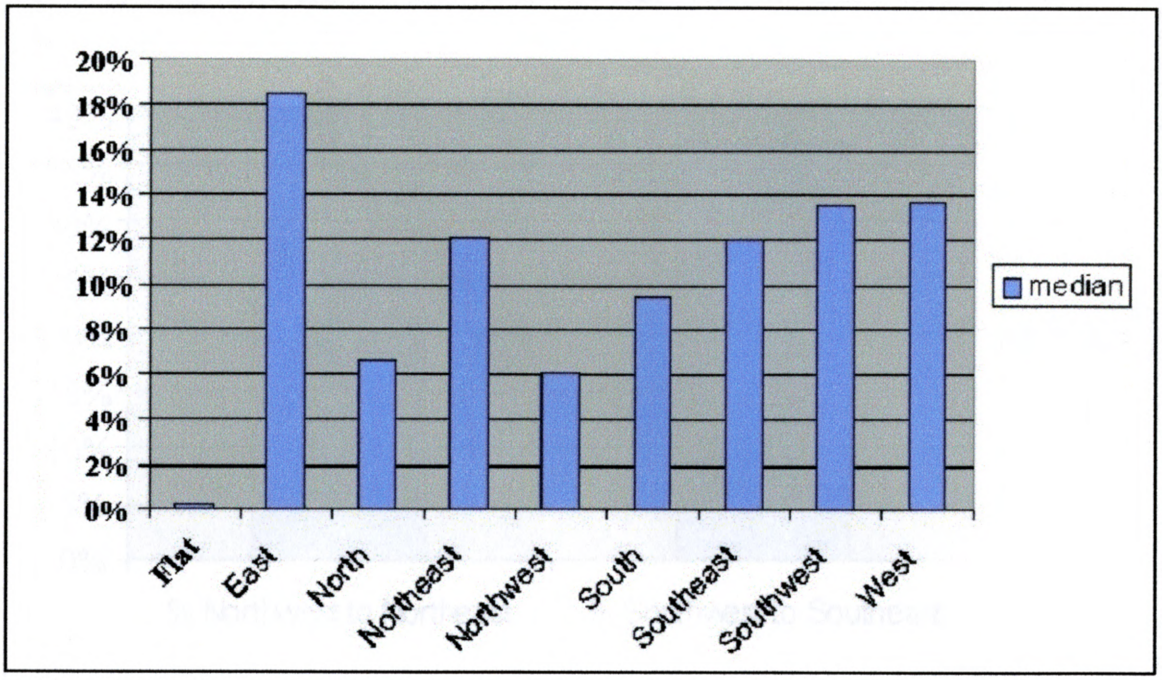

Figure 8. Median area of terrain aspect in 29 northern Flint Hills dormant season pastures

With this in mind, a higher percentage of south and southeast facing slopes was expected because that would provide cows with abundant area not only protected from the wind but also exposed to morning and mid-day sun. However, the median percent area for these were only 9.49% and 12.04%, respectively. Combining the NW, N and NE aspect data and comparing its median with that of the SW, S and SE aspect data for the twenty-nine pastures provided a better match to what was expected for the proportion of north-facing to south-facing slopes (see Figure 9). Another reason to expect a greater percentage of south-facing slopes is the potential of these sites for higher cool season forage production during the late fall and early spring.

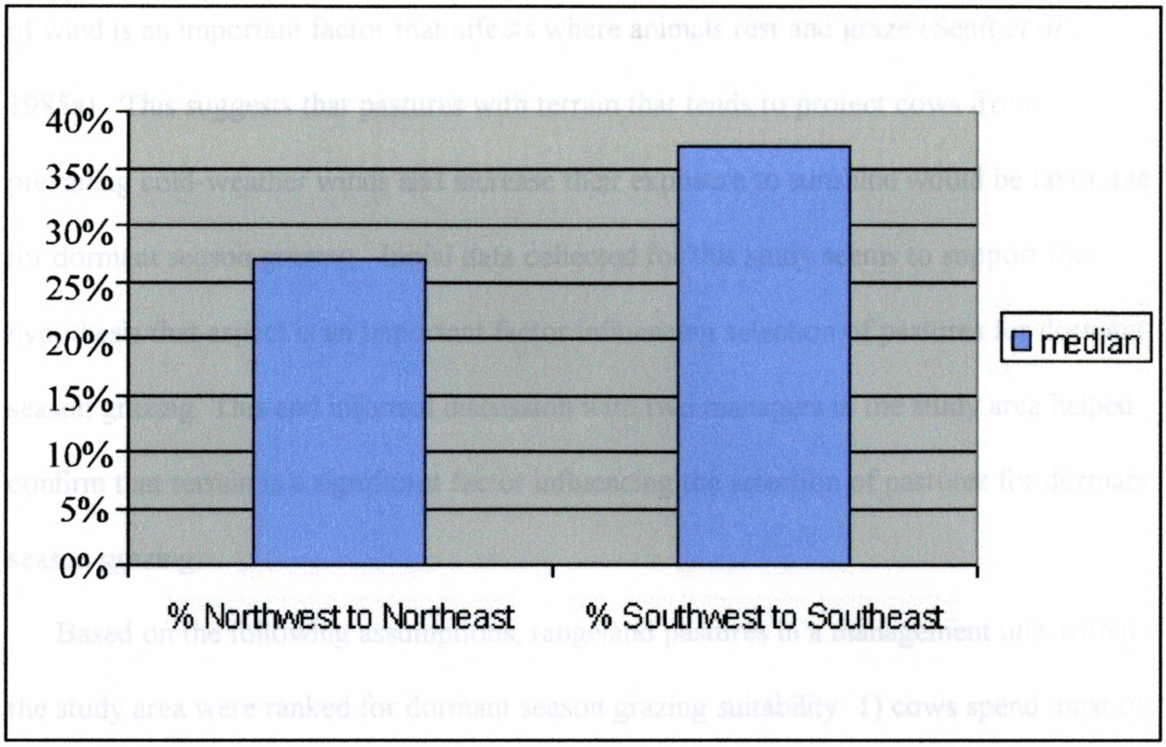

Figure 9. Median area of northerly and southerly aspect in 29 norther Flint Hills dormant season pastures.

Interestingly, dormant season pastures identified in this study had the highest percentage of their area with slopes facing either west or east. This and other terrain characteristics identified may simply be explain by general terrain characteristics of rangeland in the watersheds under study. A possible managerial/production explanation for the high percentage of East-facing slopes could be that favorable pastures have an abundance of suitable terrain for night time resting which positions the cows to warm themselves and begin grazing in the morning sunshine.

Research has found that to avoid cold stress in the winter, cattle decrease their exposure to wind or increase their exposure to sunshine, and that the presence or absence of wind is an important factor that affects where animals rest and graze (Senft *et al.*, 1985a). This suggests that pastures with terrain that tends to protect cows from prevailing cold-weather winds and increase their exposure to sunshine would be favorable for dormant season grazing. Initial data collected for this study seems to support the hypothesis that aspect is an important factor influencing selection of pastures for dormant season grazing. This and informal discussion with two managers in the study area helped confirm that terrain is a significant factor influencing the selection of pastures for dormant season grazing.

Based on the following assumptions, rangeland pastures in a management unit within the study area were ranked for dormant season grazing suitability: 1) cows spend most of their time on slopes of <10% that face directions other than north and northwest, 2) dormant season grazing in pastures with a high percentage of these areas is desirable for enterprise profitability due to forage conversion efficiency, and is desirable for water quality due to greater waste distribution, dormant season preference for upland vegetation and the ability to entice livestock away from streams with supplements. Pasture ranks and areas of desirable terrain for the eight rangeland pastures in the management unit are shown in Figure 10.

