EFFECT OF RANCHERS' MANAGEMENT PHILOSOPHY, GRAZING PRACTICES, AND PERSONAL CHARACTERISTICS ON SUSTAINABILITY INDICES FOR NORTH CENTRAL TEXAS RANGELAND

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To assess sustainability of privately owned rangeland, a questionnaire was used to gathered data from ranches in Cooke, Montague, Clay, Wise, Parker, and Jack counties in North Central Texas. Information evaluated included: management philosophy, economics, grazing practices, environmental condition, quality of life, and demographics. Sustainability indices were created based on economic and land health indicator variables meeting a minimum Cronbach's alpha coefficient ($\alpha = 0.7$). Hierarchical regression analysis was used to create models explaining variance in respondents' indices scores. Five predictors explained 36% of the variance in rangeland economic sustainability index when respondents: 1) recognized management inaction has opportunity costs affecting economic viability; 2) considered forbs a valuable source of forage for wildlife or livestock; 3) believed governmental assistance with brush control was beneficial; 4) were not absentee landowners and did not live in an urban area in Texas, and; 5) valued profit, productivity, tax issues, family issues, neighbor issues or weather issues above that of land health. Additionally, a model identified 5 predictors which explained 30% of the variance for respondents with index scores aligning with greater land health sustainability. Predictors indicated: 1) fencing cost was not an obstacle for increasing livestock distribution; 2) land rest was a component of grazing plans; 3) the Natural Resource Conservation Service was used for management information; 4) fewer acres were covered by dense brush or woodlands, and; 5) management decisions were not influenced by friends.

Finally, attempts to create an index and regression analysis explaining social sustainability was abandoned, due to the likely-hood of type one errors.

These findings provide a new line of evidence in assessing rangeland sustainability, supporting scientific literature concerning rangeland sustainability based on ranch level indicators. Compared to measuring parameters on small plots, the use of indices allows for studying replicated whole- ranch units using rancher insight. Use of sustainability indices may prove useful in future rangeland research activities.

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CHAPTER I

INTRODUCTION

Background

The present state of health of U.S. rangelands is a matter of sharp debate, even for government agencies working with rangeland assessments. Valuable products are associated with these grasslands, including forage for domestic and wild animals, species habitat, water storage and filtration, carbon sequestration, recreation, open space, and a way of life for rangeland-dependent rural communities. These products are aligned with economic, ecological. and social parameters (Maczko et al., 2004).

Lands designated as "grazing land" encompass 25.9% of all land in the U.S. (Lubowiski et al., 2006). These grazing lands are a result of the anthropocentric shift of free-range wild herbivores to a system which is sometimes characterized by overgrazing and loss of ecological function caused by domesticated livestock. The relationship between the ecosystem and livestock grazing is often the primary reason for the concern about rangeland health (Belsky et al., 1999; Centeri et al., 2009). The concern over animal impact on the environment is one of the major reasons for the debate concerning rangeland. The opposite belief is that grazing by ungulates was instrumental in the evolutionary history of grassland ecosystems (Michunas et al., 1988; Knapp et al., 1999) and grazing of indigenous rangeland is one of the most sustainable forms of agriculture known (Frank and McNaughton , 2002; Heitschmidt et al., 2004).

The interaction of livestock with the environment is very complex. Different scientists looking at the same data have come to different conclusions. Additional problems are incurred when reconciling grazing land management results from experimental studies, with commonly held beliefs and perceptions. This is especially true regarding outcomes derived from implementation of various grazing strategies (Briske et al., 2008).

A primary issue with reconciliation of experimental evidence and perceived rangeland management outcomes has been the scale of field experiments. Generally, scientific studies have not conformed to the scale of grazing operations because of the importance of replicating treatments in experimental research and the limited availability of land and other resources for conducting such research. It is impossible to capture, in small-scale research trials, the complexity of rangeland resources in operational scale grazing systems (Teague et al., 2008; Laca, 2009).

Furthermore, managers must adapt to changing biophysical and socio-economic conditions. These include variables that are extremely difficult or impossible to address in short-term and small scale grazing experiments, such as, changing weather conditions and variations in grazing behavior of animals. As a result, the high number of variables affecting ranch-scale management makes it virtually impossible to use traditional experimental protocols to compare alternative management schemes at real-world operational scales. Even though pastoralist knowledge is more focused on productivity than on maintaining ecosystem processes (Bollig and Schulte, 1999), Knapp and Fernandez-Gimenez (2009) concluded that ranchers in the West have gained insight about natural systems through daily interaction and management of landscapes. Through interviews, they found that ranch managers' knowledge complemented scientific knowledge, especially concerning active knowledge applied to management decisions, embedded knowledge from living in place, and integrative knowledge that links ecological, economic, and social aspects of rangeland systems.

As Maczko et al. (2004) indicated economic, ecologic, and social elements may be visualized as one leg of a 3-legged stool, with each aspect of sustainability representing a leg.

Understanding the complex interactions that occur between grazing management and each of these three elements will ultimately lead to conclusions concerning the sustainability of rangelands.

Perception is the process of attaining an understanding of information and is a result of interplays between past experiences and personal interpretation (Pomerantz, 2003). While experimental studies are vital, management's perception of benefits associated with grazing systems are even more crucial for successful implementation of sustainable ranch management practices; only ranch-level, adaptable grazing system management is capable of addressing all of the variables associated with sustainability of mid to tall-grass prairie ecosystems.

Overgrazing, drought, erosion, and other human and naturally induced stressors have caused severe degradation in the past. In many areas, rangeland remnants are all that remain of vast sections of mid to tall-grass prairies. These remnants are very much at risk of damage due to the mismanagement of livestock and increasing human population. Costa and Reham (2005) have shown that the traditional decisions to retain livestock, even at the expense of the environment, may be as philosophic as they are economic. Deliberate, high-stocking rate decisions appear paradoxical, even irrational given the state of knowledge regarding the consequences of overgrazing. The phenomenon appears to be linked with objectives of livestock managers. Indications are that producers view cattle ownership as a means to ensure they are able to continue land ownership, as a source of security and liquidity, and as a way of life worthy of passing to the next generation.

Sustainable resource management has evolved as the logical extension of the application of sustainable development principles to land management (Shields and Bartlett, 2002). Implementation of sustainable grazing practices is of value to protect vital natural resources such as rivers, streams and aquifers as well as to increase productivity of agricultural practices without increasing use of non-renewable resources. The application of appropriate grazing management systems has been widely found to be critical for the continued ecological health and agricultural sustainability of rangelands around the world (Klipple & Costello, 1960; Holechek, 1994; Ward, 1999).

Theoretical Premise

The theoretic premise put forward by this study is a direct response to the issues described in the background. The specific premise is that a method which investigates each aspect of rangeland sustainability separately (economic, land health, and social) is necessary. Doing so will be useful when land owners and agency personnel are assessing different perspectives known to be factors affecting the ability of mankind to utilize this natural resource sustainably; benefitting from its goods and services today, while preserving these goods and services so that future generations can benefit also. Additionally, when investigating aspects of rangeland sustainability, a study must be conducted on the whole-ranch level; whereas, small scale studies have proven to further divide the opinions within the scientific community.

The difficult task of assessing rangeland sustainability can be addressed by questioning ranch managers about their economic situation, rangeland physical properties, social satisfaction, management philosophy, grazing practices and personal characteristics. The economic information, rangeland physical properties, and social satisfaction could be the basis for indicators of sustainability. The questions concerning philosophy, grazing management and personal characteristics could be used to assess impact on sustainability.

Study Objectives

Range professionals have assigned various degrees of importance to different processes in nature (Naeem, 2002). "Applied management sciences bridge the gap between ecological information and the achievement of desired management goals by integrating knowledge from diverse disciplines. They evaluate management consequences within a research-based theoretical framework of ecological processes and how they affect ecological, economic, and social factors important to management" (Teague et al,. 2008). This analogy links closely with Sydorovych and Wossink (2008) and Calker (2005), who identified sustainability for agricultural systems in terms of economics, internal social, external social and ecological parameters. "As competing demands contend for increasingly limited rangeland resources, consistent, comparable economic, social and ecological data is necessary for informed decision-making regarding tradeoffs among goods and services derived from rangelands" (Maczko et al., 2004). The research reported here contributes new data that should be useful in this decision-making arena.

The specific objectives of the study were to contribute to the knowledge and understanding of some of the key grazing management elements essential to sustainable rangeland management as described by the 2003 SRR Executive Summary (West and Herrick, 2003), specifically:

1. Contribute to the knowledge base for research by agencies, universities, and organizations focused on developing methods to address data gaps and research needs associated with criteria and indicators,
2. Aid in improved accountability for rangelands stakeholders through multi-scale, coordinated data reporting.
3. Provide a basis for stakeholder dialogue at local, regional, and national scales and expanded understanding of rangeland sustainability.
4. Gain an understanding of range management philosophy, practices, and personal characteristics that are indicators of sustainable management at the whole-ranch scale.

Scope of Study

This study sought to understand the relationship between grazing management decisions and perception regarding long-term rangeland sustainability in whole-ranch enterprises.

Information was gathered, via a formal survey instrument, on a large number of variables related to perceptions of land health, rangeland productivity, economic viability, quality of life, and cultural experiences from the study group, which was comprised from rangeland scientists in the north Texas area. The variables were reduced to a set of factors that aid in understanding motivation concerning implementation of rangeland sustainability practices. The results of these surveys should be useful for the following reasons:

1. Important indices of critical factors affecting perceptions have been developed and could be used to develop further models that explain variations in grazing system perceptions.
2. Results can be utilized to develop effective marketing tools to promote the adoption of grazing management systems that enhance ecosystem sustainability.
3. The results comprehensively inform conflicting viewpoints regarding the benefits of planned, rotational grazing practices.

Questions

Specifically the study attempted to answer the following questions:

1. What are land managers perceptions of sustainable grazing strategies based on whole-ranch observations?
2. What management practices are ranch managers implementing?
3. What are the obstacles for land managers to implement perceived sustainable range management practices?
4. How do management practices relate to sustainability measures? 1. Economic; 2. Social and; 3. Ecological?
5. What is the relationship between rangeland management practices that are perceived as sustainable and rangeland management practices that are being implemented?
6. Do managers using any particular grazing strategy, identified as contributing to the sustainability of rangeland, have any identifying characteristics? (e.g. live on their land, are long term residents, depend on their land for a significant amount of their total household income, operate livestock enterprises with multiple classes of animals (e.g. breeding cows, heifers, stokers, small stock, etc) or, operate both livestock and wildlife enterprises more likely to use rotational grazing systems?)

Resulting Hypotheses

The questions above have led to the following hypotheses:

1. Land manager perceptions of sustainability, based on whole-ranch observations will center on productivity and profit.
2. Management practices being implemented will vary widely.
3. Land managers will limit implementation of grazing strategies perceived as sustainable based on labor and cash flow.
4. Rangeland Sustainability will be predicted by grazing management practices, philosophy, and land owner characteristics.
5. Findings concerning landowner grazing management, via the survey instrument, will compliment physical, experimental studies, solidifying whole-ranch assessment of ecological sustainability.

Data

A survey of livestock managers, operating an enterprise consisting of 500 acres or more of native rangeland, was conducted. Managers in Cooke, Montague, Clay, Jack, Wise, and Parker Counties in north central Texas were the targeted population. Data collected included: Demographic data; Personal philosophy on sustainability; Management practices being implemented; Personal perception of identified components of ecosystem functionality for respondent ranch; personal perception of economic viability for respondent ranch; Personal perception of social issues for the respondent ranch.

These data were organized into questionnaires based on a series of strategic processes. Initially a preliminary study was conducted, especially designed around the livestock managers' survey. The questionnaire was developed based on information reported in current grazing management literature and range management text books. Conducting the preliminary study was beneficial for several reasons. It helped to evaluate the survey instrument for comprehension by the reader, response rate, duplication, and usefulness of answers. Also, the application of statistical methods helped to identify interrelationships among the large number of variables.

A focus group was conducted in an effort to fully understand predominant whole-ranch grazing management perceptions pertaining to economic, social, and ecological outcomes. As suggested by Briske et al. (2008), this circumstantial evidence, derived from successful grazing manager experiences, may be compared with experimental research to gain valuable insight and develop a more robust approach to understanding and implementing successful grazing management. Qualitative data collected from our focus group were documented and used to develop the questionnaire for thorough assessment of whole-ranch management.

A formal survey was conducted to identify grazing management strategies that are perceived by ranchers to best achieve whole-ranch business objectives and ecosystem enhancing practices for mid to tall-grass rangelands in the USA. Data collected were used to evaluate perceptions regarding the effect of planned grazing systems on sustainable agricultural production in mid to tall-grass rangelands. Surveys addressed issues of sustainability questions concerning land health; rangeland productivity and economic viability; and quality of life and cultural experiences.

Finally, there was a test for non-response bias. This was conducted by sending a second, but short non-response survey. Especially, of interest was demographic data, to test if non-respondents were a representative section of the population, or if non-respondents were biased in one direction or another.

Data were collected and evaluated for statistical methodology. SPSS and R-2.13.0 computer software were used to perform multivariate analysis. Information was reduced to create indices from perception data. These data was compared with management practice and with respondent characteristics. Statistical analysis served to identify key variables that are indicators of perceived sustainable rangeland livestock management.

Project Overview

The overall goal of this research was to identify grazing management strategies that promote the long-term productivity and ecological health of grazing land as identified from the whole-ranch perspective. Technical information obtained can be used to improve awareness by the ranch manager and the public concerning grazing management strategies that best correlate with enhanced rangeland sustainability.

The study was submitted for approval to UNT‘s Institutional Review Board (IRB) for approval (Human Subjects Application No.10-235). It was determined to qualify for an exemption from further review.

The remainder of this document is divided into four main sections. The first is an in depth look at the scientific literature available concerning rangeland grazing management strategies and rangeland sustainability principles especially within the context of private land management in the United States. Second there is an overview of the materials and methods involved in developing and implementing this study. The third section is a presentation of the results and an analysis of the data collected. Finally, the findings of the study are summarized in accordance with the stated objectives which are listed above; future study needs are suggested.

CHAPTER II

LITERATURE REVIEW

Introduction

Forty to fifty percent of the terrain in the United States is rangeland. More than half is privately owned (Buckhouse et al., 1994; Lubowski et al., 2006). A large percentage of rangelands consist primarily of native plant communities managed, typically for livestock production, with 587 million acres, 25.9% of the land in the U.S. being implicated as “grazing land” (Lubowiski et al., 2006).

It is easy to see that private management of such a large portion of land in the U.S. has a very significant impact on many environmental concerns. Grazing of livestock is extremely important to the majority of the land management issues concerning rangeland. This literature review will attempt to explore the issues related to managing livestock on rangeland in the U.S.

To explore this topic thoroughly, one must investigate the ecological and philosophic literature that contributes to an understanding of livestock management. The major sections of this review are as follows:

1. Introduction
2. Rangeland Ecological Function
3. Grazing Effects on Ecosystem Function
4. Livestock Management Strategies
5. Negative Ecological Impacts of Livestock Management
6. U.S. Policy: Impact on Rangeland
7. Land Ethics
8. Social and Economic Considerations for Private Rangeland
9. Holistic Management Principles
10. Sustainable Range Management
11. Conclusion

Select literature that is sited helps the reader gain an understanding of range management in the U.S. It will investigate issues and impacts associated with private land management that are necessary to fully understand the concepts related to ongoing debate concerning preferable grazing strategies. Finally, it will review concepts that go beyond the debate, reviewing literature that is trying to put the pieces of land management concepts together: ecological, social, and economic.

Rangeland Ecological Function

Rangeland "health" is a term that is used by range managers to assess the environmental integrity of the land. The Natural Resource Conservation Service (NRCS) (2000) states there are three main attributes of rangeland that collectively define rangeland health. They are closely related, yet separate. These are biological and physical attributes which are often used as indicators of functional status of ecological processes and site integrity:

- Integrity of the biotic community – The capacity of the site to support characteristic functional and structural communities in the context of normal variability; to resist loss of this function and structure due to disturbance; and to recover following disturbance.

- Soil/site stability – The capacity of the site to limit redistribution and loss of soil resources (including nutrients and organic matter) by wind and water.

- Hydrologic function - The capacity of the site to capture, store, and safely release water from rainfall, run-on, and snow melt, to resist a reduction in this capacity, and to recover this capacity following degradation.

The attributes are susceptible to changes caused by disturbance in climate and precipitation patterns, or disturbance caused associated with land use.

Integrity of the Biotic Community

The central assertion of a relationship between biodiversity and ecosystem function is that greater diversity is associated with higher ecosystem stability. Heterogeneity is the precursor to biological diversity at most levels of ecological organization and should serve as the foundation for conservation and ecosystem management (Christensen, 2003). Rangelands have been described as inherently heterogeneous because composition, productivity, and diversity are highly variable across multiple scales (Ludwig and Tongway, 1995; Fuhlendorf and Smeins, 1998). Mac Arthur (1972) suggested that with increases of alternative pathways for energy flow within an ecosystem, the less likely that pathway destruction or disruption would unsettle the system. Supporting these claims McCann (2000), notes that decreasing biodiversity will be accompanied by less but stronger interactions within ecosystems and a decrease in ecosystem stability (Deregibus et al., 2001).

A heterogeneous patchwork on rangelands can result from differential timing of disturbances and corresponding out-of-phase succession among patches, spatial variability of resources associated with topographic and edaphic patterns, or competitive interactions among plant species (Fuhlendorf and Smeins, 1998; Fuhlendorf and Engle, 2001). Further, plant species diversity and richness are affected by grazing management. Grazing enhances diversity at low rates but reduces it at high rates (Mariott et al., 2009). The duration of agricultural intensification appears to set the rate of recovery, with high variability between situations (Bakker and Berendse, 1999).

It is also important to consider observations of the impacts of grazing on species diversity associated with non-plant species. Sward structure usually changes rapidly after a reduction in management intensity. Reduction of agriculture-use intensity generally results in more dead material and more height heterogeneity (Vickery et al., 2001). Reduction in sward height caused by intensive grazing negatively affects some insects and arachnids, especially the smaller and more sedentary species, however, abundance of arthropods increased more substantially in relation to tussocks than swards (Dennis et al., 1998). Vegetation structure is also important to birds. It has been shown that shorter swards favor birds foraging on soil invertebrates, but taller swards favor those feeding on seeds or foliage (Atkinson et al., 2005; Buckingham et al., 2006).

Soil/Site Stability

Grass steppe represented the most desirable state in term of livestock production and soil stability, while shrub steppe represented the most degraded and least productive state (Beeskow et al., 1995). According to Wilson and Tupper (1982), range condition should be based primarily on soil stability as soil degradation is the most serious manifestation of a decline in range condition. Wind erosion of soils is likely to play an important role in the desert grasslands of the southwestern United States, which have experienced dramatic vegetation changes including extensive encroachment by shrublands over the past 150 years (Buffington and Herbel, 1965; Allred, 1996; Gibbens et al., 2005). Li et al. (2007) suggests that shrubs are relatively ineffective at reducing wind erosion and nutrient loss compared to grasses. Vegetation changes and soil degradation processes are closely related and may be site specific. Bosch and Kellner (1991) emphasized the importance of understanding the process of rangeland degradation before assessing the range condition of any area.

Soil erosion and sediment delivery from agricultural areas are responsible for the supply of sediment-associated nutrients, pesticides and heavy-metal contaminants in many rivers and streams (Steegen et al., 2001; Verstaeten and Poesen, 2002; and Lal., 2003). Sediment transport capacity is 10 times greater for degraded pasture than pasture in that is not degraded (Verstraeten et al., 2007).

Hydrological Function

Scientific studies documenting hydrologic changes in rangelands are most often associated with heavy grazing intensities, although these changes do not increase linearly with grazing intensity (Naeth and Chanasyk, 1995). Increased stocking rates negatively affected water infiltration into the soil (Abdel-Magid et al., 1987) and increased stream sedimentation (Knight and Heightschmidt, 1987). The cause of the negative hydrological effect, as described by Knight and Heightschmidt (1987), is changing surface factors such as aggregate stability, surface roughness, litter cover, total grass and standing crop, combined with soil properties. Likewise, Warren et al. (1986), found that increased stocking rates have negative effects on soil properties (increased bulk density, disruption of biotic crust, reduced aggregate stability and aggregate size distribution) due to physical effects on the soil and changes in the vegetation towards dominance by lower seral plants. These effects are positively correlated with the distribution and frequency of animal trampling. The same study indicated that managing for grassland dominated by high seral plants improves hydrological function. Similarly, Pluhar et al. (1987) found that infiltration increased and sediment production declined as vegetation standing crop and cover increased.

Rest appears to be the key to soil hydrologic stability. In order to avoid long-term progressive degradation, rest periods must be of sufficient length to allow full recovery of the soil hydrologic condition prior to the reoccurrence of livestock impact. It seems logical that any increase in stocking rate must, therefore, be accompanied by an increase in the length of the rest period in order to compensate for the greater impact (Warren et al., 1986).

Grazing Effects on Ecosystem Processes

The relationship between the ecosystem and the anthropogenic practice of livestock grazing is very complex. In addition to affecting the three ecological functions of rangeland, defoliation, trampling, and mineral deposition have varied affects on rangeland health and rangeland processes. Grazing affects multiple rangeland characteristics including biomass, soil nutrients, soil carbon, plant species composition, and forage quality (Teague et al., 2004). Grazing alters plant physiological processes and nutrient cycling (Booth et al., 2003).

Rangeland ecologists generally accept that grazing by ungulates was instrumental in the evolutionary history of grassland ecosystems (Milchunas et al., 1988, Knapp et al., 1999, Frank and McNaughton, 2002). Because of this belief and other factors, to be discussed later, several scientists have proposed that grazing of indigenous rangeland is one of the most sustainable forms of agriculture known (Heitschmidt et al., 2004, Frank and McNaughton, 2002). At the same time, there are many studies that implicate grazing as a very detrimental factor affecting rangeland (Centeri et al., 2009; Belsky et al., 1999). Another controversial hypothesis is that herbivory may, in some situations, increase range productivity (Belsky, 1986; McNaughton, 1989; Verkaar, 1986; Crawley, 1987; Hobbs and Swift, 1988; Westoby, 1989).

Natural rangeland communities are constantly responding to the effects of the most recent disturbance, in most cases, never achieving a steady-state or climax stage. The absence of these disturbances in grassland ecosystems results in a decline in species diversity and deterioration of physical structure (Picket and White, 1985). Once disturbances cause damage beyond threshold levels, it may never be possible to restore ecosystem functionality. Thresholds represent a transition boundary which, when crossed, results in a new, degraded, stable state that is not easily reversed without significant inputs of resources (NRCS, 2000). Severely degraded rangelands have the propensity to shift to a stable, shrub-dominated state that will not return their original composition even with elimination of further grazing (Christensen et al., 2003).

Due to the complexity of ecological processes and their interrelationships, it is usually difficult and/or expensive to directly measure site integrity and the status of ecological processes. Therefore, biological and physical attributes are often used to indicate the functional status of ecological processes and site integrity (USGS, 2002). Complicating the relationship between grazing and the ecosystem still further is the variability between sites in relation to disturbance response levels. This indicates that rangeland management will necessarily vary from one location to the next.

Grazing management is the manipulation of grazing and browsing animals to accomplish desired results, which generally include both plant and animal performance. Critical factors with grazing management include the amount of plant material remaining after defoliation and the timing interval between defoliations. The most basic analysis of grazing management acknowledges management decisions are contingent on stocking rates and rotation timing (Hanselka et al., 2009). Additionally, grazing science and management need to incorporate heterogeneity and nonlinear scaling of spatially and temporally distributed ecological interactions such as diet selection, defoliation, and plant growth (Laca, 2009).

Defoliation by grazers significantly affects individual plants morphologically and physiologically. This in turn affects their vigor and productivity, as well as recruitment and survival through the indirect effects on competitive relationships among plants (Briske and anderson, 1990). The detrimental effects of defoliation are increased with greater intensity or frequency of defoliation (Briske and anderson, 1990) and can lead to mortality of plants, particularly if environmental conditions deteriorate. Seedlings and juveniles of palatable species are particularly vulnerable. In an early and classic study, Crider (1955) found that a single defoliation removing 50% or more of the shoot volume retarded root growth in 7 of 8 perennial species examined. This observation, among others, prompted the often used term, "take half - leave half," as a saying for grazing management that emphasizes stocking rate. However, Hormay (1956) observed that preferred plants in preferred sites are utilized closely and repeatedly even when the entire management unit is lightly or moderately stocked on average.

Other study results refute the notion that grassland herbivory leads to a reduction in root productivity, and a decline in soil carbon content. Frank et al. (2002) insists that grazers stimulated aboveground, belowground and whole-grassland productivity. They found the major effect of herbivory was a positive feedback on root growth. It is reported that grazers are important regulators of carbon and nitrogen ecosystem processes (Frank and Groffman, 1998). Grazers can increase forage nutrient concentrations and aboveground plant production (Frank and McNaughton, 2002). Grazers also enhance mineral availability for soil microbial and rhizospheric processes that ultimately feedback positively to plant nutrition and photosynthesis (Hamilton and Frank, 2001), in addition to increasing nutrient cycling within patches of their urine and excrement (Holland et al., 1992). However, the positive feedbacks from grazers on the ecosystem are contingent on suitable climatic conditions. During drought, these feedbacks are diminished (Wallace et al., 1984; Coughenour et al., 1985; Louda, 1990).

A plant can produce leaves only at an intact growing point. The lower that point is to the ground, the more grazing tolerant the plant. Destruction of that point will prevent the production of seeds and new seedlings. Thus grasses need to be rested periodically to allow for production of leaf material to feed the plant and produce seeds (Hanselka et al., 2009).

Livestock prefer to consume certain plants compared to others. In the context of rangeland evolution and ungulate migration, these preferred plants have probably always been severely grazed when encountered. It is suggested that the intermittent nature of the severe grazing prevented chronic defoliation (McNaughton et al., 1989). Overgrazing occurs on individual plants as a result of multiple, severe defoliations without sufficient physiological recovery between defoliations. Variables including site location, stock density, time-specificity, and diet selection of grazing animals which can put palatable and actively growing plants in preferred areas at a disadvantage (Earl and Jones, 1996). Stocking rate affects only the proportion of plants likely to be used heavily. Therefore, while conservative stocking is an important first step in sustainable management, it must be applied in conjunction with other management practices like short grazing periods at high stock density (O'Connor, 1992) and periodic deferment to mitigate the effects of selective grazing (O'Reagain et al., 2003). Increasing differences in palatability and abundance among different plants in a pasture, decreasing stock density, or increasing the graze period will tend to increase the likelihood of overgrazing the more palatable plants (Earl and Jones, 1996). Supplemental feeding, and other management practices that artificially sustain herbivores, break the negative feedback that promotes good range productivity and maintains long-term system stability. In general, strategies to increase cattle production in semi-arid rangelands should be based on the improvement of natural forage production (Diaz-Solis et al., 2006).

Vegetation dynamics on a landscape emerge from interactions among plant autecology, community processes, climate, and disturbance, as modified by grazing animal preferences and distribution in response to plant species, topographic and ecological site diversity (Walker, 1988).

Livestock Management Strategies

Grazing management systems were developed in an attempt to manage grazers and grazing lands in a manner that maintains or improves ecosystem structure and function while achieving social and economic goals (Heitschmidt and Taylor, 1991). In the recent past we have largely restrained the movements of domestic animals and in the process inadvertently trained herbivores to become sedentary, largely with the use of fences in continuous and conventional rotational grazing systems, and with the suppression of fire and large predators (Provenza, 2003a). Responsible rangeland stocking rate should match forage availability in both wet and dry years by allowing for adequate plant residual biomass to enable rapid regrowth following grazing, and by having buffer areas available (Teague et al., 2004). "Since the range has been domesticated, forage availability and thus production, has become dependent on stocking rates, rest, and rainfall" (Texas Parks and Wildlife, 2007).

Grazing management is defined as the manipulation of livestock to accomplish a desired result. Watson et al. (1996) claim that effective vegetation management will enable managers to "condition the resource". This will allow for maximum advantage to be made of favorable rangeland events, possibly even increasing the frequency at which favorable events occur, by lowering response thresholds of the system. In Rangeland ecosystems, vegetation management will typically involve grazing. Hormay (1956) asserted that there are only four factors that can be manipulated to influence desired management goals on rangelands with grazing: stocking rate, season of grazing, livestock distribution, and frequency of grazing. These factors are generally acknowledged by many range managers and scientists alike (Briske et al., 2008; Laca, 2009).

There are many types of grazing systems which utilize some component of the four grazing management factors listed above. However all grazing systems involve continuous use of a pasture or rotation of livestock. There are multiple strategies, with the use of rotational grazing, one of the most notable being intensive grazing (Holechek et al., 1989; Hanselka et al., 2009). When discussing specialized grazing systems it is important to understand the terms deferment, rest and rotation. Deferment is delaying grazing until seed maturity of key forage species. Rest is deferment of a pasture for a full year, rather than just part of the growing season. Rotation is the movement of livestock from one pasture to another on a scheduled basis (Holechek et al., 1989).

Continuous Grazing System

Continuous grazing is the use of livestock on a pasture, leaving the herd in the pasture permanently. The basic concept is one herd, one pasture, let the animals migrate and consume forage at will, within a given area, throughout the year (Holechek et al., 1989). It is the simplest form of grazing management.

This type of grazing system has some distinct advantages. It requires less labor and time, requires minimal capital. and allows animals to select the best plants (if not overstocked) (Hanselka et al., 2009). Numerous studies indicate that rangeland productivity and condition can be maintained under moderate stocking rates and continuous grazing (Klipple and Costello, 1960; Kothmann et al., 1971; Pieper et al., 1978). Holechek et al. (1989) suggests a grazing pressure of only 10-20% to allow adequate forage to sustain livestock during the dormant season.

Continuously grazed rangelands in poor condition lack the plant community to reproduce because of the pressure applied by livestock, less production per acre, and uneven or patchy pasture use (Hanselka et al., 2009). Areas near water and cover will often receive excessive e use (Holechek et al., 1989). In ecosystems with a short evolutionary history of grazing, repeatedly grazed patches represent the initial stages of rangeland deterioration and desertification as a result of decreased water infiltration and increased runoff (Buckhouse et al., 1994). Grazing management strategies that facilitate patch degradation increase pressure on desirable plants already weakened by heavy use (Norton, 1998).

Under continuous, moderately-stocked, grazing livestock tend to select local areas that lack accumulations of biomass from previous years. This behavior produces small, heavily grazed patches interspersed within avoided or lightly grazed patches. In effect, this creates a pattern of small-scale structural heterogeneity (Bailey et al., 1996). At a larger scale, livestock concentrate near water, thus increasing grazing pressure on vegetation near water and reducing grazing pressure on vegetation distant from water. The result is larger-scale heterogeneity. This gradient of grazing pressure associated with distance to water masks the small-scale heterogeneity both close to and distant from watering points.

This heterogeneity has some advantages and disadvantages. Failure to consider the spatial components of herbivory in carrying capacity calculations and assessments of ecosystem persistence can contribute to overgrazing, failed economic development efforts, and declines of wildlife populations (Coughenour, 1994). Grazing under enclosed conditions does not occur uniformly over time or over a landscape (Ash and Stafford-Smith, 1996; Bailey et al., 1996; Witten et al., 2005) and selective use of plants and landscape components under continuous grazing can cause a gradually widening area of degradation under, even at light to moderate stocking rates (Ash and Stafford-Smith, 1996).

Livestock grazing large paddocks exhibit spatial patterns of repetitive use, heavily using preferred patches and avoiding or lightly using others. The process of patch-selective grazing results in the effective stocking rate on heavily used patches being much higher than that intended for the area as a whole. Alternatively, the intended goal of the manager may alter the desirability for rangeland patch dynamics. Greater spatial heterogeneity in vegetation provided greater variability in the grassland bird community. Fuhlendorf et al. (2006) demonstrated that increasing spatial and temporal heterogeneity of disturbance in grasslands increases variability in vegetation structure that results in greater variability at higher trophic levels. Thus, management that creates a shifting mosaic using spatially and temporally discrete disturbances in grasslands can be a useful tool in conservation.

Rotational Grazing Systems

Rotational grazing is pasture management in which animals are rotated through a series of paddocks, generally on some flexible basis (Butterfield et al., 2006). Rotational grazing is more complex than continuous to understand. In fact, there are many specialized rotational grazing strategies. Land rest is the critical feature of any specialize grazing system. Some examples of specific systems are: Deferred Rotation, Merril Three-herd/Four Pasture, Season-Suitability, The Best Pasture, High Intensity-Low Frequency, and Short Duration (Holechek et al., 1989). This literature review will not address each system, but mentioning them is necessary to understand the complicated nature of rotational grazing.

Native grazing ecosystems evolved while being dominated by large, migratory ungulate herbivores. These ungulates would often graze selected sites very intensely. But the duration of the intense grazing was short and defoliated plants were afforded time and usually suitable conditions for re-growth (McNaughton et al., 1989). Nomadic pastoral systems that mimic these grazing patterns of wild ungulates seem to have less detrimental effects on vegetation than more sedentary grazing management (Danckwerts et al., 1993). However, with rotational systems, the grazing load on other pastures must be increased during the critical growing period (Holecheck et al., 1989).

Teague et al. (2008) explains that significant range improvement can occur by providing periodic, adequate growing season deferment. Around the world, observations have noted an increasing proportion of desired plant species and increased plant vigor following growing season deferment. Growing season rest improved range conditions when stocking rates were similar or higher to comparisons of season long grazing or rotational grazing with shorter recovery periods. (Smith 1895; Sampson, 1913; Rogler, 1951; Scott, 1953; Matthews, 1954; Merrill, 1954; Hormay, 1956; Hormay and Evanko, 1958; Hormay and Talbot, 1961; Hormay, 1970; Reardon and Merrill, 1976; Booysen and Tainton, 1978; Taylor et al., 1980; Thurow et al., 1988; Taylor et al., 1993; Tainton et al., 1999; Snyman, 1998; Teague et al., 2004; Müller et al., 2007). This is possible if adequate water and nutrients are available (Lee and Bazzaz, 1980; Wallace et al., 1984; Coughenour et al., 1985; Polley and Detling, 1989). More arid rangelands require longer recovery periods (Heitschmidt and Taylor, 1991). Additionally, Warren et al. (1986) noted at a heavy stocking rate, water infiltration into the soil was much higher in an intensively run, multi-paddock rotational grazing system than in a continuously grazed treatment at the same stocking rate.

Rangeland provided with a long rest period or low grazing pressure decreases in forage quality because of increased plant maturity. McNaughton (1979) compared grazed to non-grazed rangeland. When adequate nutrients and moisture are available, multi-paddock grazing managed at optimal grazing intensity, increased primary production. Grazing intensities greater than optimal will decrease primary productivity. Evidence supports the grazing optimization hypothesis at both the plant and community level (Belsky1986; Milchunas and Lauenroth,, 1993). The grazing pattern required to increase primary production mimics migratory herbivores because there is a period of intensive grazing, followed by a long period of little or no grazing (Frank and McNaughton, 1993). To maximize plant regrowth with intensive grazing systems, plants must have access to adequate moisture, nutrients, and recovery time. Continuous grazing does not allow for recovery on heavily grazed patches (Teague and Dowhower, 2003). Grazing distribution is more even under intensive than extensive management. This depends on how well the aspects of timing and frequency of grazing are managed. (Barnes et al., 2008), Derner et al. (1994) noted that: 1) Rotational grazing provided greater managerial control over the frequency and uniformity of tiller defoliation and ; 2)intensity of tiller defoliation was similar between the rotational and continuous grazing systems. Thus higher range condition will be maintained over the long-term in rotational system pastures; *little bluestem* will remain more competitive and productive resulting from fewer defoliation events throughout the grazing season (Derner et al., 1994). Also, rotational resting and rotational grazing should ensure improved forage plant composition and productive potential so the effects of drought are decreased and there is speedy recovery after drought (Teague et al., 2004).

Herbivores still express diet selectivity and thus patchy grazing to greater or lesser degrees when managed under rotational grazing (Hunt et al., 2007). There is often a period of time when rotational grazing performance lags behind that of continuously grazed animals as herbivores better learn which plants to consume (Provenza, 2003a). Therefore, grazing periods should be kept short enough so that the animals can maintain sufficient diet quality to meet performance goals (Teague et al., 2008).

Successful grazing managers must optimize several ecological goals to attain sustainable production goals (Heitschmidt and Taylor, 1991; Briske et al., 2008). Teague et al. (2008) argue that these goals cannot be accomplished with continuous, season-long grazing in environments that receive enough moisture to have growing periods of more than a few days. They further suggest these goals should include: (1) Planned grazing and financial planning to reduce costs, improve work efficiency, enhance profitability, and achieve environmental goals; (2) Providing sufficient growing season deferment to maintain or improve range condition; (3) Grazing grasses and forbs moderately during the growing season for a short period to allow adequate recovery; (4) Timing grazing to mitigate detrimental effects of defoliation at critical points in the life cycle of preferred species inter- and intra-annually; (5) Where significant regrowth is likely, grazing the area again before the forage has matured too much; (6) Flexible stocking to match forage availability and animal numbers in wet and dry years or having a buffer areas that can be grazed; (7) Using fire and other tools to manage livestock distribution and increase the total plants harvested; and (8) Using multiple livestock species.

Specialized grazing systems usually lead to improved livestock management. With these systems, concentration and handling of animals by the manager is increased. The results can be better health, better breeding and better supplemental feeding programs and notably tamer animals. Pastures receiving rest are available for burning, seeding and other management practices (Holechek, 1989).