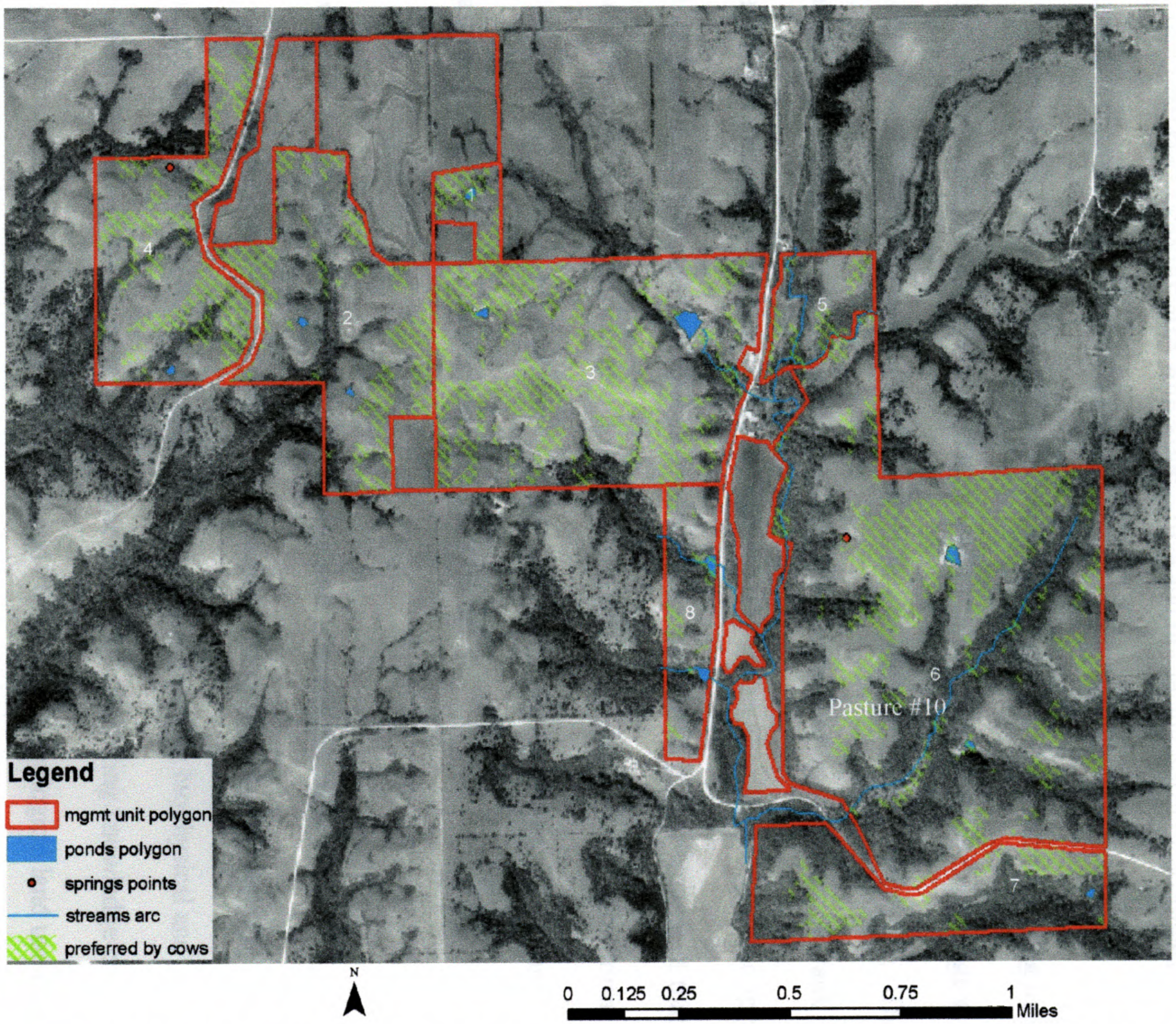

Figure 10. Desirable rangeland terrain and pastures ranked by its percent area . Dormant grazed pasture (10) ranked 6.

Only one of the pastures in this management unit was included in the 29 study area pastures identified as being used for dormant season grazing. Based on percent desirable terrain (percent of pasture area with slope <10% and not facing north or northwest), this pasture (pasture/field #10) ranked sixth among the eight rangeland pastures in the management unit. Much of the preferred terrain in this pasture was near the spring used for watering livestock. Other notable factors about this pasture is its relatively large size and the stream which separates a significant portion of the pasture from the spring. The rank of pasture/field 10 was improved slightly to fifth by excluding area from the rank calculation that might not be used heavily because it is farther than ½ mile from the spring. Since pasture/field 10 was indeed used for dormant season grazing, results suggest that variables other than terrain can also be highly influential on pasture selection for dormant season grazing. A discussion of other possible influences will follow in the Dormant Pasture Selection Module subsection of the section below.

Available Resources for Assembling a Rangeland Knowledge Base

A participatory research and knowledge base organizing process developed by Allen and others (1996) is recommended for assembling and organizing biophysical and sociocultural knowledge about tallgrass prairie rangeland. Resulting knowledge could provide foundational support for developing and implementing ecological land use plans, effective natural resource conservation programs and sustainable rangeland management strategies.

Much of the ground work needed for initiating this process is complete. Delivery of a grazing land Water Quality Financial Analysis and Resource Evaluation (WQFARE) Stewardship Program will include use of the integrated system for knowledge management (ISKM) framework (Figure 11) to exchange knowledge about grazing management and water quality (Ohlenbusch and Jones, 2001). WQFARE is a newly developed decision support tool designed to help grazing managers identify water quality concerns and develop economically viable strategies to address them. Knowledge exchange at WQFARE workshops will not only educate grazing managers and community leaders in targeted watersheds, it will also help expand and refine the grazing land water quality knowledge base embodied in the WQFARE planning process and its supporting material.

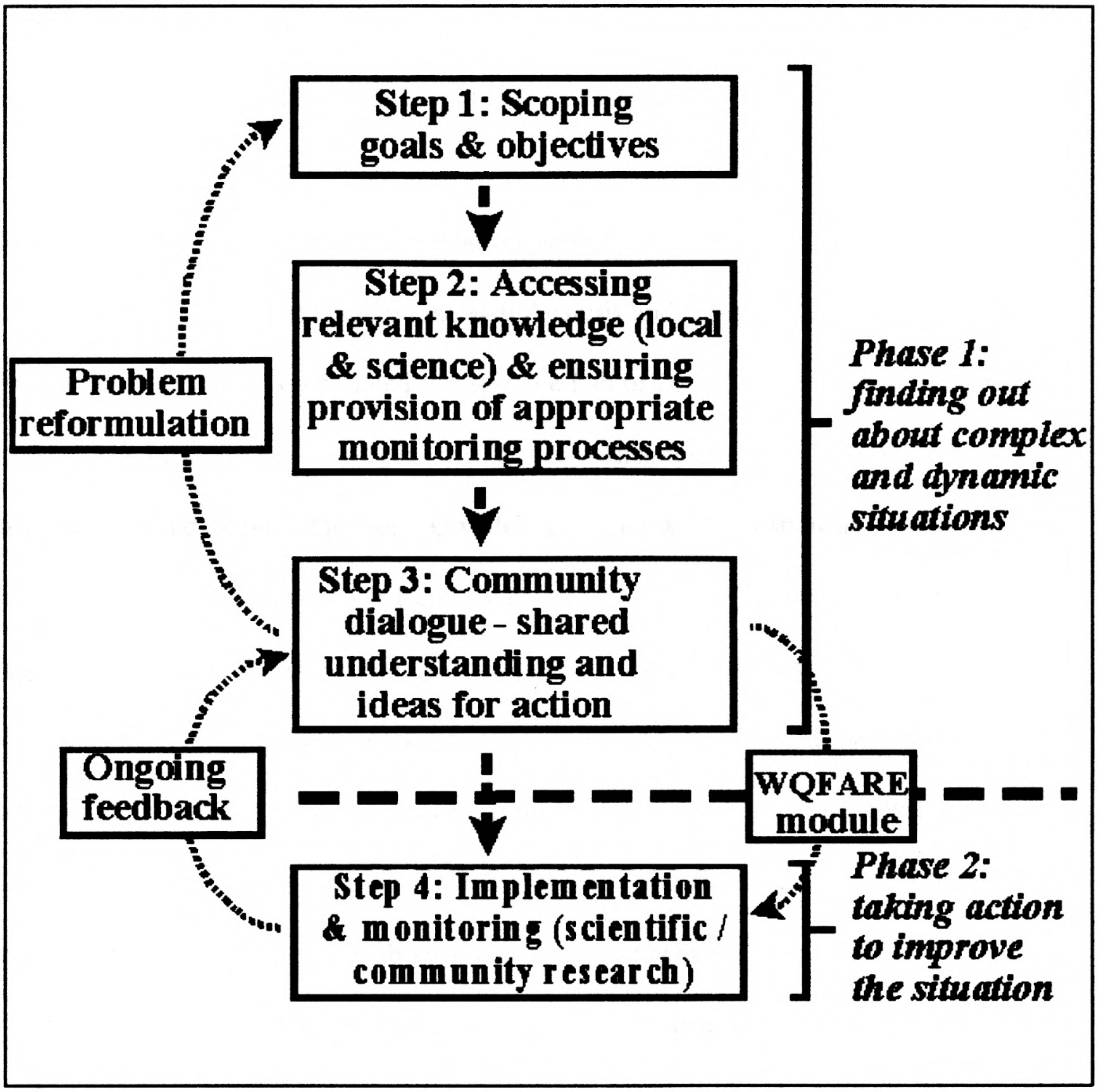

Figure 11. Integrated System for Knowledge Management framework adapted to show how the WQFARE prototype decision support tool can be used to facilitate ongoing community dialogue and participatory research (adapted from Allen *et al.*, 1996).

Several other decision support tools developed through KSU Department of Agronomy can be enhanced and adapted to meet water quality objectives through the use of the participatory research and knowledge development process. Discussion about these prototype modules will serve to illustrate how a rangeland management knowledge base and decision support tools can be simultaneously assembled.

Financial Analysis and Resource Evaluation Module

Delivery of the Water Quality Financial Analysis and Resource Evaluation (WQFARE) Stewardship Program is scheduled to begin the Fall of 2002 (Ohlenbusch and Jones, 2001). The program includes delivery of a 5-6 workshops series to be conducted in each watershed-based delivery location. One delivery team will be responsible for delivering workshops in the Kansas-Lower Republican, Missouri river Marais des Cygnes, Neosho, Verdigris and Walnut basin in the tallgrass prairie region of Kansas.

Steps for delivering these workshops (see Figure 11) corresponds with those of interactive knowledge exchange process reported by Allen and others (1996). Steps one and two will be conducted during the first workshop and the remaining workshops will consist of community dialogue about grazing management and water quality.

During the first step, invited participants, including rangeland managers, landowners, and community leaders are to establish goals and objectives for the workshop series with personnel from Kansas State University Extension. Emphasis for this step is developing a common understanding of any perceived issue or problem and clearly define the nature of the system under consideration.

Step two follows in which attendees will be provided a synopsis water quality information relevant to local watersheds and how the financial analysis and resource evaluation process was designed to provide solutions to water quality-related problems.

Similarly, local participants will be asked to contribute information they feel is relevant to grazing management and water quality in their watershed. This step should also include designing appropriate processes for accessing and organizing fragment knowledge needed to fill knowledge gaps. Suggested processes include interviews, focus groups, questionnaires, etc. (Allen *et al.*, 1996).

Water Quality Financial Analysis and Resource Evaluation (WQFARE) procedures will serve as discussion points for step three. Over a period of several months a series of interactive meetings, field exercises, and case studies will be used each step of the WQFARE process. During periods between these workshop participants will test these procedures locally and return to the next workshop with feedback to be processed through the participatory research framework.

Dormant Pasture Selection Module

The following example illustrates how Geographic Information System (GIS) technology can be used as a bottom-up participatory research tool for enterprise scale water quality and rangeland management planning. It could be used equally as well for pasture scale research and watershed scale ecological planning. GIS technology provides more than an unprecedented tool for performing complex spatial calculations like those used in the terrain analysis described earlier in this report. GIS technology also provides on-the-fly data management and visualization capabilities which also make it an effective tool for facilitating participatory processes, and for incorporating local knowledge into a what Allen and Bosch (1996) referred to as a library of useful knowledge based tools.

The *Model Builder* utility in *ArcView* GIS software is an effective and user-friendly tool that will be used to illustrate this process.

If water quality concerns discussed at a WQFARE workshop implicate undesirable winter feeding practice in a watershed, the group may choose to explore how increased reliance on dormant season grazing could protect water quality. These discussions could lead to development of a dormant pasture selection decision support module that could be used for decision making at pasture, enterprise and/or watershed scales.

The dormant season grazing literature review presented in this report could serve to initiate discussion about relevant scientific and local information. Results of the dormant pasture research used terrain analysis modeling to propose a pasture suitability ranking for eight pastures in a management unit. Figure 12 shows that ranking (in the model output format) based on terrain characteristics considered desirable to cows. When compared to actual use (see pasture #10 in Figure 10), these results indicated that additional variables must be influential in selection of pastures by managers for dormant season grazing.

Discussion of additional variables influencing dormant pasture selection would ensue following presentation of background scientific information and a pasture ranking example such as that in Figure 12. Additional variables might include additional biophysical variables influencing livestock behavior or additional economic and cultural variables influencing management decisions. Three additional variables will be presented for purposes of this module development example; livestock water type, travel distance, and total pasture acres.

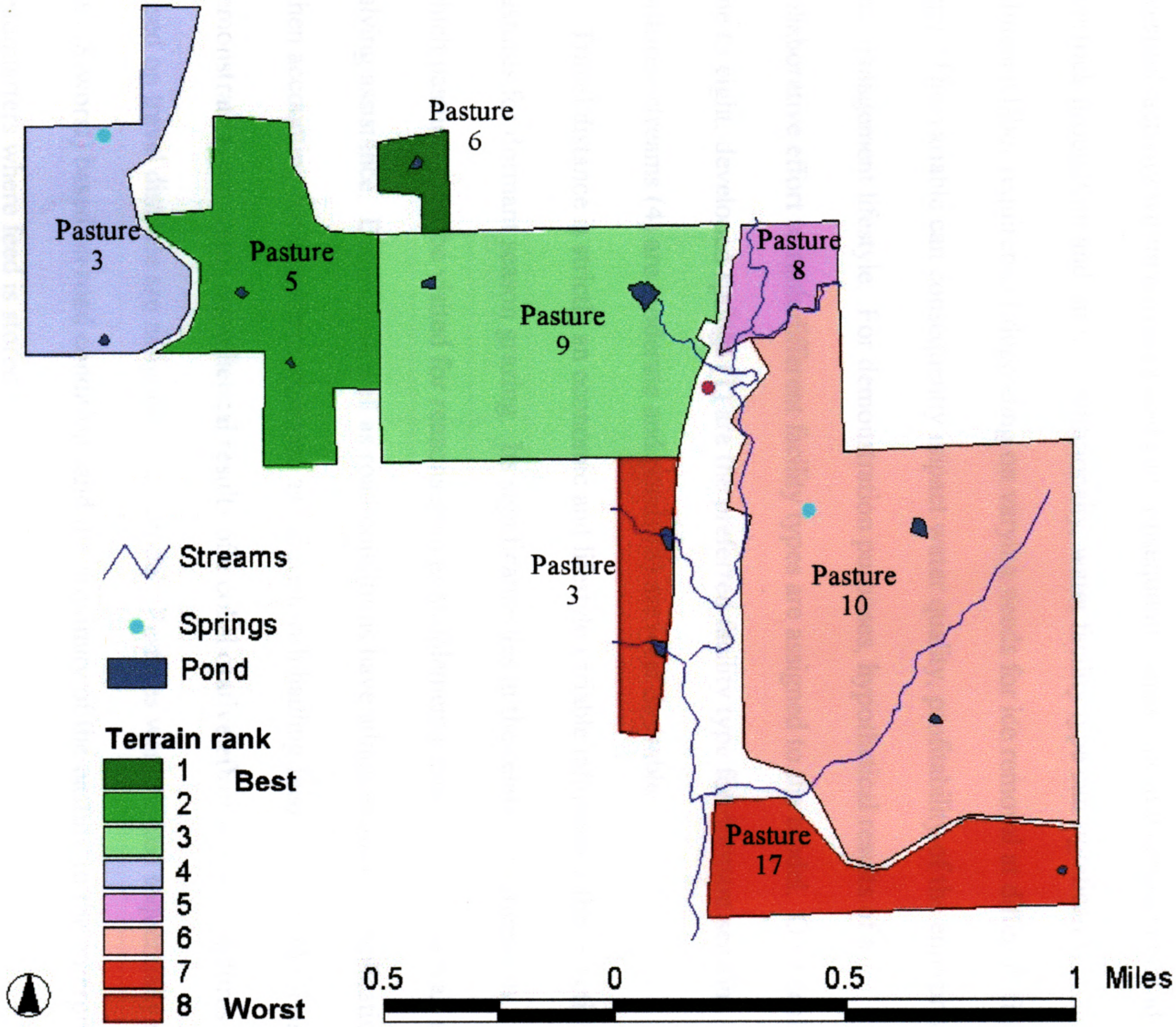

Figure 12. Pasture ranking for dormant season grazing based on percent area with terrain desirable to cows .

The type of livestock watering facilities in a pasture can have significant influence on livestock activity within a pasture and can consequently impact both water quality and livestock production and safety. Additionally, water facility type can significantly influence labor requirement depending on varying needs for ice removal at different facility type. This variable can consequently impact water quality, profitability of the enterprise and management lifestyle. For demonstration purposes, hypothetical results of a collaborative effort to rank different facility types are assigned to the model. On a scale of one to eight, developed springs (1) are the preferred facility type for dormant season pastures, streams (4) are moderate and ponds (8) are least desirable.

Travel distance is strictly an economic and lifestyle variable influencing the selection of pastures for dormant season grazing. Its significance lies in the relative frequency in which pastures must be visited for reasons such as supplemental feeding, ice removal, and calving assistance. Distance as well as road conditions have added economic implications when accounting for long-term expenses associated with hauling feed to livestock. For demonstration purposes, hypothetical results of a collaborative effort to rank pastures based on travel distance are assigned to the model. Pastures were ranked sequentially (1-best, 8-worst) based on road conditions and the proximity of the pasture to the enterprise headquarters where feed is stored.

Total pasture acres is a dormant pasture selection variable that influences water quality, economics of the enterprise, and management lifestyle. It is impractical to divide an entire herd into several smaller groups since pastures must be visited frequently. For this reason, larger pastures are generally preferred by a manager. The number of livestock per acre can also have significant water quality implications. For demonstration purposes, hypothetical results of a collaborative effort to rank pastures based on acres were assigned to the model. Ranking was based strictly on size where the largest pasture was ranked 1-best and the smallest was ranked 8-worst.

Ranking of pastures in the example management unit for dormant season grazing based on the influences of terrain, water type, travel distance, and total pasture acres is shown in Table 1.

Pasture/Field #	Terrain Rank	Water Rank	Distance Rank	Area Rank
3	4	1	6	4
5	2	8	7	3
6	1	8	8	8
8	5	4	3	7
9	3	8	2	2
10	6	1	1	1
14	8	8	4	6
17	7	8	5	5

Table 1. Assigned ranks for dormant pasture suitability variables.

By incorporating this ranking information into a GIS database and using the *ArcView Model Builder* utility, each identified variable influencing dormant pasture selection can be given different weighting to influence the results of the pasture suitability model. For example, if collaborative discussion suggests that water facility type has the greatest influence on selection of pastures desirable for dormant season grazing then it can be assigned a greater weight. Each variable can be assigned unique weights provided the total weighting of all variables equals 100%. Additionally, the ranking scale for the variable does not have to be linear. However, to simplify this demonstration, consistency was maintained in the scale ranking within each variable (1-best – 8-worst: see Table 1) the weighting of variables (see Table 2). Model results for four weighting scenarios are shown in Figures 13-16. In each scenario, one of the four variables was assigned a weight of 55% and the remaining variables were all assigned weights of 15%. These figures represent dormant pasture suitability model results based on heavier weighting for each of the following variables: terrain (Figure 13), water type (Figure 14), travel distance (Figure 15), and total pasture acres (Figure 16).

	Terrain	Water Type	Travel Distance	Total Acres
Figure 13	50%	15%	15%	15%
Figure14	15%	50%	15%	15%
Figure15	15%	15%	50%	15%
Figure 16	15%	15%	15%	50%

Table 2. Model weighting for dormant pasture selection variables.