Livestock Management Strategies: Summary

Grazing systems are management tools designed to balance the conflicting relationships between energy capture, harvest, and conversion efficiencies. They are designed firstly to enhance livestock production over time by either improving and/or stabilizing the quantity and/or quality of forage produced and/or consumed. Production improves if the benefits of rest or deferment exceed the detrimental impacts of grazing. Stabilization results if the benefits of rest exactly equal the detrimental impacts of grazing. Degradation results when the benefits of rest are less than the detrimental impacts of grazing (Heidschmidt and Taylor, 1991).

For communities to move from one stable state to another, some external force is required. Management should be aware of which stable state or states have the greatest chance of fulfilling objectives and what combination of events is required to cause or prevent success (Westoby et al., 1989; Danckwerts et al., 1993). Forage type and climate appear to be factors that determine system productivity advantages. Especially in more humid areas (> 500mm precipitation), and on seeded rangelands, short duration grazing appears to have a productivity advantage (Daugherty et al., 1982; Heitschmidt et al., 1982; Sharrow, 1983; Jung et al., 1985).

In areas of lower rainfall, and with annual grasses, studies have shown advantages for better animal performance with continuous grazing systems (McIlvain and Savage, 1951; Hoelechek et al., 1987; Reece, 1986).

Negative Ecological Impacts of Livestock Management

Taking a look inward, at a targeted portion of American agriculture practices, it is not hard to find instances of overlooking our environmental impact. When examining management on U.S. grazingland which is a use that encompasses nearly 587 million acres or 25.9% of land in the United States (Lubowiski et al., 2006), we find flawed policy, philosophy and management. These flaws all have helped to increase the instance of overgrazing, which can cause a profound change to the ecological function and productivity of rangeland. This is especially true for native flora and fauna, as Samson et al. (2004) suggest that few grassland landscapes remain adequate in area and distribution to sustain diversity sufficient to include biota and ecological drivers native to the landscape.

Historically, profits were realized by depleting the range. Today, the range must be sustained at a healthy level for ranching to be profitable. Rangeland degradation reduces the diversity and amount of the values and commodities that rangelands provide, and severe rangeland degradation can be irreversible. Overgrazing, drought, erosion, and other human and naturally induced stresses have caused severe degradation in the past. (NRCS, 2000) Overgrazing is not caused simply because livestock are present. Instead, it is a problem caused by having too many herbivores grazing on a particular area, given the climatic, soil and vegetative conditions, in a given timeframe. Or it may be caused because extensive grazing or poorly managed rotational grazing of domestic animals by humans does not emulate the movements of wild ungulates, whereby managed herds during dry seasons are held at stocking rates higher than the land can support (Teague et al., 2008). Feeding and compaction by herbivores can cause a change in vegetative structure of an area. This action causes a detrimental effect to land. Some associated negative effects are loss of plant and animal species, invasion of exotic plants, erosion, desertification, loss of hydrologic function, and spread of disease (Fleischner, 1994). For rangeland managers, this can mean a decrease in productivity and health of livestock, as well as the loss of land available for future practices (Mowry, 2007).

Overstocking with livestock and drought has caused great ecological harm on the rangeland. This, of course, is not sustainability; it is also in contrast to native grazing ecosystems (Provenza, 2003b). Conditions that caused this problem include ignorance, apathy, policy and desperation. “Ranching can be sustainable if it can convert to a self reproducing resource into a profitable commodity without undermining the long-term viability of the resource” (Sayre, 2001). Generally, the more sedentary and concentrated animal use of the vegetation under human management removes the key revitalizing element of periodic dererment and natural response to climate variation (Teague et al., 2008). The rangeland must renew itself every year, and be harvested by livestock in an economical fashion. The common practice of maintenance of artificially high animal numbers with supplementary feed during less productive periods promotes degradation (Oesterheld et al., 1992; Milchunas and Lauenroth,, 1993).

U.S. Policy: Impact on Rangeland

A close look the cattle boom years of American history (70 years between the Civil War and the Dust Bowl) indicates that rangeland deterioration began to occur because of personal philosophy and government policy surrounding cattle and land. These seven decades saw land use change from Spanish/Mexican pastoralism to modern ranching, with a hybrid (open range) period in between. Combinations of factors were necessary to have caused the devastation experienced in that time frame. These factors were the cattle themselves, the railroad, and the culture – all driven by outside capital investment (Sayre, 2002).

The origins of range management in the United States are usually traced to a critical situation in the late 1880s and 1890s, when severe drought and harsh winters led to heavy cattle losses, thereby forcing livestock producers to respond to problems of uncontrolled overgrazing (Brunson, 2003). This educational era, which was aided by the passage of the Morrill Act in 1862 and the formation of the land-grant colleges (Holechek, 1989; Sayre, 2002), led to several management practices that helped to promote overall land health. This era also produced a sense of "man can do better than nature", an attitude leading to the planting of "improved" grasses and other management practices that may not have been in the ecological best interest of certain regions. Most importantly, this era was unable to solve all of the problems caused by past land-management practices (Sayre, 2002).

The passage of the Homestead Act in 1862 paved the way for the settlement of the west, and thus the beginning of managed livestock grazing over most of the United States. This act allowed anyone who had not taken up arms against the U.S. to lay claim to government land if they filed an application, improved the land, and filed for deed of title.

Initially this caused a cattle boom in the west in the 1870's and 80's. Men wanted to make the most of the situation while it lasted. They held the belief that there was more grass than his cows could eat. They bought cattle in a time of rising cattle prices and high interest. Soon drought and economic down-turn resulted in range degradation, cattle death and economic loss. Responding to pressure by special interests and to developing circumstances a series of congressional acts aimed at expanding the economic contributions of the west were passed. Each helped to promote some aspect of the livestock industry and came with its own unintended side effect. Some of the important congressional acts prior to the dust bowl years include: The

Transcontinental Railroad Act of 1862; the Forest Reserves Act of 1891; the Enlarged Homestead Act of 1909; the Stockraising Homestead Act of 1916 (Holechek et al., 1989).

Because of governmental policy, individuals settled on the productive land and used the surrounding government land (open range) freely. In 1934 came the Taylor Grazing Act, which ended open range. This act was a result of a realization that private lands in the West were typically too small to support a household. This led to private lands near natural waters and floodplains, where homesteaders managed to carve out a living long enough to perfect the title; with government lands and Indian reservation getting the rest of the land. (Sayre, 2005).

These acts defined the formation of the ranching industry. They encompassed 70 years that "produced by far the worst ecological damage ever done to western rangelands" (Sayre, 2002). Since that time several congressional acts have been passed which try to address environmental concerns of rangeland use in the United States. These include: the Soil Erosion Act of 1935; the Multiple Use Act of 1964; and the National Environmental Policy Act of 1969 (Holechek et al., 1989).

Recent years have seen a gradual shift from economic policies and practices furthering productive capacity to those encouraging ecosystem health and restoration. For example, the policies of the Conservation Reserve Program, contained in multiple Farm Bills of the past 20 years, have provided new and increased emphasis on improving soil stability, water quality and wildlife habitat, along with a reduction in crop production (Maczko and Hidinger, 2008).

Trends for today surrounding grazing lands are equally disturbing to those interested in preserving the original ecosystem. Sayre (2002) tells us that by the 1970's an urban boom was under way in the United States, especially in the West. This was because of post war prosperity, improved infrastructure, air-conditioning and automobile ownership. These developments helped urban land area quadruple from roughly 15 million acres in 1945 to an estimated 60 million acres in 2002 (Lubowski et al., 2006).

In areas on the fringe of urbanization, non-traditional overgrazing issues are arising. Many suburbanites have moved to the country, seeking a more rural home site. When people purchase land, they often desire a ranchette, a place where they can maintain a few livestock, for the sheer enjoyment of having them. This recent trend has added a different twist to the old problem. Often owners of ranchettes may fail to manage the vegetation on their land due to status and lack of land management education. Ranchette subdivisions may increase overgrazing impacts locally in areas where livestock are kept as pets or status ornaments on small holdings (Dudley, 1997). The problem is advanced further because economics may not be an issue, and supplemental feed costs may be of no concern to the landowner. Land around cities, national parks, attractive scenery, and good climate are experiencing faster rural growth rates than urban growth. This can be explained by an increase in land fragmentation. Ranchettes can cause serious ecological changes (Sayre, 2005).

Land Ethics

It is evident that agriculture is the first front in a conflict between man and the environment, between natural succession and technologically enhanced land usage. Mankind has continuously sought to provide for himself a more comfortable existence. In doing so, history has shown that he has often overlooked his impact on the world in his quest to change and improve his plight in life. " Before agriculture was midwifed in the Middle East, humans were in the wilderness. We had no concept of "wilderness" because everything was wilderness and we were a part of it. But with irrigation ditches, crop surpluses, and permanent villages, we became apart from the natural world…" (Foreman, 1991).

This phenomenon of overlooking our ecological impact is typical in many cultures, in geographic locations all around the globe. Even in North America, it is believed that some Native Americans negatively affected nature through their primitive domesticated livestock rearing, farming, hunting and gathering techniques. Some primitive cultures practiced land use principles that were solely anthropocentric, without regard to environmental degradation (Nabhan, 1995). It is very possible that these practices along with region-wide drought helped to bring about the demise of some of these native cultures.

Aldo Leopold (1949) wrote about land ethics. He believed that when we view something as property, it is ours; we do with it what we wish. When we see something as part of a community we tend to feel responsibility to at least consider the impacts we will have on others. Leopold takes this philosophic concept and applies it to land; he concludes that the forces that are out there in 1948 are not likely to bring about the change that is necessary to instill the feelings needed to bring land out of the realm of "property" and into the concept of community cooperation and responsibility. In particular, he was disillusioned with the education system for the lack of ecological ethics being taught in agronomic course work.

When land is stocked to capacity, drought causes temporary reduction of productivity in rangeland. Unless a land manager recognizes the threat and de-stocks, rangeland degradation will occur. Research by Costa and Reham (2005) shows traditional decisions to retain livestock, even at the expense of the environment may be as physiological as they are economic. High stocking rates are deliberate and crucial decisions taken by the farmers. These decisions appear paradoxical even irrational given the state of knowledge regarding the consequences of overgrazing. The phenomenon appears to be linked with objectives of livestock managers. Indications are that producers view cattle ownership as a means to ensure they are able to continue land ownership, as a source of security and liquidity, and as a way of life worthy of passing to the next generation. Leopold (1949) believed the problem was with management system that was in place, which is driven by governmental policy and by economics. Without being able to suggest economic gains, it is nearly impossible for many land managers to implement more ecologically sound practices.

Social and Economic Considerations for Private Rangeland

Social and economic infrastructures provide the context in which rangeland use occurs and continues (Tanaka et al., 2003). Most agricultural land in modern societies is used in the production of marketable products. In areas where climatic, topographic and/or soil characteristics, or desires of the owner, render the land unsuited for cultivation, it is used to produce livestock and/or wildlife and related products through grazing. These livestock/wildlife production operations, or ranches, are generally operated as businesses. In the ranching business the forage grown on the land supplies a significant portion, if not all, of the feed for the animals. The grazing land and animals are used in conjunction with labor, capital, management, expertise, etc. to induce animal reproduction and/or growth which can be sold for currency. The currency can then be used to maintain and/or replace the resources used in the production process and provide income to the rancher which he can then use to meet his personal goals (Conner, 1991).

Rangeland ecosystem goods and services have value because they satisfy human needs which can be personal and/or subjective. These needs may include eating a good steak or lamb chop, watching a sunset from a high butte, galloping a horse over open range, meditating in wilderness and fishing in a mountain stream (Tanaka et al., 2003).

Economic Processes include demand, household production, recreation, manufacturing production, trading, investment and consumption or use of goods and services (Becker, 1974; Lancaster, 1966). Social processes include management and social regulation, reflecting social policies pertaining to natural resource use and management. Human population processes on the socio-economic side of the framework include birth, migration, aging and morbidity. Other elements occurring on the right side of the framework include cultural resources, education, governance structures, markets, legal system, social interaction and family. These processes determine the organization of society. Taken together, economic and social processes act on existing conditions and result in Social Capacity & Economic Capital and Current Human Condition in the next time period (Maczko and Hidinger, 2008).

Economic dividends of ecosystem services are a subset of social dividends. The two are necessarily linked. These economic dividends are merely particular outcomes of ecosystem functions that are used to result in specific interactions and transactions in an economy (Maczko and Hidinger, 2008). When the resulting transactions or interactions occur at levels capable of economically supporting a given purpose, the purpose is economically viable.

Economic viability is affected by many external forces. Drought is a natural force that, almost without exception, has negative economic repercussions relative to grazing pressure (Hart et al., 1988; Valentine, 1990; Conner, 1991). Costs such as fossil fuel prices and land prices have effects on economic viability for rangeland management (Heidschmidt et al., 2004). The same is true for prices of goods produced, which are predominantly driven by supply and demand.

Maslow (1954) argues that there is a hierarchy of psychological needs common to all humans. In his conceptual model, biological survival is the most basic goal and spiritual tranquility the most advanced goal. He theorizes attainment of higher goals is only attempted after the more basic goals have been met. In highly developed societies with sophisticated institutions and technologies, man's biological survival becomes more certain and its place as his predominate goal is overtaken by needs for financial security, social prominence and intellectual stimulation.

Social acceptance or rejection of any social process, event, or phenomena is based upon perceived truths, all of which are subject to emotional and political manipulation. In fact, man is better able to survive temporary ecological imbalances in developed societies because of the existence of sophisticated institutions and technology. Therefore man's suffering is expressed in the form of financial losses and reduced social status and self esteem instead of loss of life, as is common in primitive societies (Conner, 1991).

At the local ranch level, production strategies commonly employ goals of profit maximization; however, this is not always the case. Important ranch outputs are not easily incorporated into conventional economic analyses (Maczko and Hidinger, 2008). Surveys show that ranchers tend to value lifestyle over economic well-being (Torell et al., 2001). This indicates that aesthetic and cultural dividends, such as family, tradition and rural way of life, are of equal or greater value to sustainability than are economic well-being (Smith, 1972; Torell, 2001; Maczko and Hidinger, 2008).

Population and Demographics

Potential impacts of an aging farm and ranch population is not well known. The average age of farmers and ranchers is about 55 years (versus 37 years for all Americans) and it continues to climb, while the percentage of young (< 35 years) farm and ranch operators has declined from 15 % to 5 % since 1982 (Allen and Harris, 2005). One possible outcome from an inverted population pyramid is the consolidation of ranches from family operations into larger corporate ones (Maczko and Hidinger, 2008).

Land Ownership and Grazing Management

Land use is closely interlinked with land ownership, and these proportions reflect historic land management priorities. Over 60 % of the land in the United States is privately owned. The federal government is the second largest landowner with more than 28 %, mostly in the Western United States. State and local governments own nearly 9 % and Indian trust land accounts for over 2 % (Lubowski et al., 2006).

If the land is privately owned it may be used, with few restrictions, as its owner wishes to satisfy his or her goals and objectives. If it is publicly owned, the land must be used to satisfy the goals of society (Conner, 1991). Property rights and the way different landowners interpret them, can influence social factors affecting sustainability. The classic 1968 paper by Garrett Hardin, *The Tragedy of the Commons*, sounded a warning that the sustainable management of rangelands is unattainable without some consideration of property rights.

Values and perspectives about property rights may differ between existing landowners and newcomers or neighboring communities. Two common property right issues include water pollution and endangered species (Maczko and Hidinger, 2008). In the context of a business firm, ranches included, the major goal is continuous survival of the business enterprise. This goal predicates other goals for the property owner (Conner, 1984). While survival of the business, may be the primary goal of property owners of rangeland, they also express a strong agreement that they had obligations to be good environmental stewards of their land based on their individual morals, not because of a belief that proper land management would be beneficial to society as a whole (Kreuter et al., 2006).

Private land is America's working land. It includes 99 % of the Nation's cropland, 61 % of the grassland pasture and range, 56 % of the forest-use land, and 30 % of the special-use, urban, and miscellaneous land (Lubowski et al., 2006). With privately owned land, business survival is necessary for retaining ownership. To survive, a ranch must produce a profit in most years and in years when losses occur, they must not be of sufficient magnitude to eliminate the ranch owner's net worth. Over the long term then, the goal of firm survival requires that the rancher also achieve the goals of obtaining profits and avoiding catastrophic losses. Generally, the land is used to produce a product or service for which current markets exist, even if the process results in irreversible degradation of the resource (Conner, 1991).

Publicly owned grazing land is characterized by its intended role in meeting non-market goals of conservation, preservation and equity of opportunity to enjoy unique recreational and aesthetic experiences. Dual use is common, with grazing being the major economical use applied. The role of grazing management is expanded to include facilitating many simultaneous but different land uses and users and usually amounts to keeping livestock from damaging the resource or from impinging on the other uses and users (Conner, 1991)

Economic Benefits of Grazing Management Strategies

The desired result derived from grazing management varies depending on one's view of acceptable ecosystem use. As sophisticated institutions are established and expanded knowledge bases are developed, more complex livestock production practices are adopted, such as those incorporating use of supplemental feeds and cultivated forages, feed grains in finishing yards and grazing systems. Desired results of rangeland ecosystem use are a function of many social factors of which economics is usually dominant (Conner, 1991). Grazing patterns are rarely spatially uniform and extrinsic economic factors vary through time in ways which are not under the control of the individual manager (Pickup and Stafford-Smith, 1993).

The Effect of Number of Animals on Economic Goals

Stocking rate is the major factor affecting the potential profits for ranching enterprises. As stocking rate increases, production per animal decreases, at the same time production per land area increases to a maximum point and then declines (Peiper et al., 1978; Heitschmidt et al., 1990). Thus, as stocking rate is increased beyond a moderate level, profit levels begin to decline (Holechek, 1994). Heitschmidt et al. (1990) further identified that optimal stocking rates vary dramatically among years and that catastrophic loss potential is much greater with heavy stocking rates compared to moderate. Moreover, it is anticipated that over time the production potential of the heavily stocked treatment will continue to decline as range condition declines. Thus, economic stability will decline and financial risks will increase substantially (Conner, 1991).

The Effects of Species and Class of Animals on Economic Goals

Many sources (Holechek et al., 1989; Conner, 1991, Hanselka et al., 2009) implicate the importance of selecting both the species and class of grazing animal that can best affect the manager's ability to meet financial goals. This is most often influenced by the species of forage that is available. Combinations of livestock species, such as cattle and goats, and combinations of classes of livestock such as mother cows and stocker cattle may be difficult to manage, but offer reduced risk because of increased diversity.

Effects of Spatial Distribution of Livestock on Economic Goals

Conner (1991) rationalizes the effects of spatial distribution of livestock on profits and risk avoidances are difficult to assess because the potential impact varies tremendously among enterprises. Although it is believed that an increase in livestock production can be attained through enhanced livestock distributional patterns (Frank and McNaughton, 1993) increased costs may limit or totally eliminate profit potentials (Holechek, 1989; Conner, 1991).

Effects of Temporal Distribution of Animals on Economic Goals

Launchbough (1986) reports greater net returns/hectare when a grazing strategy was implemented in an effort to graze at the optimum time of plant production. Seasonality may play an important role in designing economically advantages grazing strategies. Sims and Singh (1978) suggest that the positive results observed by Launchbough may be related to temporal patterns of forage growth; the rate of forage production in the region studied is consistently greatest in spring and early summer. A major factor affecting the relative success of any grazing strategy used in rangeland environments must be related to climatic rainfall patterns particularly with regards to the temporal distribution of animals (Conner, 1991).

Effects of Grazing System on Economic Goals

From a rancher's perspective, there is little incentive t o implement a specialized grazing system unless it can be shown that the additional livestock and/or wildlife production will more than repay the cost of installation (Holechek, 1989). Economic documentation of specialized grazing systems is limited. Much practical experience indicates that they have been economically successful in a variety of range types. Information collected by Gray and Fowler (1980) shows that well over 50% of ranches in New Mexico use specialized systems. Fowler and Gray (1986) reported a case study of economic impact of specialized grazing systems on New Mexico ranches. With only a few exceptions, on 26 ranches, deferred-rotation, rest-rotation, and short-duration grazing systems all increased net annual monetary returns over those prior to system implementation. This was true in both drought and nondrought years. Calving rates and calf market weights almost always increased after specialized grazing systems were established. Stocking rates were generally increased by about 4% after grazing systems were installed. Stocking rates declined 18% from nondrought to drought years, both with and without grazing systems. This study reflects the fact that management skills of the individual rancher have much to do with the success or failure of a specialized grazing system. Similar results were derived from a study conducted by Heitschmidt et al. (1990) in Texas. Specialized systems economically outperformed continuous grazing.

The effects of any given grazing system on the attainment of economic goals, is complex and difficult to assess. The complexity arises because there is essentially an infinite number of grazing systems and their effects on economic goals vary as a function of current numbers and configuration of pastures, labor constraints, managerial ability and personal preference (Conner, 1991). It is known that by using grazing management to better control where and when livestock graze, the manager can achieve modest ecological impacts by shortening the grazing period. At the same time he can favor animal production by improving distribution and increasing exposure to forage resources over the landscape, and by preventing exposure to heavily used areas with depleted forage. The degree of such control over timing of occupancy of any part of the ranch, and the potential for production benefits is a function of the number of paddocks at the manager's disposal for an individual rotation cycle (Teague et al., 2004).

Societal Considerations for Private Rangeland

The ecological aspects of a grazed ecosystem are functionally constant regardless of the socio-cultural aspects of the human population interacting with it. Thus, regardless of how sophisticated his society, manipulation of temporal and spatial distribution and kinds and numbers of grazing animals are the only means by which man to can manage grazing land to achieve his desired goals (Conner, 1991).

Perceived benefits of a particular ecosystem will vary from person to person or from time to time based on individual and social values (Maczko and Hidinger, 2008). In general the public's perception of the actual act of ranching is negative. The public recognizes pasture degradation when driving down the highway and concludes that the livestock in the pasture have contributed to the demise of the landscape (Knight et al., 2002). On the other hand, it is a nationally recognized, even romanticized national symbol. Knight (2002) also sites a Farm Bureau Federation survey finding 85% of citizens rate farmers and ranchers as contributing greatly to society.

Perceptions of individual managers are different than those of society at large. When examining stocking rate considerations, Rowan et al. (1994) identified ranchers' decisions for stocking rate adjustments as being influenced by rainfall or drought. Other factors with significant influences on stocking rate change were age, grazing rights (owned vs. leased), traditional stocking rate factors, traditional grazing program factors, and weed/brush information factors. Livestock performance was perceived as the goal.

Interactions between the ecological and social/economic systems can lead to both positive and negative consequences. Human use of rangelands may produce benefits such as food and fiber, recreation and a sense of well-being. Human use can also result in alterations of the ecosystem and its processes so that rangelands no longer provide the desired goods and services. Feedbacks between ecosystem goods and services and ecological and social/economic processes are usually complex and nonlinear (Maczko and Hidinger, 2008).

Suggestions for Economic Stability

The functional aspects of grazed ecosystems remain constant regardless of social and economic factors (Conner, 1991). It has been theorized that high stocking rates and overgrazing have occurred because land managers have chosen short term economic gains over long-term stability (Costa and Reham, 2005). This does not have to occur; lighter stocking rates may actually give higher financial returns. Several studies have shown that light stocking will benefit land managers with a higher financial return and will minimize financial risk compared to moderate or heavy stocking rates (Holechek, 1992). The improved financial returns are a result of enhanced environmental conditions like soil stability and watershed health. Improving environmental conditions increases forage yield in time on most rangelands (Ward, 1999).

Economics is the study of how humans, individually and collectively, use scarce resources to satisfy their wants and needs (Samuelson, 1964). Thus, sustainability demands positive economic returns. It is impossible to persuade the masses not to impede on the ability of tomorrows citizens to thrive, if they themselves cannot thrive. Butterfield et al. (2006) devote the first section of the book to planning for success. They note there is no simple step by step process and every situation is different due to numerous variations in climate, management, goals and economics.

Callicott (1991) points out that some economic activity could enhance ecosystems and then he quotes Leopold speaking about agriculture: "When land does well for its owner, and the owner does well by his land; when both end up better by reason of their partnership, we have conservation". Research, technology and education of land managers all have a role to play to help swing the pendulum the other way, in the direction of sustainable use.

Diversification

Diversification means to reduce economic risk by using a greater variety of investments. This is the same with ranch management. Having a greater number of income bearing enterprises on a ranch reduces the potential for failure based on weather or markets. Butterfield et al. (2006) states, "Diversity of enterprises is generally wise as a hedge against changing conditions in the market place." It then goes on to say biological diversity is important too, if one wishes to have a sustainable farming or ranching enterprise. As environmental concerns and the need for open space increases opportunities for increased ranch diversification abound. Urban residents are hungry for the experiences that rural residents take for granted. Selling the experience is one way to diversify.

Knight et al. (2002) explain other ways to diversify. They suggest that diversification may come thru development of enterprises that increase goods, services, or experiences produced or created. Finding niche markets that cater to high-end users is a way to diversify. Grass-fed beef, organic food production, and specialized textile production could be examples of this.

Diversification through combinations of livestock may also enhance a rancher's ability to avoid catastrophic losses because the probability of simultaneously suffering economic losses in any given year in two or more diverse enterprises is usually much less than the probability of experiencing losses in any given year for a single enterprise. This risk management strategy, known as investment diversification, has long been an accepted business practice (Conner, 1991).

Holistic Management Principles

There is *a* dichotomy that exists between those interested in preserving the ecosystem surrounding grazing lands. Scholars *(*Belsky, 1986; Briske et al., 2008) along with environmental activists (Raether, 2002) site articles that show that livestock have promoted invasive species of plants, that rotational grazing does not increase animal or plant productivity, or that absence of livestock does not lead to reduction of rangeland productivity. Others believe that the rangeland is best managed for diversity and ecological function under the watchful eye of the conscious agrarian (Hughes, 1983; Dagget, 1995).

One philosophy concerning rangeland management that began to draw interest in the late 1970's and early 1980's is "Holistic Resource Management" (HRM). This movement continues to have a strong following today. "The holistic decision-making process incorporates values-based goal setting, the appropriate use of tools, financial planning, land planning, biological planning, and careful monitoring of effects. All these aspects are managed as a whole unit. The benefits are higher quality of life, financial stability, consistent profitability, and the confidence of knowing that your decisions are improving the environment and the community you live in. It provides people with a means to make decisions that more accurately mirror the way nature functions (in wholes), and thereby ensure that our civilization is truly sustainable over time" (Sullivan, 2001).

This management style addresses the fact that everything is interconnected; altering one part of an ecosystem will necessarily alter something else, possibly unintentionally. Benefits of holistic resource management in ranching include increased likely-hood of continued ecological function, increased profitability and improved way of life. Holistic principles involve a great deal of time in planning. Ranch managers are using practices like high density, rapid rotation grazing and multiple species grazing. Fertilizers and herbicides are not generally used. Choosing grazing systems and management practices that mimic nature will reduce pollution, erosion, and consumption of nonrenewable resources (Hanselka, 2007).

In practice much planning is necessary to establish a predetermined goal for the land in question. The goal will always rest on four fundamental foundation blocks or ecological concepts. These are: 1) succession of plants, animals and soils together as one entity; 2) water cycle in the ecosystem; 3) mineral cycle in the ecosystem, and; 4) energy flow through the ecosystem (Savory, 1983). Ranching is a biological process, not an industrial process. The objective is to promote life and turn it into dollars (Davis, 1996).

Holistic management is a movement that strives to merge environmentalism with anthropocentric use. If this movement can be truly viewed as an effort to mimic the natural processes, such as those of animal migration with rotational grazing, the movement could actually make environmentalists into ranching advocates. The complexity of this system has resulted in various incorrect perceptions of how it behaves, both by managers themselves, and by those who make and enforce policy in the rangelands. "Developing an understanding of the system is the key to developing risk management strategies, in both economic and ecological spheres" (Pickup and Stafford-Smith, 1993).

HRM has been reported as a way to decrease societal tension between "cows, recreationists and rangers" in a National Forest Wilderness (Bradford, 1998). The Holistic Management movement and Rotational grazing do contribute to a better image of ranching as evidenced by *Forging a West that Works: An Invitation to the Radical Center* (Johnson, 2003). This publication is "dedicated to building bridges between ranchers, environmentalists, scientists, state and federal land managers and a concerned public".

Dagget and Dusard (1995) offer a solution to environmental conflict occurring in the West. Government officials, environmentalists and ranchers coming together to develop range management plans may be able to find a way to all get what they need individually. Careful livestock rotation has improved the health of riparian areas, rangeland and increased wildlife numbers. Successful ranches are a vital component of the west if open space is to remain a part of the landscape. These ranches compliment the government's land holdings. When it is all put together we preserve a large portion of the country where we can allow the land to function as it once did. This allows future generations the opportunity to experience a truly unique, American treasure.

The problem of rangeland mismanagement must be attacked through improved education about long-term effects of overgrazing. The land manager needs to understand that environmental and the economic ramifications of pushing rangeland past its recovery threshold. The primary concern for the present should be not only the development of responsible grazing practices, but also the education of ranchers to ensure that such practices are used more often, to prevent future problems with overgrazing. (Ward, 1999; Mowry, 2007). It is possible that many managers have no understanding of the ecological indicators: soil stability, hydrological function, and integrity of biotic community. Instead their sole focus is on the condition of the livestock.

Environmental restoration is possible through livestock manipulation. Dagget (1995) and Sayre (2001, 2002 and 2005) explain the process in detail. However, ecological processes do not necessarily return if livestock grazing is curtailed or eliminated (Butterfield et al., 2006).

Focusing on good land management, as opposed to strictly livestock production allows a landowner to adjust the presence or absence of livestock as well as a grazing time and intensity level that is beneficial for plant health and diversity (Mowry, 2007). Elimination of grazing does not provide an acceptable alternative because it does not maintain ecological balance or function. When properly utilized, grazing can be a useful tool to promote range health. Proper grazing practices will help maintain vegetation that is conducive to soil retention and even will even be beneficial to wildlife habitat. "When the livestock management system is superimposed on the landscape, it can exacerbate or reduce the effects of variability in the natural system" (Pickup and Stafford-Smith, 1993).

Sustainable Range Management

Ecological systems and processes provide the biological interactions underlying ecosystem health and viability. Socio-economic infrastructures and processes serve as the context in which rangeland use and management occurs and rangeland health improves or deteriorates. These systems and processes interact across time and space. Integration of ecological and socio-economic processes within a conceptual framework provides a holistic means for "seeing through the complexity to the underlying structures generating change" (Senge, 1990).

A recent analysis of the United States' natural resource trends by Cordell and Overdevest (2001) reports that an overwhelming majority of survey respondents indicate they care deeply about the environment, global ecosystems, and a sustaining future for natural lands. This survey reflects and increasing national and international interest in public concern over irreversible environmental degradation and depletion of finite natural resource reserves.

Sydorovych and Wossink (2008) identified sustainability for agricultural systems in terms of economics, internal social, external social and ecological. As did Calker et al. (2005), when identifying and ranking dairy farm sustainability. A brief overview of these three sustainability issues for U.S. rangelands follows:

Beginning with social concerns related to rangeland in the U.S., Mazcko and Hidinger. (2008) point out that we have moved from a primitive society prior to the year, 1700, to a much more complex society by 1970. Originally, land was synonymous with life. It provided the basics for life, food from plants and animals, shelter, and water. Now, we have evolved as a society to a point where the rangeland is viewed as providing

1. Value of open space, where livestock are to be used as an ecosystem management tool
2. Water for functioning riparian systems, protecting endangered species
3. Private lands as natural capital society desires sustainable management of rangelands

Economically, it is noted that tangible and intangible products are currently derived from rangeland, providing a diverse array of economic and social benefits. Commodities, such as forage for livestock, wildlife habitat, water, minerals, energy, recreational opportunities, some wood products, and plant and animal genes, are important economic goods. Rangelands also produce intangible products such as natural beauty and wilderness that satisfy important societal values and that can be as economically important as more tangible commodities (Buckhouse et al., 1994).

Across the globe, there is an ongoing need for production increases of tangible products. Opening comments at the World Food Prize 2009 Norman Borlaug Dialogue in Des Moines, Iowa, indicated the world's farmers must double their production of food between now and 2050 if the world's population is to avoid widespread famine. (Law, 2009). With this realization, the concerns for food security, optimum production, technological innovation and preservation of environmental functions increase simultaneously. Therefore, ecologists are often investigating agricultural systems. In fact, over 20% of recent papers in the *Journal of Applied Ecology* represent a pre-eminent area of agriculture such as: the effects of pesticides, fertilization, drainage, crop choices and habitat modifications on farmland organisms and agro-ecosystems (Ormerod et al., 2003).

Finally, rangeland is of value because it provides important ecological function. A healthy rangeland ecosystem supports a diverse mixture of plant and animal communities. These communities promote three key cycles:

- Water cycle—the capture, storage, and redistribution of precipitation;
- Energy flow—conversion of sunlight to plant and animal matter;
- Nutrient cycles—the cycle of nutrients such as nitrogen and phosphorus through the physical and biotic components of the environment. (USGS, 2002)

Ecologists recognize the need for productive, yet sustainable system. Responsible natural resource management demands that mankind use resources in a manner that does impede on the ability of future generations to thrive. Looking for sustainable solutions should involve finding a cure for the cause of a problem, not reacting to a symptom (White, 2003).

Aldo Leopold (1949) was one of the first to challenge us to live in a manner that did not spoil the land. Since that time, many have followed his challenge and have generally accepted the principle that sustainable agriculture seeks to sustain economic viability, environmental stewardship, and social responsibility (FAO, 1991; Heitschmidt et al., 2004; Maczko et al., 2004). Therefore, landowner decisions concerning a sustainable agriculture should then enhance the environment and the farmer's economic situation and benefit the regional society (Sullivan, 2001). In agreement with this principle Larry Butler (2002) wrote, "A workable economic solution must be a sound ecological solution and an acceptable cultural solution. Any solution that fails this test will be short lived."

Sustainable agriculture is linked to one's value system (Clark and Wiese, 1993) and thus is a matter of much debate, (MacRae et al., 1993). Ecologic, economic, and social interactions are intertwined and drive rangeland management decisions. Long term ecological sustainability is necessary for long-term economic viability and economic and social sustainability are tied to social perceptions (Heidschmidt et al., 2004).

The Sustainable Rangeland Roundtable (SRR) acknowledges the fact that the environmental, social, and economic attributes of rangeland are all connected by goods and services provided by normal ecological function. Sustainability of rangelands implies availability of a full suite of goods and services for future generations, which requires that we ensure the proper functioning of core ecosystem processes. The linkage of management actions and policy decisions to effects on ecological processes and functions is of critical importance (West and Herrick, 2003).

According to Bartlett et al. (2003) the SRR participants concluded that the sustainability puzzle has 64 pieces, or indicators, that can be assembled to describe progress toward sustainable rangeland management. These indicators are categorized under five overarching criteria:

1. Conservation and maintenance of soil and water resources on rangelands: Human civilization declines over the past 7000 years can be contributed to soil erosion (Lowdermilk, 1953). This is because soils provide a medium for water capture, retention, and release (Whisenant, 1999). Soil and water also support primary production processes

such as energy capture and flow (Committee on Rangeland Classification, 1994). Thus, soil and water indicators provide valuable information on rangeland sustainability status and associated human communities.

2. Conservation and maintenance of plant and animal resources on range-lands: Assessment and monitoring methods and protocols are needed to describe structure and functional dynamics of plant and animal communities on U.S. range-lands.

3. Maintenance of productive capacity on rangelands: Sustainable Rangelands Roundtable participants defined productive capacity to include forage-based products, such as livestock, as well as non-forage goods, such as wildlife habitat, open space, medicinal plants, and wood products. It is important to look at maintenance of rangeland productivity over time and within local and eco-region scales.

4. Maintenance and enhancement of multiple economic and social benefits to current and future generations: Social systems are the least studied component of rangeland science and management (Vavra, 1995), and few range-specific measures of social and economic attributes exist (Tanaka et al., 2002). Bartlet et al. (2003) explains that socioeconomic indicators illustrate how changes in ecological, legal, and political systems are manifested in economic systems. They say, “Three groupings of indicators offer a more complete view of rangelands and rangeland use within the larger social and economic context: ‘National Economic Benefits’ indicators define the types of products derived from rangelands; ‘Community Well-Being and Capacity’ indicators measure community health and welfare in range-land-dominated areas; and, "Community Level Explanatory Indicators”.

5. Legal, institutional, and economic frameworks for rangeland conservation and management: Issues of equity, economic efficacy, cultural traditions, legal rights and obligations, and advancing management theories and skills greatly influence long term rangeland sustainability. These issues are influenced by U.S. laws, regulations, guidelines, and policy framework. Local-level data is important for regional and national assessments, and require collection and integration of county, state or regional, and national information.

Summary of Literature Review

Since we all depend directly on the landscape for our very existence (food, clothes, water, etc.), we benefit greatly from gaining a complete understanding of how the landscape functions (Sullivan, 2001). We are continuously modifying our environment because of dependence upon it. Therefore, ecological damage is continually levied on it. Man, with a burgeoning population and an exorbitant appetite for consumable products, is necessarily charged with the task of modifying his behavior to protect and preserve the ecosystems of the earth.

Traditional grazing methods have been based on a paradigm that is static, assumes equilibrium conditions, and does not consider scaling issues, neither in time nor in space. Operant conditioning of foraging behavior, conditioned aversions, plant spatial pattern, pasture size and shape, timing and duration of grazing periods, and number of animals are precision tools to manage grazing systems (Laca, 2009). Grazing management with careful manipulation of these principles may soften ecological impacts caused by livestock.

Still, grazing certainly should not be practiced everywhere, as there are conflicts between predators and domestic species, and problems with land prone to erosion and land fragmentation. As discussed earlier, holistic resource management of grazingland practiced with ecological function in mind can increase species biodiversity and environmental preservation. The land and the flora can help filter nutrients and sediment from run-off water, aid in the peculation of water to the aquifers, and provide habitat for a vast assortment of wild fauna. Properly managed rangeland can provide these worthwhile functions while it continues to provide a productive forage source for livestock which provides food for a growing global population.

Certainly, one can see civilization's maturity as being contingent on meeting the needs of earth's population while preserving its systems. The focus on agriculture coexisting with nature puts man as steward of the land. This makes us "plain members or fellow citizens of the community of life, permitting us to do our increasingly sophisticated thing as a species, while respecting the opportunity of all other species to do theirs" (Nash, 2001).

CHAPTER III

MATERIALS AND METHODS

This chapter documents the process by which the research was conducted. First, the chapter identifies the precise region of which the target population resides. The chapter then discusses specific study design issues, including the process for development of the questionnaire, identification of the target population and delivery of the research instrument. Next the processes of data collection and coding are summarized. Finally, statistical procedures which were utilized are identified. This chapter describes the process, techniques, significance testing and in some cases the theory behind sophisticated data search procedures in an effort to discover patterns and correlations affecting sustainability of grassland ecosystems.

Study Area

A six-county area in north central Texas was the focus of this study. The six counties included Clay, Montague, Cooke, Jack, Wise, and Parker Counties. These counties are characterized as belonging to the West Cross Timbers Subregion (Texas Parks and Wildlife , 2010) (Figure 3-1).

This subregion is a concentrated area of America's rangelands which constitute approximately 770 million acres of the U.S. land base. Lands of this nature provide commodity, amenity, and spiritual values that are vital to the well-being of counties, regions, and the Nation (Maczko, et al., 2004). It is classified as part of the tall grass prairie, which is consistent with many of the more productive rangeland systems in the United States. The counties in the study are characterized by climate with moderate rainfall of approximately 30 inches of rainfall per year (Texas Historical Commission, 2010).

Figure 3-1. Location of Study Area, in relation to Texas and the West Cross Timbers.

The Western Cross Plains sub-region has a complex geologic history, resulting in a variety of soil types, terrain features, and vegetative plant communities. The terrain in most of this sub-region is hilly, with sandstone and limestone escarpments, steep slopes, and irregular surface features. Exposed sandstone rocks and boulders dominate landscape features in many areas. Sandy loam soils are productive for agricultural crops such as peanuts, small grains, fruit trees, sorghum, pecans, and truck crops. In other areas, limestone surface formations and shallow clay soils support grasslands and vegetative plant communities adapted to higher alkalinity.

Extensive open grasslands and brushy rangelands occur in the 6 county area. In the western counties, where the average size of land tracts increases, cattle ranching is the predominant land use. In this area during the time frame from 2007 thru 2010 cash receipts for livestock have totaled more than $191.7 million per year and have outperformed all other agricultural enterprises in terms of gross receipts by more than 10:1. (Texas AgriLife Extension Service, 2010).

Much of the sub-region contains habitat that supports populations of white-tailed deer and other wildlife species. Leasing land for deer hunting is an important economic enterprise of the sub-region. Fragmentation of wildlife habitat is also rapidly increasing in the eastern counties of the West Cross Timbers where larger land holdings are being subdivided and sold as small home building site, farms and ranchettes.

The overall profile for selected social characteristics helps to identify the population of the target counties (Table 3-1).

Table 3-1.

Select Social Characteristics Data for 6 County Study Region

County	High School	Some College	Bachelor's	Grad School	Population	Population Change since 2000	Median Household Income
Cooke	31.5%	32.0%	10.4%	5.3%	38,650	6.3%	$49,705
Montague	35.4%	26.2%	8.3%	3.0%	19,568	2.4%	$41,652
Clay	39.6%	26.9%	11.1%	2.8%	10,893	-1.0%	$48,445
Jack	36.6%	26.4%	9.1%	3.8%	8,497	-3.0%	$43,173
Wise	34.8%	28.3%	9.2%	3.8%	59,415	21.8%	$56,290
Parker	30.4%	31.5%	12.5%	6.1%	114,919	29.9%	$61,151

Data from U.S. Census Bureau, 2009 estimates

Study Design

The development of the study occurred over the course of several years. Extensive literature review, personal experience and interaction with people in the region and in the livestock industry all played a role in development of the project.

Questionnaire Development

Pilot Study

Initially, a preliminary study was conducted in the spring of 2009, designed to help develop the livestock manager's survey. This questionnaire was developed based on information reported in current peer-reviewed grazing management articles and range management text books.

The instrument for this pilot study was focused on land managers in Cooke and Montague Counties in north Texas, but it was not an attempt to get an all-inclusive list of range managers in the study area. Instead, this preliminary study was given to range managers that have a relationship with the researcher or with Texas AgriLife Extension in Cooke County. Specifically, members of the Cooke County Farm Bureau Board of Directors (17 total), the Cooke County Beef Cattle Improvement Association Board of Directors (10 total), and select persons associated with Cooke and Montague County Farm Service Agencies (20 total). This resulted in polling of 47 individuals. The response rate was 45%, with 21 surveys being returned.

Data were collected in person and through the mail. Surveys were hand delivered. No formal scientific method or procedure was used for contacting possible respondents to improve response rate. Instead the response rate was dependent on affiliation of respondents with the researcher. It is noteworthy that this collection method could skew the data collected. Once again, a comprehensive scientific study was not the goal of the pilot study. The study was implemented to improve the quality of the final survey instrument and to formalize some of the analytic procedures that would ultimately be used. Study population was not random, nothing more than procedural "practice" and research refinement could be obtain from the data collected.

Focus Group

A Focus group was conducted during February of 2010. The focus group was made up of key stakeholders from the north Texas cross timbers area. Identification of focus group members occurred with the help of the Natural Resource Conservation Service's (NRCS) management and the research team. Criteria for inclusion was management of a ranching enterprise, which NRCS management or research team members perceive as superior for ecosystem, economic or social outcomes. These perceived superior outcomes may have been identified by received awards garnered by ranchers, or by physical evidence. Once identified, selected focus group members were invited to participate by telephone, and then formally invited by mailed invitation. It included 1 rangeland researcher, 2 rangeland educators, and 3 ranchers. This focus group was conducted with the intent to more fully understand predominant whole-ranch grazing management perceptions pertaining to economic, social, and ecological outcomes. As suggested by Briske et al. (2008), this circumstantial evidence derived from successful grazing managers experiences may be compared with experimental research to gain valuable insight and develop a more robust approach to understanding and implementing successful grazing management. Qualitative data collected from our focus group was documented and used to develop questionnaires necessary for thorough assessment of whole-ranch management.

A summary of the focus group discussion was compiled and the information was used along with the information gathered in the pilot survey to compile a second pilot survey. This survey was sent to focus group participants. They were asked to evaluate the instrument. The only suggestions that were received from their evaluation were in regards to typos and question wording, rather than the substance or intent of the questions.

Target Population

Initially, the group to be targeted was native range livestock producers from Cooke, Montague, Clay, Wise, Jack, and Parker counties in TX, who received benefits under the 2005-2007 Livestock Disaster Program. This represented the most comprehensive, known listing of cow/calf producers in the given area.

The request for the list was sent to Juan Garcia, acting Texas State Executive Director for the USDA Farm Service Agency. The request was processed under the Freedom of Information Act on Feb 9, 2009. At that time the request was determined to fall within the jurisdiction of the Kansas City Admnistrative Services Branch of FSA and was reffered to them. The list was received in spring of 2009. Because USDA limits compensation under government programs to individuals with gross earnings under $250,000, the survey population may have omitted managers with more available resources or those who were qualified but chose not to participate in the government's disaster program. Therefore, it was decided to utilize information from the tax appraisal district for each of the 6 counties identified earlier.

The final decision was made that the population to be evaluated would be defined as all landowners in the Cooke, Jack, Montague, Wise, Parker, and Clay county areas with 500 acres of native grass land with agricultural use property tax evaluations. The designation of 500 acres was set because the objective of the research is to reconcile experimental studies and "ranch-scale" evidence. This criterion requires limiting survey population to include only those with "ranch-scale" experience rather than "hobby ranchers."

The list of the individuals, in the target population, was obtained by request from the county appraisal districts of each respective county. Original lists included much duplication of families or ranches due to ownership of multiple parcels of land with slight variations in listed name, such as the use of a complete middle name versus the use of middle initials. Also, there were instances of multiple names to the exact same address. and finally, some individuals owned land in 2 or more counties. The original list was therefore merged in an attempt to eliminate a potential respondent's likelihood of receiving multiple survey instruments and to more accurately reflect the number of individuals with separate ranch units. The final sample was comprised of 550 individual ranches which the tax appraisal district indicated were greater than 500 acres in size and as having an agricultural use evaluation of native grass.

This mail-based survey was conducted over a 5 month period, with initial contact being mailed on June 10, 2010 and the first survey following shortly after on June 14, 2010. The survey concluded with the last survey being returned by mid-November 2010. All 6 counties with individuals being polled had participants responding. The total number of respondents was 188 for a 34% response rate. Table 3-2 gives specific dates and response rates.

Table 3-2.

Response Rate Per Mail Contact

	Initial Survey	First Reminder	Second Survey	Second Reminder
Percent Response per Mail Contact (Respondents)	48%	11%	36%	5%
Cumulative Response (Total Population)	16%	20%	32%	34%
Date of Invitation	June 14, 2010	July 14, 2010	August 11, 2010	Sept 16, 2010
Total Number Responding	89	21	68	10

Research Instrument

A formal mail survey was initiated in June of 2010. The mail survey was administered using the Dillman (2000) multiple contact method. Its purpose was to identify grazing management strategies that are perceived by ranchers to best achieve whole-ranch business objectives and ecosystem enhancing practices for mid to tall-grass rangelands in the USA. Surveys addressed the same issues as identified in the previous pilot survey and focus group analysis: management philosophy; economic indicators; land health; management practices; quality of life and cultural experiences, and personal characteristics.

Finally, non-response bias was tested. This was accomplished by sending a second, but short non-response survey. Bias was determined by statistically significant differences in demographic make-up of the two groups.

Questionnaire Design

The questionnaire (Appendix A) was an 8 ½ x 11 inch booklet printed front and back on white paper. The instrument was 11 pages in length and had 5 sections. Page 1 was the cover; page 2 was survey instructions; pages 3-4 were the first section, Management Philosophy; page 4-5 contained section 2, Economic Considerations; page 6-7 had section 3, Native Rangeland Management; page 8-9 included section 4, Land Health. Section 5, Quality of Life, began on page 9 and concluded on page 10. Finally, section 6, Personal Characteristics began on page 11. The entire questionnaire consisted of 118 separate questions.

Questionnaire Implementation

Manager data were collected using a four-wave mailing (Dillman, 2000) multiple contact method. A tracking code was included on all mailings, to facilitate follow up mailings. One month after the initial mailing, a reminder post card was mailed to all potential respondents. Responses were tracked over time. Four weeks after the reminder post card was mailed another cover letter, questionnaire and business reply envelope was mailed to all non-respondents. One more reminder post card was sent to all non-respondents.

Description of Data

To gain adequate understanding of a respondent's operation and characteristics, many were included for evaluation. As such, the survey instrument included a total of 118 separate questions. These questions were later coded into 214 separate variables. The increase in the number of variables versus the number of questions was due to the need to analyze all possible answers associated with each question. For example, "check all that apply" could result in more than one potential answer.

Table 3-3 gives a breakdown of the questions and variables by section.

Table 3-3.

Sectional Summary of Variables from Questionnaire

Section	Questions	Variables
Section 1: Philosophy	24	37
Section 2: Economic Considerations	14	30
Section 3: Native Rangeland Management	25	43
Section 4: Land Health	25	25
Section 5: Quality of Life	13	33
Section 6: Personal Characteristics	17	46

Data Preparation

Handling and preparation of data were done in accordance with guidelines and recommendations set by Dillman (2000), Fields (2005), and Trochim (2006). To ensure accuracy during sampling, all surveys were coded with a unique letter and number sequence to allow for documentation of respondent's return of the survey, either with a completed questionnaire or with a refusal to reply.

Data were initially entered into a Microsoft Excel spreadsheet. Then, each of the 214 variables were entered into SPSS 18.0 and coded as numeric, given values, and identified as ordinal, scale, or nominal. Variable names were given to all variables, based on the position it occurred in the survey. The first number in the variable relates to the section in which it was located. The second number relates to the question number on the survey. Further numbers were assigned when individual questions required additional variable names, such as cases where the question asked "check all that apply", e.g. 3.3.1 or 6.14.5 etc.

Data Entry

Seven point Likert scale data was entered exactly as recorded by the respondent, with numeric, ordered rankings of 1 through 7: 1 = *strongly agreed*; 2 = *agree*; 3 = *somewhat agree*; 4 = *neutral*; 5 = *somewhat disagree*; 6 = *disagree*; and 7 = *strongly disagree*. Section 4 included a 4 point Likert scale. These data were entered as ordered data, 1 through 4: 1 = *increased*; 2 = *remained constant*; 3 = *decreased*; 4 = *unknown*. All other ordered data were entered with the first listed category = 1 and sequentially increasing until all additional categorical options were exhausted. These questions were found in Section 1, Question 5; Section 3, Native Rangeland Management, Questions 1, 5, 6, and 7; Section 5, Quality of Life, Question 2; and Section 6, Personal Characteristics, Questions 1, 5, 7, 8, and 17.

True/False data were coded as 1 = True, 2 = False

Other categorical questions were coded as yes/no dichotomous variables, with 0 = no and 1 = yes. These questions were found in Section 1, Questions 1, 2, 3, and 4; Section 2, Economic Considerations, Question 1 and 2; Section 3, Native Rangeland Management, Questions 3 and 4; Section 5, Quality of Life, Questions 1, 3, and 4 ; and Section 6, Personal Characteristics, Questions 10, 11, and 12.

Finally, continuous data were entered with actual values. These included section 3, Native Rangeland Management, Question 2; and Section 6, Personal Characteristics, Questions 2, 3, 4, 9, 13, 14, 15, and 16.

Missing values were coded as 99. Questions where the respondent marked "DK", indicating "Don't Know", were coded as 98. Data were analyzed initially with SPSS (SPSS, 2009).

Statistical Analysis

Statistical analyses were conducted using a combination of statistical software. SPSS 18.0 (SPSS, 2009) was used whenever possible. When procedures called for methods not supported by SPSS, statistical packages which were available in R-version 2.13.0 (R-2.13.0, 2011) software was utilized. An analysis of descriptive statistics including N, mean, sum, standard deviation, variance, range, minimum, maximum, standard error of the mean, kurtosis, kurtosis standard error, skewness, and skewness standard error was conducted using SPSS.

Missing Data

The complexity of the desired analysis and the small size of the data set, made it imperative to retain all cases available, therefore, missing data needed to be addressed. One common solution is omission of variables or cases in the study with many instance of missing data (Starkweather, 2011a).

There are numerous ways to deal with missing data. Wayman (2003) stated, “It is important to understand that once data are missing, it is impossible not to treat them –once data are missing, any subsequent procedure with that data set represents a response in some form to the missing data problem. As a result, there are many different methods of managing missing data”. Abrams (2007) suggested, “If there are missing values for several cases on different variables, omission of the variable or the case would lead to data being lost.” He then implied that some form of analysis would be recommended to impute missing values. Imputation of missing values can be done by several methods. According to Gelman and Hill (2006) the last value could be carried forward, information from related observations could be used, indicator variables for “missingness” of categorical or continuous predictors is an option, or imputation could be done based on logical rules. However, when more than just a “trivial fraction” of data contains missing information, it is preferred to use some form of random imputation.

Garson (2011e) recommends checking for data missing completely at random (MCAR) versus missing at random (MAR). He states most often data is (MAR). Additionally he states, “If data are MCAR, then the researcher may choose listwise or pairwise deletion of cases. If data are not MCAR, missing values should be imputed.”

MCAR can be confirmed by dividing respondents into those with and without missing data, then using t-tests of mean differences on income, age, gender, and other key variables to establish that the two groups do not differ significantly (Garson, 2011e). Therefore, an independent t-test was used to check for differences between groups of respondents with missing information and those without.

The random imputation approach was taken during this analysis. Variables and cases were subjected to analysis by the R package ‘seqKnn’ in version 2.13.0. This package estimates missing values sequentially from the gene, that has least missing rate in microarray data, using weighted mean of k nearest neighbors, where 1 row (case) is represented as one gene (Kim et al., 2004).

While much of the literature implies the use of ‘seqKNN’ with the use of missing data concerning gene expression (Hastie et al., 1999; Kim et al., 2004; Kim et al., 2009), the package ‘seqKNN’ uses Euclidean distance to impute missing data and is applicable for many situations. This method is quite simple in principle but is effective and often preferred over other methods Nearest neighbors are records that have similar completed data patterns; the average of the *k*-nearest neighbor’s completed data are used to impute the value for a variable that is missing its value (where *k* can be set by the analyst or R user) (Kim and Yi, 2008; Starkweather, 2010b). Hastie, et al. (1999) have shown choosing *k* ranging from 5 to 10 is adequate.

The advantage of the knn approach is that it missing data only depends on the observed data. This package assumes data are missing at random. This then allows the knn approach to take advantage of multivariate relationships in the completed data. The disadvantage of this approach is it does not include a component to model random variation; consequently uncertainty in the imputed value is underestimated (Starkweather 2011a).

Imputation of missing values was conducted using package ‘SeqKnn’ in R version 2.13.0 (Kim and Yi, 2009). Imputed values were used throughout all analyses during inferential statistical procedures. For the purposes of these analyses, 5 was chosen as *k*.

Rounding

Data imputed with the R package ‘SeqKnn’ was not necessarily a whole number. In order to have these values fit into the ordered and nominal data categories insuring consistency with other data, these values were rounded to the nearest whole number. This task was accomplished using the ‘round’ function which is available with the ‘base’ package of R version 2.13.0. (R-2.13.0, 2011).

Internal Consistency

Sections 2, 4, and 5 of the questionnaire were designed to gather information about ranch level indicators to assess the degree of sustainability associated with economic, ecological and social elements of rangeland management as indicated by literature (West and Herrick, 2003; Maczko et al., 2004; Heitschmidt et al., 2004). These sections were used for creation of three indices which implicate the degree of sustainability which can be assigned to each respondent's ranch concerning each of the three sustainability elements.

One of the stated objectives of this research is to assess the impact of grazing management philosophy, land management practices, and respondent's personal characteristics on grassland sustainability (which the survey attempts to capture in Sections 1, 3, and 6). There must be a way to measure the impact. Creating a metric from responses to Sections 2, 3, and 5 will allow for these critical comparisons. When creating the metric, which referred to as the sustainability indices," the extent to which questions within each section assessed the same characteristic needed to be measured to reduce the number of ambiguous variables.

Also, there is a need to demonstrate the testing instrument is reliable. Internal consistency is a gauge of the relationship between each item and each other item. It may help researchers interpret data and predict the limits of the relationship among variables (Howell et al., 2005).

Furthermore, Garson (2011a) states that indices are sets of items which are thought to measure a latent variable. Items in an index will normally be more intercorrelated with each other than with other items. Cronbach's alpha is a common test of whether items are sufficiently interrelated to justify their combination in an index (Starkweather, 2011b) and is a useful coefficient for assessing internal consistency (Cronbach, 1951; Bland and Altman, 1997). Likewise, when attempting to measure a construct with multiple indicator variables, as done here, it must be demonstrated that the items measure the same thing because lack of unidimensionality is a form of measurement error (Garson, 2011c). For this reasoning, internal consistency of variables was very important to the sustainability sections.

As a result, the first step in creating sustainability indices for inferential purposes was the identification of variables which maximized Cronbach's Alpha coefficient. This analysis was conducted using SPSS 18.0. This procedure was much the same as those preformed by Doll and Jackson (2009), in their effort to understand farmer attitudes.

Derived Scales

Scaling is the branch of measurement that measures what is originally an "unmeasurable" construct. Trochim (2006) gives examples of these constructs like authoritarianism and self esteem. In the context of this study the "unmeasurable" construct is sustainability.

Trochim, (2006) also acknowledges, "On some scales, you will have items that are reversed in meaning from the overall direction of the scale. These are called reversal items. You will need to reverse the response value for each of these items before summing for the total. That is, if the respondent gave a 1, you make it a 5; if they gave a 2 you make it a 4; 3 = 3; 4 = 2; and, 5 = 1." This is the case with some of the variables to be included in the sustainability indices. All variables were transformed so that scale scores would align consistently within each index.

A summation of the selected variables from section 2, "Economic Considerations" was identified as a good metric for sustainability of economic indicators. Scale scores were calculated by simply adding each respondents selection of 1 through 7 from Likert scale information; the lower the sum, the greater the sustainability.

The Likert scale for section 4 "Land Health" was a 4 point scale. Variables were measured on the scale as 1= *increase*; 2 = *constant*; 3 = *decrease*; and 4= *unknown*. Some of the variables would tend toward sustainability if they were increasing, some if they were decreasing. For example, an increase in brush does not align with sustainable rangeland indicators (West and Herrick, 2003), while an increase in wildlife would. Transformation of values for increasing and decreasing was applied to some variables in the index so all were consistent with respect to sustainability. Ultimately, 3 was a value indicating greater sustainability, 1 lesser; 4 (unknown categories were replaced using software available in the R environment, package 'seqKNN').

In section 5, "Quality of Life" all variables included in the sustainability index were 7 point Likert scale questions. Simple summation of respondent answers was used for creation of this Social Sustainability Index. All questions aligned so that the lower the score, the more sustainable the case.

Economic Considerations

Prior to maximizing for Cronbach's alpha coefficient, transformations to select variables were necessary. Preliminary analysis may reveal inconvenient coding schemes or coding errors, or data transformations may be required in order to expose the true relationship between variables (SPSS, 2009a).

Section 2, Economic Considerations, originally was composed of 14 questions and 30 variables. The last questions, 2.1 and 2.2 were questions asking the respondent to "check all that apply." These were originally coded into SPSS with each possible response being a single, dichotomous, yes/no variable, resulting in 18 total variables. When analyzing for Cronbach's alpha using SPSS 18.0, without transformation of these variables, the determinant of the covariance matrix was zero. Therefore, statistics based on its inverse matrix could not be computed. This causes questionable output in SPSS 18.

Transformation of the problem variables to a single categorical variable was accomplished by simply adding the number of selections with a "yes" per question, per respondent. The questions were, 2.1:"I measure economic success on the ranch by: (Check all that apply)" and 2.2: "My ranch uses diversification of enterprises to reduce risk or increase income. If yes, I diversify by: (Check all that apply)".

Question 2.1 became the number of economic measures used to detect economic success and 2.2 became the number of diversified enterprises used on the respondent's ranch. It was theorized that the greater the number of measures for economic success, or the greater the diversification, the more sustainable the operation may be. The end result was a reduction of 30 original variables to 14, one per question. These were evaluated for internal consistency.

SPSS version 18.0 was used to evaluate the Cronbach's alpha coefficient. The analysis was computed consecutively with reduction of variables as suggested by the item to correlation score, until Cronbach's Alpha Coefficient was maximized. Desired outcome to variables as unidimensional for confirmatory purposes was set at a critical value of alpha as 0.7($\alpha = .7$) (Nunnaly & Bernstein, 1994; Starkweather, 2011b; Garson, 2011c).

Land Health

Section 4, "Land Health", was comprised of 25 ordered questions which resulted in an equal number of 25 ordered variables. All variables were evaluated for internal consistency using SPSS version 18.0 and evaluating for the Cronbach's alpha coefficient greater than 0.7. SPSS version 18.0 was used to evaluate the Cronbach's alpha coefficient. The analysis was computed consecutively with reduction of variables as suggested by the item to correlation score.

Quality of Life

Finally, Section 5, “Quality of Life”, was evaluated for internal consistency. All thirty-three variables were analyzed . SPSS version 18.0 was used to evaluate the Cronbach’s alpha coefficient. The analysis was computed consecutively with reduction of variables as suggested by the item to correlation score, until Cronbach’s Alpha Coefficient was maximized.

Optimal Scaling

Nominal and ordinal variables, relative to interval variables, are less amenable to analysis. Garson (2011a) states that retaining categorical data when utilizing inferential statistical procedures could lead to the presence of empty cells and can undermine traditional regression. He also reports, the presence of empty factor cells in the model will undermine the validity of the ensuing goodness of fit tests and model validity will be uncertain. To deal with this problem, nominal and ordinal variables can be converted to interval variables through one of several techniques known as optimal scaling (Moss, 2008). Certain statistical software packages such have been developed to implement data conversion by optimal scaling (SPSS Inc, 2009b; de Leeuw and Mair, 2010).

The optimal scaling process turns qualitative variables into quantitative. How this occurs is dependent on the data set and the criterion for optimization. Various methods exist for creation of optimality. These include discrimination among objects, maximization of homogeneity or internal consistency among variables, making pairwise relationships as linear as possible, maximization of variance accounted for (in the analysis of interdependence), and transformations toward additivity, maximization of *r2*, canonical correlation, and the ratio of between to total dispersion; in the optimal scaling process an appropriate quantification level has to be chosen (Meulman, J., 1988)

Mair and de Leeuw (2010) describe a general framework for multivariate analysis with optimal scaling whereby, multivariate data are collected into a multivariable "aspect". This aspect of a multivariable is a function that is used to measure how well the multivariable satisfies some criterion. Two different families of aspects exist: non-correlational and correlational. It is quite possible that the two will give the same transformations. If the goal is to achieve bilinearization, then the non-correlational aspect, LINEALS, should be chosen. "A function of two variables is bilinear if it is linear with respect to each of its variables. The simplest example is *f(x, y) = x y"* (Weisstein, 2011).

Many parametric statistical routines, like regression assume that the effects of each variable on the target are linear; if the effects are non-linear, transformation of data are recommended (Field, 2005). Therefore, because binearization was desirable, the R package 'aspect' and the non-correlational aspect, LINEALS was chosen for use in optimal scaling of data obtained during the study.

When using the R package 'aspect', the LINEALS function makes transformations of the variables such that all bivariate regressions are exactly linear. This is a function combining elements of two vector spaces (consisting of an ordered collection of numbers) to yield an element of a third vector space that is linear in each of its arguments. In the case of LINEALS this is r_{jl} of the Pearson correlation matrix and the Pearson correlation ratio. A matrix of these quantifications is available in the R output. After optimization, asymptotic tests and estimates can still be used on the transformed data (de Leeuw and Mair, 2010)

To assess the relative success of the imputation, part of the output is characterized as "loss". Loss of information occurs when discretizing (grouping) variables and then performing optimal scaling (Mair and de Leeuw, 2010). They do not quantify loss, but simply state, "the lower, the better". They explain further by reporting that eventually, the value of the LINEALS loss function can be used as total discrepancy index or criteria for determining acceptability of cases. Smaller loss equates to more closely achieving bilinearizability a discrepancy index of 0 would be perfect. This is not realistic for real-life applications. In fact, de Leeuw et al. (1999) mention that we may be able to successfully approximate bilinearizability in ordinal data but it is very unlikely in purely nominal variables. Still, minimization using LINEALS, even with nominal data leads to a lower discrepancy compared to other optimal scaling techniques. Therefore, if the aim is to achieve bilinearization, LINEALS should be considered (Mair and de Leeuw, 2010).

Continuous variables were not optimally scaled. Instead these were removed from the data set prior to optimization. The discretized variables and the continuous variables were then recombined into a data set and used for further the analysis. Handling of the continuous data in this manner is similar to ordinal regression as carried out by SPSS (SPSS Inc, 2009b).

Principal Component Analysis

With 214 original variables, it was necessary to methodically select a subset of variables, based on which original variables have the highest correlations with the principal component factors within each section of the survey. The subsets retain only those variables with meaningful relationships to the structure of the survey (Garson, 2011b).

When attempting to measure a construct with multiple predictors, the items must measure the same thing or measurement error will be present. Also, measurement error would increase standard error in subsequent regression analysis (Garson, 2011c). Because of this, some form of variable reduction must occur. This can be accomplished with principal component analysis (PCA), which is a preferred method for data reduction, (StatSoft Inc., 2011).

Traditional PCA is a variable reduction technique which maximizes the amount of variance accounted for in the observed variables by identifying a smaller group of variables called components (Starkweather, 2010a).

Principle component analysis was used as a means of identifying a subset of variables based on which original variables have the highest correlation with the principal components, also known as component loadings (Garson, 2011b; StatSoft Inc., 2011). The analysis was run using SPSS 18.0. Data was loaded into SPSS after optimal scaling. Sections, 1, 3, and 6 were analyzed with PCA separately. An extra, fourth PCA was also conducted using variables that did not help to maximize Crobach's Alpha and were therefore not used in resulting sustainability indexes.

Selection of Components

According to Field (2005) a scree plot should be used to determine number of factors in instances where the number of variables is between 30 and 250, which is consistent with the data derived from the questionnaire. However, he also explains that the sample size needs to be greater than 200, which is not consistent with this study.

Another method beginning to gain popularity for determining the number of principal components is the use of "Parallel Engine Analysis". This analysis is based on parameters provided by the researcher. It calculates eigenvalues from randomly generated correlation matrices. These can be then compared with eigenvalues extracted from the researcher's dataset. The number of factors to retain will be the number of eigenvalues that are larger than the corresponding random eigenvalues (Horn, 1965). A parallel analysis engine to aid determining number of factors to retain is available online at: http://ires.ku.edu/~smishra/parallelengine.htm/. The engine utilizes a SAS-based code written by O'Connor (2000).

Scree plot analysis is extremely reliable, even compared to parallel engine analysis (Patil et al., 2007). A scree plot is a graphical method first proposed by Cattell (1966). The object is to plot the eigenvalues for each additional component and connect them with a line. As the amount of variance explained in each component decreases, the line will level off to the right of the plot. To the right of this point, presumably, you find only meaningless components. The problem is that this techinque is very subjective (Turner, 1988).

Still a third criterion is Kaiser's criterion, simply stated this is retaining all components with eigenvalues greater than 1 (Field, 2005). Therefore, an approach using more than one technique is preferred to a single approach for factor selection. This multiple approach, reduces subjectivity yet allows for greater discernment by the researcher (Patil et al., 2007).

This study followed those guidelines and determined the number of principle components to extract by a combined analysis using both Parallel Engine Analysis and Scree Plot Analysis and additionally, Kaiser's criterion. Determination of the number of components to be used was done initially, with no rotation procedure applied to the principle component analysis.

Rotation

The goal of rotating components is to a determine pattern of loadings identifying the variables of interest. After considering various rotation strategies, Varimax rotaion was selected. If fit best with the purpose of the study. The goal is to maximize the variance (variability) of the "new" variable (factor), while minimizing the variance around the new variable. This should obtain a pattern of loadings on each factor that is as diverse as possible, lending itself to easier interpretation (StatSoft, 2011; Field, 2005).

Communalities

Communality is the squared multiple correlation for the variable as dependent using the factors as predictors. Generally, they help to identify the measured variables for which the factor analysis is working best. Likewise, low communalities may indicate that a predictor is not working well and should be removed from the model. However, this is not always necessarily so. Communalities must be interpreted in relation to the interpretability of the factors/components. A communality of 0.75, which seems high, could actually be meaningless if the component is not interpretable. On the other hand, a low communality may be meaningful if it contributes to a well defined factor. Therefore, what is most important, more so than the actual value, is the extent to which it contributes to the interpretation of the factor (Garson, 2011b). Communalities are reported in this section of the results, so as to not lose sight of that fact, and to aid in interpretation of variables.

Component Identification

Once the number of components, to be accepted as relevant is determined, component loadings must be interpreted. Interpretation involves selecting variables which contribute to each component's identity. There is some subjectivity involved when interpreting component loadings. Various researches follow different rules of thumb. In confirmatory factor analysis, as opposed to PCA, loadings should be 0.7 or higher to confirm that independent variables identified a priori are represented by a particular factor. Reasoning is such that the 0.7 level corresponds to about half of the variance in the indicator being explained by the factor. With many data sets, the .7 standard is a high one and often data cannot meet this criterion. Often, especially for exploratory purposes (PCA), researchers will use a lower level such as .4 for the central factor and .25 for other factors (Raubenheimer, 2004). One example, Hair et al. (1998), call loadings above 0.6 "high" and those below 0.4 "low". Factor/component loadings must be interpreted in the light of theory, not by arbitrary cutoff levels (Garson, 2011b).

For the purpose of this study, loading equal to, or more extreme than + or - 0.6 are described as high; loadings (both positive and negative between 0.6 and 0.4 are considered moderate, and those less than + or – 0.4 are considered low.

Sampling Adequacy and Bartlett's Test

Recommended procedures for accepting that the PCA has yielded reliable factors are a check of Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity. Kaiser (1974) recommends accepting values greater than 0.5. If values are found to be lower, then rethinking which variables to include or collection more data may be a good idea (Field, 2005).

Bartlettt's Test of sphericity tests the null hypothesis that the original correlation matrix is an identity matrix. A significant result ($p < .05$) indicates the matrix is not an identity matrix, and thus factor analysis would be appropriate (Field, 2005).

Bayesian Model Averaging

Bayesian model averaging (BMA) is a robust statistical technique which was useful for selecting regression models (Raftery, 1995). It is the most appropriate model for comparison and model fit statistics (Schwarz, 1978; Moore 2008). The BMA package/library (Raftery et al., 2011) was used to select variables, as predictors for input into ordinary least squares regression. These variables originated from Sections 1, 3, 6, and also included the variables from Sections 2, 4, and 5 which did not become part of the sustainability indices. These potential sustainability predictors addressed respondents land management philosophy, native rangeland management practices, and personal characteristics.

Specifically, the "bicreg" function was used. This function accounts for the model uncertainty, which is inherent in the variable selection process. It does this by first selecting models that are likely to be the best, using “approximate posterior model probability.” This means finding the post regression probability that each variable is non-zero (Raftery et al., 2011). It then averages variables, over the best models in the model class (Raftery, 1995; Raftery et al., 2011).

This function is capable of selecting the best set of predictor variables for a linear prediction model by building a normal curve distribution of how frequently a predictor is coming up in a significant model. The model with the best fit is determined by the model with the largest posterior probability and the lowest Bayesian information criterion (BIC) (Starkweather, 2011d). When estimating model parameters, it is possible to “overfit”, or superficially improve the outcome, by continually adding additional parameters. This method of model selection protects against the possibility of “overfitting” by introducing a penalty for additional parameters as opposed to simply maximizing for the amount of variance explained (McQuarrie, 1998).

To determine predictors impact on the sustainability indexes created from sections 2, 4, and 5, impact was assessed from each set of predictors (variables) in section 1, 3, 6 and “other variables”. Whereas, the sustainability index from section 2 becomes the first dependent variable, all variables identified in prior PCA computations are then inputted into the “bicreg” function using the BMA package in R version 2.13.0. The same holds true for section 4, and then section 5. This necessarily means that 3 separate analyses must be run, one for each dependent variable: the sustainability indices. Output indicated which variables should be inserted into ordinary least squares regression. The variables which have been identified as returning the best model was accepted (Raftery, 1995).

Hierarchical Regression Analysis

Multiple regression analysis was employed to account for the variance in the derived sustainability indexes (sections 2, 4 and 5) based on predictors which were indicative of respondents land philosophy, land management, or personal characteristics (sections 1, 3, and 6). The goal is to gain insight concerning the amount of variance explained by the independent variables identified through BMA, which is the most appropriate model for comparison and model fit statistics (Schwarz, 1978).

In order to minimize predictors being selected purely by chance, hierarchical regression analysis, a specific form of ordinary least squares, multiple regression analysis, was chosen as a means of relating management philosophy, native rangeland management, and personal characteristics to the sustainability indexes of economic considerations, land health, and quality of life. Hierarchical regression predictors are entered into the analysis one block at a time, with the researcher, not the computer, determines the order of entry of the variables. F-tests are used to compute the significance of each added variable (or set of variables) to the explanation reflected in R-square. The order they are entered should be selected based on past work (Field, 2005). Known predictors should be entered first, also known as covariates; followed by new predictors, together or one at a time. Distinction between a covariate and a predictor is often simply a matter of semantics (Starkweather, 2011c). The reason for the use of hierarchical regression and the use of predictor entry in blocks is that this method isolates the effects caused by specific variables in terms of both the predictive model and the relative contribution of variables in each block. Essentially, variables that are conceptually linked to each other were entered together in a block. Those variables which literature identified as most important were entered first, while those which were more abstract concerning their role as a predictor, were entered later.

After the regression analysis, the relative predictive importance of the independent variables will be established by comparing beta weights. All predictor and dependent variables were interval due to the optimal scaling process that was employed earlier in the analysis. This analysis was conducted using SPSS 18.0.

Assumptions

Garson (2011c) explains that all statistical procedures have underlying assumptions. Sometimes violations of these assumptions can be tolerated without changing substantive research conclusions. In other cases, violation of assumptions is critical to meaningful research. Every effort was made to adhere to relevant assumptions in order to assure the ability to draw accurate conclusions.

- Error was checked for normal distribution, using histograms and (P-P) plots.
- Residual analysis was undertaken to check for lack of homoscedasticity and presence of outliers, ensuring stability across the accepted model.
- Multicollinearity was assessed to ensure that it is not present. Correlations were visually assessed; VIF and Tolerance test were employed.
- Robust techniques were employed to ensure that all data would fit with linearity assumption (see section on optimal scaling).
- Leaving variables out of the model when literature suggests they should be included is a serious deviation from data assumptions. When constructing the most parsimonious model, literature was has implicated independent variables of importance far beyond those in the model. The regression model is, in part, an attempt to discern which areas/variables are, in fact the most important for obtain sustainable rangeland production.