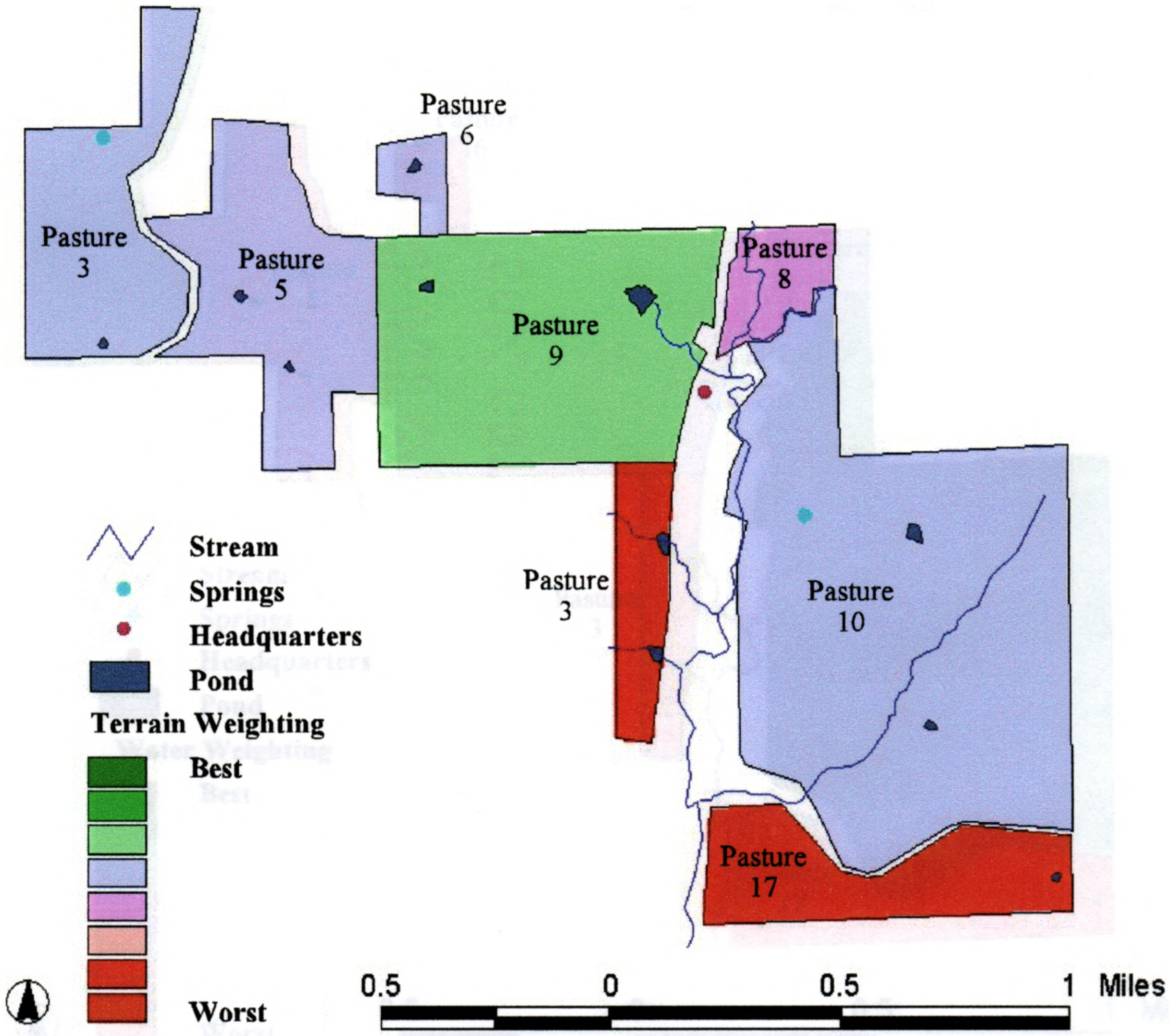

Figure 13. Pasture ranking for dormant season grazing based on desirable terrain weighting.

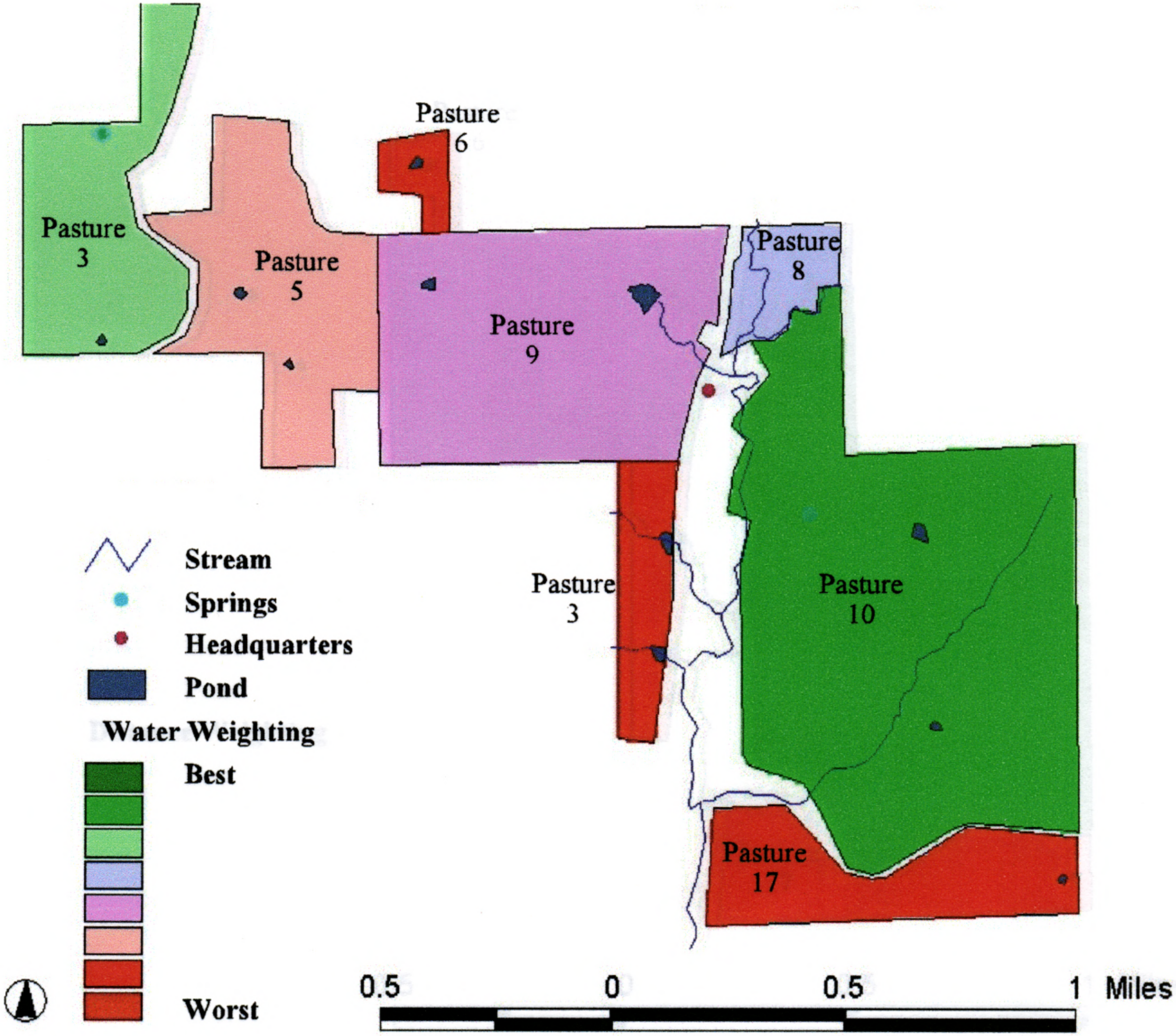

Figure 14. Pasture ranking for dormant season grazing based on water type weighting.