Cross Validation

Careful application of multiple regression methods requires that the regression weights be cross-validated on a different population (Stockburger, 2006). Field (2005) explains cross validation as a useful tool to identify if the model derived from the study can be used to predict the outcome in a different sample. Two methods can be used to do this: Shrinkage and Data Splitting.

Shrinkage

The manner in which regression weights are computed guarantee that they will provide an optimal fit with respect to the least square criterion for the existing set of data. Prediction using a different data set leads to regression weights that are no longer optimal. This loss in predictive power is referred to as shrinkage (Stockburger, 2006).

In SPSS adjusted R^2 indicates shrinkage when variance is applied to other populations, while R^2 explains the variance in Y accounted for from the sample in the study. SPSS uses Wherry's formula to derive at the adjusted R^2. A much better indication of cross validation is Steins's formula (Yin and Fan, 2001). Because of this fact, all adjusted R^2 were recalculated by hand then inserted in place of Wherry's formula for the most parsimonious block of the hierarchical regression analysis. Whereas, Stein's formula is as follows, where n = number of cases, and k is the number of predictors:

adjusted $R^2 = 1 – [(n – 1/n – k – 1) (n - 2/n – k – 2) (n + 1/n)] (1 – \mathrm{R}^2)$

Data Splitting

Data splitting is a good technique, but Field (2005) explains that researchers rarely have enough cases t make splitting the data set practical. The procedure would be simply splitting the cases in the study, computing a regression equation on two halves and comparing the results.

An alternative cross-validation method to simple data splitting is K-fold cross-validation. With this method k – folds are randomly removed from the data set. (Starkweather, 2011e) The original data set is randomly divided into K subsamples. A single subsample is retained as the validation data for testing the model, and the remaining $K - 1$ subsamples are used as training data. The number of folds selected (K) determine the number of times the cross-validation process is repeaed (Moore, 2008).

Software provided by R version 12.13.0. package 'DAAG' and the function "CVlm" perform K-fold cross-validation analysis (Maindonald, 2011). This function gives internal and cross-validation measures of predictive accuracy for multiple linear regressions.   Therefore, it was used in all cross-validation statistical procedures in this study.

Non-Response Bias Survey

Using SPSS 18.0, non-respondents returning the non-response bias questionnaire were evaluated for differences in demographics, grazing patterns, and source used to obtain management information (Appendix B).

CHAPTER IV

RESULTS

Chapter 4 provides the results of the study. It is divided into 3 parts. First, results concerning the response rate and related agricultural statistics concerning the amount of land from the six counties polled were discussed. Next and overview of the descriptive statistics is given for sections 1, 2, 3, 4, and 5. A question by question description of section 6, “Personal Characteristics” is given. Finally, results from each of nine statistical procedures are given. Seven of these procedures lead up to hierarchical regression analysis. After the regression, results from the non-response bias survey are given.

Study Implementation

Of the 188 respondents, 124 indicated that they managed livestock on native rangeland and went on to answer most questions in the survey. The remaining 64 respondent indicated that they either did not own native rangeland, that they did not manage livestock on their land, or that they simply lacked the knowledge of the land to answer the survey. Essentially, when discounting the 64 unintentionally sampled respondents who indicated they were unable to complete the questionnaire because they did not fit the target population, the total population would have been 486. With 124 responding from this population, response rate would be 25.5%. While this response rate is not ideal, it is in line with other studies seeking the opinion of agricultural producers. Greiner et al. (2008) conducted a survey of farmer’s motivations, polling 685 producers. They were able to gather 114 responses, or 16.6%. Similarly, Sydoravych and Wossink (2008) polled a mixed group of agricultural producers, scientists and agriculture industry employees; of that group they were only able to get a response rate of 25%. They “believed that response rate was adequate, given no reward was offered”. It is possible that agriculture industry professionals, especially those in production agriculture are extremely adverse to disclosure of personal information and perceptions.

Respondents with acreage completely within the 6 county area were in control of a total of 327,017 acres, ranging from the smallest acreage of around 80 acres, to the largest ranch comprising 18,000 acres. The area represented by respondents is approximately 13.65 % of the acreage in pasture and rangeland in the 6 counties. When including respondents with acreage outside of the 6 county area, the total number of acres being represented were 358,717. USDA only reports the single category "pasture and rangeland" and there is no single category recognized as only "rangeland". The term "pasture" would include all types of improved and introduced grasses such as bermudagrass (*Cynodon dactylon)*, kleingrass (*Panicum coloratum)*, and improved bluestems (*Bothriochloa ischaemum* and *Bothriochloa bladhii*) (Table 4-1). The first question in the survey asks perspective respondents, "Do you own and/or manage native rangeland that is utilized for livestock grazing?" If the answer was "No", the potential respondent was asked to "Please stop here and return questionnaire in the attached postage-paid envelope." No was selected by 64 of the respondents as indicated earlier.

Descriptive Statistics

Because of its complex, muti-dimensional nature, agricultural sustainability is most often assessed using numerous indicators, (Sydorovych and Wossink, 2008). This fact is reflected by the large number of questions and variables included in the survey. Because of this each variable will not be discussed by itself. Appendix C records the descriptive statistics for each variable. A brief discussion concerning general characteristics of each section will follow.

Table 4-1.

Selected Agricultural Statistics by County

County/ Number of Respondents per County	Actual acreage in pasture range	Acreage in County	Acreage Reported as "Rangeland Managed" by County	Value of livestock, poultry, and their products ($1,000)
Cooke/25	324,873	579,200	35,062	38,881
Montague/38	375,980	600,320	72,336	28,117
Clay/19	55,5750	714,240	126,420	35,239
Jack/13	452,963	588,800	38,144	14,761
Wise/8	316,474	579,200	19,100	25,739
Parker/11	369,649	582,400	21,955	34,818
Other*/5	-----------	-----------	31,700	-----------
Total/119	**2,395,692**		**358,717**	

*Other counties reported as primary county of land managed: Combinations of the 6; Palo Pinto; Presidio; Wichita; Archer; and Denton

Variables of Interest by Section

In section 1, titled, "Management Philosophy", the respondents tended to respond to questions in such a way that indicates, in general, they were in agreement with management practices that related philosophically to sustainable practices. The amount of agreement did vary from question to question. Of the questions with a 7 point Likert scale the question with the least amount of agreement among the participants was "1.0.11". This question stated, "Proper grazing management on rangelands should include periodic prescribed fires" (M = 3.17, SD = 1.619). The question most agreed with was "1.0.13"; "Rangelands provide environmental services such as water capture, erosion control, soil fertility, soil structure and wildlife habitat" (M = 1.54, SD = 0.693).

Questions ranged in degree of skewness and kurtosis. Range of skewness was for this section was from -3.854 to 3.085. Kurtosis ranged from -2.034 to 13.068. Expected skewness for normal distributions is near zero, while the using the origin for computing kurtosis for a standard normal distribution is 3 (Trochim, 2006). SPSS adjusts this by using Fisher's kurtosis, which assumes that 3 has been subtracted to center on zero. Since SPSS was used for this portion of the analysis, normality was assessed as skewness being within the +2 to -2 range and kurtosis within +3 to – 3 range (Garson, 2011e). The range of skewness and kurtosis indicate that grouping of responses varied widely among questions. Indications are that data were not normally distributed. Some questions will have particularly high distributions of responses both to the left and the right of the normal distribution curve. High kurtosis values indicate "peakedness", or a high number of responses near the mean for the question; low values indicate thick tails, or responses spread evenly from one extreme to the other (Trochim, 2006).

Section 2, "Economic Considerations", questions were responded to with slightly more disagreement as judged by the average score of Likert scale. The question least agreed with was question "2.0.4"; "Decision to adopt my grazing system was affected because of tax measures or depreciation considerations" (M = 4.84, SD = 1.586). The question with the most agreement was "2.0.3"; "Deterioration of range conditions will cause long-term economic difficulties" (M = 1.74, SD 0.988). Once again skewness and kurtosis were noteworthy ranging from -1.442 to 4.162 and -2.020 to 21.640 respectively. Indications are that data are not normally distributed. Data are slightly more symmetrical in their degree of skewness, but range in response varied from a very tight cluster around a mean answer, to even distribution across the response range.

Section 3, "Native Rangeland Management", had questions pertaining to land management. It contained a question that was considered to be one of the key indicators for this study, based on the literature review. This question, "3.1", ask respondents to characterize their grazing system where, pasture was synonymous with paddock, as continuous, rotation with 4 or fewer paddocks, rotation with 4 to 8 paddocks, rotation with more than 8 paddocks or other (M = 2.28, SD = 1.124). The results indicate that 69% of respondents implemented some form of rotational grazing (4- 2).

In section 3 extremes for skewness and kurtosis were -1.511 to 6.053 and -2.015 to 25.911 respectively, thereby indicating non-normal data.

Table 4-3.

Frequency f Response Question "3.1" Characteristics of Grazing System

Grazing System	Frequency	Percent	Valid Percent	Cumulative Percent
Continuous	36	29.3	31.0	31.0
Rotation – 4 or fewer paddocks	32	26.0	27.6	58.6
Rotation – 4-8 paddocks	29	23.6	25.0	83.6
Rotation – 8 or more paddocks	17	13.8	14.7	98.3
Other	2	1.6	1.7	100.0
Total	116	94.3	100.0	
Missing	7	5.7		
Total	123	100.0		

In section 4, "Land Health", the question with the highest level of agreement was "4.8.15", "Wild Hogs" (M = 1.34, SD = 0.791). This indicated that wild hogs are certainly on the increase, with 76.4% of respondents reporting as such. The question was question with the lowest level of agreement was "4.0.4", "Bare ground can be seen in some areas of my grazinglands" (M = 4.55, SD = 0.791) standard deviation was 1.867. Kurtosis and skewness varied widely. Data were not considered normally distributed.

In section 5, "Quality of Life", kurtosis associated with question "5.3.1" (M = 0.96, SD = 0.624), was noticeable due to its high value: 74.205. The question asked respondents to check this box if they themselves were involved in the decision making of the ranch. This high number is not unexpected, given the questionnaire requested, “We are asking that this questionnaire be completed by the person who is currently most involved in making decisions about land management on the property.” It is an indicator that the correct person was filling in the survey. Overall mean scores for the 7 point Likert scale indicated a more neutral position than with the previous sections as indicated by the mean scores being nearer to “4” and the skewness (at least for the likert scale questions) indicating a more normal distribution. Implications are that respondents are more neutral in their beliefs that their rangeland affects their quality of life in either a positive or a negative way.

Respondent Characteristics

Section 6 was “Personal Characteristics”. This is the section where demographic information was compiled. A closer look at the descriptive statistics revealed certain characteristics of our respondents (Table 4-4). These data help to describe the basic demographic information about the respondents, such as: “Acres Owned”; “Years Land Has Been in Family; “Years Experience Ranching”; “Year Born/Age”; “Hours/year Self Study”; and “Percent Income from Ranching”. They also describe the ranch the respondent manages, including enterprises used for income: “Cow/Calf”; “Stockers”; “Sheep”; “Goats”; “Hunting”; “Exotic Animals”; “Hay/Crop”; “Recreation”; “Mineral Production”; “Other” and “No Income from Land” . Statistics reveal “Investment in Property Over Past 5 Years”; “Planning to Sell Property” and “Male/Female”. Also table 4-3 describes the type of terrain/plant cover associated with their ranch: “Short Grass”; “Mid Grass”; “Tall Grass”; “Grass/Tree Mix”; “Dense Brush”; “Water”; and “Other”.

Other personal characteristics were best understood through visualization. Figures 4-1 through 4-7 aid in understanding of non-numeric characteristics, including: Figure 4-1 “Study area response by county”; Figure 4-2, “Respondent’s Association with the Land”; Figure 4- 3, “Respondent Level of Education”; Figure 4-4, “Respondents’ Source of Continuing Education”; Figure 4-5, “ Years Living on Ranch” (if living on ranch); Figure 4-6, “Home for Respondents if Not on Ranch”; Figure 4-7, “Respondent Income by Category”.

Table 4-3.

Personal Characteristics of Respondents

Demographic Type	Average	Standard Deviation
Acres Owned	3072.56	3621.415
Years Land Has Been in Family	53.74	39.931
Years Experience Ranching	33.19	16.233
Year Born (Age)	1947.9 (62)	11.683
Hours/Year of Self Study (Ranching)	23.78	46.638
Percent Income from Rangeland	40.77	35.944
Percent Rangeland Income Derived from		
Cow/Calf	52.74%	41.470
Stockers	12.27%	22.018
Sheep	.03%	.279
Goats	.17%	1.129
Hunting	5.43%	13.467
Exotic Animals	1.65%	10.070
Hay/Crop	3.28%	8.752
Recreation	1.26%	6.319
Mineral Production	21.09%	31.216
Other	2.10%	7.719
No Income from Land	0.00%	0.00
Investment in Property Over Past 5 Years	$102,312.31	142,746.92
Percent of Property with Following Land Cover:		
Short Grass	17.51%	16.271
Mid Grass	28.67%	90.60
Tall Grass	24.44%	17.76
Grass/Tree Mix	11.81%	14.52
Dense Brush	18.15%	15.56
Water	3.76%	3.34
Other	4.54%	13.72
Planning to sell property:	8 Yes / 111 No	
N = 124:	103 Male / 16 Female	

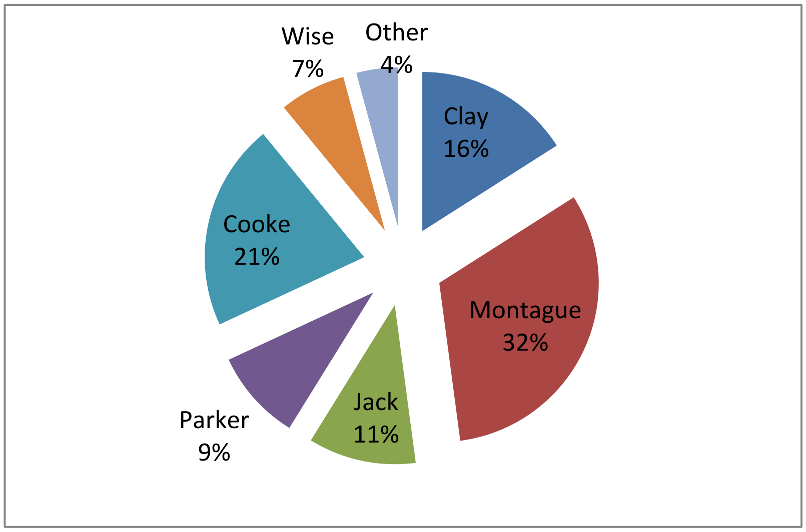

Figure 4-1. Study area response by county

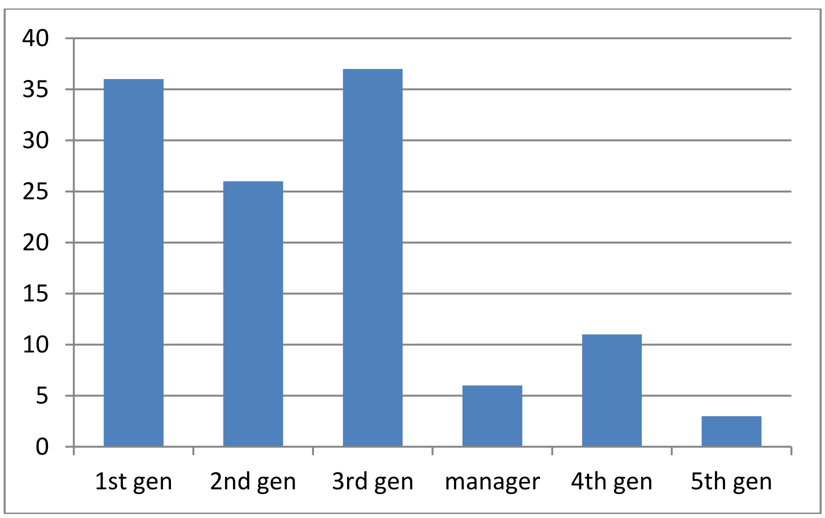

Figure 4-2. Respondents' association with the land.

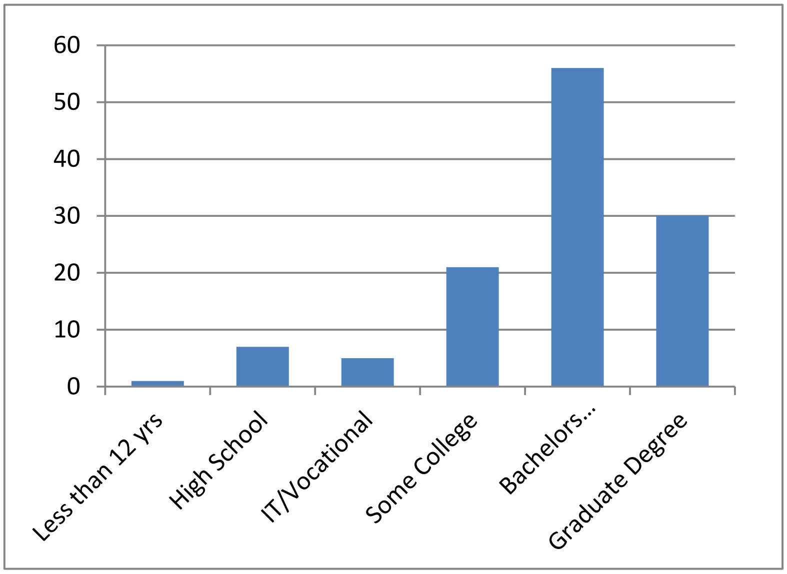

Figure 4-3. Respondent level of education.

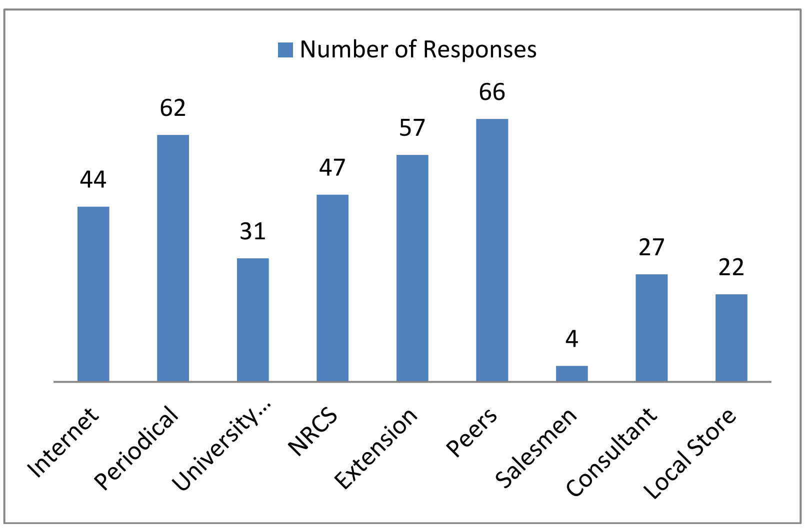

Figure 4-4. Respondent source of continuing education

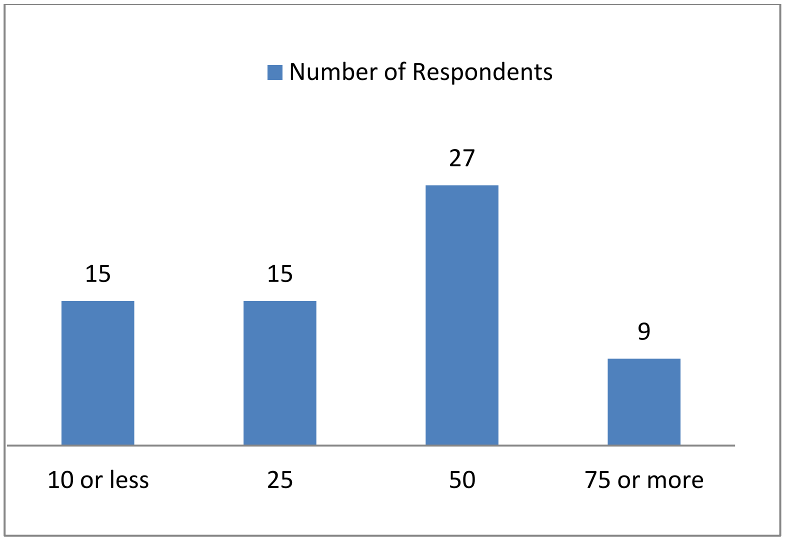

Figure 4-5. Years living on ranch.
Other respondents live in “Not on Ranch”.

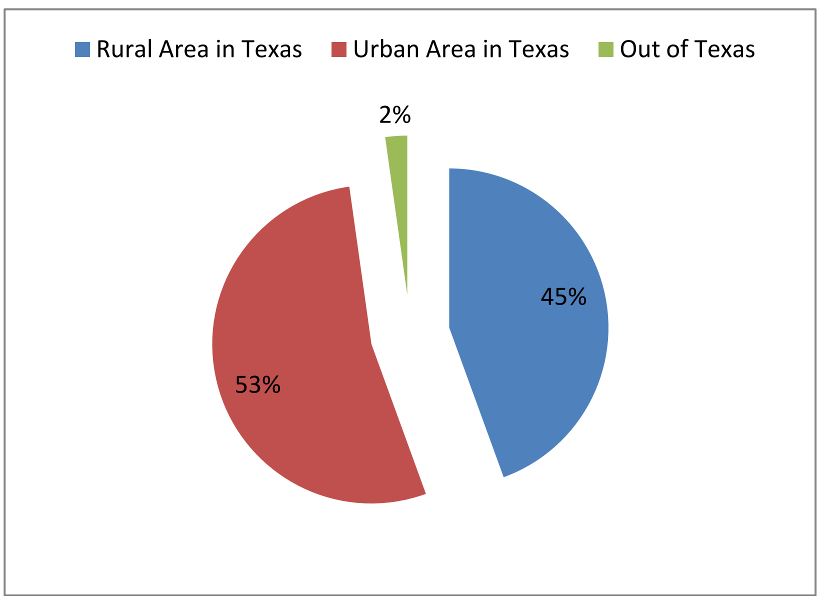

Figure 4-6. If not living on ranch, location of home.

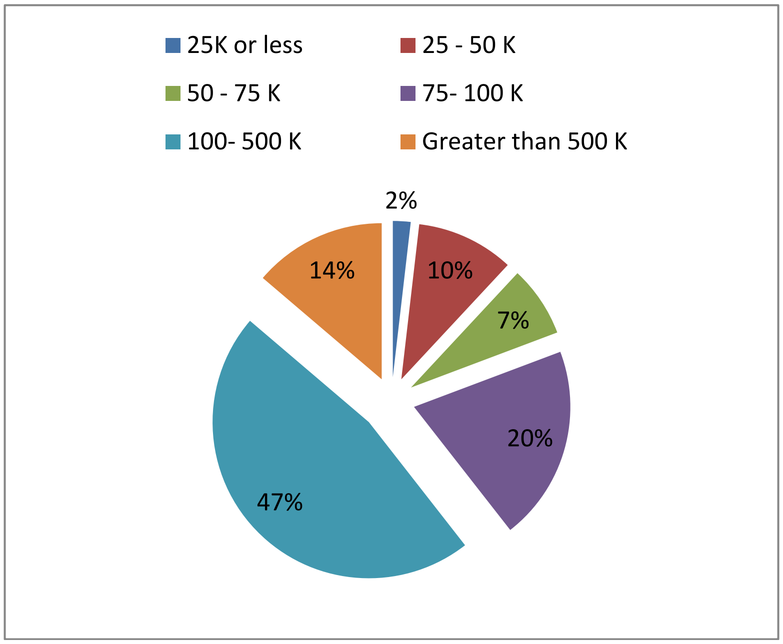

Figure 4-7. Respondent annual income.

Data Issues

It should be noted that data are not necessarily normal in distribution. Skewness and Kurtosis were evident throughout the variables in all of the sections of the questionnaire. Skewness is indicative of people tending to agree on certain variables, especially tending toward the agreement side of 7 point Likert scale questions. This could indicate that the respondents were generally aware of the tenants of sustainable ranching, as many of these questions ask respondents if they agreed with ideals that literature has identified as sustainable philosophies or management.

Likewise kurtosis means that the responses are either "peaked" or "heavy tailed". This means that responses are grouped tightly in the middle of a standard bell curve, or they are spread further out than what would normally be expected. Again, given the nature of the questions and the population being polled, this should not be unexpected.

Acceptability of the somewhat non-normal distribution hinges on statistical procedures as well (Field, 2005). For the purposes of this study, non-normality of variables is not expected to present a problem. Regression models make no distributional assumptions about the independent variables themselves. However, residual error must be normally distributed for smaller samples sizes. Where error is not normally distributed, t-tests of regression coefficients are not accurate. (Garson, 2011b) and PCA only requires normality for certain significance test; when performing PCA merely to gain factor scores, “significance testing is beside the point” (Garson, 2011d).

Statistical Procedures

The ultimate goal of the data analysis was to analyze the set of variables to determine relationship to sustainability. Statistical procedures are carried out in nine steps. Seven steps are in preparation for multiple regression analysis. One step is the regression and the last step is checking for non-response bias.

Removal of Missing Data

The number of respondents multiplied by the number of variables (124 x 218) made it possible to have values in 27,032 cells. The raw data contained 1211 missing values in those cells. Of those 1108 were simply not filled in, 103 were coded as don’t know (DK) by the respondent.

Independent samples t-test was used to check for significant differences in characteristics between those respondents with missing data, and those without to test if data are *Missing Completely at Random* (MCAR). It was found that there was a significant difference ($p = < .01$) in percent income derived from the ranch land between the groups. Levene's Test for Equality of Variances confirmed equality of variance between the groups ($F = 6.346$; $p = .017$. This indicates the “missingness” is not MCAR, therefore data imputation is appropriate. Application of software available in the R environment, package ‘seqKNN’, replaced all missing data.

Internal Consistency

Economic Sustainability

The initial computation for Cronbach's alpha coefficient, using all 14 variables in section 2, "Economic Considerations", did not meet minimum critical value ($\alpha = .484$). SPSS computed "Cronbach's Alpha if Item Deleted". This was the estimated value of alpha if the variable were removed from the model. If "alpha if deleted" was lower for all items than for the computed overall alpha, then no further removal of variables was necessary. Variables were systematically removed using this procedure, until Cronbach's alpha was maximized by retaining 6 variables ($\alpha = .722$). This exceeds the critical value ($\alpha = .70$).

The six variables which maximize Cronbach's Alpha for "Economic Considerations" are identified as:

1. Financial risk can be reduced by implementation of proper grazing practices.
2. Proper grazing management of rangeland will positively influence the long-term profitability of a ranch.
3. Deterioration of range conditions will cause log-term economic difficulties.
4. When compared to other ranches, I perceive the rate of return that I receive from grazing rangeland as being above average.
5. I consciously plan for long-term economic sustainability (5 or more years).
6. I know my production costs.

Land Health Sustainability

The initial computation for Cronbach's alpha coefficient, using all 25 variables from section 4, "Land Health", did not meet minimum critical value ($\alpha = .649$). Variables were systematically removed until Cronbach's alpha was maximized by retaining 18 variables ($\alpha = .730$). This exceeds the critical value ($\alpha = .70$).

The 18 variables were all were related to self-assessments of change in land characteristics. Respondents were instructed, "Change in the environment is certain". They were then asked, "In relation to your property, please indicate your perception of the change noticed for each issue over the past 10 years. The items may have increased, remained constant, decreased, or unknown.

The validity of each variable identified when maximizing Cronbach's Alpha was assessed. Two variables indicating a change in the population of quail and a change in the population of wild hogs were removed from the index. This is because of the extreme widespread reduction of quail and the rampant invasion of wild hogs noticed across the state. It was hypothesized that these two variables were indicators of a phenomena that exists regardless of philosophy, management or personal characteristics. Selection of only the 16 remaining variables maintained an Alpha coefficient of $\alpha = .71$, which is still above the critical value.

" The 16 variables which used in the Land Health Sustainability Index were:

Mesquite
Juniper
Other Brush
Bare Ground
Invasive Weed Species (thistle, cacti, greenbriar, etc.)
Livestock Trails
Gullies
Soil Compaction
Small Pedestals (rocks or plants that appear elevated)
Evidence of plant litter around obstructions like grass clumps and stones.
Other evidence of non-gully water flow patterns
Tall grasses
Short grasses
Turkey
Other birds
Deer

Social Sustainability

The initial computation for Cronbach's alpha coefficient, using all 33 variables in section 2, "Economic Considerations", did not meet minimum critical value ($\alpha = .224$). Variables were systematically removed until Cronbach's alpha was maximized by retaining 6 variables (α = .656). This did not exceed the critical value (α = .70).

With the variables used in section 5, "Quality of Life", the critical value for Cronbach's Alpha was not met, because the highest alpha achievable was 0.656, which is less than the critical value of 0.70 (Nunnaly and Bernstein, 1994; Starkweather, 2011b).

Other sources have indicated instances exist where a "moderate" value for Cronbach's alpha (α = .6) can be accepted as meeting the critical value necessary for creation of a meaningful scale, instead of strictly adhering to a more stringent value (α = .7 or α = .8) (Karahoca et al., 2010; Winter et al., 2004; Leontitits and Pagge, 2007). Specifically, Winter et al. (2004) accepted as relevant the moderate Cronbach alpha coefficient (α = .670) and Leontitis and Pagge (2007) even proved that lower levels were highly significant and resulting scales could be accepted. Therefore, the maximum Cronbach's alpha coefficient possible (α = .655) was considered to meet critical levels necessary for creation of a scale.

This may seem arbitrary, given the prior standard of acceptance for Cronbach's alpha of α = .7. The reason for the change was to prevent possible loss of information. In the context of this dissertation, it is desirable to investigate the index further in order to fully understand all methods and possible associations between variables and indices.

To increase the similarity of the derived quality of life, or social sustainability index to relevant literature (West and Herrick, 2003), the variable indicating personal satisfaction of the manager was re-introduced, because it was deemed useful in the derived quality of life index and it affected the Cronbach's alpha minimally (α = .655). Seven variables from section 5 suggested respondent's perceptions of key factors in relation to their quality of life. They are explained by statements from the questionnaire as follows:

1. Livestock management on my ranch does not infringe on my free time or ability to enjoy occasional recreation activities.
2. Livestock management on my ranch does not interfere with family involvement
3. I derive a great deal of satisfaction from my work on the ranch.
4. I am actively involved with my community.
5. I have the time to learn about subjects that are of interest to me.
6. I have a good relationship with neighboring ranches.
7. All decision makers (ranch owners or family) are involved in long range planning and goal making.

Creating Indices

The variables identified as internally consistent indexes were used to develop sustainable ranching indices. A single metric from each section which utilized the variables in the optimized Cronbach's Alpha was developed. When analyzing the data, all scores for scale items need to be in the same direction where high scores mean the same thing and low scores mean the same thing (Trochim, 2006). Therefore, data from all three sustainability indicator sections which were reduced to a set of factors by optimizing Cronbach's Alpha coefficient were transformed so that all variables were aligned. Transformations resulted in low indices scores being indicators of perceived sustainable practices and higher scores were indicators of unsustainability in the Economic Sustainability Index and the Social Sustainability Index. The Land Health Index was aligned so that a higher score resulted in greater sustainability and a lower score, less sustainability.

A summation of the selected variables from section 2, "Economic Considerations" was identified as a good metric for economic sustainability; the lower the sum, the greater the sustainability. Summation of data for selected variables in section 4 "Land Health" were the variables which required transformation so that 3 was a value indicating greater sustainability, 1 lesser; 4 (responses of "unknown" were replaced using nearest neighbor analysis with ‘seqKNN’). Variables that required reversal of scale included: Tall grasses, Turkey, Other birds, and Deer.

Summation of section 5 “Quality of Life” was all that was required, so that the lower the score the more sustainable the case. This section depicts social sustainability and will hereafter be referred to as “Social Sustainability Index”.

Table 4-4 gives the basic descriptive statistics for the indices that were created. Normality was assessed as skewness being within the +2 to -2 range and kurtosis within +3 to -3 range (Garson, 2011e).

Optimal Scaling

In order to achieve the objectives of this research (i.e. further the knowledge and understanding of sustainable ranching practices) it would be necessary to compare management philosophy, native rangeland management and personal characteristics associated with sustainability parameters. In the questionnaire these characteristics were measured in questions contained in sections 1, 3 and 6. They were measured in a variety of ways including dichotomous, nominal, ordinal, and interval variables.

Table 4-4.

Indices Descriptive Statistics

	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Economic Index	6.00	30.00	13.4677	4.19143	1.149	.217	2.948	.431
Land Health Index	27	45	34.48	4.291	.337	.217	-.696	.431
Social Index	13	37	21.48	4.816	.664	.217	.727	.431
N = 124								

The R package 'aspect' and the bilenearization approach LINEALS was used for optimal scaling of all ordinal and nominal variables in the dataset derived from the questionnaire. The resulting matrix was optimally scaled unidemensional category quantifications for nominal and ordinal data. Table 4-5 quantifies the "loss" associated with optimum scaling of the data. The loss function equates smaller loss values with more closely achieving bilineraizability, where a "0" would be perfect, yet not realistic (de Leeuw et al., 1999).

Table 4-5.

Loss Values Associated with Optimal Scaling of Data Set

Section	Number of Variables Optimally Scaled	Loss
1.) Land Management Philosophy	37	19.52616
2.) Economic Considerations	30	13.65851
3.) Native Rangeland Management	42	14.28141
4.) Land Health	25	13.15666
5.) Quality of Life	33	18.70316
6.) Personal Characteristics	39	7.544608

Principal Component Analysis

A close look at the components of each PCA and interpretation of variable loadings follows. Varimax rotation was applied to all 4 principal component analyses. Orthoganality of variables was checked by saving factor scores, then computing a correlation to ensure the correct rotation strategy was used.

PCA 1: Land Management Philosophy (4 components)

Section 1, Land Management Philosophy, contained 37 separate variables. The parallel engine analysis (Patil, 2008) eigenvalues for random data coincided with eigenvalues from section 1, when 3 components were accepted, percentile values of 2.018843 and 2.457 respectively, then dropping to eigenvalues of 1.814744 and 1.786 on the 4th component. The scree plot on the other hand identified either 4 or 5 components (Figure 4-8). A compromise seemed logical and 4 components were selected which explained 40.131% of the variance in the unrotated model. Varimax rotation was applied, the variance explained remained at 40.131%.

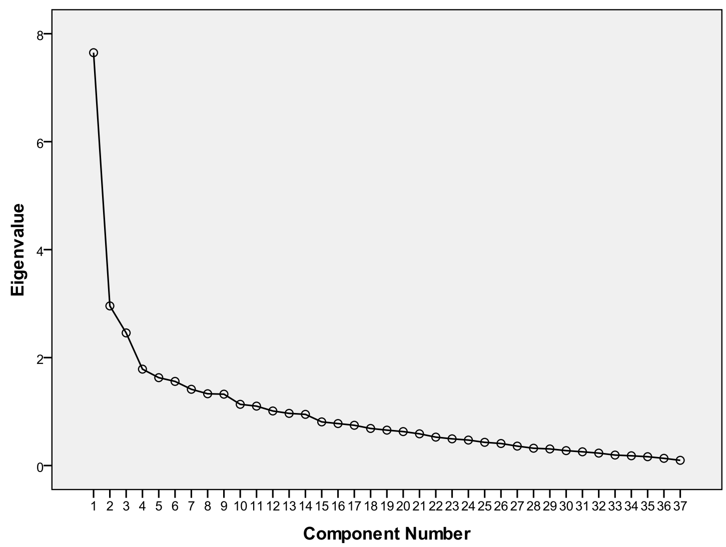

Figure 4-8. Scree Plot Principal Component Analysis 1.

The KMO statistic is well within the specified range for sample adequacy (0.74). The Bartlett's Test of Sphericity is highly significant ($p < .001$) that the correlation matrix is not an identity matrix (Table 4-6); indicating variables in the population correlation matrix are uncorrelated. Therefore it may be assumed multicollinearity is not a problem. The observed significance level here allows rejection of the null hypothesis. It is concluded that the strength of the relationship among variables is strong, but not multicollinear.

Table 4- 6.

Principal component analysis 1   Kaiser-Meyer-Olkin and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.747
Bartlett's Test of Sphericity	Approx. Chi-Square	1842.454
	df	666
	Sig.	.000

Principle component analysis was used for the purpose of identifying a subset of variables based on which original variables have the highest correlation with the principal components, also known as component loadings. Additionally, communalities help to identify the measured variables for which the factor analysis is working best. (Garson, 2011b; StatSoft Inc., 2011). Variables with significant component loadings were retained for inclusion in BMA procedures. Twenty-nine of the 37 original variables were retained (Table 4-7).

PCA 2: Land Management Practices (5 components)

Section 3, Land Management, contained 43 separate variables. The parallel engine analysis (Patil, 2008) eigenvalues for random data become greater than eigenvalues from unrotated PCA Component eigenvalues, at 3 components. Percentile values of for the random engine and the actual PCA were 2.163686 and 2.278 respectively. These eigenvalues then dropped to 2.033229 and 1.989 on the 4th component; thus suggesting acceptance of 3components. The scree plot on the other hand, identified 7 components (Figure 4-9). Again, compromise seemed logical and 5 components were selected. Selection of 5 components accounted for 37.593% of the variance in the unrotated model. Varimax rotation was applied; the variance explained was reduced to 30.241%.

The results of the KMO would suggest that the sample was not adequate (0.426). The sum of partial correlations is large relative to the sum of the correlations indicating diffusion in the pattern of correlations. PCA may not be appropriate. The Bartlett's Test of Sphericity, on the other hand, is highly significant, ($p < .001$), indicating variables in the population correlation matrix are uncorrelated (Table 4-8).