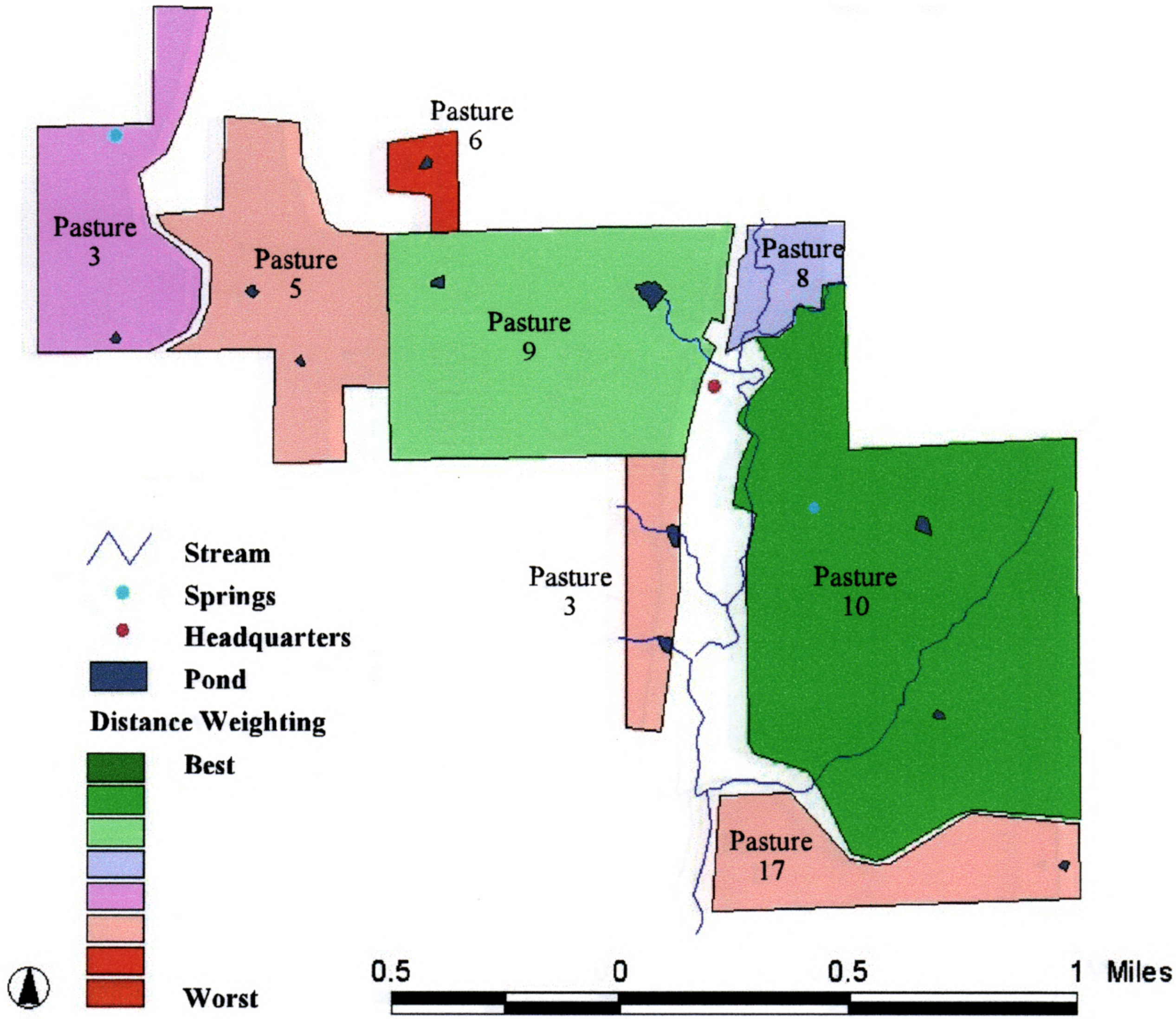

Figure 15. Pasture ranking for dormant season grazing based on travel distance weighting.

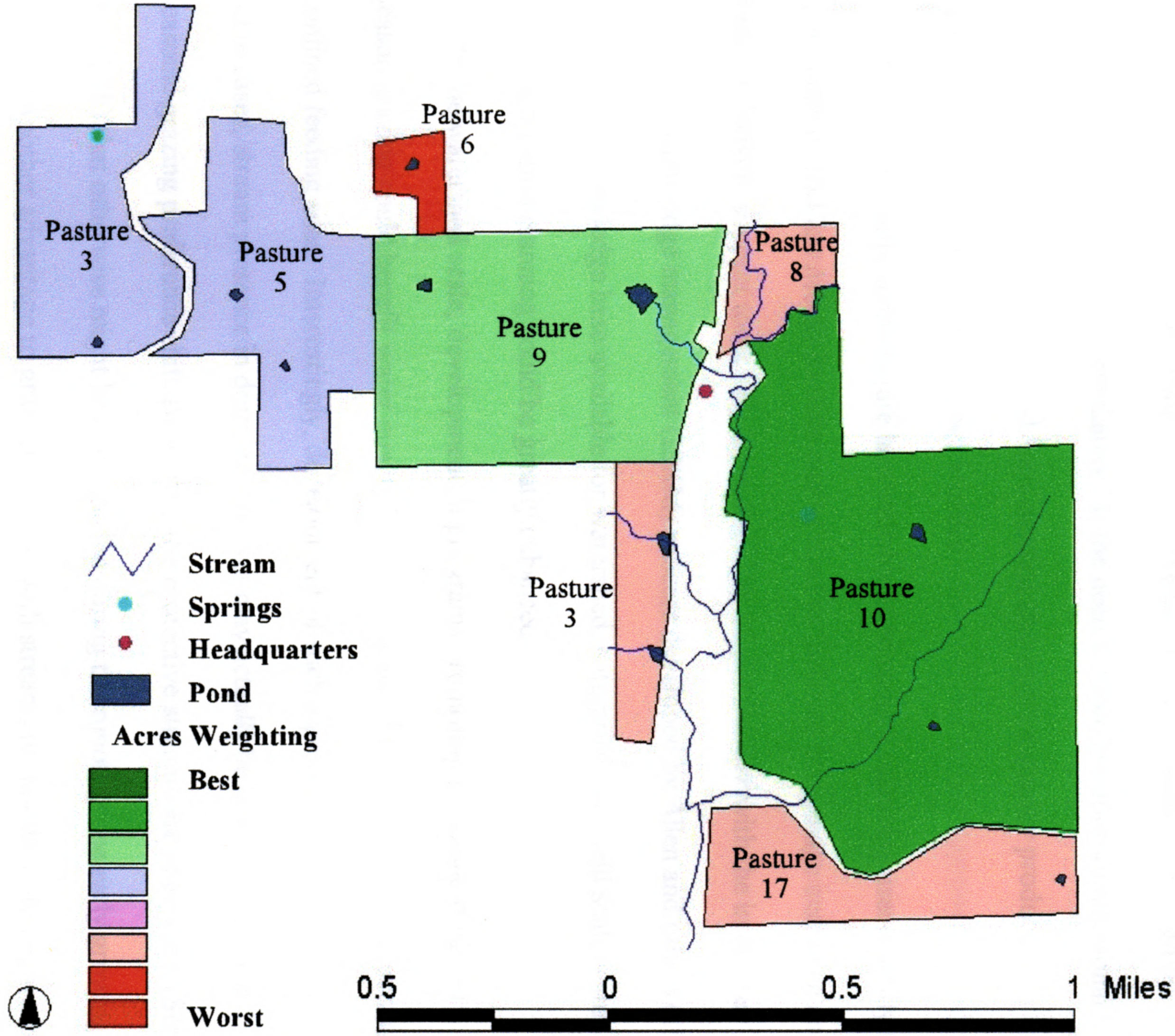

Figure 16. Pasture ranking for dormant season grazing based on total pasture acres weighting.

Once the prototype model parameters have been assigned, the initial output can be easily displayed to prompt additional collaborative discussion about needed refinements to the model. Subsequent outputs with adjusted weighting and/or scale values can be produced for review almost immediately. If the need for incorporation of additional variables into the model is identified, new outputs also may be quickly produced depending on their nature of the new variables.

This example helps demonstrate how collaboration using a relatively user-friendly GIS tools such as *ArcView Model Builder* can be used to facilitate knowledge exchange and develop decision support tools. By using *ArcView Model Builder* with the integrated system for knowledge management (ISKM) process developed by Allen and others (1996) the resulting knowledge base available for watershed, enterprise, and field scale water quality protection planning could be greatly enhanced.

At the watershed scale, development of programs promoting increased dormant season grazing could benefit water quality by reducing use of un-permitted confined/semi-confined feeding sites. Interestingly, development of such a program could find that in some cases, stream presence in dormant pastures may actually be desirable due to a seasonal grazing preference shift away from the protective stream-side vegetation (Senft *et al.* 1985b) that otherwise might be over utilized during the runoff prone early growing season. Another advantage to grazing pastures with streams during the dormant season is the ability to entice livestock away from streams with nutritional supplements and off-stream water (Miner *et al.*, 1992). Water quality hazzards to be considered for developing such a program include runoff prone frozen soils and the slowed capacity of the system to assimilate livestock waste during the dormant season.

At the enterprise and pasture scale, prototyping a decision support module for dormant pasture selection would not only directly support Water Quality Financial Analysis and Resource Evaluation (WQFARE) planning, it would also contribute needed information for prototyping other grazing land water quality decision support modules. For example, dialogue about the water quality and pasture selection variables could also help prototype an enterprise scale water quality decision support module (building from *Kansas Grazer* software) designed for a) reducing supplemental feed requirements, b) selecting season of pasture use, and c) determining appropriate stocking rates. The Kansas Rural Center has already expressed interest in using this approach to help grazing land managers protect water quality (Jost, 2001).

Similarly, a pasture scale prototype decision support modules could be developed to support WQFARE planning to reduce heavy grazing and livestock concentration near streams during the growing season. To this end, the GIS based model for predicting grazing distribution developed by Brock and Owensby (2000) could be used as a foundation for analyzing the expected response of livestock to management changes for water quality protection.

Organizational Contributions to a Rangeland Knowledge Base

Three types of organizations are expected to make valuable contributions to rangeland knowledge exchange a) organizations with a rangeland science staff, b) organizations that facilitate knowledge exchange between scientists and stakeholders, and c) grass-roots organizations with local knowledge of rangeland systems.

An essential quality for the rangeland science leadership organizations will be their ability to commit resources to a participatory research and natural resource management process (Bellamy and Johnson 2000). At this time it is uncertain to what extent rangeland science organizations will be able to commit resources for this purpose. However, delivery of the Water Quality Financial Analysis and Resource Evaluation Stewardship Program by Kansas State University is a step in that direction and it will expose several other organizations with rangeland knowledge to the knowledge base development process developed by Allen and others (1996). The existing grazing management and water quality knowledge base could serve as a core, around which a broader knowledge base can be assembled.