Table 4-7.

Principal Component Analysis 1 Components

Variable	Component Loading	Communalities	Component Identity*
High Density/Short Duration	.752	.598	1
Grazing Mngmt Iproves Rng	.692	.530	1
Consider Cost of Inaction	.688	.496	1
Minimize Risk by Grazing	.682	.595	1
Rest	.641	.601	1
Plant Growth/Time/Weather	.622	.425	1
Provide Env Services	.610	.539	1
Light = to Rotation	-.562	.348	1
Repair Problems	.545	.325	1
Physical Characeristics	.522	.418	1
Maintain Genetics	.501	.534	1
Plan for Rng Health	.507	.627	1
Management is Sustainable	.489	.348	1
Forbs Valuable	.799	.713	2
Incororate Wildlife Needs	.780	.689	2
Plan for Rng Health	.595	.627	2
Management is Sustainable	.537	.534	2
Lvstk is Most Important	-.472	.264	2
GovInvYes/No	-.808	.684	3
BrushControl	-.698	.571	3
Disaster/Drought Relief	.649	.551	3
GovParticipateYes	.617	.774	3
Disaster/Drought	.562	.646	3
GrazingDistribution	.490	.287	3
GovParticipateYes	.458	.774	4
Disaster/Drought	.477	.646	4
Education	-.678	.498	4
Internship	-.409	.253	4
ReactingMismngmt	-.404	.176	4

*Indicates which component the variable contributes toward indentifying

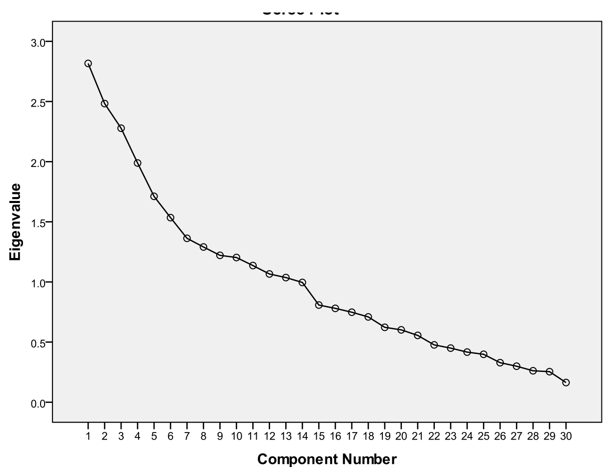

Figure 4-9. Scree plot principal component analysis 2.

Because of the value of the KMO statistic being near the criterion level of 0.5 and the rigor involved selecting questions for the study (by literature review and focus group) and the highly significant indications of the Bartlett's measure, PCA was still used as a method of variable reduction.

Table 4-8.

Principal Component Analysis 2 Kaiser-Meyer-Olkin and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.426
Bartlett's Test of Sphericity	Approx. Chi-Square	1374.906
	df	903
	Sig.	.000

Twenty-four of the original forty-three variables with significant component loadings were retained for inclusion in BMA procedures (Table 4-9).

PCA 3: Personal Characteristics (5 components identified)

Section 6, Personal Charcteristics, contained 46 separate variables. The parallel engine analysis (Patil, 2008) eigenvalues for random data coincided with eigenvalues from the unrotated PCA when 2 components were accepted. Acceptance was based on the fact that the random eigenvalue dropped became greater than the actual between the 2nd and 3rd component eigenscores. The percentile values were 2.36 5726and 2.571 respectively then dropping to eigenvalues of 2.221982 and 1.913 on the 3rd component.

The scree plot made a slight adjustment to the right at 4 components and then again at 8 components (Figure 4-10). Analyzing the scree plot suggested retaining three more components than that suggested by the parallel engine. Since section 6 was not seeking to identify a general theme, but merely an effort to learn as much about the respondent as was possible, removing too many variables from consideration for later analysis was not desirable. Considering the purpose of the study, to assess grazing management sustainability, identifying variables associated with sustainability losing key demographic data could easily leave out information that is being sought. Therefore, in an effort to retain relevant variables a third criterion for selection of components was employed for this particular PCA. The third criterion was Kaiser's criterion, the practice of retaining all components with eigenvalues greater than 1.

The results of careful consideration, concerning component structure, lead to the retention of 5 components, which resulted in accounting for 44.621% of variance initially. Varimax rotation was applied; the variance explained was reduced, now explaining 31.841%.

Table 4-9.

Principal Component Analysis 2 Components

Variable	Component Loading	Communalities	Component Identity Number*
FireUse	.563	.437	1
PrescribedBurn	.529	.416	1
PictureNotes	.507	.352	1
SupplDrought	.488	.460	1
LandHealth	-.480	.268	1
Patches	.444	.310	1
EaseApplication	.439	.240	1
AU	.653	.524	2
StockingRateSelfCharc	.643	.428	2
FertAppl	-.563	.507	2
MultipleClass	.469	.298	2
QualityLife	-.445	.303	2
Years Using System	-.642	.428	3
GrazingSystem	-.619	.603	3
RestLand	.605	.530	3
InternalFence	.446	.377	3
SupplFeed	.674	.536	4
SaltLick	-.652	.470	4
Herding	.479	.238	4
Shade	.450	.284	4
UnevenForage	.454	.230	5
OtherFence	.449	.279	5
CostFence	.449	.284	5

*Indicates which component the variable contributes toward indentifying

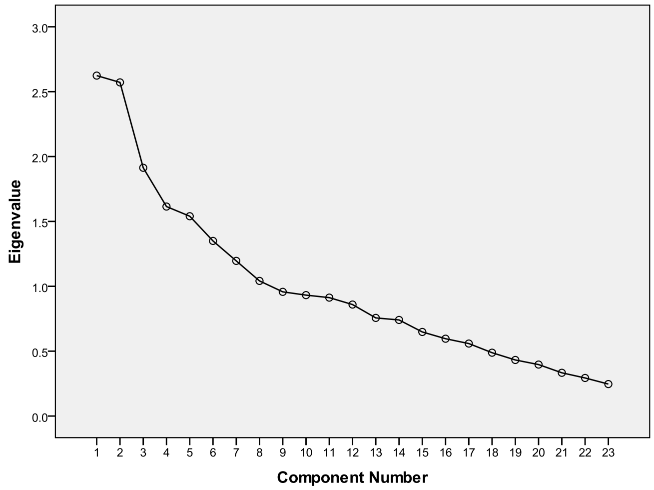

Figure 4-10. Scree plot principal component analysis 3.

As in PCA 2, the results of the KMO would suggest that the sample was not adequate (0.475). The sum of partial correlations is large relative to the sum of the correlations indicating diffusion in the pattern of correlations. PCA may not be appropriate. The Bartlett's Test of Sphericity, on the other hand, is highly significant, ($p < .001$). Therefore, the correlation matrix is not an identity matrix (Table 4-10).

Because of the value of the KMO statistic being near the criterion level of 0.5 and the rigor involved selecting questions for the study (by literature review and focus group) and the highly significant indications of the Bartlett's measure, PCA was still used as a method of variable reduction.

Table 4-10.

Principal component analysis 3 Kaiser-Meyer-Olkin and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.496
Bartlett's Test of Sphericity	Approx. Chi-Square	940.918
	df	528
	Sig.	.000

Twenty-six of the original forty-six variables with significant component loadings were retained for inclusion in BMA procedures (Table 4-11).

PCA 4: Other Variables (8 components identified)

The PCA which was run on “Other variables” was use as a means of retaining variables that were left behind from section 2, 4, and 5 during the creation of scales to create indices. This resulted in the inclusion of 55 separate variables. The parallel engine analysis (Patil, 2008) identified 7components as important. Comparison of eigenvalues between the random data and the actual data between the 7th and the 8th component were 1.998811 and 2.041 then dropping to eigenvalues of 1.926439 and 1.821 respectively.

The scree plot developed a crook at 7 components, but clearly trailed to the right at 8 components (Figure 4-11). Also, there were 21 components with eigenvalues greater than 1. Therefore, 8 components were selected to retain in the analysis. The initial variance explained by the 8 components was 39.341%; after varimax rotation the variance explained remained at 39.341%.

Table 4-11.

Principal Component Analysis 3 Components

Variable	Component Loadings	Communalities	Component Identity Number*
YearsLOPY	.802	.693	1
LiveOnPropertyY/N	.759	.775	1
LOPNurban	.629	.464	1
YearsExperience	.577	.452	1
%IncomeFromProperty	.559	.271	1
DistanceLOPN	-.504	.668	1
LOPNnotTexas	-.610	.550	2
Hunting	.581	.432	2
Woodland	.552	.440	2
NRCS	.483	.335	2
Store	-.461	.314	2
Stocker	-.794	.658	3
#Acres	-.751	.686	3
County	.602	.458	3
LandInvestment	-.459	.323	3
Consultant	.455	.395	3
YearsInFamily	-.708	.579	4
AssociationWithProperty	.627	.583	4
LOPNrural	.437	.552	4
Internet	.552	.362	5
Periodical	-.525	.358	5
Extension	.522	.374	5
Peers	-.501	.336	5
Age	-.493	.615	5
Goat	-.426	.254	5
Salesman	.413	.189	5

*Indicates which component the variable contributes toward indentifying

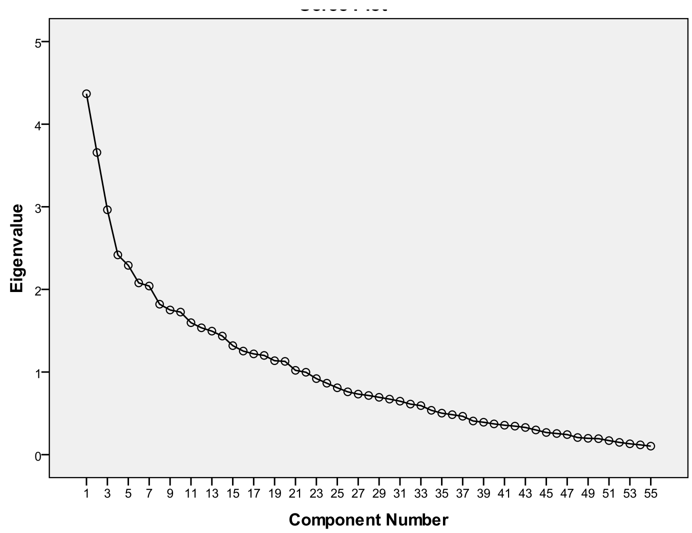

Figure 4-11. Scree plot principal component analysis 4.

As in prior analysis, the results of the KMO would suggest that the sample was not adequate (0.490). The sum of partial correlations is large relative to the sum of the correlations indicating diffusion in the pattern of correlations. PCA may not be appropriate. The Bartlett's Test of Sphericity, on the other hand, is highly significant, ($p < .001$). Therefore, indicating variables in the population correlation matrix are uncorrelated (Table 4-12).

Because of the value of the KMO statistic being near the criterion level of 0.5 and the rigor involved selecting questions for the study (by literature review and focus group) and the highly significant indications of the Bartlett's measure, PCA was still used as a method of variable reduction.

Table 4- 12.

Principal component analysis 4 Kaiser-Meyer-Olkin and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.490
Bartlett's Test of Sphericity	Approx. Chi-Square	2194.302
	df	1485
	Sig.	.000

Thirty-seven of the original fifty-five variables with significant component loadings were retained for inclusion in BMA procedures (Table 4-13).

In all the results of 4 principal component analyses have reduced the total number of variables from 193 to 110. The total variables could have been reduced to a greater extent if a more stringent parameter had been employed for deletion of variables.

The PCA was conducted primarily to help reduce the number of variables for consideration using regression analysis. An alternative to using the PCA would have been arbitrarily choosing variables based on the literature review and on the focus group session. The greatest threat to the PCA successfully reducing the number of variables was the fact that the KMO statistic is based on correlation and partial correlation. KMO did not indicate that data were likely to load on factors well. In the past the conclusion was that a factor analysis should be run. This was extremely useful before computers, allowing researchers to save much unnecessary work. Now, with the relative ease of computing multiple PCA or factor analyses quickly, KMO is more useful for assessing issues with multicollinearity (Garson 2011b).

KMO values range between 0 and 1. A value closer to 1 indicates that patterns of correlations are relatively compact and so far as factor analysis should yield distinct and reliable factors; whereas values above .5 are acceptable. “Values below that should cause one to rethink which variables to include” (Field, 2005). Garson (2011b) also indicates that variables may be removed prior to factor analysis based on low individual KMO scores, which will make PCA or factor analysis more amiable. Considering this study chose to retain variables with high component loadings, which are the correlation coefficients between the variables and the components, it is unlikely that these would be variables removed in order to increase KMO.

Table 4-14.

Principal Component Analysis 4 Component 1

Variable	Component Loading	Communalities	Number
MyNeighbors	.738	.562	1
LocalCommunity	.723	.555	1
MyFriends	.628	.479	1
MyEmployees	.618	.632	1
AllPeoplePassingThru	.571	.471	1
Profit	.676	.551	2
LandHealth	-.614	.566	2
WillOverstock	.609	.397	2
ESTaxStmT	-.425	.284	2
Family	.401	.404	2
ESProductionMsr	.741	.601	3
ESI/ERatio	-.605	.413	3
Tax	-.543	.425	3
ReasonForRanching	.512	.383	3
ESBalanceSht	-.401	.487	3
OtherConsid	.615	.481	4
OtherDecMkr	.598	.493	4
ESOther	.517	.359	4
MltplSpecies	.469	.305	4
OtherDiv	.424	.349	4
MyTime	.592	.408	5
Myself	.509	.451	5
NegativeHealth	.495	.380	5
Hay	-.457	.494	5
MyHealth	.443	.481	5
DYes	.777	.633	6
Mineral	-.679	.556	6
Hunting	.533	.459	6
Predators	.513	.372	6
DYes	.777	.633	6
Other Wildlife	.549	.388	7
Reptiles/Amphibians	.542	.322	7
LeastCostPrctc	.534	.329	7
$LimitsInputs	.403	.543	7
RanchEmployees	.525	.467	8

NeighborIssues	.500	.309	8
FamilyIssues	.446	.313	8

Confirmatory factor analysis was not the purpose of this procedure. Exploratory PCA was used to select a subset of variables from a larger set, based on which original variables have the highest correlations with the principal component factors. This goal was achieved.

Bayesian Model Averaging (BMA)

BMA Economic Sustainability Index

When estimating model parameters, it is possible to "overfit"; or superficially improves the outcome by continually adding additional parameters. The BMA method of model selection introduces a penalty for additional parameters as opposed to simply maximizing for the amount of variance explained (McQuarrie, 1998). Therefore, based the output table (Table 4-14), the first model 'model 1' is likely the best model with the largest posterior probability (0.035), and the lowest BIC (-31.375). It retained 6 variables.

For the Economic Sustainability Index, there were a total of 113 separate models evaluated. On the first column of the output is the column 'p!=0'. This indicates the percentage/probability that the coefficient for a given predictor is not zero. "Consider Cost of Inaction (X.1.0.18)" is the most important variable identified at 100% probability of the coefficient for this predictor NOT being zero. From there, the probability declines with the next variable identified, "LOPNurban (X.6.12.2.) having an 85.7% probability of the coefficient not being zero. The most suspect variable identified is "Repair Problems (X.1.0.19)" with a 43.2% likelyhood of its coefficient not being equal to zero.

The BMA model for the Economic Sustainability Index includes 6 predictors, suggesting respondent's perceptions of key factors in relation to their economic sustainability index. For the 6 identified predictors, explanations based from statements on the questionnaire are as follows:

ConsiderCostofInaction	Consider Cost of inaction as well as cost of action before making management decision
Forbs Valuable	Respondent considers forbs as a valuable source of forage for wildlife or livestock
Repair Problems	Belief they are grazing in a manner that will repair environmental problems
Brush Control	Government should offer incentives for brush control
LOPNurban	Live in an urban area of Texas; not on the ranch
RankofLandHealth	Rank concern for Land Health in comparison with : Profit; Cattle Productivity; Tax Issues; Family Issues; Neighbor Issues; Weather

Table 4-14.

Bayesian Model Averaging Economic Sustainability Models

bicreg(x = sb136o.predictors, y = sb2.SusMetric)

113 Models were selected

Best 5 Models (cumulative posterior probability = 0.1523):

Predictor	p!=0	SD	model 1 b	model 2 b	model 3 b	model 4 b	model 5 b
Intercept	100	0.514	13.468	13.468	13.468	13.468	13.468
Forbs Valuable	73	5.96	-12.238	-12.054	-13.239	-10.959	-11.454
Consider Cost of Inaction	100	4.36	-19.576	-19.293	-22.363	-19.95	-22.088
Repair Problems	43.2	5.31	-8.712	-9.368	.	-10.317	.
BrushControl	69.4	4.90	-8.776	-9.198	-8.321	-8.812	-8.791
MultipleClass	28.5	3.67	.	.	.	-7.014	.
LOPNurban	85.7	4.93	-10.77	-11.561	-9.993	-11.259	-9.722
Mineral	50	4.70	.	7.149	.	7.748	.
LandHealth	76.8	6.30	11.332	12.07	9.488	11.037	.
nVar			6	7	5	8	4
r2			0.385	0.408	0.36	0.429	0.331
BIC			-31.375	-31.286	-31.163	-30.962	-30.485
Post probability			0.035	0.034	0.032	0.029	0.023

BMA for Land Health Index

Based the output table (Table 4-15), the first model 'model 1' is likely the best model with the largest posterior probability (0.053), and the lowest BIC (-23.3). It retained 6 variables. There were a total of 88 separate models evaluated. According to the column labeled "p!=0"", "CostFence" (X.3.3.3) is the most important variable identified at 100% probability of the coefficient for this predictor not being zero. From there, the probability declines slightly, with the next variable identified, "RestLand "(X.3.8.13) having a 99.7% probability of the coefficient not being zero. The variable identified with the lowest probability of not being zero, in model 1, is "DenseBrush" (X.1.0.16)" with a 62% likelyhood of its coefficient not being equal to zero.

Table 4-15.

Bayesian Model Averaging Land Health Index Sustainability Models

bicreg(x = sb136o.predictors.3, y = LHindex)
88 models were selected. Best 5 models (cumulative posterior probability = 0.2011):

			model 1	model 2	model 3	model 4	model 5
	p!=0	SD	b	b	b	b	b
Intercept	100	0.665	35.4	35.4	34.8	34.5	35.0
Minimize Risk by Grazing	30.8	4.59	.	.	-8.32	.	.
Light = to Rotation	96.9	4.88	-11.7	-11.6	-14.2	-12.5	-11.4
CostFence	100	3.68	12.1	12.0	13.2	12.4	11.9
RestLand	99.7	3.69	11.3	11.1	11.0	11.4	11.1
NRCS	97.1	4.31	-10.2	-9.64	-10.3	-11.9	-9.56
Salesman	64.5	5.61	.	7.37	11.1	.	9.77
LandInvestment	39.6	0.00000294	.	.	0.00000521	.	0.00000463
DenseBrush	62	0.0301	-0.05	-0.053	-0.0493	.	-0.519
MyFriends	90	4.93	-10.3	-10.7	-12.2	-9.06	-9.85
nVar			6	7	9	5	8
r2			0.344	0.368	0.412	0.313	0.388
BIC			-23.3	-23.1	-22.4	-22.4	-22.4
Post probability			0.053	0.047	0.034	0.034	0.033

The 6 predictors, from model 1, suggest respondent's perceptions of key factors in relation to their economic sustainability index. For the 6 identified predictors, explanations based from statements on the questionnaire are as follows:

Light = to Rotation	Degree which respondents believe lightly or moderately stocked, continuous grazing has ecological benefits equal to rotation of livestock to different pastures.
CostFence	Fence cost is an obstacle to increasing grazing distribution
RestLand	Respondents rest the land for a portion of the growing season as a critical component of my grazing plan.
NRCS	Respondent uses the NRCS as a source of grazing management information
DenseBrush	Percent of respondent's native grassland currently covered by dense brush or woodlands
My Freinds	Respondents consider their friends when making management decisions.

BMA for Social Sustainability Index

Based the output table, the first model 'model 1' is likely the best model with the largest posterior probability (0.228), and the lowest BIC (-3.0872). This model retained six variables (Table 4-16).

There were a total of 117 separate models evaluated. According to the column labeled "p!=0"", "Salesman (X.6.10.7)" is the most important variable identified at 97.9% probability of the coefficient for this predictor NOT being zero. From there, the probability declines with the next variable identified, "Patches (X.3.8.8)" having an 87.2% probability of the coefficient not being zero. The most suspect variable identified is "Herding (X.3.4.1)" with a 38.5% likelyhood of its coefficient not being equal to zero.

The six predictors, identified as having the best model fit, suggest respondent's perceptions of key factors in relation to their social sustainability index. For the six identified predictors, explanations based from statements on the questionnaire are as follows:

InternalFence	The use of internal fencing to distribute livestock over the rangeland
Patches	Having heavily used and lightly used (uneven) forage utilization.
Salesmen	Obtain grazing management from salesmen
Goat	Percentage of income from goat browsing
Hunting	Percentage of income from hunting lease
Mineral	Income received from mineral sale/lease

Table 4-16.

Bayesian Model Averaging Social Sustainability Index Models

bicreg(x = sb136o.predictors, y = sb5.SustMetric)
117 models were selected
Best 5 models (cumulative posterior probability = 0.1152):

	p!=0	SD	model 1 b	model 2 b	model 3 b	model 4 b	model 5 b
Intercept	100	0.722419	21.0617	21.4839	21.0137	21.0876	21.4839
Herding	38.5	5.677456	.	.	-9.4875	.	.
InternalFence	59.2	6.112092	10.0771	.	10.3318	.	.
Patches	87.2	6.744342	13.3908	.	15.7451	13.1245	9.85424
Salesman	97.9	5.360357	-17.755	-13.248	-16.654	-15.566	-13.895
Goat	53.3	0.570572	-0.937	.	-0.958	.	.
Hunting	77.2	0.060451	0.11115	.	0.12102	0.07583	.
Mineral	61	6.690645	9.9954	.	9.78648	9.85658	.
nVar			6	1	7	4	2
r2			0.228	0.062	0.256	0.163	0.095
BIC			-3.0872	-3.0529	-2.9933	-2.8224	-2.7934
Post probability			0.025	0.024	0.024	0.022	0.021

Regression Analysis

Regression for Economic Sustainability Index

Economic sustainability index scores were regressed on land management philosophy variables identified as the best model by Bayesian Model Averaging, using hierarchical regression analysis (Table 4-17). The six predictors from BMA Economic Sustainability Index, model 1, accounted for just under over 1/3 of the variance in economic sustainability index scores in the final model ($R^2 = .385$; adjusted $R^2 = .354$; $F(6,117) = 12.212$; $p < .001$), which was highly significant. Even though the best model only account for approximately 39% of the variability in the respondents data, the model is considered significantly better than would be expected by chance, and therefore the null hypothesis of no linear relationship of y to the independents is rejected.

Model Validation

General assumptions for regression were met with block three from the original model for Economic Sustainability Index. Cross-validation of the model was computed using R-version 12.13.0 software, package 'DAAG', which uses the *K* – fold method. In this procedure *K* was selected as 4 to maintain a 5:1 ratio of cases to predictors for each fold. It was noted that "Repair Problems" did not significantly contribute to the model (p = .2152) (Table 4-18).

Table 4-17.

Hierarchal Regression Results For Economic Sustainability Index

	Block 1			Block 2			Block 3		
	b	β	Sig	b	β	Sig	b	β	Sig
Constant	13.468 (.330)			13.468 (.311)			13.468 (.303)		
Consider Cost of Inaction	-20.823 (4.029)	-.435	.000	-19.968 (3.180)	-..417	.000	-19.576 (3.711)	-.409	.000
Repair Problems	-6.327 (4.11)	-.130	ns	-6.502 (3.981)	-.133	ns	-8.712 (3.957)	-.178	.030
Forbs Valuable				-10.448 (3.742)	-.220	.006	-12.238 (3.70)	-.257	.001
Brush Control				-9.198 (3.562)	-.198	.011	-8.776 (3.470)	-.189	.013
LOPNurban				-10.263 (3.529)	-.221	.004	-10.770 (3.440)	-.232	.002
Rank ofLand Health							11.332 (4.123)	.209	.007
R-squared		.245			.345			.385	
Adjusted R-squared		.233			.318			.315*	
No. observations		124							

Standard errors are reported in parentheses
* denotes *adjusted* R^2 using Stein's Formula

Table 4- 18.

K – Fold Cross-Validation of Economic Sustainability Index

Variable	df	Sum Sq	Mean	Sq F	Value Pr (> F)
Consider Cost of Inaction	1	467	467	41.08	3.2e -09 ***
Repair Problems	1	18	18	1.55	0.2152
Forbs Valuable	1	91	91	8.01	0.0055 **
Brush Control	1	70	70	6.14	0.0146 *
LOPNurban	1	101	101	8.93	0.0034 **
LandHealth	1	86	86	7.55	0.0069 **

n = 31
Overall means square 12.6
*** (p < .0001) **(p < .001) *(p < .01)

Economic sustainability index scores were regressed on land management philosophy variables identified as the best model after cross-validation, using hierarchical regression analysis (Table 4-19). The five predictors from BMA Economic Sustainability Index, model 1, accounted for just under over 1/3 of the variance in economic sustainability index scores in the final model ($R^2 = .360$; adjusted $R^2 = .304$; $F(5,118) = 12.212$; $p < .001$), which was significant ($p < .05$). Therefore, the model is considered significantly better than would be expected by chance thus the null hypothesis of no linear relationship of y to the independents is rejected.

The hierarchical regression model was checked for correlations between the predictors (Table 4-20). Finding none, Variance Inflation Factor (VIF) values were found to be below 10 as well as noticing tolerance values well above .2; ranging from .882through .989 (Table 4-21). These facts indicate that multicollinearity is not an issue. Neither was homoscedasticity, as indicated by the Durban-Watson test (2009). Values less than 1 or greater than 3 are cause for concern (Field, 2005).

The histogram of the standardized residual values was produced (Figure 4-12). It is as expected, close to normally distributed around a mean of zero. Also the The Normal Probability Plot (Figure 4-13) of Regression Standardized Residual values was computed. The plotting of points very near the reference line indicates little deviation of expected values from observed values.

Table 4-19.

Hierarchal Regression Results for Economic Sustainability Index

	Block 1			Block 2			Block 3		
	b	β	Sig	b	β	Sig	b	β	Sig
Constant	13.468 (.330)			13.468 (.313)			13.468 (.308)		
Consider Cost of Inaction	-22.966 (3.801)	-.480	.000	-22.088 (3.607)	-.462	.000	-22.363 (3.545)	-.467	.000
Forbs Valuable				-11.454 (3.717)	-.241	.003	-13.239 (3.731)	-.278	.001
Brush Control				-8.791 (3.578)	-.189	.015	-8.321 (3.520)	-.179	.020
LOPNurban				-9.722 (3.538)	-.209	.007	-9.993 (3.477)	-.215	.005
Rank ofLand Health							9.488 (4.102)	.175	.022
R-squared		.230			.331			.360	
Adjusted R-squared		.224			.308			.304*	

Standard errors are reported in parentheses
* denotes *adjusted* R^2 using Stein's Formula

Table 4-20.

Pearson Correlation Economic Sustainability Regression Variables

	Economic Index	1.	3.	4.	5.	6.
DV = Economic Index	1.000	**-.480**	**-.205**	-.112	**-.184**	.106
1. Consider Cost of Inaction	**-.480**	1.000	.082	-.046	.035	.054
3. Forbs Valuable	**-.205**	.082	1.000	**-.217**	**-.155**	**.224**
4. BrushControl	-.112	-.046	**-.217**	1.000	-.020	-.106
5. LOPNurban	**-.184**	.035	**-.155**	-.020	1.000	.002
6. LandHealth	.106	.054	**.224**	-.106	.002	1.000

Bold = Sig. (1-tailed) ($p < .05$)
N = 124

Table 4-21.

Collinearity Statistics Economic Sustainability Regression Variables

	Tolerance	VIF
Consider Cost of Inaction	.989	1.011
Forbs Valuable	.882	1.133
BrushControl	.946	1.057
LOPNurban	.970	1.031
LandHealth	.944	1.059

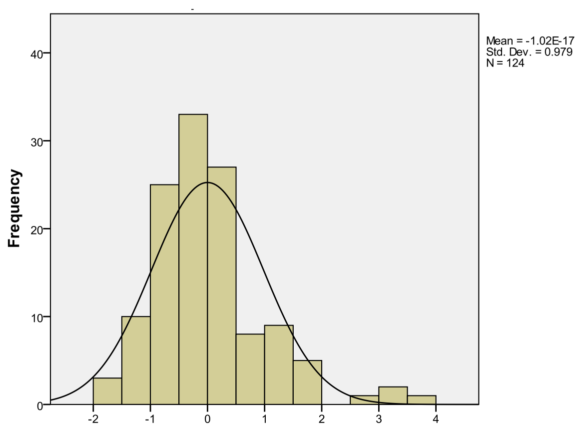

Figure 4-12. Economic index standardized residual values.

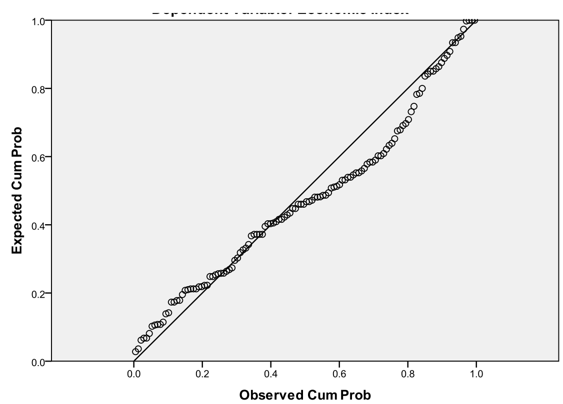

Figure 4-13. Economic index normal probability plot.

Standard Deviation of the Standardized residuals was .979, which is within the 95% confidence level of normally distributed samples (Field, 2005). Finally the box plot (Figure 4-14) using Mahalanobi's distance indicates the absence of outliers.

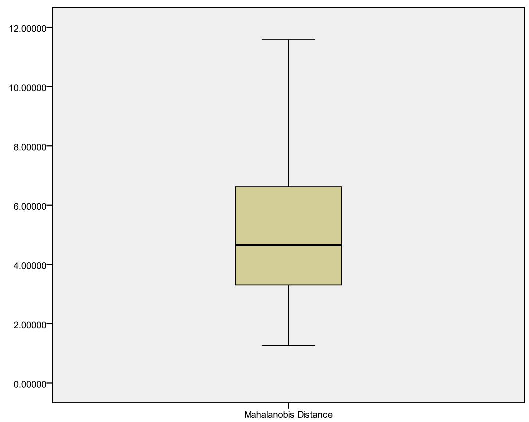

Figure 4-14. Economic index Mahalaboni's distance plot.

Model Validation

Cross-validation of the new model was computed using R-version 12.13.0 software, package 'DAAG', which uses the *K* – fold method. . All predictors were validated in the model contributing significantly (p < .01) (Table 4-22).

Table 4- 22.

K – Fold Cross-Validation of Economic Sustainability Index

Variable	df	Sum Sq	Mean	Sq F	Value Pr (> F)
Consider Cost of Inaction	1	467	467	39.78	5.1e -09 ***
Forbs Valuable	1	91	91	7.76	0.0062 **
Brush Control	1	65	65	5.54	0.0202 *
LOPNurban	1	92	92	7.83	0.0060 **
LandHealth	1	63	63	5.35	0.0225 *

n = 31
Overall means square 13.0
*** (p < .0001) **(p < .001) *(p < .01)

Regression for Land Health Index

Variables identified by BMA were used in hierarchical regression analysis to ensure use of the most parsimonious model. Land Health Sustainability Index scores were regressed on 6 predictors. These independent variables accounted for 34.4% of the variance in Land Health

Sustainability index scores in the final model (R^2 = .344; *adjusted* R^2 = .310; $F(6,117)$ = 10.216;, which was highly significant ($p < .001$) (Table 4-23). Therefore, the model is considered significantly better than would be expected by chance thus the H_0 of no linear relationship of y to the independents is rejected.

Table 4-23.

Hierarchal Regression Results for Land Health Sustainability Index

	Block 2			Block 3		
	b	β	Sig	b	β	Sig
Constant	34.476 (.350)			35.83 (.502)		
Light = to Rotation	-13.375 (4.434)	-.254	.003	-11.692 (4.124)	-.218	.005
CostFence	10.824 (3.951)	.227	.007	12.114 (3.636)	.255	.001
RestLand	11.613 (3.967)	.244	.004	11.336 (3.630)	.238	.002
NRCS				-10.224 (3.764)	-.215	.008
Woodlands				-.050 (.021)	-.181	.020
MyFriends				-10.308 (3.730)	-.217	.007
R^2		.195			.344	
Adjusted R^2		.175			.310	
N = 124						

Standard errors are reported in parentheses

The box plot of distribution of scores using Mahalanobi's distance indicated the presence of outliers for this model (Figure 4-15).

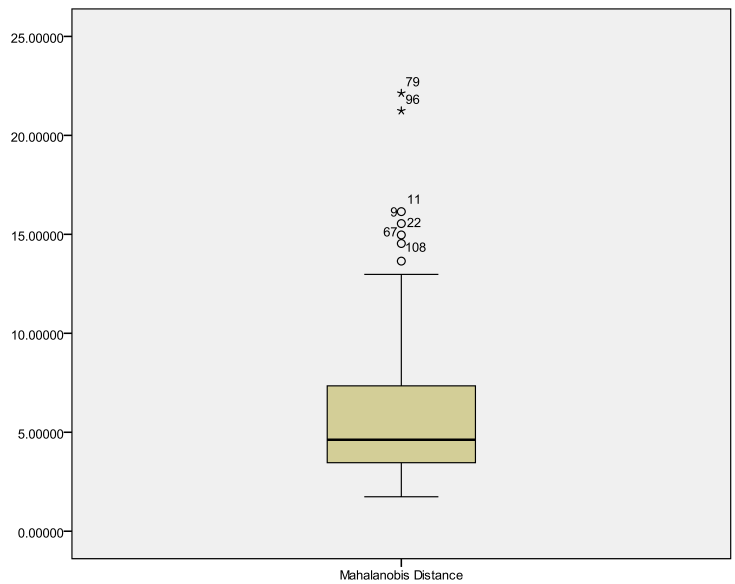

Figure 4-15. Box Plot of Mahalaboni's distance scores for land health index.

In an effort to determine the severity of the outliers, the criterion suggested by Field (2005) was enacted. Seven outliers were identified. Severity of influence was analyzed using DFFit statistics DFFit statistics (Table 4-24) which should tend toward zero if outliers are not a significant threat. DFFit is the difference between the predicted value for a case when the model is calculated including that case and when the model is calculated excluding that case (Field, 2005).

Table 4-24.

Dffit Statistic For Land Health Mahalaboni's Distance Scores

Case	DFFit	Standardized DFFit
108	-.33582	-.27260
96	.21959	.14435
79	.02889	.01862
67	.22950	.18063
22	-.64889	-.50695
11	.36757	.27565
9	.17838	.13599

The evaluation of the DFFit statistics did not yield readily identifiable outliers, therefore Mahalaboni's Distance scores were analyzed, and those with values greater than 15 were removed from consideration. The cases removed and their respective Mahalaboni's score were 96 (21.24); 79 (22.13); 11 (16.15); and 9(15.54).

The regression model was computed a second time. The resulting model indicated that the variable Light=to Rotation was no longer significant in the 3rd block of the hierarchical regression model (t = -1.478; p = .142). Therefore the variable was removed from consideration as a predictor.

The Land Health Sustainability Index was regressed on the remaining 5 predictors. (Table 4-25). This computation accounted for 30.0% of the variance in Land Health Economic Sustainability scores in the final model ($R^2 = .300$; *adjusted* $R^2 = .269$; F (5,114) = 9.766; p < .001), which was highly significant. Therefore, the null hypothesis of no linear relationship of Land Health Sustainability Index with the independent variables was rejected.

When assessing the accuracy of the hierarchical regression model first there is a need to check how well the model fits the observed data. There was an absence of high correlations between predictors (Table 4-26). Variance Inflation Factor (VIF) values were below 10 and tolerance values well above .2 ranging between .954 and .984, indicate that multicollinearity is not an issue (Table 4-27). Neither was homoscedasticity, indicated by the Durban-Watson test (1.868). Values less than 1 or greater than 3 are cause for concern (Field, 2005).

The histogram of the standardized residual values was produced (Figure 4-16). It is as expected, close to normally distributed around a mean of zero. Also the Normal Probability Plot of Regression Standardized Residual values was computed (Figure 4-17). The plotting of points very near the reference line indicates little deviation of expected values from observed values.

Table 4-25.

Hierarchal Regression Results For Land Health Sustainability Index

	Block 1			Block 2		
	b	β	Sig	b	β	Sig
Constant	34.314 (.364)			35.312 (.519)		
CostFence	9.889 (4.085)	.210	.017	11.141 (3.735)	.236	.003
RestLand	13.002 (4.105)	.275	.002	12.767 (3.743)	.270	.001
NRCS				-11.374 (3.882)	-.241	.004
Woodland				-.054 (.002)	-.200	.015
MyFriends				-9.118 (3.828)	-.193	.019
R-squared		.133			.300	
Adjusted R-squared		.119			.230*	
No. observatons		119				

Standard errors are reported in parentheses
* denotes *adjusted* R^2 using Stein's Formula

Table 4-26.