According to Born and Genskow (2000), organizations providing scientific information to agricultural producers should also have extensive field experience and local credibility. Only two state-level organizations in Kansas stand out as having the rangeland science staff which work on a regular basis with rangeland managers, Kansas State University (KSU) Department of Agronomy and the Natural Resources Conservation Service (NRCS). A third organization, the U.S. Fish and Wildlife Service, has sizeable staff of biologists, some of whom have prairie ecology experience.

Both the Department of Agronomy and NRCS have an extensive network across the state they use to facilitate program delivery to rural residents; County Extension Offices and NRCS field offices, respectively (see Appendix A). These organizations have demonstrated their commitment to two-way knowledge transfer and one-on-one communications with land managers. These are essential qualities, according to Duram and Brown (1999), for organizations responsible for facilitating agricultural knowledge exchange between scientists and agricultural producers. A third organization that has demonstrated commitment to knowledge transfer and one-on-one communications with land managers is the Kansas Rural Center.

Grass-roots organization responsible for contributing local knowledge to the rangeland knowledge base should ideally have an established culture of rangeland resource information exchange (Bellamy and Johnson, 2000; Hassanein and Kloppenburg, 1995). There are several established organization in Kansas that may have this qualification. Examples of these include private grazing information networks, Soil and Water Conservation Districts, the Kansas Grazing Land Coalition, and the Tallgrass Prairie Legacy Alliance (see Appendix A).

Many of the organizations in the three categories above have working relationships with organizations in other categories. These types of associations will help establish settings in which organizations can use the integrated system for knowledge management (ISKM) to develop a broad based tallgrass rangeland management knowledge base.

KSU Department of Agronomy will likely be the first Kansas rangeland science organization to gain necessary organizational commitment to using the ISKM knowledge management process. They will receive support from County Extension Agents in organizing workshops and ensuring that essential members of the local community participate (Ohlenbusch and Jones, 2001). Ideally this participation will include local grass-roots organizations with an established knowledge exchange culture. Staff of local Natural Resources Conservation Service (NRCS) will also be encouraged to attend.

Under existing programs rangeland scientists for the NRCS deliver technical support to ranchers via contacts made in local field offices across the state. Staff at these field offices would be appropriate personnel for facilitating ISKM knowledge exchange workshops led by NRCS. These personnel already facilitate information exchange with local work groups responsible for providing input into the NRCS administered Environmental Quality Incentives Program. They also help facilitate meetings conducted by local Soil and Water Conservation Districts. Neither the Environmental Quality Incentives Program nor programs of the Soil and Water Conservation Districts focus exclusively and rangeland conservation so these participants may not be the best source of local knowledge about rangelands. However, a rancher-led group that serves in an advisory role to NRCS called the Kansas Grazing Land Coalition could be a useful source of rangeland knowledge, and could help encourage NRCS to commit resources to development of a rangeland knowledge base. Similarly, the grasslands committee of the Kansas Association of Conservation Districts would be a valuable knowledge source and could encourage both NRCS and Soil and Water Conservation District to allocate resource to development of a rangeland knowledge base.

The U.S. Fish and Wildlife Service (FWS) is the final organization with a resource base suitable for leading efforts in contributing to a rangeland knowledge base. It has scientific staff familiar with prairie ecology, and they have recently dedicated increased resource to conservation efforts made on private lands. In comparison to KSU

Department of Agronomy and NRCS, they may not have sufficiently demonstrated the commitment to two-way knowledge transfer and one-on-one communications with land managers recommended by Duram and Brown (1999). Their efforts in promoting establishment of the Tallgrass Legacy Alliance appears to be an important step in demonstrating that commitment. This group includes members with diverse backgrounds (including many ranchers) but having common interests in the protection of ranching lifestyles, biodiversity and open space on the tallgrass prairie. Certainly it could contribute significant local and scientific knowledge to development of a tallgrass rangeland knowledge base.

Finally, the role of the Kansas Rural Center as a facilitating organization could play a crucial role in the development of a tallgrass rangeland knowledge base containing local knowledge about biophysical and sociocultural variables influencing grazing management. The Rural Center has demonstrated commitment to knowledge transfer and one-on-one communications with an extensive group of rangeland managers already familiar with the value of local knowledge exchange (Kansas Rural Center, 2001).

Conclusions and Recommendations

Knowledge of the dynamic interactions between biophysical and sociocultural systems is fundamental to sound ecological planning and management. Kansas tallgrass prairie knowledge includes scientific findings, such as the importance of fire and grazing to prairie resilience (Knapp *et al.*, 1998), and experiential knowledge of rangeland managers. Use of participatory research and knowledge exchange is recommended for assembling this knowledge and using it to develop successful plans, programs and grazing management strategies for tallgrass prairie. The integrated system for knowledge management (ISKM) framework has been effectively used to assemble a rangeland knowledge for ecosystem planning and management in New Zealand (Allen *et al.*, 2001; Bosch. *et al.*, 1996).

Delivery of the Water Quality Financial Analysis and Resource Evaluation (WQFARE) Stewardship Program by Kansas State University Research and Extension would expose rangeland managers and agency/organization professionals in Kansas to the ISKM framework. Building from an existing grazing management and water quality knowledge base, they will promote collaborative exchange between community leaders, scientists and rangeland managers to help the knowledge base grow. Efforts to expand and improve this knowledge base will be greatly enhanced with workshop participation by members of grazing knowledge organizations such as the grasslands committee of the Kansas Association of Conservation Districts, the Kansas Grazing Land Coalition, and private grazing networks supported through the Kansas Rural Center (see Appendix A). Knowledge management and collaboration will be expedited through use of technologies such as Geographic Information Systems (GIS) for developing decision support tools, and such as Geographic Information Systems (GIS) for developing decision support tools, and the internet for supporting ongoing dialogue and providing others accessibility to knowledge base.

Other agencies and organizations with appropriate resources could effectively use this or a similar participatory research process. If their goals can be met through sustainable rangeland management the could easily use, and possibly contribute to, the same knowledge base. Since societal values such as water quality (Ohlenbusch *et al.*, 1995), biodiversity (Knapp *et al.*, 1998), air quality (Conant, 2001), and open space (Smart Growth Network, 2001) are supported by the common objective of sustainable grazing management, working from and contributing to a central knowledge base would be most productive.

The Natural Resources Conservation Service could effectively contribute knowledge for a broader, natural resource oriented, rangeland management knowledge base through knowledge exchange with established contacts in local organizations such as Soil and Water Conservation Districts, the Kansas Grazing Land Coalition, and the Kansas Association of Conservation Districts. The potential also exists for U.S. Fish and Wildlife Service to lead knowledge exchange workshop with the Tallgrass Legacy Alliance in efforts that will develop useful knowledge about tallgrass rangeland management for the protection of biodiversity and open space.

Beyond knowledge for pasture and enterprise scale decision-making, the recommended system for knowledge management will yield foundational knowledge needed for effective community based ecological planning. Local governments such as knowledge base to support decision making. Cities and other public water suppliers may find that collaboration with rangeland managers in Kansas to be a cost effective way to protect drinking water supplies (Blain, 2001; KDHE, 1998). Counties could use knowledge about rangeland burning and grazing management when establishing ordinances to control invasive weeds and to regulate burning practices. Knowledge of rangeland burning to control wood species would also be valuable for fire protection and growth management decision making.

A broad and well organizing rangeland management knowledge base would be useful for coordinated decision making among policymakers, scientists and rangeland managers. Interestingly, the knowledge base development process may be just as valuable as the product itself. Community based ecological research and planning can first lead participants toward mutual respect for each other's knowledge, then to understanding of different points of view, and finally to identification of common objectives for tallgrass prairie.

Future Applications

Pasture use data for this project, at both the watershed and enterprise scales, was scant; but it adequately served to help illustrate how GIS can be used to facilitate knowledge exchange and subsequent development of decision support tools. Before introducing the prototype dormant pasture selection model to participants in a knowledge exchange format, additional field inventory, GIS analysis and survey data collection should be conducted.

Pasture use field data should be collected from November to April to better establish expected terrain characteristics for rangeland pastures preferred for dormant season grazing. In addition to aspect, pasture slope characteristics could be further analyzed with regard to the potential influence slope and length of slope have on wind protection, foraging and resting behavior and the suitability of sites for supplemental feeding. Watershed-scale terrain characteristics should also be analyzed to help identify typical terrain for study area watersheds and rangeland pastures within them.

Since terrain is likely only one of the factors influencing the selection of pastures for dormant season grazing a survey should be administered to gain a better understanding of variables that could be needed to develop the decision support tool. Presenting this survey to a large audience of rangeland managers could prove to be an effective means to encourage participation in a knowledge exchange process for develop the dormant pasture selection decision support tool.

Establishing a structural organization for the knowledge base and protocols for its development is also needed. Web accessible databases, software, publications and list serves are currently used by the KSU Department of Agronomy grazing management and water quality programs. A core database will be needed to better connect these resources on the internet. Protocols for cataloguing knowledge will need to be established as knowledge exchange workshop begin to produce list discussion, survey results, field research results and decision support tools. KSU Information Support Services for Agriculture can be consulted for these needs.

Evaluating the effectiveness of using internet, GIS and the knowledge exchange format to develop a tallgrass rangeland knowledge base should also be evaluated. Exit surveys administer at the end of knowledge exchange workshops will be one method used in this effort. Since the proposed knowledge base will be internet based, documenting web site and list serve activities can be primary measure. Other measurable products include the results of participatory research projects, the quality and number of decision tools developed and the production use of associated extension and research publications.

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Appendix A - Rangeland Knowledge Organizations

Organization with Local Knowledge of Rangeland Management
Organizations with Rangeland or Prairie Science Staff
State Agencies in Kansas with Natural Resource Responsibilities
Facilitating Organizations

Organization with Local Knowledge of Rangeland Management

Name	Knowledge Exchange Topics	Contact Information
Chautauqua Hills	improving range and grass management	Dale Goode 1084 Road 11 Sedan, KS 67361 (316) 725-3543.
Flint Hills Graziers	learning how management intensive grazing and a mix of forages extends the grazing season	Gerald Rziha 3483 Kanza Tampa, KS 67483 (785) 965-2651
Four Seasons Graziers	management intensive grazing and clean water farming practices	Donn Teske 17925 Golden Belt Road Wheaton, KS 66551 (785) 396-4542 dteske@bluevalley.net
Grassroots Graziers	management intensive grazing and direct marketing	Denise Noonan, 19547 72nd. Road Burden, KS 67019 (620) 394-2446 noonfarm@SKTC.net
Grazing Options	management intensive grazing and good range management	John Betz 1781 1800 Avenue Chapman, KS 67431 (785) 263-8352
Kansas Graziers Association	linking the grazing clusters of the Heartland Network together by sponsoring grazing conferences and tours	Mary Howell 1532 Yonder Rd. Frankfort, KS 66427 (785) 363-7306 marshallcofair@networksplus.net
Kansas Grazing Lands Coalition	cooperative management, economics, ecology, production, education, and technical assistance programs	Rodney Einsel Wilmore, KS 67143 (316) 738-4484
Smoky Hills Graziers	management intensive grazing	David Morrison 1717 Stimmel Road Salina, KS 67401 (785) 823-8454 morrisonbd@informatics.net
Tallgrass Legacy Alliance	keep the ranching community healthy and on the landscape, protect prairie from invasive species and fragmentation	Jeff Davidson 311 N. Main Eureka, KS 67045–1321 620 583-7455
Tallgrass Prairie Producers	ranching systems that promote profitability and good range management.	Annie Wilson Rt.1, Box 53 Elmdale, KS 66850 (316) 273-8301 tallgrss@kansas.net

Organizations with Rangeland or Prairie Science Staff

Organization	Contact	Close Affiliates
Kansas State University Department of Agronomy	Paul Ohlenbusch Grazingland Management Specialist 2014 Throckmorton Hall Manhattan, KS 66506 (785) 532-5776	County Extension Offices (see Organizations with Local Knowledge of Rangeland Management)
Natural Resources Conservation Service	Dewayne Rice Rangeland Management Specialist 760 S. Broadway Salina, Kansas 67401 785-823-4582	NRCS County Field Offices (see Organizations with Local Knowledge of Rangeland Management)
U.S. Fish and Wildlife Service Private Lands Program	Jim Minnerath Biologist 530 West Maple Hartford, KS 66854	Tallgrass Legacy Alliance (see Organization with Local Knowledge of Rangeland Management)

State Agencies in Kansas with Natural Resource Responsibilities

Agency Address	Contact	Contact Information
Animal Health Department 708 S.W. 9th Street, Suite 500 Topeka, KS 66603-3714	George Teagarden, Livestock Commissioner	(785) 296-2326 www.kin.org/public/kahd
Conservation Commission 109 S.W. Jackson Topeka, KS 66612-1215	Tracy D. Streeter, Executive Director	(785) 296-6172 tstreeter@scc.state.ks.us
Dept. of Health and Environment 1000 S.W. Jackson, Suite 400 Topeka, KS 66612-1367	Mike Heideman, Information Officer	(785) 296-8464 mheideman@kdhe.state.ks.us
Dept. of Wildlife & Parks 900 S.W. Jackson, Suite 502 Topeka, KS 66612-1233	Steve Adams, Natural Resources Director	(785) 296-2281 stevea@wp.state.ks.us
Kansas Water Office 901 S. Kansas Avenue Topeka, KS 66612-1249	Al LeDoux, Director	(888) 526-9283 www.kwo.org

Facilitating Organizations

County	Cooperative Research and Extension Service	Natural Resource Conservation Service
ALLEN COUNTY	Courthouse PO Box 845 Iola, KS 66749–0845 620 365-2242	202 West Miller Road Box 408 Iola, KS 66749-0408 620 365-2901
ANDERSON COUNTY	411 S. Oak PO Box 423 Garnett, KS 66032–0423 785 448-6826	519 South Elm Street Box 100 Garnett, KS 66032-0100 785 448-6323
ATCHISON COUNTY	751 S. 8th, Suite 224 Atchison, KS 66002 913 833-5450	603 Sixth Street Effingham, KS 66023-4041 913 833-5740
BOURBON COUNTY	210 S. National Avenue Fort Scott, KS 66701–1393 620 223-3720	1515 South Judson, Suite B Fort Scott, KS 66701-3467 620 223-3170
BROWN COUNTY	Courthouse, 601 Oregon, Hiawatha, KS 66434–2288 913 360-6194	1310 Oregon Hiawatha, KS 66434-2203 785 742-3161
CHASE COUNTY	PO Box 100 Cottonwood Falls, KS 66845–0100 620 273-6491	219 Broadway, Suite A, Box F Cottonwood Falls, KS 66845-0166 620 273-6462
CHAUTAUQUA COUNTY	Courthouse Sedan, KS 67361–1326 620 725-5890	205 West Main, Suite 205 Sedan, KS 67361-1501 620 725-3330
CHEROKEE COUNTY	124 W. Country Rd, Box 148 Columbus, KS 66725–0148 620 429-3849	206 South Indiana Columbus, KS 66725-1828 620 429-3013
CLAY COUNTY	322 Grant Avenue Clay Center, KS 67432–2804 785 632-5335	610 Fifth Street Clay Center, KS 67432-2910 785 632-2215
CLOUD COUNTY	Courthouse, 811 Washington Concordia, KS 66901–3415 785 243-8185	1501 East Seventh Street Concordia, KS 66901-2652 785 243-1509

County	Cooperative Research and Extension Service	Natural Resource Conservation Service
COFFEY COUNTY	110 S. 6th, PO Box 269 Burlington, KS 66839–0269 620 364-5313	313 Cross Street Burlington, KS 66839-1190 620 364-2182
CRAWFORD COUNTY	120 E. Buffalo St. Girard, KS 66743–1547 620 724-8233	207 South Summit Girard, KS 66743-1540 620 724-6227
DONIPHAN COUNTY	Courthouse, Box 487 Troy, KS 66087–0487 785 985-3623	510 East Locust Troy, KS 66087-4208 785 985-3524
DOUGLAS COUNTY	2110 Harper Lawrence, KS 66046–3242 785 843-7058	3010 Fourwheel Drive, Suite B Lawrence, KS 66047-3149 785 843-4288
ELK COUNTY	Courthouse, PO Box 845 Iola, KS 66749–0845 620 374-2174	129 North Wabash, Box 128 Howard, KS 67349-0128 620 374-2511
FRANKLIN COUNTY	1418 S. Main, Suite 2 Ottawa, KS 66067–3543 785 229-3520	107 East 23 Road, Suite 2 Ottawa, KS 66067-9536 785 242-1109
GEARY COUNTY	119 E. 9th Street, PO Box 28 Junction City 66441–0028 785 238-4161	841 South Washington Junction City, KS 66441-3803 785 238-3822
GREENWOOD COUNTY	311 N. Main Eureka, KS 67045–1321 620 583-7455	1819 East River Street Eureka, KS 67045-2157 620 583-6461
JACKSON COUNTY	400 New York Holton, KS 66436–1791 785 364-4125	307 Montana Holton, KS 66436-1127 785 364-4638
JEFFERSON COUNTY	PO Box 326, Courthouse Oskaloosa, KS 66066–0326 785 863-2212	700 Jefferson Oskaloosa, KS 66066-5317 785 863-2201
JEWELL COUNTY	307 N. Commercial Mankato, KS 66956–2511 785 378-3174	112 North Commercial Mankato, KS 66956-2207 785 378-3961

County	Cooperative Research and Extension Service	Natural Resource Conservation Service
JOHNSON COUNTY	13480 S Arapaho Drive Olathe, KS 66062–1553913 913 764-6300	930 East 56 Highway Olathe, KS 66061-4989 913 764-1931
LABETTE COUNTY	528 Huston St., PO Box 38 Altamont, KS 67330–0038 620 784-5337	115 West Fourth, Box 437 Altamont, KS 67330-0437 620 784-5613
LEAVENWORTH COUNTY	500 Eisenhower, Suite 103, Leavenworth, KS 66048 913 250-2300	2050 Spruce Leavenworth, KS 66048-2144 913 682-2133
LINCOLN COUNTY	Courthouse, PO Box 8 Lincoln, KS 67455–2056 785 524-4432	112 East Court, Box 156 Lincoln, KS 67455-0156 785 524-4482
LINN COUNTY	115 S. 6th St., PO Box 160 Mound City, KS 66056–0160 913 795-2829	431 Spruce Street, Box G Mound City, KS 66056-0606 913 795-2317
LYON COUNTY	618 Commercial Emporia, KS 66801–3902 620 341-3220	2501 West 18Th Street, Suite B Emporia, KS 66801-6105 620 343-2813
MARSHALL COUNTY	Courthouse, 1201 Broadway, Marysville, KS 66508–1844 785 562-3531	1133 Pony Express Highway Marysville, KS 66508-9542 785 562-3133
MIAMI COUNTY	20 S. Gold Paola, KS 66071–1403 913 294-4306	100 North Angela, Suite 3 Paola, KS 66071-1390 913 294-3751
MITCHELL COUNTY	115 S. Hersey, Beloit KS 67420–3230 785 738-3597	112 North Bell Street Beloit, KS 67420-2739 785 738-5019
MONTGOMERY COUNTY	410 Peter Pan Rd, Suite B Independence, KS 67301–9372 620 331-2690	Route 3, Box 290A Independence, KS 67301-9309 620 331-4920