Pearson Correlation Economic Sustainability Regression Variables

Pearson Correlation	LHindex	1.	2.	3.	4.	5.
LHindex	1.000	**.300**	**.243**	**-.208**	**-.299**	**-.247**
1. RestLand	**.300**	1.000	.120	-.001	.027	-.040
2. CostFence	**.243**	.120	1.000	.079	.062	-.020
3. MyFriends	**-.208**	-.001	.079	1.000	**.207**	-.084
4. NRCS	**-.299**	.027	.062	.207	1.000	**.200**
5. Woodland	**-.247**	-.040	-.020	-.084	**.200**	1.000

Bold = Sig. (1-tailed) (p < .05)
N = 124

Table 4-27.

Collinearity Statistics Land Health Sustainability Index

	Tolerance	VIF
RestLand	.983	1.017
CostFence	.977	1.023
MyFriends	.936	1.068
NRCS	.906	1.104
Woodland	941	1.063

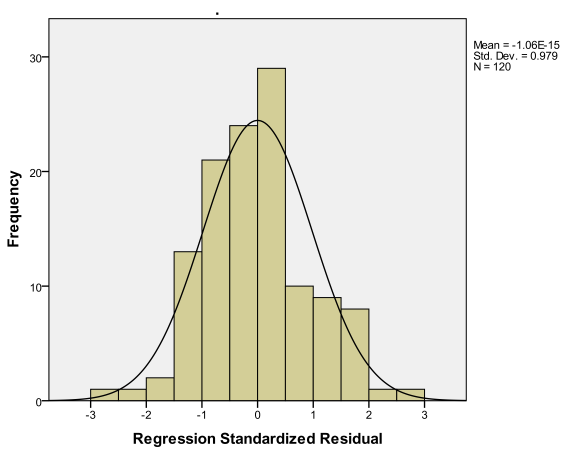

Figure 4-16. Standardized residuals histogram for land health sustainability index.

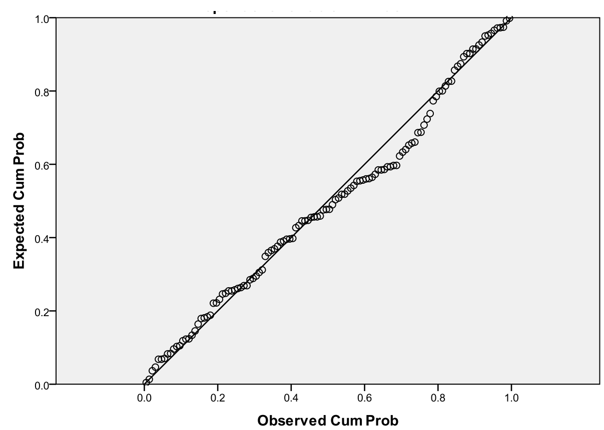

Figure 4-17. Normal probability plot for land health sustainability index residuals.

Standard Deviation of the Standardized residuals was .979, which is within the 95% confidence level of normally distributed samples (Field, 2005).

Finally the box plot (Figure 4-18) of distribution of scores, using Mahalanobi's distance indicate the absence of outliers, except for case 104. This case has a Mahalanobi's distance value of 13.24, which is acceptable based on the standard set for removing outliers with Mahalanobi's distances greater than 15.

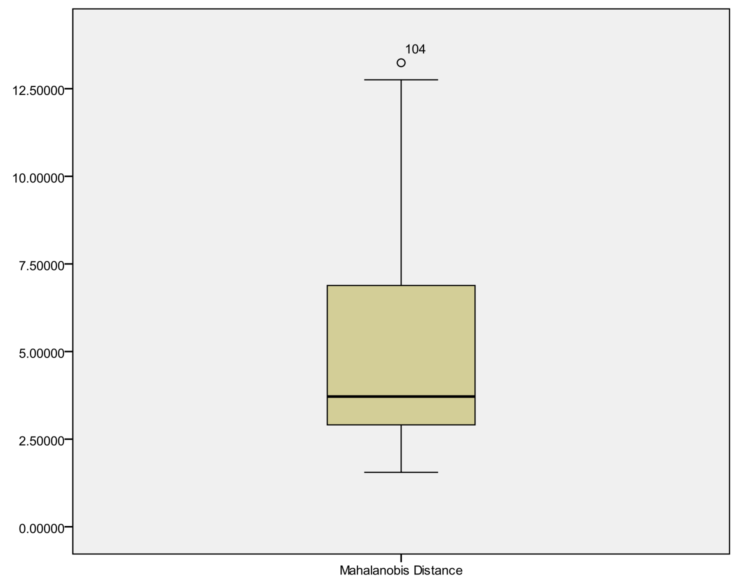

Figure 4-18. Box plot for Mahalanobi's distance scores of land health sustainability index.

Model Validation

Cross-validation of the new model was computed using R-version 12.13.0 software, package 'DAAG', which uses the *K* – fold method; whereas *K* was set to 3. All predictors were validated in the model contributing significantly (p < .01) (Table 4-28).

Table 4- 28.

K – Fold Cross-Validation of Land Health Sustainability Index

Variable	df	Sum Sq	Mean	Sq F	Value Pr (> F)
RestLand	1	160	159.5	12.10	.00071***
CostFence	1	127	126.7	9.61	.00244**
MyFriends	1	75	74.8	5.67	.01889*
NRCS	1	220	220.1	16.70	.000082***
Woodland	1	63	62.6	4.75	.03139*

n = 40
Overall means square 13.7
*** (p < .0001) **(p < .001) *(p < .01)

Regression for Social Index

Using the best fit model specified by BMA, six predictors accounted for just under 1/4 of the variance in economic sustainability index scores in the final model (R^2 = .228; adjusted R^2 =.118; $F(6,117) = 5.743$; $p < .001$) Therefore, null hypothesis of no linear relationship of Social Sustainability Index with the independent variables was rejected. Block two of the hierarchical regression model retained all 7 predictors (Table 4-29).

Table 4-29.

Hierarchal Regression Results for Social Sustainability Index

	Block 1			Block 2		
	b	β	Sig	b	β	Sig
Constant	21.088 (0.430)			21.062 (.422)		
InternalFence	10.381 (4.449)	.194	.021	10.077 (4.374)	.189	.023
Patches	12.859 (4.594)	.241	.006	13.391 (4.520)	-.251	.004
Goat	1.896 (0.408)	-.204	.030	-.937 (0.401)	-.213	.021
Hunting	.105 (0.035)	.285	.003	.111 (0.034)	.302	.001
Salesman	-16.613 (4.543)	-.311	.000	-17.775 (4.492)	-.332	.000
Mineral				9.995 (4.382)	.187	.024
R-squared		.193			.228	
Adjusted R-squared		.159			.188	
No. observatons	124					

Standard errors are reported in parentheses

In the first attempt to regress predictors on *Y* when analyzing Social Sustainability, potential undue influence was noted when a box plot was used to graph the distribution of Mahalanobis' distances (Figure 4-19). Indications were that 9 outliers were possibly creating instability in the sample.

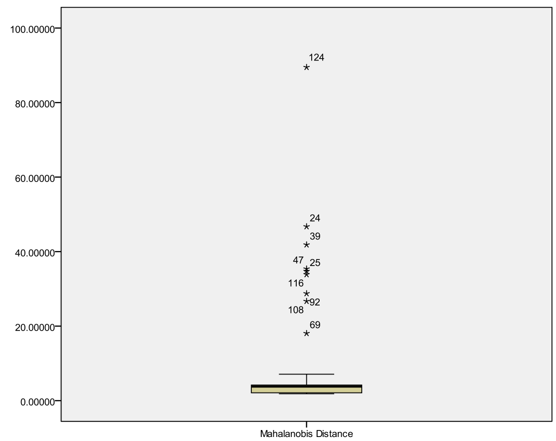

Figure 4-19. Box plot for Mahalaboni's distance scores of social sustainability index.

Again, an effort to determine the severity of the outliers was enacted. Outliers were identified as case number 24, 25, 39, 47, 69, 92, 108, 116, and 124. Mahalanobi's distance values were 46.72, 34.74, 41.84, 35.38, 18.06, 28.75, 26.68, 33.86, and 89.48 respectively. Raw DFFit statistic was used as primary criterion for case analysis, but standardized results were considered as well (Table 4-30).

Table 4-30.

Dffit Statistic For Land Health Mahalaboni's Distance Scores

Case	DFFit	Standardized DFFit
24	-.65875	-.24275
25	2.34647	1.00939
39	1.82120	.71090
47	-.87185	-.36836
69	-.87185	-.36836
92	.77466	.36205
108	.60542	.29321
116	-1.03335	-.44634
124	-.04891	-.01309

Keeping with the same standards set to identify outliers in the Land Health Sustainability regression analysis, by first attempting to use the DFFit statistics as an indicator of influence, a comparison of both the raw scores and the standardized scores was conducted. Of the nine cases, case 24, 92, 108, and 124 appeared to only be causing marginal issues with influence. Therefore, they were retained and the other 5 cases (25, 39, 47, 69, and 116) were removed. The model was re-run without these cases and the model was regressed again without the 5 selected outlying cases.

The original seven predictors accounted for 14% of the variance in Social Sustainability index scores in block 2 of the model (R^2 = .149; adjusted R^2.104; F (6, 112) = 3.272; p = .005), which was significant. Therefore, the null hypothesis was rejected. However, six outliers still were present in the new model (Figure 4-20).

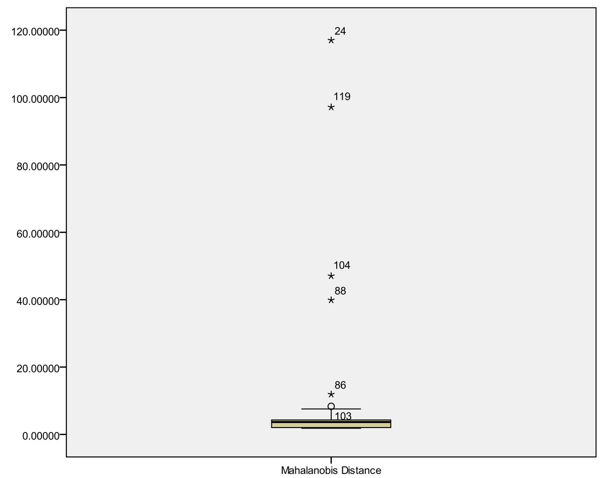

Figure 4-20. Box plot for Mahalanobi's distance scores of social sustainability index.

Outliers were identified again. They were case numbers 24, 86, 88, 103, 104, and 119. Mahalanobi's distance values were 117.01, 11.91, 39.89, 8.35, 47.05, and 97.14 respectively. Therefore, the DFFit statistic was used as primary criterion deletion of cases, once again (Table 4-31).

Table 4-31.

Dffit Statistic for Land Health Mahalaboni's Distance Scores – 2

Case	DFFit	Standardized DFFit
24	*	*
86	-.83689	-.58520
88	1.10207	.42826
103	.02451	.01989
104	1.94134	.69709
119	-1.76046	-.44096

* No value given by SPSS 18.0

From these statistics, the values for case 103 appear to be acceptable. Values from the other variables implicate them for removal. In particular the extremely high Mahalaboni's

Distance value associated with case 24 caused complications with SPSS software computation of DFFit values. Case 24, 86, 88, 104, and 119 were removed. The analysis was rerun.
Using the best fit model specified by BMA, 7 predictors accounted could not be conducted. The variable "salesman" has missing correlations and it was also removed.

Results, with just six predictors accounted for just about 16% of the variance in Social Sustainability index scores in the model (R^2 = .162; adjusted .123; $F(5,108) = 4.173$; $p = .002$) Therefore, null hypothesis of no linear relationship of Social Sustainability Index with the independent variables was rejected.

At this point, there had been removal of ten cases; eight additional cases were identified as outliers. Evaluation of their Malahabonis' distance scores revealed all were below a score of 14, which may be acceptable for purposes of this analysis. However, one case, 83, now had a Malahaboni's Distance score of 112.01. Therefore, it was removed. Another regression was computed.

Finally, a model was found with no Malahaboni's Distance scores above 13.83. The boxplot graph still identified several cases as extreme, but the normal (Q-Q) plot of Mahalanobi's Distance gave a visual representation of the expected normal distance when compared to the observed (Figure 4-21). The potential influence of all outliers was accepted, given the lower Mahalaboni's distances associated with these outliers.

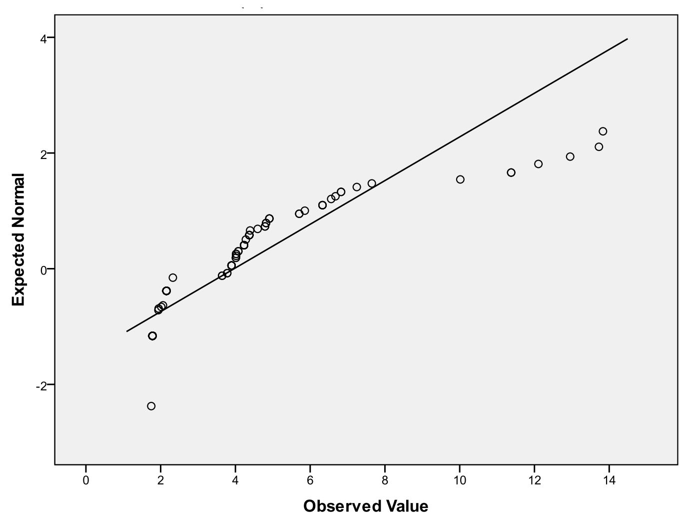

Figure 4-21. Mahalaboni's distance score (Q_Q) plot for social sustainability index.

Now that outliers are satisfied, the variable "goat" also had missing correlations and could not be used. The model with Social Sustainability Index regressed on the remaining four predictors (Table 4-32). Block two indicated 14% of variance in the Sustainability Index was explained (R^2 = .162; adjusted R^2 = .111; F (4,108) = 4.173) at a significant level (p = .002). Therefore, null hypothesis of no linear relationship of Social Sustainability Index with the independent variables was rejected.

The intent is to find the predictors that contribute a significant explanation to the variance of the Sustainability index. Hunting did not contribute at a significant level (t = 1.624; p = .107). Therefore it was removed from consideration and the model was rerun.

Table 4-32.

Hierarchal Regression Results for Social Sustainability Index

	Block 1			Block 2		
	b	β	Sig	b	β	Sig
Constant	20.910			20.831		
	(.476)			(.466)		
InternalFence	10.633	.207	.025	9.974	.194	.032
	(4.681)			(4.579)		
Patches	10.967	.212	.025	11.820	-.228	.014
	(4.829)			(4.727)		
Hunting	.106	.129	ns	.121	.149	ns
	(.076)			(.075)		
Mineral				11.471	.225	.013
				(4.567)		
R-squared		.093			.143	
Adjusted R-squared		.068			.111	
No. observatons	113					

Standard errors are reported in parentheses

The results of the next regression analysis still indicated significance, so that the null hypothesis that no linear relationship of Social Sustainability Index with the independent variables was rejected again. This time, only twovariables, “Patches”, and “InternalFence” were identified as significant (Table 4-33). Therefore, block 1 of the hierarchical regression analysis was accepted as the most parsimonious model, explaining less than 8% of the variance in the index (R^2 = .077; adjusted R^2 = .060; F (2,110) = 4.599) at a significant level (p = .021).

When assessing the accuracy of the hierarchical regression model first there is a need to check how well the model fits the observed data. There was an absence of high correlations between predictors (Table 4-34). Variance Inflation Factor (VIF) values below 10 and tolerance values well above .2 indicate that multicollinearity is not an issue (Table 4-35) (Field, 2005).

Neither was homoscedasticity, indicated by the Durban-Watson test (2.297). Values less than 1 or greater than 3 are cause for concern (Field, 2005).

Table 4-33.

Hierarchal Regression Results for Social Sustainability Index – 2

	Block 1			Block 2		
	b	β	Sig	b	β	Sig
Constant	21.228			21.507		
	(0.419)			(.513)		
InternalFence	10.483	.204	.028	10.657	.208	.026
	(4.700)			(4.706)		
Patches	9.558	.185	.046	9.895	.191	.040
	(4.740)			(4.756)		
Mineral				-.013	-.087	ns
				(.013)		
R-squared		.077			.085	
Adjusted R-squared		.035*			.059	
No. observatons		113				

Standard errors are reported in parentheses
* denotes *adjusted* R^2 using Stein's Formula

Table 4-34.

Pearson Correlation Social Sustainability Index

		1.	2.	4.
DV = Social Index	1.000	**.207**	**.188**	**.214**
1. InternalFence	**.207**	1.000	.017	.058
2. Patches	**.188**	.017	1.000	-.054
4. Mineral	**.214**	.058	-.054	1.000

Sig. (1-tailed) (p < .05)
N = 113

Table 4-35.

Collinearity Statistics Social Sustainability Index

	Tolerance	VIF
(Constant)		
InternalFence	.985	1.015
Patches	.924	1.082

The histogram of the standardized residual values was produced (Figure 4-22). It is as expected, close to normally distributed around a mean of zero. Also, the Normal Probability Plot of Regression Standardized Residual values was computed (Figure 4-23). The plotting of points very near the reference line indicates little deviation of expected values from observed values.

Standard Deviation of the Standardized residuals was .987, which is within the 95% confidence level of normally distributed samples (Field, 2005). Outliers were still within tolerable levels with the case with the most extreme Mahalaboni's distance being case 106, with a score of 9.28.

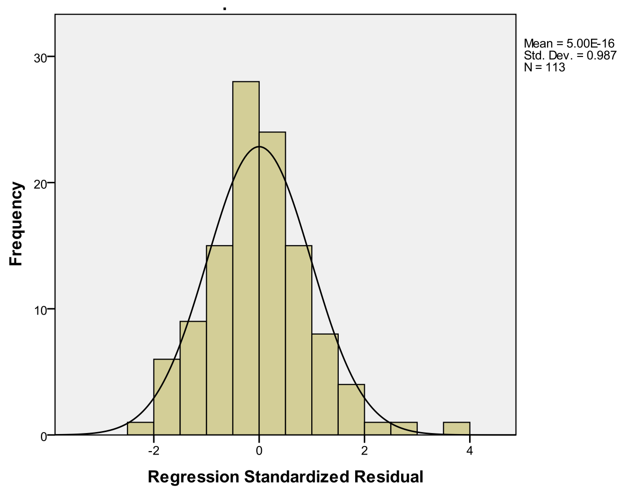

Figure 4-22. Standardized residual histogram
for social sustainability index.

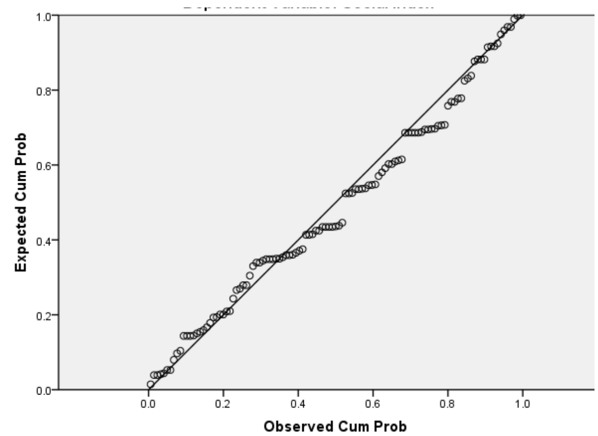

Figure 4-23. Normal probability plot for standardized residuals for social sustainability index.

Model Validation

Cross-validation of the new model was computed using R-version 12.13.0 software, package 'DAAG', which uses the *K* – fold method; whereas *K* was set to 4. All predictors were validated in the model contributing significantly (p < .01) (Table 4-36).

Table 4- 36.

K – Fold Cross-Validation Of Social Sustainability Index

Variable	df	Sum Sq	Mean	Sq F	Value Pr (> F)
InternalFence	1	101	101.5	5.13	0.025 *
Patches	1	80	80.4	4.07	0.046 *
n = 28					
Overall means square		20.6			
*(p < .01)					

Non-Response Bias

A one page mail questionnaire was sent to 50% of the non-respondents. This equated to sending 181 surveys to a list of non-respondents which was derived by random generation using Microsoft Excel containing 362 names and addresses.

The questionnaire included 9 questions. These questions were simple and easy to answer. They were designed to link each question directly with a question in the initial questionnaire in order to compare response patterns between the original respondents and the non-respondents who answer the short questionnaire. The first question allowed the respondent to clarify why they had not responded to the original survey. Questions collected information concerning personal characteristics: amount of rangeland managed, years at current address, age, gender, percentage household income dependent on the land, if they utilized rotational grazing, and where they obtained grazing management information.

The one page mail questionnaire was intended to be sent only one time, thus no coding was included. The rate of response targeted for a random subset of non-respondents is only 10% (U. Kreuter, personal communication November 7, 2010). Therefore the response rate obtained here (28 respondents or 15.4%) was deemed adequate. Survey respondents not responding the first time are likely not to complete and return a shorter mail survey either.

Of the 28 respondents, one (1) did not return any information, only a blank form. Two (2) more only answered the question number one, the reason for not responding. An additional 4 indicated they had responded to the original survey. The survey with no information had to be discarded and the information from the 4 that claimed to have responded to the other survey were also removed from the data set so as not to duplicate the cases. This left 23 unique non-response survey participants from a population of 177, making the response rate 12.99%. Only 21 cases (11.86%) contained enough information for analysis, meeting the target number of responses.

The 4 respondents replying that they had already responded were examined to assure that respondents only replied one time. The possibility of not including respondents that did attempt to reply was investigated. A short explanation of possible reasons for the inconsistency is discussed in the following bullets:

- Obvious complications could arise from returns being lost in the mail, or lost during transport. Returned questionnaires were handled by the University post office, the administrative personnel at the Institute of Applied Science at UNT and by this researcher.
- There were two (2) instances of returned questionnaires with the unique coding removed. This action could have been intentional or an inadvertent result from the respondent removing the cover page during their response or prior to returning. One of these cases was received after the first mailing of the questionnaire and one after the second mailing of the questionnaire. Therefore, they were visually evaluated for similarities. Finding none, they were both used during the analysis.
- A potential respondent could have filled in the survey and not remembered that they had not mailed it.
- A final explanation for respondents to the original survey receiving a nonresponse questionnaire would be sending multiple surveys to the same household. This is possible, while every effort was made to eliminate the possibility of sending multiple surveys to the same person, one must consider the original data set. The set was obtained from the local tax appraisal offices. One person, or household, with separate land holdings greater than 500 acres would be returned as two or more cases as long as the name on the tax offices list had any differences at all. This included different addresses (e.g. a post office box vs. a rural mailbox), different names (e.g. a land holding owned by one spouse vs. a land holding in both spouses names; or a landholding listing the same owner with different versions of the same name – one using the middle initial. one without the middle initial or one holding in the individuals name and one in a farm name).

Of the 21 remaining surveys, the reasons for not responding varied. One person checked 4 reasons for not responding. Everyone else checked only 1. Reason for not responding, with the number choosing that reason, is as follows:

- Did not receive survey – 0
- Did not believe the survey was really anonymous – 1
- Did not pertain to me – 1
- Lack of time – 8
- Survey was too long – 2
- Chose not to participate – 5
- Other – 6

Of the selections for other, explanations were: Cancer; Received Mailings/didn't notice survey; Gave to mother; Land is leased out (3); and don't do surveys with comparisons.

Table 4-37 gives the descriptive information collected from numeric variables for the non-respondents.

Table 4-37.

Non-Response Descriptive Statistics For Select Variables

	N	Mean		Std. Deviation
	Statistic	Statistic	Std. Error	Statistic
Years Managing Range	20	37.60	6.772	30.287
Years at Current Address	21	26.14	4.210	19.293
Age	20	45.75	2.522	11.281

Other information collected indicated that of the 21 in the population is included in Table 4-38.

Table 4-38.

Percentages Non-Respondents Vs. Respondents

Statistic	Non-Respondents	Respondents
Percent Male Respondents	76%	83%
Percent Using Some form of rotational grazing	80%	69%
Internet	48%	35%
Periodicals	33%	1%
University	29%	0%
NRCS	33%	40%
Extension	48%	46%
Peers	43%	53%
Salesman	48%	3%
Consultant	10%	24%
Store	10%	18%

The demographic data "years managing range" and "age" were subjected to nonparametric independent samples significance tests to compare means between the respondents and the non-respondents (Table 4-39). Neither variable could disprove the null hypothesis that the samples were not random ly distributed using the Wald-Wolfowitz Runs test. The variable “years managing range” could not disprove the null hypothesis that the distributions were significantly different using Median, the Mann Whitney U test, nor the Kolmogorov-Smivov test. However, all of these tests suggested that there was a significant difference in the age of the respondent vs. the non-respondents.

Table 4-39.

Non-Response Hypothesis Test Summary

Null Hypothesis	Test	Significance	Decision
Distribution of Years Managing Range is the same across categories of groups	Mann Whitney U	.653	Retain
	Kolmogorov-Smimov	.773	Retain
	Wald-Wolowitz Runs	.673	Retain
Distribution of Age is the same across categories of groups	Mann Whitney U	.000	Reject
	Kolmogorov-Smimov	.000	Reject
	Wald-Wolowitz Runs	.598	Retain
Median of Years Managing Range is the same across categories of groups	Median Test	.396	Retain
Median of Age is the same across categories of groups	Median Test	.000	Reject

CHAPTER V

SUMMARY

This summary begins with useful information for interpretation of the results. Then three separate sections discuss the findings from the regression analyses. The sections are separated based on results which aid in assessing economic, environmental and social sustainability for rangeland in North Central Texas. Each section first describes the indices which is the dependent variable for the regression analysis and is representative of one part of rangeland sustainability. Then the meaning of the relationship of each predictor is discussed. Finally, conclusions are drawn about the results of each model.

After the statistical conclusions, the findings are compared to the original hypotheses formulated prior to initiation of the study. Then there is a discussion of how these findings compare to the general study objectives and what implications they may have in effecting rangeland sustainability. Continuing next, there are acknowledgements of study limitations and implications for future research. Finally, a conclusion is drawn.

Interpretation of Regression Results

A thorough understanding of the predictors and the direction of the relationship with the sustainability indices is key to understanding the results of this study. It is important to remember that the original data, used for the predictors, was transformed using optimal scaling with the LINEALS approach, using the R package 'aspect'. With this approach, transformations occurred which changed the interpretation of the results. These transformations reversed the direction of the original coding for some predictors. This was caused because the LINEALS approach may "flip" the original variable input when it transforms the data to make it more linearly related (Starkweather, personal communication, July 18, 2011).

The LINEALS approach makes transformations which minimize the sum of differences between the correlation ratios and the squared correlation coefficients on each variable separately. The LINEALS output was a data matrix, which was optimally scored and could be used for subsequent analysis (Mair, and de Leeuw, 2008). The computed data matrix made comparisons between differing types of variables achievable (e.g. dichotomous and Likert Scale). Since such a re-expression is better suited for further analysis than the original data, that re-expression was used (de Leeuw, 1988).

Because of the ability of the optimal scaling process to flip the original variable scores, interpretation of the subsequent analysis must be done carefully. Optimal scaling to achieve bilinearization with LINEALS will have the effect of transposing the direction of the original coding for some of the variables, but not all; whereas "aspect-based techniques "unstrain" the distribution by finding the inverse transformations, for some families of data, which makes the distribution of the variables multinormal (Mair, and de Leeuw, 2008). It is apparent that the transformation must be examined in relation to the original variable coding to understand the direction (positive or negative) of the relationship between predictors and the dependent variable with multivariate regression analysis. Therefore, optimal scaling transformations will be examined for each predictor of the 3 sustainability models investigated in this study. Category scores, which are available as output from LINEALS, reveals this relationship.

Table 5-1, 5-2, and 5-3 identify each of the predictors, indicate positive or negative association with the applicable index, describe the original question, the effect of the optimal scaling process on the original variables and offers rationale suggested by the direction of the relationship with the index.

Table 5-1.

Predictors Relationship with the Economic Sustainability Index

Variable	Relationship with Index	Question /Type of Question	Original Coding*	Value by Optimal Scaling	Rationale
Consider Cost of Inaction	Negative	I Consider Cost of inaction as well as cost of action before making management decision /7 Likert	1=Strongly Agree… 7=Strongly Disagree	1 0.1516 2 -0.0195 3 -0.0914 4 -0.0914 5 -0.0914	Considering the cost of inaction tends to move respondents toward greater economic sustainability. - Increase in agreement = greater optimally scaled score. The negative association with the index results in respondent's move down the Index (toward greater economic sustainability)
Forbs Valuable	Negative	I considers forbs as a valuable source of forage for wildlife or livestock /7 Likert	1=Strongly Agree… 7=Strongly Disagree	1 0.1446 2 - 0.0411 3 - 0.0656 4 -0. 0656 5 - 0.0656 7 -0.0656	Considering forbs as a valuable source of forage tends to move respondents toward greater economic sustainability. - Increase in agreement = greater optimally scaled score. The negative association with the index results in respondent's move down the Index (toward greater economic sustainability)
Brush Control	Negative	Government should offer incentives for brush control / Yes/No	0 = no;1= yes	0 -0.0927 1 0.0870	Belief that the Government should provide incentives for brush control tends to represent a move toward economic sustainability. - Yes response = higher optimal scaled value; the negative association makes this a move down the index (toward economic sustainability)
LOPNurban	Negative	I Live in an urban area of Texas; not on the ranch / Yes/no	0 = no;1= yes	0 0.0445 1 - 0.1830	Living in an urban area of Texas tends to move the respondent away from economic sustainability. - Yes response = lower optimal scaled value; the negative association with the index results in a move up the index for a yes response (away from economic sustainability)
RankofLand Health	Positive	Rank concern for Land Health in comparison with : Profit; Cattle Productivity; Tax Issues; Family Issues; Neigbr Issues; Weathr	1 = first preference… 7 = last preference	1 0.1012 2 - 0.0170 3 - 0.0170 4 -0.0989 5 -0.0989 6 -0.0989	Valuing land health above other choices results in a loss of economic sustainability. - Increase in preference = increase in optimal scale value. The positive association with the index means that the greater the value placed on land health, the greater the score on the index – resulting in a move away from economic sustainability

*Frequency of Likert Scale selections not listed = 0

Table 5-2.

Predictors Relationship With The Land Health Sustainability Index

Variable	Index Relation	Question /Type of Question	Original Coding		Optimal Scaling	Rationale
CostFence	Positive	Recognition that fence cost is an obstacle to grazing distribution	0 = no;1= yes	0 1	0.0802 -0.1006	Not recognizing the cost of fence as an obstacle for increasing livestock distribution tends toward greater land health sustainability. - Yes response = lower optimal scaled value; the positive association with the index resulting in a move down the index (away from land health sustainability)
RestLand	Positive	I rest the land for a portion of the growing season as a critical component of my grazing plan.	1 = true; 2 = false	1 2	0.0417 -0.1934	Including land rest as component of grazing plan tends toward greater economic sustainability. – A response of false results in lower optimally scaled scores. Positive relationship represents trend of both predictor and dependent variables to move in positive or negative direction together. True response = higher optimally scaled score and a move toward land health sustainability
NRCS	Negative	Respondent uses the NRCS as a source of grazing management information	0 = no;1= yes	0 1	0.0738 -0.1092	Using the NRCS as a source of grazing management information tends to move respondents toward economic sustainability. – A response of no results in greater optimally scaled values. Negative relationship represents trend of predictor and dependent variables to move in opposite directions (one moves higher/the other lower). Resulting: Yes response = move(toward land health sustainability)
DenseBrush	Negative	Percentage of respondents' rangeland covered in dense brush or woodlands	Percentage (treated as continuous data; no optimal scaling utilized)		Not Applicable	The greater the respondents land area covered in woodland and brush; the less sustainable the trend is toward less economic sustainability. – Optimal scaling is not an issue; negative relationship represents trend of predictor and dependent variables to move in opposite directions (one moves higher/the other lower). Resulting in: Higher percentage reported = move down the index (away from land health sustainability)
MyFriends	Negative	Respondents Consider friends when making management decsns	0 = no;1= yes	0 1	-0.1833 0.044	Not considering friends when making management decisions results in greater economic sustainability. - A response of yes results in greater optimally scaled values. Negative relationship represents trend of predictor and dependent variables to move in opposite directions (one moves higher/the other lower). Yes response = move down the index (away from land health sustainability)

Table 5-3.

Predictors Relationship With The Land Health Sustainability Index

Variable	Relationship with Index	Question /Type of Question	Original Coding		Transformed Value by Optimal Scaling	Rationale
InternalFence	Positive	Respondent utilizes internal fencing to distribute livestock over the rangeland /Yes-No	0 = no;1= yes	0 1	- 0.1432 0.0563	Using internal fence to distribute livestock over the rangeland does not increase social sustainability. - Yes response = greater optimally scaled value. The positive association with the index indicates that as respondents select "yes" their scores tend to move up the index (away from social sustainability)
Patches	Positive	Respondent has heavily used and lightly used (uneven) forage utilization / True-False	1 = true; 2 = false	1 2	0.0631 - 0.1278	As respondents notice uneven forage utilization, they tend to be less aligned with social sustainability. - True response = greater optimally scaled values. The positive association with the index means that as respondents tend to answer "true"; their index score moves up the index (away from social sustainability

Key Predictors Influence on Economic Sustainability

This Economic Sustainability Index was a combination of 6 indicator variables that favored respondents with the point of view that rangeland economics were affected by environmentally conscious grazing practices. It also identified respondents' perception of the ability of grazing practices to decrease future risks and therefore reduce future economic difficulties. The index gave preferential scores to those who managed their ranch in a sound business manner by planning ahead and knowing production costs. Finally, self assessment of financial stability was included in the index with scores indicating greater sustainability going to those who perceived their rate of return as above average.

A reliability analysis confirmed that respondents had similar answer patterns for the variables included in this scale ($\alpha = 0.722$). This is an acceptable level of similarity by most standards (Nunnaly & Bernstein, 1994; Starkweather 2011b; Garson, 2011c). The economic index was only able to identify those who perceived that they conducted their business, in what would be assumed to be consistent with sound economic practices. The only direct link to actual financial success was the self assessment of rate of returning being greater than average. A truly comprehensive economic sustainability index would necessitate the investigation of financial records, which could not happen in the environment of this study nor under the IRB approval for the study.

The model regressing Economic Sustainability Index included five variables from the questionnaire. They were named "Consider Cost of Inaction", "Forbs Valuable", "Brush Control", whether the respondent lives in an urban area rather than on the ranch "LOPNurban", and "RankofLand Health". The model explained 36% of the variance in the respondents' Economic Sustainability Index scores ($R^2 = .360$; adjusted $R^2 = .304$; F (5,118) = 12.212; p <

.001). The results show that all predictors in the model were statistically significant in assessing the variance in economic sustainability for the study population ($p < .05$).

The standardized model predicting outcome of the Economic Sustainability Index (adjusted $R^2 = .195$; $p < .001$) is as follows:

Economic Sustainability Index = -.467(Consider Cost of Inaction) - .278 (Forbs Valuable) -.179 (Brush Control) -.215(LOPNurban) + .175(Rank ofLand Health)

The economic sustainability index had a negative relationship with variables "Consider Cost of Inaction". The negative association with the index is explained by the investigating the relationship between the optimally scaled variable score and the original coding with the index. The closer to "1" or "Strongly Agree" a respondent's answer, the greater the optimal scaling score. Therefore, as a land manager more strongly agreed with the fact that they considered the cost of inaction as well as action the negative association with the index resulted in respondent's move down the index (toward greater economic sustainability). In essence when respondents more strongly agreed with the statement that they considered both the cost of action and the cost of inaction when making management decisions, they tended to move their economic index score toward sustainability. These results are consistent with what one may assume a conscientious land management philosophy may be. Considering inaction equally, with action, would align with pasture deferment from use at times of greater stress, such as during a drought, which has land health benefits (Teague et al., 2004). Sullivan (2001) noted that holistic resource management provides people with a means to make decisions that more accurately mirror the way nature functions, and thereby ensure that our civilization is truly sustainable over time" (Sullivan, 2001). In this case, "Consider Cost of Inaction" also indicates willingness to accept natural processes as a part of the management scheme. Disagreement with this would indicate a philosophy whereby man can adjust for nature.

Also "Forbs Valuable" had a negative association with the economic index. The relationship between the optimally scaled score and the original Likert Scale coding are the same as in the prior example. Therefore, this association is affirmation that respondents who did consider forbs as a valuable source of forage for livestock and wildlife tended to have more sustainable scores on the economic index. This indicates that economic sustainability is at least somewhat aligned with use of diverse enterprises, as domestic goats and sheep are greater consumers of forbs than cattle (Holechek, 1984). Diverse enterprises could also be described as multiple species of livestock, wildlife production, wildflower viewing, etc. In general biodiversity is desirable, and would indicate ecological conscientiousness. This is evident with findings that indicate the rangeland is best managed for diversity and ecological function under the watchful eye of the conscious agrarian (Hughes, 1983; Dagget, 1995).

The relationship identified may indicate optimizing opportunity, especially in that of capitalizing from wildlife resources and recreation whereas hunting, exotic animals, and recreation resulted in 8.34% of respondent's income. However, the use of multiple species of livestock to enhance sustainability and diversity still appears to be an untapped economic opportunity. Respondents utilizing sheep or goats enterprises only comprise 0.2% of respondent's income.

A negative relationship was noticed with the variable "Brush Control" and the economic sustainability index. Optimally scaled values were greater for respondents choosing "yes", meaning a negative relationship to "Brush Control" would indicate greater Economic Sustainability; as the optimally scaled value moved up, the index score moved down (toward sustainability). Therefore, greater economic sustainability was obtained by those agreeing with government providing incentives for brush control. This relationship may be an indication that government assistance in areas of critical concern, such as brush encroachment, adds stability to rangeland enterprises, thus moving the respondent toward economic sustainability. It is known that brush encroachment is expensive in both the cost of control and the cost of lost productivity (Towne and Ohlenbusch , 1992). This variable being identified as a predictor for economic sustainability, leads to the belief that the problem of brush encroachment is one that presents economic strain to ranch managers. Implications are that managers do not have the resources, on their own accord, to fully deal with this problem. There obviously exists a desire to eliminate brush from the rangeland. This is also aligned with the native ecological state of the tall grass prairie. Bakker and Berendse (1999) suggest that the current intensity of agricultural use sets the rate of recovery for rangeland which has been encroached upon by brush.

The variable "NOPNurban" was a demographic variable added to separate the urban respondents from rural respondents. Living in an urban area of Texas predicted a less sustainable index score. A respondent indicating that they lived in an urban area corresponded with a lower optimal scaled value. Because of the negative association with the index this meant a response of "yes" caused a move up the index (away from economic sustainability). There are several theories that could explain this phenomenon. Living in an urban setting would suggest that ranching may not be the primary source of income for the respondent. Economic sustainability may not be as important to these respondents as there may be additional income sources. Without economic incentive an urban resident may be less proactive in their business procedure, possibly less likely to implement a long-range plan, or know production costs, or hold a lesser degree of belief that grazing management is influential on economic risk and long-term economic performance of the ranch. In addition to these theories, Beem (2010) suggests that absentee landowners would incur economic difficulties because they lack knowledge concerning tenants care for the land.

Valuing land health above 6 other choices resulted in a decline of economic sustainability. An increase in preference was similarly met with an increase in optimal scale value. The positive association with the index means that the greater the value placed on land health, the greater the score on the index – resulting in a move away from economic sustainability. The positive relationship between the Economic Sustainability index and the variable "RankofLand Health" indicates a lack of desire for the economically sustainable ranch to maintain a healthy landscape. Respondents were asked to rank seven things in order of importance. These were: profit, productivity, land health, tax issues, family issues, neighbor issues, and weather. The choice of land health was denoted as "RankofLand Health". The relationship of this predictor with the index indicates that conscious, environmental stewardship choices and economic sustainability are not aligned in the mind of the respondents.

Most of the predicting variables are philosophic in nature; in fact, three of the variables came directly from the section 1 of the questionnaire, titled "Management Philosophy". The other variables identified as predictors are also philosophic in their nature. "RankofLand Health", which originated in section 5, "Quality of Life", suggests respondents' values. It can be hypothesized that living in an urban area would lead to different values and resulting philosophy from respondents living in a more rural setting, as indicated by the predictor "LOPNurban, a demographic variable from section 6. These facts result in the conclusion that the Economic Sustainability Index, as calculated within this study is a function of ranchers' philosophy, or mind set.

The results presented here also agree with research that has shown that the traditional management regarding livestock is as philosophic as it is economic. Attaining philosophic and economic goals outweigh expenses incurred to the environment. Indications are that producers view cattle ownership as a means to: (1) ensure they are able to continue land ownership; (2) as a source of security and liquidity, and; (3) as a way of life worthy of passing to the next generation (Costa and Reham, 2005). These findings are also in alignment with Chouinard et al. (2008), who found profit-maximizing motivations coincided with valuing environment only to the extent that it provided direct personal benefits for farmers in Washington State. If nothing else, one can begin to understand the dilemma between the "sustainability movement" and the rancher. The sustainability movement tends to focus on land health, where the economically successful rancher doesn't readily recognize the connection. This realization is a confirmation of the traditional rancher stereotype.

Even with confirmation of the stereotype, the predictors "Consider Cost of Inaction" and "Forbs Valuable" may be identifying the beginning of a shift from these historic trends. Even though ranchers have not embraced land health has a means of economic sustainability (indicated by "Rank of Land Health"), this study provides a means of qualifying diversity and natural processes as aligning with economic sustainability. Obviously some ranchers have begun to recognize this and are implementing these philosophies in their management practices. Comparison of these philosophies has now revealed alignment with economic benefits. Further evidence that some adoption of land friendly management has occurred is supported by the Sustainable Rangeland Roundtable (2005). They stated an examination of rangeland health and productive capacity, showed that rangeland health, although measured differently over the 20 years, had clearly improved during this time in most regions.

Kreuter et al. (2006) hypothesized that land owners in states with significant areas of public land might be less resistant to managing land in ways that enhance the delivery of socially desirable ecosystem services compared to landowners in private land states (such as Texas). The implication was that land managers might be need assurances that private property rights will not erode as a result of adoption of land management practices that enhance delivery of ecosystem services on privately owned rangelands. This hypothesis could be expanded to combine the notion that private land ownership may indirectly include profit maximizing motivations. In order to motivate landowners to adopt ecosystem friendly practices, it must be demonstrated how placing value in the environment could provide direct personal benefits like profit maximization. Again, evidence that this is beginning to occur is reiterated by this study as two predictors ("Forbs Valuable" and "Brush Control") indicating concern for natural processes, and increased interest in biodiversity are significant predictors for economic sustainability

Rangeland economic sustainability does not appear to be a motivator which would result in adoption of different management purely for the broad sense of societal or ecological needs. Instead, in order to motivate landowners to adopt ecosystem friendly practices, it must be demonstrated how placing value in the environment could provide direct personal benefits like profit maximization.

The objectives of this study stated a desire to address data gaps and research needs associated with rangeland sustainability indicators. The predictors for economic sustainability indicate that valuing land health is not indicative of economic sustainability. Historically, profits were realized by depleting the range (NRCS, 2000). Further, Leopold (1938) believed over 60 years ago, that the overall societal management system in place was a problem. It was then driven by governmental policy and by economics. In that atmosphere, it was impossible for many land managers to implement more ecologically sound practices without the notion of economic gains. The findings of this study cannot dispute this notion.

This model emphasizes the need for research to address ecology and/or social satisfaction as an economic resource; specifically there are two suggested actions. First, target education to ranchers where sustainability is addressed in a manner which fosters recognition of direct benefits to their economic well-being. Secondly, continued investigation of interactions between land rest and other grazing management variables is necessary to fully understand how to best deliver education concerning ecological benefits it offers.

Key Predictors Influence on Land Health Sustainability

The Land Health Sustainability index was composed of a series of 16 questions that asked respondents to identify changes in characteristics of their rangeland as evaluated by the plant community, the native animal community, land erosion and water infiltration. The 16 questions are assessments of land health indicators which ask for the direction of change, rather than a direct measurement. This is important given that ecological sites are constantly changing. Self assessment of land health in this manner is relevant as revealed by Knapp and Fernandez-Gimenez (2009) when they found that rancher knowledge complemented scientific knowledge in its ability to provide site-specific information on management practices and ecological responses, and insight regarding potential indicators of rangeland health. Therefore, this index should be capable of gauging ecological attributes of a ranch as assessed by Cronbach's alpha (α =.710).

The Land Health Sustainability scores were calculated so that greater sustainability was aligned with a decrease in level of mesquite, juniper, other brush, bare ground, invasive weeds, livestock trails, gullies, soil compaction, short grass, evidence of elevated rocks or clumps, evidence of plant litter clinging to grass clumps and stones, and other water flow patterns. Greater sustainability was indicated by an increase in tall grasses, turkey, quail, other birds, wild hogs, and deer.

The Land Health Sustainability Index was regressed on 5 predictors CostFence, RestLand, NRCS, DenseBrush, and MyFriends. This model explained 30% of the variance in

Land Health Sustainability Index scores in the final model ($R^2 = .300$; *adjusted* $R^2 = .23$; (5,114) = 9.766; $p < .001$), which was highly significant.

The standardized model predicting outcome of the Economic Sustainability Index is as follows:

Land Health Sustainability Index =.238(RestLand) - .215(NRCS) + .255(CostFence) - .181(Woodland) -.217(MyFriends)

When investigating the relationship of the predictors to the Land Health Index, the predictor "RestLand" had a positive relationship with the index. Given that the optimally scaled values align with a higher value being place on a response of "true" by the respondents; this relationship indicates that respondents who are including pasture rest in their grazing management plan obtain more sustainable scores on the Land Health Sustainability index. This observation is supported by overwhelming evidence from literature (Smith 1895; Sampson 1913; Rogler 1951; Scott 1953; Matthews 1954; Merrill 1954; Hormay 1956; Hormay and Evanko 1958; Hormay and Talbot 1961; Hormay 1970; Reardon and Merrill, 1976; Booysen and Tainton 1978; Taylor et al., 1980; Thurow et al., 1988; Taylor et al., 1993; Tainton et al., 1999; Snyman 1998; Teague et al., 2004; Müller et al., 2007;Teague et al., 2011, in press) .

The variable "CostFence" describes the respondent's view of the cost of fencing as an obstacle to increasing livestock distribution on their property. Since the optimally scaled score is greater for those respondents who indicate that the cost of fence was not an obstacle to livestock distribution, the positive association with the land health index indicates that a respondent believing cost of fence is an obstacle is less likely to have a high score on the land health sustainability index. It would be intuitive that those seeking to rest pastures would consider additional fencing to increase livestock distribution across their rangeland. This variable compliments the predictor "RestLand". Not considering the cost of building the fence as an obstacle would indicate that the respondent had the notion that additional fencing was a management practice they could implement. Therefore, respondents who were able to utilize more fencing were able to afford each pasture more rest, and therefore, they noticed a change in their land that is in agreement with greater land sustainability.

The variable “NRCS is an indicator of where respondents obtain information concerning grazing management. The Natural Resource Conservation Service (NRCS) is a branch of the USDA that is designed to recommend management practice that would be in accordance with grazing management which would conserve natural resources. Investigation of prescribed grazing guidelines for NRCS personnel are revealed in Section 5.1-2 of the National Range and Pasture Handbook, (NRCS, 2003). This is a resource for NRCS personnel that addresses prescribed grazing. It states “The management objective must meet the needs of the landowner, the resource, and the grazing animals.” The negative relationship observed in this study indicates that they are accomplishing their purpose. Where one may expect the relationship between “NRCS” and the land health sustainability index to be positive, the process of optimal scaling has clouded the issue somewhat. Optimally scaled scores are lower when respondents indicated they utilized the NRCS as a source of grazing information. As a result the negative association between the predictor and the index actually indicate that as respondents tended to utilize information from the NRCS, their resulting Land Health Index moved toward sustainability.

The negative association with the variable “DenseBrush” and the land health sustainability index is to be expected. This negative association can be taken at face value, as the nature of the original coding for the variable “DenseBrush” did not require optimal scaling procedures. One of the threats to the rangelands includes encroachment of woody plant species (Maczko and Hidinger, 2008). Specifically, past land use practices have created a landscape that has experienced invasion and domination, in some areas, by problematic brush species (Texas Parks and Wildlife, 2010). It has been shown that severely degraded rangelands have the propensity to shift to a stable, shrub-dominated state that will not return their original composition even with elimination of further grazing (Christensen et al., 2003).

The final variable under consideration is “MyFriends” had a negative relationship with the Land Health Sustainability Index. Optimal scaling resulted in scores which were greater when respondents did favor consideration of their friends when making management decisions. The finding tends to suggest that consideration of one’s friends would move the respondent’s index score away from land health sustainability. While it is difficult to develop a rational connection between sustainability and this variable, there is more than one possible explanation for consideration of friends in decision making. First, this consideration may be indicative of a hobby rancher, or of a ranch manager with little experience and a need for suggestions from a neighbor. This analysis would be consistent with the predictor “NRCS” being identified earlier. It is logical that this predictor may be an extension of where information is obtained. Another explanation would be that the ranch is recreational; ranch management and the ranching experience are desired to be shared with friends. Yet another explanation could be that it indicates pride in manager’s land and therefore, desire to include those close to the manager in the ranching experience.

It can be ascertained that “CostFence”, “RestLand”, “NRCS”, “DenseBrush” and “MyFriends” are predictors for the land health sustainability index. Results have been shown to be in agreement with many other sources of literature. The only predictor that leaves any uncertainty as to understanding the basis of its contribution is “MyFriends”, yet an explanation has been offered. The findings suggest whole-ranch assessment of land health sustainability is aligned with management philosophies where NRCS recommendations are utilized and friends are not included in the decision making process; where management practices such as additional fencing is not an obstacle and resting land is a component of the management plan; and where woody plants are not a major percentage of land characteristics.

Key Predictors Influence on Social Sustainability

The Social Sustainability Index was developed like the others, by maximizing the variables in the relevant section of the questionnaire for Cronbach's alpha coefficient. This index was derived from Section 5, which was titled Quality of Life. The index scores were calculated on the summation of the variables that were identified. The result of summing the question is that lower index scores indicated greater social sustainability.

Ultimately this index was made of seven questions, six of them resulting from the maximization for Cronbach's alpha, plus inclusion of one additional variable because of its perceived relevance to the index and minimal reducing impact on the overall coefficient. The procedure was only marginally successful ($\alpha = .655$). The variables making the index were indicators of work not infringing on free time; lack of interference with family; measure of satisfaction from ranch work; activity in the community; time to learn; existence of good relationships with neighbors; and involving stakeholders in the decision-making process. At face value these seem to be good indicators of social sustainability. But the Cronbach's coefficient score is never reached the critical value of ($\alpha = .70$). This low value is certainly cause for extra consideration concerning validity.

Two predictors were significant when the model for Social Sustainability Index was regressed. These two predictors were InternalFence and Patches. Results indicated that the model explained approximately 8% of the variance in the sample ($R^2 = .077$; adjusted $R^2 = .035$; F (2,110) = 4.599; p = .021). The standardized model predicting outcome of the Social Sustainability Index is as follows.

Sustainability Index = .185(Patches) + .204(InternalFence)

"Patches" had a positive association with the Social Sustainability Index, meaning that respondents noticing pasture utilization with heavily used and lightly used (uneven) forage tended to have Land Health Index scores that were indicative of less social sustainability. Patchiness is often a phenomenon associated with continuous grazing, or at least with long durations of animal herbivory without recovery time. Having patchiness was aligned with the social sustainability index in this study.

A positive relationship was noted between "InternalFence" and Social Sustainability scores. The variable was indicative of those who use internal fencing to distribute livestock; this is a measure that is consistent with rotational grazing. The more likely fencing was to be utilized, the less sustainable the index score. Grazing systems without internal fencing are typically continuous grazing.

Both of these variables come from section 3 in the questionnaire, "Native Rangeland Management". It is logical that management practices would directly relate to the social sustainability index. Positive relationship between the index and both variables implicates continuous grazing as a socially sustainable management practice. Of the 7 questions included in the index, 5 of them included a component that could identify time as an issue as it relates to the respondents ability to do other things. A possible explanation for the association of the predictor with the sustainability index could be continuous grazing has an advantage in that requires less labor and time (Hanselka et al., 2009).

The resulting conclusion is that the Social Sustainability Index model had several critical complications. First, the index had a very marginal score for internal consistency. Next outliers in the data were a great concern when working to discern the most parsimonious regression model. Finally, the best model that can be defended as accurately identifying the variability in the sample can only account for 8% of the variance. Even though, when carefully considering the relationship of the predictors with the independent variable, they do implicate continuous grazing as an easier means of managing grazing, the final conclusion is that acceptance of the model presented here would be a mistake because of the likelyhood of committing a type one error. Therefore, not much can be learned from this portion of the study.

Hypotheses

Five hypotheses were formulated prior to the onset of the study. In relation to these hypotheses, 4 out of the 5 were confirmed during the analyses. The 1 that was not confirmed was partially found to be correct. A discussion of each of these hypotheses follows.

First land manager perceptions of sustainability based on whole-ranch observations were only partially confirmed as centering on productivity and profit. Whole-ranch observations concerning sustainability of rangeland did not specifically identify a predictor that pin-pointed these motivations. However, analysis of the economic sustainability did reveal tendencies towards profit and production motivators. Specifically, it implicated philosophic values which aligned with, 1) consideration for natural processes; 2) diversity; 3) ready acceptance of government assistance; 4) lower esteem for land health than productivity, profit, and other concerns; and 5) not living in an urban area of Texas. These predictors seem to indicate profit motivation above concern for land health.

Next management practices being implemented did vary widely. Looking at section 3, “Native Rangeland Management”, most questions were dichotomous. The results indicated answers of “true” and answers of “false” for every question. Frequency of responses were nearly equal for most variables, indicating a range of management practices. Further, the question, “3.1”, ask respondents to characterize their grazing system where, pasture was synonymous with paddock, as continuous, rotation with 4 or fewer paddocks, rotation with 4 to 8 paddocks, rotation with more than 8 paddocks or other (*M* = 2.28, *SD* = 1.124). The results were that 69% of respondents implemented some form of rotational grazing. The distribution of the number of paddocks utilized varied near what would normally be expected indicating a variety of management practices being utilized.

Land managers did limit implementation of grazing strategies perceived as sustainable based on cash flow but not labor. Cash flow was indentified in two separate instances by regression models. The analysis of the economic sustainability index identified "Brush Control" as predictor, indicating a need for government financial assistance to manage brush. Similarly, the analysis of the land health sustainability index identified "CostFence" as a possible obstacle in distributing livestock, indicating that a lack of cash flow available to build fence could limit the distribution of livestock on respondents' land.

Another hypothesis was that rangeland sustainability will be predicted by grazing management practices, philosophy, and land owner characteristic. Indeed, rangeland sustainability was predicted by these latent concepts. Variables from all sections of the questionnaire were implicated as predictors of varying sustainability indices.

Finally in regards to hypotheses, findings concerning landowner grazing management, via the survey instrument, did compliment physical, experimental studies, solidifying whole-ranch assessment of ecological sustainability. In the north Texas area, Teague et al. (2011) found positive results for long-term maintenance of resources and economic viability by ranchers who use adaptive management and multi-paddock grazing relative compared to those who practice continuous season-long stocking. The land health sustainability model indicated land rest as a critical component of respondents' grazing plan does move respondents toward unsustainable land health.

Objectives

Beyond the hypotheses, in accordance with study objectives, the study contributed to the knowledge base which can be used by agencies, universities, and organizations that are focused on developing methods to address data gaps and research needs associated with rangeland indicators. Specifically, using indices for whole-ranch assessment of rangeland indicators allows self assessment of rangeland by ranch managers. Self assessment is accomplished through the use of a questionnaire which was used to create sustainability indices by which to compare ranch manager's philosophies, economic condition, management practices, land health, quality of life, and personal characteristics. Using indices as indicators in this manner was a novel method.

The study also improved accountability for rangeland stakeholders by using the sections pertaining to philosophy, management practices, and personal characteristics, to quantify sustainability. This helped improve muti-scale, coordinated data reporting. Once the data are reported in peer reviewed journals, the study will aid in providing a basis for stakeholder dialogue at local, regional and national scales to further understanding of rangeland sustainability.

General Findings and Implications

In this study, the average respondent was 62 years old, had 33 years of ranching experience, and was working with land that had been in the family for an average of 53 years. Using a survey instrument empowered the researcher to utilize land mangers to help assess whole-ranch sustainability measures. Results may help separate solid producer evidence from activist based testimonials and speculation. This notion is supported by Knapp and Fernandez-Gimenez (2009). They found ranchers consider experience as being one of the most important factors in understanding how to manage landscapes.

What is novel about this study are not the findings. In fact the study findings are somewhat in line with past research. The greater contribution comes from the approach that was taken. While there were only 124 respondents in the study, the scope of the study represents 124 whole ranch assessments of sustainability indicators. This is quite a significant number in the context of physical grazing studies. Much of the literature cited as implicating sustainable management was limited by some prevailing complication. Some were limited by the size of the study, only assessing small plots; others were limited by the number of replications, as whole ranch comparisons are difficult to measure; finally others could only measure one aspect of sustainability, be that the effect on economics, the environment, or social implications. The use of sustainability indices may prove useful in future rangeland research activities.

It is known that ecological systems and processes provide the biological interactions underlying ecosystem health and viability. Socio-economic infrastructures and processes serve as the context in which rangeland use and management occurs and rangeland health improves or deteriorates. These systems and processes interact across time and space (Senge, 1990). Still, this study indicated ranchers did not recognize a philosophic link between the importance of land health and economic sustainability.

Even though it is useful to measure each aspect of rangeland sustainability separately, true sustainability is a dependent on all three aspects of sustainability (economic, ecological, and social) working together. Overall rangeland sustainability cannot be separated so that the various elements of sustainability are at odds with each other. Methods which can help producers make the connection between land health and economic viability are already being developed, but current manager philosophy and resulting perceptions are not entirely aligned with this fact. Therefore, education of producers concerning the connection of all three aspects of rangeland sustainability has not been accomplished and should be pursued.

Findings from this study would agree with Doll and Jackson (2009) as they maintain that understanding farmer attitudes at the local level should help to build successful, incentive-based conservation programs and inform research projects and policy initiatives aimed at blending natural resource management and agronomic goals. Therefore, further investigation concerning the interactions of anthropocentric land utilization and natural phenomena occurring in our landscapes is certainly warranted. The challenge is, as suggested by Aldo Leopold (1938), to live on a piece of land without spoiling it. It is evident that agriculture is the first front in a conflict between humans and enhanced land usage. Providing range managers with tools and education that helps keep them prosperous, maintain land health, meet the needs of society, ensures the survival of open space, and at the same time provides for the physical needs of a growing population is challenging.

Implications from this study revolve around increasing economic sustainability. All avenues for this means should be investigated. The possibilities are numerous. Social values have begun to have economic incentives for land managers. Natural resource "experiences" are able to be sold. Examples of these can be birding, wildflower viewing, hiking, hunting, riding, biking, wildlife viewing, organic production, and many more. Also, traditional agricultural practices for rangeland can be improved upon. The study identified that respondents garnered only 0.2% of rangeland income from small animal production. Benefits realized by increasing the diversity of livestock enterprises to include sheep and goat production, thus adding to an agricultural business, may be very substantial. Overall, the most readily identifiable implication is that researching and then educating producers on avenues for economic viability that compliment social and ecological rangeland sustainability.

Landowner decisions concerning a sustainable agriculture should enhance the environment and the farmer's economic situation and benefit the regional society (Sullivan, 2001). In agreement with this principle Larry Butler (2002) wrote, “A workable economic solution must be a sound ecological solution and an acceptable cultural solution. Any solution that fails this test will be short lived.” There is a need of further investigation and/or promotion of identified best management practices as opportunity to land managers. The examples given above offer a good place to begin the investigation and promotion.

The results point to a need for agency personnel, policy makers and producers to take action. There is a need for agency personnel to further investigate the relationships with economic viability which compliments societal and environmental values. Policy makers need to provide rules and/or incentives that promote ecological stewardship. Finally, producers need to investigate methods of diversifying income. There is a great amount of opportunity to move forward with efforts to motivate rangeland managers to adopt first a philosophy, and then management practices that place importance on all aspects of sustainability.

It is important to begin with a philosophic shift as noted by Aldo Leopold (1949) who wrote about land ethics. He believed that when we view something as property, it is ours; we do with it what we wish. When we see something as part of a community we tend to feel responsibility to consider the impacts we will have on others. Leopold takes this philosophic concept and applies it to land; he concludes that the forces that are out there in 1948 are not likely to bring about the change that is necessary to instill the feelings needed to bring land out of the realm of “property” and into the concept of community cooperation and responsibility. In particular, he was disillusioned with the education system for the lack of ecological ethics being taught in agronomic course work. To begin the desired philosophic shift, the immediate addition of a land ethics course work to traditional agronomic curriculum should be implemented.

Also, Leopold (1938) was one of the first to identify that both governmental policy and economics provided the atmosphere where land managers can implement more ecologically sound practices. The governmental policy has historically provided the stimulus to motivate ranchers (Sayre, 2002). Recent years have seen a gradual shift from economic policies and practices furthering productive capacity to those encouraging ecosystem health and restoration. For example, the policies of the Conservation Reserve Program, contained in multiple Farm Bills of the past 20 years, have provided new and increased emphasis on improving soil stability, water quality and wildlife habitat, along with a reduction in crop production (Maczko and Hidinger, 2008). Governmental programs rewarding carbon sequestration are being investigated as well as new implementation of programs providing environmental quality incentives.

Limitations of the Study

As in any study, there are limitations. The primary limitation here may have to do with funding. The sample population was limited to 6 counties primarily because of funding. While the overall expense of the survey process was not too great, mail surveys do come with a price. This research garnered $3000 from the Grazing Lands Conservation Initiative, plus a small amount (< $200) from the University of North Texas, resulting in a fairly narrow scope. How many participants as could be afforded was the determining factor in the number of counties to include in the study. This in turn, limited the number of cases in the data set which was more than likely the complication causing poor performance of the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy statistic during the variable reduction phase of the statistical work.

Another limitation of the study included the length of the questionnaire. The document was 11 pages, 6 sections, and 118 questions. Reducing the document to only a couple pages would likely increase the response rate. The number one reason that non-respondents gave for not returning the survey instrument, was lack of time, additional reasoning by 2 others was “too long”.

In particular, the length of the study may have been a greater impediment to younger ranchers. The non-response bias survey indicated that there was a significant difference between the study population and the non-respondents when using both the Man-Whitney U and the Kolmogorov-Smimov significance test. Further investigation reveals that the non-respondents also implemented rotational grazing a higher percentage of the time (80% vs. 69%). These results would be consistent with Greiner et al. (2009) who noticed self identified risk takers showed higher levels of implementation of rotational grazing, whereas Wang and Poutziouris (2010) show age and risk taking in business are positively associated.

Future Studies

Much work has been conducted which suggests the benefits of ecological management back to society, but little has been done that can quantify economic benefits of ecologically conscientious land management. Future studies of interest should include rangeland studies that focus intently on the effects of environmental stewardship and relate those effects to specific benefits which the land owner may desire, especially economic. Agreement with this analysis is indicated as Sayre (2001) said, "Ranching can be sustainable if it can convert a self reproducing resource into a profitable commodity without undermining the long-term viability of the resource".

Land rest is the critical feature of any specialized grazing system of which there are many specific types with alterations to each type (Holechek et al., 1989). Grazing selectivity, described as patchy vegetation, is a function of contained livestock grazing. It is affected by topography, distribution of water, mineral licks, livestock cover, and other interactions (Coughenour, 1991; Bailey and Provenza, 2008). These factors combine to increase vegetative heterogeneity and the impact of selective grazing as paddock size increases. Respondents within this study utilized less than 8 paddocks 83.6% of the time. Recognizing that the average ranch unit was 3073 acres, resulting paddock size would generally be greater than 680 acres. At this scale, the effect of grazing deferment minimizing selectivity of vegetation by livestock would be questionable, even if respondents were considering land rest as a critical component of their grazing plan. Designing a questionnaire to differentiate between intensive grazers and those merely with the notion of pasture deferment as a beneficial component of grazing systems would be very useful for investigation of maximum achievable results in accordance with rangeland sustainability.

Additionally, more could be ascertained from the data already collected within the realm of this study. Investigation of data for differences with causal-comparative research would help describe conditions that exist. Specifically, how is urbanization impacting management practices, land health, or management philosophy. Investigation of data with that intent is certainly a possibility.

Finally, future studies seeking to identify management practices for whole ranch business enterprises may utilize various sections detailed within this study to further eliminate questions from consideration, thereby reducing the overall length of the questionnaire and possibly improving upon response rate.

Conclusion

This research has investigated management philosophy and grazing practices which have been a source of debate among scientists and rangeland managers for nearly a century. This debate has escalated in the recent past due to conflicting findings based on small scale research. The relationship between grazing management decisions and perception regarding long-term rangeland sustainability is relevant only as it pertains to whole-ranch enterprises due to the fact that small scale comparisons cannot account for the amount of variability that is present between various locations, and over various years. Sustainability of rangeland has been identified as being dependent on economic viability for ranches, maintaining ecological function of the land, and providing desired goods and services to society as a whole.

This study gathered data from ranches in Cooke, Montague, Clay, Wise, Parker, and Jack counties in North Central Texas. The data were gathered using mail questionnaires that investigated a wide variety of factors: philosophic, economic, management, environmental, quality of life, and demographic. These data were subjected to rigorous statistical procedures to assess the whole-ranch units; thereby discovering linkage between management philosophy, grazing practices and personal characteristics to rangeland sustainability.

This research added to the body of knowledge by identifying predictors of rangeland sustainability indices. Identification of these predictors and the knowledge of the variance they explain as it relates to different aspects of sustainability will be useful for targeted education to ranchers and to agency personnel alike. Conclusion drawn from prediction of economic sustainability, in this study, are that greater consideration of diversity of rangeland goods and services should be incorporated into business plans in order to further increase economic sustainability while preserving social and ecological sustainability.

In addition to providing practical information, projects like this study bring a social component to range research. We should not lose sight of the fact there is a need to focus on understanding the whole farm, not simply isolated aspects. Therefore, combining social components with production oriented research should be seen as very useful. This combination will help to understand ranch manager's perceptions which are based on interplays between past experiences and personal interpretation. While experimental studies are vital, management's perception of benefits associated with sound grazing management and strategies are just as crucial for successful implementation of sustainable ranch management practices.

APPENDIX A

STUDY QUESTIONNAIRE

Assessing Landowner Perspectives Regarding Sustainable Livestock Grazing Management Systems for Rangelands in Texas

Survey of Range Managers in Mid to Tall-Grass Prairie Ecosystems

This survey may help to establish key sustainability issues regarding livestock and rangeland from the ranch manager's perspective. Information gained is expected to:

- **Help determine future direction of educational efforts for ranchers and general public.**
- **Provide input to decision makers concerning producer needs.**
- **Provide insight to grazing system management from real ranch units to improve understanding of small "scientific" studies.**

You are being asked to participate in a research study which involves answering questions pertaining to your livestock management practice on native rangeland. **We are asking that this questionnaire be completed by the person who is currently most involved in making decisions about land management on the property.** All information provided by respondent will remain confidential and will be used solely for the purpose of this study.

Dr. Samuel Atkinson, Director of the Institute of Applied Science at the University of North Texas (UNT) is the principle investigator in this study. If you have questions, please contact Dr. Atkinson () or Wayne Becker, UNT graduate student (phone: or email:).

Thank you for taking the time to complete this survey! You will be able to finish it in approximately 20-25 minutes. Your information will help to address critical questions being raised by scientists about best management practices for native rangeland.

This research study has been reviewed and approved by the UNT Institutional Review Board (IRB). The UNT IRB can be contacted at (940) 565-3940 with any questions regarding the rights of research subjects.

COMPLETING THE QUESTIONNAIRE

Please answer all questions that apply to your property, this will help improve the significance of this study. Your participation in this survey is voluntary. No penalty or loss of rights or benefits will be associated with participating or withdrawing from the study. You may withdraw from the study at anytime. By completing this questionnaire, you are giving your consent to be included in the study.

If you encounter a question that does not apply to your property, please indicate this by writing “NA” in the margin next to the question.

If you encounter a question for which you do not know the answer, please indicate this by writing “DK” in the margin next to the question.

Many of the questions in this survey use a rating scale with 7 options. Please circle the number that best describes your opinion. For example, if you were asked to use such a scale to indicate the extent to which you agree or disagree with the statement that —Texas is the best state in the USA” and you strongly agree, you would circle *number 1*, as follows:

	Strongly Agree	Agree	Somewhat Agree	Neutral	Somewhat Disagree	Disagree	Strongly Disagree
Texas is the best state in the USA	(1)	2	3	4	5	6	7

In making your markings, please remember the following points:

- Your identity will remain anonymous.
- There are no foreseeable risks involved in this study.
- You may print or copy this questionnaire for your records.
- There will not be any financial compensation for answering this survey.

FIRST QUESTION

Do you own and/or manage native rangeland that is utilized for livestock grazing? Please check (☑) one.

☐ No - Please stop here and return questionnaire in the attached postage-paid envelope. It is important that we hear back from everyone who receives a questionnaire. We thank you for taking the time to place the questionnaire in the enclosed envelope and returning it to us.

☐ Yes - Please proceed to complete the whole questionnaire.

If you own or manage both improved pasture and native rangeland, mark answers only in reference to management on native rangeland.

Section 1. Management Philosophy

This section is designed to help understanding motivation of range steward management practices. Please circle the number that best indicates your level of agreement with the corresponding statement.	Strongly Agree	Agree	Somewhat Agree	Neutral	Somewhat Disagree	Disagree	Strongly Disagree
I thoughtfully considered physical characteristics, such as precipitation pattern, soil, and topography prior to implementing management practices.	1	2	3	4	5	6	7
I consider stage of plant growth, time of year, or weather conditions when making decisions about livestock movement.	1	2	3	4	5	6	7
I am open to considering new ideas and techniques for land management.	1	2	3	4	5	6	7
I consider my management style to be a sustainable use of rangeland.	1	2	3	4	5	6	7
I incorporate wildlife needs into my grazing plan.	1	2	3	4	5	6	7
I consider forbs as a valuable source of forage for wildlife or livestock.	1	2	3	4	5	6	7
I plan for improving rangeland health by grazing management and/or other management practices.	1	2	3	4	5	6	7
Good grazing management can improve the quality and quantity of forage on my rangeland.	1	2	3	4	5	6	7
Risk to rangeland health can be minimized by implementing proper grazing practices.	1	2	3	4	5	6	7
Resting land after grazing is an integral part of grazing management.	1	2	3	4	5	6	7
Proper grazing management on rangelands should include periodic prescribed fires.	1	2	3	4	5	6	7
The most important ecosystem product provided by rangelands is livestock production.	1	2	3	4	5	6	7
Rangelands provide environmental services such as water capture, erosion control, soil fertility, soil structure and wildlife habitat.	1	2	3	4	5	6	7
Rangelands are valuable from a spiritual, aesthetic or cultural perspective.	1	2	3	4	5	6	7
Rangeland preservation is critical for maintaining genetic services like pollination and cultivation of native, wild plants.	1	2	3	4	5	6	7

Lightly or moderately stocked, continuous grazing has ecological benefits equal to rotation of livestock to different pastures.	1 2 3 4 5 6 7
Short periods of high livestock density and adequate recovery are beneficial to the ecosystem.	1 2 3 4 5 6 7
When considering management practice implementation, I consider both the cost of the action, and the cost of inaction.	1 2 3 4 5 6 7
Brush encroachment, water infiltration, sediment run-off, and wildlife abundance have been identified as ecological problems for rangeland. I believe my grazing management practices will contribute to repair of these problems.	1 2 3 4 5 6 7

1. **Threats to the grassland ecosystem of North Texas include: (check all that apply)**
   ☐ Urban encroachment ☐ Overgrazing ☐ Climate Change
   ☐ Fire Suppression ☐ Other (please describe) ________________________

2. **Do you participate in Government Land Management/Livestock Assistance Programs?**
   ☐ Yes ☐ No
   If yes, please indicate those utilized:
   ☐ EQUIP ☐ Disaster/Drought Relief ☐ Other_____________

3. **Do you believe the Government should be involved in ranching with assistance programs??**
   ☐ Yes ☐ No

4. **Do you believe Government should increase involvement by offering more incentives? (Check all that you believe need more funding or increased program efforts)**
   ☐ Disaster/Drought Relief ☐ Brush Control ☐ Grazing Distribution
   ☐ Reacting to Impacts of Mismanagement ☐ Education
   ☐ Internships ☐ Other (please describe) _________________________

5. **When implementing new practices, how long do you allow for observable results before deciding to continue the practice?**
   ☐ 1 year ☐ 2-5 years ☐ 5-7 years ☐ 7-10 years ☐ Other__________

Section 2. Economic Considerations

This section is designed to understand rangeland stewards' perceptions of key sustainability factors in relation to their operation. Please circle the number that best indicates your level of agreement with the corresponding statement.	Strongly Agree	Agree	Somewhat Agree	Neutral	Somewhat Disagree	Disagree	Strongly Disagree
Financial risk can be reduced by implementation of proper grazing practices.	1	2	3	4	5	6	7
Proper grazing management of rangeland will positively influence the long-term profitability of a ranch.	1	2	3	4	5	6	7

Deterioration of range conditions will cause long-term economic difficulties.	1	2	3	4	5	6	7
Decision to adopt my grazing system was affected because of tax measures or depreciation considerations.	1	2	3	4	5	6	7
When compared to other ranches, I perceive the rate of return that I receive from grazing rangeland as being above average.	1	2	3	4	5	6	7
I consciously plan for long-term economic sustainability (5 or more years).	1	2	3	4	5	6	7
I utilize least cost practices on my grazing land.	1	2	3	4	5	6	7
I am unable to make as many land improvements on my property as I would like because of financial constraints.	1	2	3	4	5	6	7
I utilize separate accounts for my ranch and my household.	1	2	3	4	5	6	7
I know my cost of production.	1	2	3	4	5	6	7
I utilize high input methods on my grazing land, such as fertilization, chemical weed control, planting of improved forages, etc.	1	2	3	4	5	6	7
The need to increase revenue will sometimes lead me to overstock the pasture.	1	2	3	4	5	6	7

1. **I measure economic success on the ranch by: (Check all that apply)**
   - ☐ Production Measure (i.e. weaning percentage, calving percentage)
   - ☐ Gross Income
   - ☐ Net Income
   - ☐ Animal Sale Price
   - ☐ Income/Expense Ratio
   - ☐ Tax Statement
   - ☐ Balance Sheet
   - ☐ Increase/Decrease of Net Worth
   - ☐ Other (please describe) ______________________

2. **My ranch uses diversification of enterprises to reduce risk or increase income.**

   ☐ Yes ☐No

   If yes, I diversify by: (Check all that apply)
   - ☐ Multiple Livestock Species (i.e. cattle and sheep)
   - ☐ Multiple Livestock Classes (i.e. Cow/Calf and Stockers)
   - ☐ Mineral Extraction (i.e. oil, gas, gravel, wind)
   - ☐ Hay, Seed or Other plant production
   - ☐ Hunting or Wildlife Recreation
   - ☐ Other Recreation
   - ☐ Niche Market (i.e. Specialty Beef, Honey, Wool, etc
   - ☐ Other (please describe) ______________________

Section 3. Native Rangeland Management

Please check the most appropriate box or fill in the blank with your answer.