County	**Cooperative Research and Extension Service**	**Natural Resource Conservation Service**
MORRIS COUNTY	Courthouse, 501 W. Main Council Grove, KS 66846–1796 620 767-5136	209 Hockaday Council Grove, KS 66846-1830 620 767-5111
NEMAHA COUNTY	604 Nemaha, Suite 201 Seneca, KS 66538–1763 785 336-2184	411 North Street Seneca, KS 66538-2504 785 336-2186
NEOSHO COUNTY	Courthouse,100 S Main Erie, KS 66733–1301 620 244-3826	124 West State Street, Suite 1 Erie, KS 66733-1333 620 244-3269
OSAGE COUNTY	Courthouse, 717 Topeka Ave Lyndon, KS 66451 785 828-4438	115 West 17Th Lyndon, KS 66451-9561 785 828-3831
POTTAWATOMIE COUNTY	612 E. Campbell, Box 127, Westmoreland, KS 66549 785 457-3319	5th And State Streets, Box 368 Westmoreland, KS 66549 785 457-3398
REPUBLIC COUNTY	1815 M Street, PO Box 429, Belleville, KS 66935–2799 785 527-5084	1319 23Rd Street Belleville, KS 66935-2533 785 527-2725
RILEY COUNTY	110 Courthouse Plaza Manhattan, KS 66502–0111 785 537-6350	2615 Farm Bureau Road Manhattan, KS 66502-3066 785 776-8595
SHAWNEE COUNTY	1740 SW Western Ave. Topeka, KS 66604–3095 785 232-0062	3231 Southwest Van Buren Topeka, KS 66611-2291 785 267-5721
WABAUNSEE COUNTY	215 Kansas , PO Box 248 Alma, KS 66401–0248 785 765-3821	107 East Sixth Street Route 2, Box 1 Alma, KS 66401-9694 785 765-3836
WASHINGTON COUNTY	214 C Street, Courthouse, Washington, KS 66968–1928 785 325-2121	705 B Street Washington, KS 66968-2399 785 325-2321

County	Cooperative Research and Extension Service	Natural Resource Conservation Service
WILSON COUNTY	Courthouse, 615 Madison Fredonia, KS 66736–1383 620 378-2167	930 North Second Fredonia, KS 66736-2105 620 378-3282
WOODSON COUNTY	Courthouse, 105 W. Rutledge Yates Center, KS 66783–1471 620 625-3113	704 South Fry Yates Center, KS 66783-1612 620 625-3292
WYANDOTTE COUNTY	Courthouse Annex, 9400 State Kansas City, KS 66112–1592 913 299-9300	9400 State Ave., Rm 117 Kansas City, KS 66112-1540 913 334-6075

Appendix B - Study Area Terrain Data

Pasture	% flat	% E	% N	% NE	% NW	% S	% SE	% SW	% W
1	0.14%	25.11%	4.45%	13.50%	2.90%	19.94%	12.32%	15.16%	6.47%
2	0.00%	4.29%	2.59%	4.26%	5.89%	15.97%	9.18%	28.48%	29.35%
3	0.00%	18.47%	0.00%	12.39%	1.11%	28.28%	7.15%	23.76%	8.85%
4	0.12%	7.17%	10.31%	4.38%	2.42%	23.16%	14.61%	24.07%	13.75%
5	0.02%	14.05%	5.91%	20.85%	0.57%	23.51%	10.22%	16.04%	8.83%
6	0.06%	14.98%	6.48%	23.10%	2.46%	14.45%	10.55%	17.30%	10.62%
7	0.33%	19.03%	13.10%	17.12%	3.34%	17.37%	11.40%	13.34%	4.99%
8	1.06%	6.58%	8.32%	7.41%	18.64%	12.01%	3.12%	15.22%	27.64%
9	1.05%	27.80%	3.17%	4.64%	10.89%	8.64%	8.97%	9.33%	25.52%
10	0.25%	28.44%	5.81%	14.32%	1.86%	12.14%	12.04%	15.40%	9.71%
11	1.47%	11.25%	3.51%	4.49%	12.87%	6.94%	21.41%	14.88%	23.17%
12	0.34%	24.59%	4.19%	17.77%	4.98%	13.66%	12.24%	9.09%	13.13%
13	0.00%	18.06%	19.15%	45.73%	9.55%	1.14%	3.38%	0.34%	3.00%
14	0.04%	14.28%	12.99%	6.49%	6.08%	12.15%	31.06%	10.63%	6.12%
15	0.60%	24.87%	3.85%	12.09%	6.77%	8.03%	11.99%	17.83%	13.98%
16	0.15%	31.38%	10.53%	14.45%	15.38%	2.45%	12.86%	2.87%	9.94%
17	0.00%	37.19%	0.84%	14.03%	2.98%	8.58%	30.99%	1.34%	4.05%
18	0.36%	26.21%	6.66%	20.33%	5.99%	10.37%	15.41%	7.82%	6.85%
19	0.00%	3.51%	4.58%	0.34%	5.92%	18.79%	12.74%	37.27%	16.84%
20	1.07%	27.55%	3.91%	7.41%	7.38%	6.98%	15.52%	9.42%	20.76%
21	0.52%	4.89%	8.15%	9.28%	24.13%	1.65%	1.76%	16.16%	33.47%
22	0.14%	20.01%	3.28%	4.68%	13.78%	4.81%	13.76%	9.08%	30.46%
23	1.28%	28.18%	6.76%	10.90%	3.53%	5.27%	8.25%	16.04%	19.79%
24	0.24%	8.52%	8.76%	6.22%	17.83%	6.95%	12.54%	13.54%	25.42%
25	1.16%	10.00%	8.81%	4.66%	20.29%	9.47%	10.05%	13.58%	21.99%
26	0.50%	25.08%	10.26%	30.73%	10.51%	4.58%	5.49%	5.29%	7.57%
27	0.07%	6.90%	8.67%	5.95%	17.53%	11.46%	13.44%	14.86%	21.12%
28	0.24%	26.31%	8.67%	15.82%	5.89%	9.49%	15.94%	11.67%	5.98%
29	0.42%	14.47%	13.48%	22.80%	16.28%	1.06%	1.84%	7.92%	21.72%

	%flat	% E	% N	% NE	% NW	% S	% SE	% SW	% W
median	0.24%	18.47%	6.66%	12.09%	6.08%	9.49%	12.04%	13.58%	13.75%

Note: Terrain data above shows the distribution of directional orientation (aspect) for slopes in twenty-nine study area pastures. Percentages represent portions of total pasture area.

Appendix C - Glossary of Terms and Acronyms

biodiversity
- an indicator or ecosystem health based on species richness, or abundance of different species plus the morphological and genetic differences between individuals within each species

biophysical
biological (ie. grazing) and physical (ie. fire and drought) factors

dormant season
- grazing period beginning in the fall marked by translocation of above ground nutrients by grasses to below ground structures which later support new above ground growth in the spring

dss
decision support system - a research based tool for aiding decision-making

ecological planning
-the use of biophysical and sociocultural information to suggest opportunities and constraints for decision making about the use of the landscape

ecologically sustainable
- usually referring to land use practices to which affected ecosystem(s) can retain needed resilience and adaptability for ensuring that future generations are able to meet future land use goals

grass-roots
- describing a rural community group composed of individuals dependent on natural resources for their economy and typically having local knowledge useful for both public and private decision-making

GIS
geographic information system - computer base technology for storing, retrieving, processing and displaying spatial data

ISKM
integrated system for knowledge management - a participatory research and knowledge management framework

KDHE
Kansas Department of Health and Environment - state level agency responsible for administering water quality programs and regulations including those administered at the federal level by EPA

NPS pollution
Non-point source pollution - pollution originating from dispersed and relatively indiscrete locations such as livestock waste on rangelands

NRCS
Natural Resource Conservation Service - branch of the U.S. Department of Agriculture responsible for administering programs associated with resource conservation on private land

participatory research
- a collaborative effort between scientists and managers to compile local knowledge and test hypotheses for identification and introduction of sustainable management practices

open space
- land with little or no development in a relatively natural state

sociocultural
- characteristics of an area and its people as influenced by social factors such as economics and lifestyle preferences, and cultural factors such as tradition

tallgrass prairie
- North American grassland type characterized by an abundance of grasses that typically grow three or more feet tall, including Big Bluestem, Indian Grass, Switch Grass and Prairie Cord Grass

tallgrass rangeland
- tallgrass prairie used for grazing livestock

TMDL
Total Maximum Dailey Load - the maximum amount of a pollutant a water body can receive without violating a water quality standard; also used when referring to watershed scale plans for controlling specific pollutants

WQFARE
Water Quality Financial Analysis and Resource Evaluation - process for guiding grazing land managers in development and implementation of economical water quality protection measures – to be delivered across Kansas as the WQFARE Stewardship Program (Ohlenbusch and Jones, 2001)