1. **I would characterize the system of grazing that I utilize as (Check the best answer):**
   - ☐ Continuous (1 pasture/paddock per herd)
   - ☐ Rotation, with 4 or fewer paddocks
   - ☐ Rotation with 4 to 8 paddocks
   - ☐ Rotation with more than 8 paddocks
   - ☐ Other (please describe) ____

2. **Years using the system checked above? ___________years**

3. **The largest obstacle to increasing livestock distribution is (Check all that apply):**
   - ☐ Lack of or poorly distributed water sources
   - ☐ Uneven forage distribution
   - ☐ Cost of fencing
   - ☐ Management concerns
   - ☐ I do not feel that there is a benefit
   - ☐ Other (please specify) ________________

4. **I utilize the following to help distribute livestock over the rangeland (Check all that apply):**
   - ☐ Herding
   - ☐ Internal fencing
   - ☐ Water placement
   - ☐ Prescribed burning
   - ☐ Supplemental feeds
   - ☐ Salt/mineral licks
   - ☐ Fertilizer application
   - ☐ Shade
   - ☐ Other (please describe) _____________________

5. **In relation to Natural Resources Conservation Service (NRCS) recommendations for my area, I utilize a stocking rate that can best be characterized as:**
   - ☐ High
   - ☐ Moderate
   - ☐ Conservative
   - ☐ Light

6. **On average, how many acres do you allocate per animal unit (AU) on native rangeland on your land?**
   (***1 AU = one mature cow weighing about 1,000 pounds, either dry or with a calf up to 6 months of age; 5 mature sheep or 5 mature goats.***)
   - ☐ < 8
   - ☐ 8-12
   - ☐ 13-18
   - ☐ 19-24
   - ☐ > 24

7. **Rank these in order of prioritization (1 thru 6) when considering grazing management.**
   - _____Livestock performance
   - _____Land health
   - _____Profitability
   - _____Quality of life
   - _____Tradition
   - _____Ease of application

Please circle true or false to indicate your management style as it relates to the corresponding question.

I never stock for complete utilization with breeding livestock.	True False
I utilize multiple classes of livestock (i.e. mother cow and stockers).	True False
I utilize stockers or bale hay to add flexibility, dependent on conditions.	True False
I typically utilize purchased supplemental hay.	True False
I typically utilize purchased supplemental protein.	True False
During a drought I de-stock to leave a minimum amount of forage residue.	True False
During a drought I supplement livestock with more hay or other feed.	True False
Due to normal pasture utilization, I have patches of heavily used and lightly used forage.	True False
I usually raise my replacement livestock.	True False
I make stocking decisions based on forage amount	True False
I make stocking decisions based primarily on livestock condition.	True False
I view the season of the year as critical to the amount of defoliation that is acceptable.	True False
I rest the land for a portion of the growing season as a critical component of my grazing plan.	True False
I use chemical to control brush, forbs and grasses.	True False
I use fire to control brush, forbs and grasses.	True False
I visually monitor range condition and make ―mental notes" to gauge progress.	True False
I use pictures or notes to monitor progress or regression of range condition.	True False
When weather forces hay feeding, I restrict livestock access to most of my pasture in order to minimize overgrazing on as much of the land as possible.	True False

Section 4. Land Health

This section is designed to help understand your perspectives about rangeland health. Please circle the number that best indicates your level of agreement with the corresponding statement.

	Strongly Agree	Agree	Somewhat Agree	Neutral	Somewhat disagree	Disagree	Strongly Disagree
Plant cover and distribution on my grazing land is such that it encourages water infiltration and minimization of erosion.	1	2	3	4	5	6	7
The most desired native grasses produce seed annually.	1	2	3	4	5	6	7
Woody plants do not increase as a result of fire suppression.	1	2	3	4	5	6	7
Bare ground can be seen in some areas of my grazinglands.	1	2	3	4	5	6	7
I consider my rangeland to be in excellent condition.	1	2	3	4	5	6	7

Change in the environment is certain.

In relation to your property, please indicate your perception of the change noticed for each issue over the past 10 years. The items may have increased, remained constant, or decreased.

	Please circle one.			
Mesquite	Increased	Constant	Decreased	Unknown
Juniper	Increased	Constant	Decreased	Unknown
Other Brush	Increased	Constant	Decreased	Unknown
Bare Ground	Increased	Constant	Decreased	Unknown
Invasive Weed Species (thistle, cacti, greenbriar, etc.)	Increased	Constant	Decreased	Unknown
Livestock Trails	Increased	Constant	Decreased	Unknown
Gullies	Increased	Constant	Decreased	Unknown
Soil Compaction	Increased	Constant	Decreased	Unknown
Small Pedestals (rocks or plants that appear elevated.	Increased	Constant	Decreased	Unknown

Evidence of plant litter around obstructions like grass clumps and stones.	Increased	Constant	Decreased	Unknown
Other evidence of non-gully water flow patterns.	Increased	Constant	Decreased	Unknown
Tall grasses	Increased	Constant	Decreased	Unknown
Short grasses	Increased	Constant	Decreased	Unknown
Turkey	Increased	Constant	Decreased	Unknown
Quail	Increased	Constant	Decreased	Unknown
Other birds	Increased	Constant	Decreased	Unknown
Predators (coyote, bobcat etc.)	Increased	Constant	Decreased	Unknown
Wild Hogs	Increased	Constant	Decreased	Unknown
Deer	Increased	Constant	Decreased	Unknown
Reptiles/Amphibians (snakes, toads, frogs, etc)	Increased	Constant	Decreased	Unknown
Other Wildlife	Increased	Constant	Decreased	Unknown

Section 5. Quality of Life

This section is designed to understand rangeland stewards' perceptions of key factors in relation to their quality of life. Please circle the number that best indicates your level of agreement with the corresponding statement.

	Strongly Agree	Agree	Somewhat Agree	Neutral	Somewhat disagree	Disagree	Strongly Disagree
Livestock management on my ranch does not infringe on my free time or ability to enjoy occasional recreation activities.	1	2	3	4	5	6	7
Livestock management on my ranch does not interfere with family involvement.	1	2	3	4	5	6	7
I am satisfied with the income that I derive from my ranch.	1	2	3	4	5	6	7
I derive a great deal of satisfaction from my work on the ranch.	1	2	3	4	5	6	7
I am actively involved with my community.	1	2	3	4	5	6	7
I have the time to learn about subjects that are of interest to me.	1	2	3	4	5	6	7
I have a good relationship with neighboring ranches.	1	2	3	4	5	6	7

Ranching has affected my health negatively.	1 2 3 4 5 6 7
All decision makers (ranch owners or family) are involved in long range planning and goal making.	1 2 3 4 5 6 7

1. **<u>My main reason for ranching is: (Choose the one answer that best describes your situation.)</u>**
   - ☐ It is my chosen profession
   - ☐ Tax Benefits
   - ☐ I own land and need a productive use for the land
   - ☐ Hobby
   - ☐ Other (please describe) _________________________

2. **<u>Rank the following issues in relation to level of concern. Rank from 1 thru 7 with 1 being area of greatest concern and 7 being the area of least concern.</u>**
   - _____ Profit
   - _____ Cattle Productivity
   - _____ Land Health
   - _____ Tax Issues
   - _____ Family Issues
   - _____ Issues with Neighbors
   - _____ Weather

3. **<u>The following are involved in making ranch management decisions: (Check all that apply.)</u>**
   - ☐ Myself
   - ☐ Ranch Employees
   - ☐ Family Members
   - ☐ Other (please describe) _________________________

4. **<u>I consider the following when making ranch management decisions: (Check all that apply.)</u>**
   - ☐ My Health
   - ☐ My Time
   - ☐ My Standard of Living
   - ☐ My Family
   - ☐ My Friends
   - ☐ My Neighbors
   - ☐ My Employees
   - ☐ The Local Community
   - ☐ Ecosystem and watershed health
   - ☐ Future Generations
   - ☐ All People That May Pass By or Through the Area
   - ☐ Other (please describe) _________________________

Section 6. Personal Characteristics

To understand differences among rangeland stewards, concerning their interests and experiences, we ask you to provide some information about yourself. YOUR RESPONSES WILL BE KEPT STRICTLY CONFIDENTIAL.

1. **In which COUNTY is your land predominantly located?** ____________________________
2. **How many acres of native rangeland do you own or manage?** ____________**acres**
3. **How many years experience do you have raising livestock?** ____________**years**
4. **How many years have you or your family owned or managed the property?** __________**years**
5. **How are you associated with the land?**
   ☐ 1st Generation Owner ☐ 2nd Generation Owner ☐ 3nd Generation Owner ☐ Manager
   ☐ Other (please describe) ___________________
6. **In which year were you born?** ___________________
7. **Gender:** ☐ Male ☐ Female
8. **How many years of formal education have you had?**
   ☐ Less than 12 ☐ High School Graduate ☐ IT/Vocational School
   ☐ Some College ☐ Bachelor's Degree ☐ Graduate Degree
9. **How many hours have you invested in self-study or continuing education concerning grazing management during the past year?** _____________**hours**
10. **Where do you get grazing management information? (Check all that apply)**
    ☐ Internet ☐ Industry Periodicals ☐ University information ☐ NRCS ☐ Extension
    ☐ Peers ☐ Salesmen ☐ Consultant ☐ Local Store
11. **Is there a plan to sell the property in question within the next five years?** ☐ Yes ☐ No
12. **Do you live on your property for which you provided answers?** ☐ Yes ☐ No
    If Yes, how many years you have lived on a ranch? ______________ years
    If No, about how far by road do you live from your property? ______________miles
    If No, do you live in: ☐ a rural area in Texas ☐ an urban area in Texas ☐ out of Texas
13. **About how much money did you invest in land improvements on your property during the last five years?** $________________

14. **Of your native grassland, about what percentage of your property is currently covered by each of the following types of land cover? (<u>Please ensure that your answers add to 100%</u>)**

Short grass (i.e. Buffalo, Hairy Grama, Blue Grama, Sedge, Signal Grass) _________%
Mid grass (i.e. Sideoats Grama, Dropseed, Texas Wintergrass, Silver Bluestem) _________%
Tall grass (i.e. Big Bluestem, Switch Grass, Indian Grass, Little Bluestem) _________%
Grass and tree mixed savanna _________%
Dense brush or Woodlands _________%
Water bodies (ponds, tanks, lakes, etc.) _________%
Other (Please describe) ________________________________ _________%

15. **About what percentage of your total annual income in 2009 was derived from your rural property?** _________%

16. **About what percentage of the gross income from your property was obtained from the following land uses over the past 5 years? (<u>Please make sure your answers add to 100%</u>)**

Cow/Calf grazing _________%
Stocker grazing _________%
Sheep grazing _________%
Goat browsing _________%
Fee hunting _________%
Exotic wildlife production and/or hunting _________%
Crop production (hay) _________%
Recreation related activities (other than hunting) _________%
Mineral sales and leases _________%
Other (Please describe) ________________________________ _________%
☐ Check here if you do not derive any income from your land.

17. **Please check the category that best describes your total household income in 2009. We remind you that your identity will remain anonymous and your answers are confidential.**

☐ Less than $25,000
☐ $25,000 - $50,000
☐ $50,001 - $75,000
☐ $75,001 - $100,000
☐ $100,001 - $500,000
☐ Greater than $500,000

On the last page, please write any other comments or suggestions that would help us understand what resources you could best utilize to help improve your land management practices. Also, please provide any comments about questions or clarifications you needed as you were answering the survey. Institute of Applied Science, University of North Texas.

Your participation is greatly appreciated. Please send the questionnaire back to us in the enclosed postage-paid envelope. Feel free to offer any addition comments or thoughts on native range grazing management that you may have.

Thank You!

Optional:

Name: ____

Address: ____

City, State, Zip: _____________________________________

Email: ____

APPENDIX B

NON-RESPONSE BIAS QUESTIONNAIRE

November 2010

Landowner Perspectives Regarding Grazing Management of Native Grass

The individual in your household who is most knowledgeable about your rangeland management should complete the questionnaire.

1. In order to assess the broader impact of this survey, please let us know why you did not respond. Check all that apply.
   - ☐ I did not receive the survey
   - ☐ I did not believe the survey was really anonymous
   - ☐ The survey did not pertain to me
   - ☐ Lack of time
   - ☐ Survey was too long
   - ☐ I chose not to participate
   - ☐ Other ____

2. How many years have you owned/managed your rangeland? _____________ years

3. How many years have you lived at your current address? _____________ years

4. In which year were you born? 19___________________

5. What is your gender? ☐ Male ☐ Female

6. Do you derive more than 25% of total household income from your land? ☐ Yes ☐ No

7. Is livestock production the primary activity on your land? ☐ Yes ☐ No

8. Do you practice any form of rotational grazing on your land? ☐ Yes ☐ No

9. Where do you get grazing management information? (Check all that apply)
   ☐Internet ☐Industry Periodicals ☐University information ☐NRCS
   ☐Extension ☐Peers ☐Salesmen ☐Consultant ☐Local Store

On the back, please write any other comments or suggestions that you think can help us in future surveys.

Your participation is greatly appreciated. Please send the questionnaire back to us in the enclosed postage-paid envelope.

APPENDIX C

DESCRIPTIVE STATISTICS

Management Philosophy Descriptive Statistics

	N	Range	Minimum	Maximum	Sum	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Physical Characteristics	122	5	1	6	231	1.89	.084	.925	.856	1.360	.219	2.711	.435
Plant Growth/Time/Weather	123	4	1	5	206	1.67	.074	.825	.680	1.473	.218	2.562	.433
New Ideas	123	3	1	4	211	1.72	.069	.763	.582	.984	.218	.820	.433
Management is Sustainable	123	5	1	6	226	1.84	.076	.843	.711	1.652	.218	4.851	.433
Incorporate Wildlife Needs	122	6	1	7	301	2.47	.126	1.392	1.937	1.041	.219	.831	.435
Forbs Valuable	118	6	1	7	270	2.29	.108	1.170	1.369	.981	.223	1.188	.442
Plan for Rng Health	122	3	1	4	224	1.84	.077	.847	.717	.986	.219	.620	.435
Grazing Mngmt Iproves Rng	121	3	1	4	172	1.42	.053	.588	.346	1.311	.220	2.043	.437
Minimize Risk by Grazing	123	3	1	4	183	1.49	.053	.592	.350	1.012	.218	1.338	.433
Rest	123	4	1	5	206	1.67	.076	.844	.713	1.427	.218	2.167	.433
Fire	121	6	1	7	383	3.17	.147	1.619	2.622	.506	.220	-.367	.437
Lvstk is Most Important	122	6	1	7	318	2.61	.114	1.257	1.579	1.164	.219	1.583	.435
Provide Env Services	123	3	1	4	189	1.54	.062	.693	.480	1.219	.218	1.334	.433
Value for Spiritual/Aesthetic	123	5	1	6	240	1.95	.099	1.093	1.194	1.055	.218	.523	.433
Maintain Genetics	123	3	1	4	222	1.80	.075	.836	.699	.896	.218	.294	.433

Light = to Rotation	120	6	1	7	414	3.45	.157	1.724	2.972	.486	.221	-.814	.438
High Density/Short Duration	118	5	1	6	319	2.70	.118	1.283	1.646	.549	.223	-.586	.442
Consider Cost of Inaction	121	4	1	5	257	2.12	.079	.871	.760	.677	.220	.361	.437
Repair Problems	120	5	1	6	271	2.26	.094	1.033	1.067	.810	.221	.738	.438
Encroachment Threat	122	1	0	1	90	.74	.040	.442	.195	-1.094	.219	-.816	.435
Overgrazing Threat	122	1	0	1	115	.94	.021	.234	.055	-3.854	.219	13.068	.435
Climate Change Threat	122	1	0	1	46	.38	.044	.487	.237	.514	.219	-1.765	.435
Fire Suppression Threat	122	1	0	1	48	.39	.044	.491	.241	.442	.219	-1.835	.435
Other Threat	122	1	0	1	14	.11	.029	.320	.102	2.448	.219	4.057	.435
GovParticipateYes	122	1	0	1	55	.45	.045	.500	.250	.200	.219	-1.993	.435
EQIP	122	1	0	1	26	.21	.037	.411	.169	1.419	.219	.012	.435
Disaster/Drought	122	1	0	1	41	.34	.043	.474	.225	.703	.219	-1.531	.435
Other	122	1	0	1	10	.08	.025	.275	.076	3.086	.219	7.648	.435
GovParticipateNo	122	1	0	1	66	.54	.045	.500	.250	-.167	.219	-2.005	.435
GovInolveYes	118	1	0	1	61	.52	.046	.502	.252	-.069	.223	-2.030	.442
GovInvolveNo	119	2	0	2	57	.48	.048	.518	.269	.271	.222	-1.506	.440
Disaster/Drought Relief	121	1	0	1	58	.48	.046	.502	.252	.084	.220	-2.027	.437
BrushControl	120	1	0	1	60	.50	.046	.502	.252	.000	.221	-2.034	.438
GrazingDistribution	121	1	0	1	12	.10	.027	.300	.090	2.716	.220	5.466	.437
ReactingMismngmt	121	1	0	1	11	.09	.026	.289	.083	2.882	.220	6.411	.437
Education	121	1	0	1	55	.45	.045	.500	.250	.185	.220	-1.999	.437
Internship	121	1	0	1	10	.08	.025	.276	.076	3.070	.220	7.548	.437
Other	121	1	0	1	9	.07	.024	.263	.069	3.285	.220	8.939	.437
YrsToAdopt	119	4	1	5	246	2.07	.047	.516	.267	2.355	.222	11.601	.440
Valid N (listwise)	101												

Economic Considerations Descriptive Statistics

	N	Range	Minimum	Maximum	Sum	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Less$Risk w/Grazing	119	4	1	5	237	1.99	.076	.828	.686	.743	.222	.757	.440
Proper Grazing Increases Profit	121	2	1	3	194	1.60	.056	.612	.375	.482	.220	-.625	.437
Range Degrdtion=EcDfclty	121	6	1	7	211	1.74	.090	.988	.975	2.806	.220	12.034	.437
GrazingSystemTaxIssue	117	5	2	7	566	4.84	.147	1.586	2.517	-.163	.224	-1.020	.444
AboveAveragROR	121	6	1	7	391	3.23	.122	1.340	1.796	.559	.220	.295	.437
PlanEcStnblty	121	6	1	7	292	2.41	.111	1.222	1.494	1.387	.220	2.471	.437
LeastCostPrctc	118	6	1	7	346	2.93	.129	1.407	1.978	.872	.223	.594	.442
$LimitsInputs	122	6	1	7	334	2.74	.153	1.690	2.856	1.236	.219	.726	.435
SeparateAcctsHmRnch	120	6	1	7	283	2.36	.155	1.699	2.887	1.376	.221	.972	.438
KnowProduction$	122	6	1	7	304	2.49	.122	1.344	1.806	1.077	.219	.844	.435
HighInputs	122	6	1	7	384	3.15	.162	1.785	3.185	.750	.219	-.392	.435
WillOverstock	122	7	0	7	575	4.71	.163	1.802	3.248	-.344	.219	-.908	.435
ESProductionMsr	118	6	0	6	74	.63	.071	.771	.595	3.487	.223	21.640	.442
ESGross$	121	1	0	1	39	.32	.043	.469	.220	.770	.220	-1.431	.437
ESNet$	121	1	0	1	76	.63	.044	.485	.236	-.537	.220	-1.741	.437
ESAnimalSalePrice	121	1	0	1	48	.40	.045	.491	.241	.428	.220	-1.848	.437
ESI/ERatio	121	1	0	1	57	.47	.046	.501	.251	.117	.220	-2.020	.437
ESTaxStmT	121	1	0	1	29	.24	.039	.429	.184	1.235	.220	-.483	.437
ESBalanceSht	121	1	0	1	31	.26	.040	.438	.192	1.131	.220	-.733	.437
ESNetWorth	97	1	0	1	24	.25	.044	.434	.188	1.189	.245	-.599	.485
ESOther	121	1	0	1	11	.09	.026	.289	.083	2.882	.220	6.411	.437

DYes	119	1	0	1	94	.79	.038	.409	.167	-1.442	.222	.079	.440
MltplSpecies	119	1	0	1	6	.05	.020	.220	.048	4.162	.222	15.584	.440
MltplClasses	119	1	0	1	53	.45	.046	.499	.249	.223	.222	-1.984	.440
Mineral	119	1	0	1	57	.48	.046	.502	.252	.085	.222	-2.027	.440
Hay	119	1	0	1	49	.41	.045	.494	.244	.363	.222	-1.900	.440
Hunting	118	1	0	1	60	.51	.046	.502	.252	-.034	.223	-2.034	.442
OtherRec	119	1	0	1	7	.06	.022	.236	.056	3.798	.222	12.637	.440
Niche	119	1	0	1	8	.07	.023	.251	.063	3.501	.222	10.430	.440
Other	119	1	0	1	8	.07	.023	.251	.063	3.501	.222	10.430	.440
DN	119	1	0	1	21	.18	.035	.383	.147	1.719	.222	.971	.440
Valid N (listwise)	81												

Native Rangeland Management Descriptive Statistics

	N	Range	Minimum	Maximum	Sum	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Grazing System	116	5	0	5	264	2.28	.104	1.124	1.262	.333	.225	-.849	.446
Years Using System	112	131	1	132	2779	24.81	2.424	25.649	657.847	2.475	.228	7.212	.453
LackWater	114	1	0	1	36	.32	.044	.467	.218	.803	.226	-1.379	.449
UnevenForage	115	1	0	1	49	.43	.046	.497	.247	.303	.226	-1.942	.447
CostFence	115	1	0	1	52	.45	.047	.500	.250	.195	.226	-1.997	.447
ManagementConcern	115	1	0	1	17	.15	.033	.356	.127	2.011	.226	2.079	.447
NoBenefit	115	1	0	1	13	.11	.030	.318	.101	2.477	.226	4.206	.447

Other	115	1	0	1	16	.14	.032	.348	.121	2.113	.226	2.509	.447
Herding	116	1	0	1	22	.19	.037	.394	.155	1.604	.225	.583	.446
InternalFence	116	1	0	1	83	.72	.042	.453	.205	-.968	.225	-1.082	.446
WaterPlacemnt	116	1	0	1	66	.57	.046	.497	.247	-.282	.225	-1.954	.446
PrescribedBurn	116	1	0	1	12	.10	.028	.306	.094	2.638	.225	5.048	.446
SupplFeed	116	1	0	1	54	.47	.047	.501	.251	.140	.225	-2.015	.446
SaltLick	116	1	0	1	81	.70	.043	.461	.213	-.875	.225	-1.256	.446
FertAppl	116	1	0	1	33	.28	.042	.453	.205	.968	.225	-1.082	.446
Shade	116	1	0	1	25	.22	.038	.413	.171	1.402	.225	-.036	.446
Other	116	1	0	1	3	.03	.015	.159	.025	6.053	.225	35.245	.446
StockingRateSelfCharc	115	3	1	4	296	2.57	.072	.773	.598	-.136	.226	-.309	.447
AU	115	4	1	5	302	2.63	.109	1.166	1.359	.602	.226	-.344	.447
LivestckPerform	111	5	1	6	246	2.22	.113	1.194	1.426	1.203	.229	1.104	.455
LandHealth	114	5	1	6	218	1.91	.110	1.179	1.390	1.392	.226	1.725	.449
Profitability	110	5	1	6	364	3.31	.133	1.393	1.940	.383	.230	-.461	.457
QualityLife	107	5	1	6	440	4.11	.132	1.362	1.855	-.777	.234	-.097	.463
Tradition	107	7	0	7	527	4.93	.135	1.392	1.938	-1.511	.234	2.051	.463
EaseApplication	109	6	0	6	477	4.38	.140	1.464	2.144	-.715	.231	.028	.459
CompleteStkBreeding	112	1	1	2	150	1.34	.045	.476	.226	.688	.228	-1.555	.453
MultipleClass	117	1	1	2	163	1.39	.045	.491	.241	.443	.224	-1.835	.444
Diversity	115	1	1	2	149	1.30	.043	.458	.210	.907	.226	-1.198	.447
PurchaseHay	113	1	1	2	179	1.58	.047	.495	.245	-.346	.227	-1.915	.451
PurchaseSup	116	1	1	2	122	1.05	.021	.222	.049	4.101	.225	15.081	.446
DestockDrought	118	1	1	2	147	1.25	.040	.432	.187	1.196	.223	-.579	.442
SupplDrought	119	1	1	2	134	1.13	.031	.333	.111	2.282	.222	3.263	.440
Patches	119	1	1	2	156	1.31	.043	.465	.216	.827	.222	-1.338	.440
RaiseReplacement	117	1	1	2	155	1.32	.043	.470	.221	.758	.224	-1.450	.444
StckBasedonForage	118	1	1	2	126	1.07	.023	.252	.064	3.483	.223	10.305	.442
StckBasedonBC	118	1	1	2	170	1.44	.046	.499	.249	.242	.223	-1.975	.442

SeasonCritical	117	1	1	2	126	1.08	.025	.268	.072	3.217	.224	8.493	.444
RestLand	117	1	1	2	139	1.19	.036	.392	.154	1.618	.224	.627	.444
ChemicalUse	116	1	1	2	151	1.30	.043	.461	.213	.875	.225	-1.256	.446
FireUse	117	1	1	2	207	1.77	.039	.423	.179	-1.295	.224	-.330	.444
MentalNotes	119	1	1	2	123	1.03	.017	.181	.033	5.242	.222	25.911	.440
PictureNotes	117	1	1	2	206	1.76	.040	.429	.184	-1.238	.224	-.476	.444
RestrictFeedArea	114	1	1	2	186	1.63	.045	.485	.235	-.553	.226	-1.725	.449
Valid N (listwise)	84												

Land Health Descriptive Statistics

	N	Range	Minimum	Maximum	Sum	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
GoodPlantCover	118	5	1	6	241	2.04	.092	.999	.998	1.222	.223	1.978	.442
ProduceSeed	121	4	1	5	256	2.12	.085	.933	.870	.894	.220	.652	.437
WoodysStable	112	6	1	7	439	3.92	.162	1.714	2.939	.258	.228	-.943	.453
BaregroundSeen	119	6	1	7	541	4.55	.171	1.867	3.487	-.332	.222	-1.321	.440
LandExcellentCond	91	6	1	7	256	2.81	.152	1.452	2.109	.846	.253	.100	.500
Mesquite	113	3	1	4	247	2.19	.095	1.014	1.028	.193	.227	-1.204	.451
Juniper	106	3	1	4	271	2.56	.106	1.096	1.202	.074	.235	-1.328	.465
OtherBrush	113	3	1	4	216	1.91	.084	.892	.796	.560	.227	-.682	.451
BareGround	114	3	1	4	303	2.66	.065	.689	.475	-.258	.226	.020	.449
InvasiveWeeds	118	3	1	4	228	1.93	.078	.845	.713	.390	.223	-.868	.442
LivestockTrails	118	3	1	4	248	2.10	.058	.632	.400	.743	.223	1.666	.442
Gullies	116	3	1	4	265	2.28	.066	.708	.501	.278	.225	.044	.446

SoilCompaction	117	3	1	4	295	2.52	.072	.783	.614	.639	.224	-.449	.444
Pedestals	117	3	1	4	298	2.55	.075	.815	.664	.527	.224	-.603	.444
PlantLitterObstructions	112	3	1	4	268	2.39	.084	.894	.799	.676	.228	-.426	.453
WaterFlowPatterns	116	3	1	4	290	2.50	.080	.860	.739	.501	.225	-.611	.446
TallGrass	118	3	1	4	206	1.75	.070	.764	.584	.819	.223	.288	.442
ShortGrass	116	3	1	4	207	1.78	.063	.683	.466	.801	.225	1.332	.446
Turkey	116	3	1	4	199	1.72	.078	.842	.710	1.026	.225	.367	.446
Quail	117	3	1	4	307	2.62	.072	.774	.599	-.708	.224	.072	.444
OtherBirds	115	3	1	4	262	2.28	.090	.960	.922	.684	.226	-.458	.447
Predators	115	3	1	4	201	1.75	.064	.686	.471	.869	.226	1.413	.447
Hogs	116	3	1	4	155	1.34	.073	.791	.625	2.436	.225	4.979	.446
Deer	116	3	1	4	169	1.46	.057	.610	.372	1.454	.225	3.288	.446
Reptiles/Amphibians	116	3	1	4	257	2.22	.080	.863	.744	.806	.225	.168	.446
OtherWildlife	114	3	1	4	263	2.31	.090	.961	.923	.749	.226	-.444	.449
Valid N (listwise)	62												

Quality of Life Descriptive Statistics

	N	Range	Minimum	Maximum	Sum	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
FreeTime	115	6	1	7	354	3.08	.174	1.864	3.476	.719	.226	-.774	.447
FamilyInvolve	116	6	1	7	332	2.86	.158	1.699	2.885	1.021	.225	-.113	.446
Satisified$	116	6	1	7	458	3.95	.156	1.683	2.832	.250	.225	-1.133	.446
PersonalSatisfaction	116	4	1	5	208	1.79	.081	.870	.757	1.385	.225	2.466	.446
ActiveCommunity	117	5	1	6	325	2.78	.136	1.469	2.157	.609	.224	-.540	.444

TimeToLearn	116	6	1	7	282	2.43	.120	1.294	1.673	1.356	.225	1.786	.446
GoodNeighbors	117	6	1	7	223	1.91	.090	.974	.948	2.073	.224	7.661	.444
NegativeHealth	117	6	1	7	618	5.28	.147	1.586	2.515	-.793	.224	-.128	.444
AllInvolvLongPlanning	118	6	1	7	297	2.52	.126	1.370	1.876	1.436	.223	2.131	.442
ReasonForRanching	121	4	0	4	239	1.98	.098	1.076	1.158	.254	.220	-1.598	.437
Profit	114	7	0	7	317	2.78	.167	1.779	3.164	.713	.226	-.361	.449
CattleProductivity	115	6	1	7	342	2.97	.143	1.530	2.341	.687	.226	.068	.447
LandHealth	113	5	1	6	283	2.50	.141	1.495	2.234	.718	.227	-.536	.451
Tax	112	7	0	7	466	4.16	.180	1.901	3.614	-.179	.228	-1.067	.453
FamilyIssues	113	6	1	7	498	4.41	.172	1.826	3.333	-.364	.227	-.991	.451
NeighborIssues	112	6	1	7	689	6.15	.120	1.268	1.607	-1.938	.228	3.976	.453
Weather	113	6	1	7	516	4.57	.156	1.658	2.748	-.454	.227	-.608	.451
Myself	121	7	0	7	116	.96	.057	.624	.390	7.336	.220	74.205	.437
RanchEmployees	121	2	0	2	38	.31	.044	.484	.234	1.035	.220	-.375	.437
Family	121	3	0	3	92	.76	.044	.483	.234	-.087	.220	2.666	.437
Other	121	4	0	4	19	.16	.044	.483	.233	4.907	.220	33.205	.437
MyHealth	121	1	0	1	71	.59	.045	.494	.244	-.357	.220	-1.904	.437
MyTime	121	1	0	1	92	.76	.039	.429	.184	-1.235	.220	-.483	.437
MyStandardLiving	120	1	0	1	58	.48	.046	.502	.252	.068	.221	-2.030	.438
MyFamily	121	1	0	1	101	.83	.034	.373	.139	-1.825	.220	1.352	.437
MyFriends	121	1	0	1	24	.20	.036	.400	.160	1.532	.220	.353	.437
MyNeighbors	121	1	0	1	38	.31	.042	.466	.217	.811	.220	-1.365	.437
MyEmployees	121	1	0	1	45	.37	.044	.485	.236	.537	.220	-1.741	.437
LocalCommunity	121	1	0	1	29	.24	.039	.429	.184	1.235	.220	-.483	.437
Ecosystem	121	1	0	1	83	.69	.042	.466	.217	-.811	.220	-1.365	.437
FutureGenerations	121	1	0	1	91	.75	.039	.434	.188	-1.182	.220	-.613	.437
AllPeoplePassingThru	121	1	0	1	25	.21	.037	.407	.165	1.468	.220	.156	.437
Other	121	1	0	1	8	.07	.023	.250	.062	3.536	.220	10.681	.437
Valid N (listwise)	107												

Personal Characteristics Descriptive Statistics

	N	Range	Minimum	Maximum	Sum	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
County	124	6	1	7	357	2.88	.152	1.695	2.871	.855	.217	-.238	.431
#Acres	124	17920	80	18000	393930	3176.85	332.348	3700.866	1.370E7	2.108	.217	3.991	.431
YearsExperience	124	70	0	70	4134	33.34	1.428	15.903	252.909	-.215	.217	-.610	.431
YearsInFamily	124	148	2	150	6726	54.24	3.577	39.829	1586.364	.648	.217	-.577	.431
AssociationWithProperty	124	4	1	5	283	2.28	.096	1.064	1.131	.442	.217	-.212	.431
Age	124	56	1924	1980	241557	1948.04	1.042	11.599	134.527	.318	.217	-.235	.431
Gender	124	1	1	2	140	1.13	.030	.337	.113	2.240	.217	3.068	.431
Education	124	5	1	6	593	4.78	.098	1.094	1.196	-1.185	.217	1.409	.431
SelfStudy	124	300	0	300	2821	22.75	3.989	44.418	1972.953	4.412	.217	23.737	.431
Internet	124	1	0	1	44	.35	.043	.480	.231	.614	.217	-1.650	.431
Periodical	124	1	0	1	62	.50	.045	.502	.252	.000	.217	-2.033	.431
UnivInfo	124	1	0	1	31	.25	.039	.435	.189	1.169	.217	-.644	.431
NRCS	124	1	0	1	50	.40	.044	.493	.243	.399	.217	-1.871	.431
Extension	124	1	0	1	57	.46	.045	.500	.250	.164	.217	-2.006	.431
Peers	124	1	0	1	66	.53	.045	.501	.251	-.131	.217	-2.016	.431
Salesman	124	1	0	1	4	.03	.016	.177	.031	5.360	.217	27.164	.431
Consultant	124	1	0	1	30	.24	.039	.430	.185	1.220	.217	-.520	.431

Store	124	1	0	1	22	.18	.034	.384	.147	1.710	.217	.937	.431
PropertyForSale	124	1	1	2	240	1.94	.022	.247	.061	-3.589	.217	11.058	.431
LiveOnPropertyY/N	124	1	1	2	174	1.40	.044	.493	.243	.399	.217	-1.871	.431
YearsLOPY	124	75	0	75	2200	17.74	1.856	20.672	427.331	.927	.217	-.297	.431
DistanceLOPN	124	575	0	575	3113	25.10	5.920	65.924	4345.965	5.582	.217	40.785	.431
LOPNrural	124	1	0	1	20	.16	.033	.369	.136	1.864	.217	1.500	.431
LOPNurban	124	2	0	2	26	.21	.038	.428	.183	1.755	.217	1.962	.431
LOPNnotTexas	124	1	0	1	1	.01	.008	.090	.008	11.136	.217	124.000	.431
LandInvestment	124	1000000	0	1000000	12686726	102312.31	12819.052	142746.921	2.038E10	3.518	.217	16.180	.431
ShortGrass	124	80	0	80	2171	17.51	1.461	16.271	264.740	1.767	.217	3.922	.431
MidGrass	124	1020	0	1020	3555	28.67	8.168	90.960	8273.768	10.693	.217	117.362	.431
TallGrass	124	79	0	79	3030	24.44	1.595	17.766	315.630	.751	.217	.260	.431
GrassTreeMix	124	98	0	98	1464	11.81	1.307	14.552	211.751	2.436	.217	9.757	.431
Woodland	124	70	0	70	2251	18.15	1.398	15.564	242.245	1.282	.217	1.185	.431
Water	124	20	0	20	466	3.76	.300	3.338	11.144	1.721	.217	4.381	.431
Other	124	98	0	98	563	4.54	1.232	13.724	188.348	4.607	.217	24.843	.431
%IncomeFromProperty	124	100	0	100	5316	42.87	3.171	35.309	1246.747	.349	.217	-1.386	.431
Cow/Calf	124	303	0	303	6490	52.34	3.618	40.289	1623.185	1.871	.217	10.586	.431
Stocker	124	100	0	100	1547	12.48	1.992	22.187	492.284	2.380	.217	5.715	.431
Sheep	124	3	0	3	4	.03	.025	.283	.080	9.829	.217	100.908	.431
Goat	124	10	0	10	21	.17	.098	1.095	1.199	7.401	.217	58.883	.431
Hunting	124	80	0	80	648	5.23	1.174	13.074	170.940	4.135	.217	19.225	.431

Exotics	124	85	0	85	197	1.59	.875	9.742	94.911	7.505	.217	58.178	.431
Crop	124	50	0	50	385	3.10	.763	8.494	72.143	3.760	.217	15.133	.431
Recreation	124	50	0	50	147	1.19	.549	6.117	37.421	6.599	.217	46.219	.431
Minerals	124	100	0	100	2718	21.92	2.786	31.026	962.611	1.173	.217	-.095	.431
Other	124	50	0	50	244	1.97	.672	7.482	55.983	4.220	.217	18.804	.431
NoIncome	124	0	0	0	0	.00	.000	.000	.000	.	.	.	.
Income	124	5	1	6	545	4.40	.106	1.181	1.395	-.933	.217	.333	.431
Valid N (listwise)	124												

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