PUBLIC RESOURCE ALLOCATION FOR PROGRAMS AIMED AT MANAGING WOODY PLANTS ON THE EDWARDS PLATEAU: WATER YIELD, WILDLIFE HABITAT, AND CARBON SEQUESTRATION

A Thesis

by

AMBER MARIE DAVIS

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2006

Major Subject: Rangeland Ecology and Management

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Approved by:

Chair of Committee,	Urs P. Kreuter
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ABSTRACT

Public Resource Allocation for Programs Aimed at Managing Woody Plants on the Edwards Plateau: Water Yield, Wildlife Habitat, and Carbon Sequestration. (May 2006)

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The Edwards Plateau is the drainage area for the Edwards Aquifer, which provides water to over 2.2 million people. The plateau also provides other ecosystem services, such as wildlife habitat and the sequestration of atmospheric carbon dioxide. The public concern for continued delivery of these ecosystem services is increasing; with private landowners of the plateau region affecting the delivery of these services. A geographic information systems spatial analysis was conducted for Bandera and Kerr counties, with two components being: (1) biophysical and (2) landowner interest. Together these resulted in an overarching map depicting the optimal locations to allocate government assistance to landowners for managing their property to support three ecosystem services: water yield, wildlife habitat, and carbon sequestration.

In April 2003, a mail survey of selected landowners was conducted to determine their opinions regarding ecosystem services and cost-share programs (Olenick et al. 2005). In July 2004, a supplemental survey of respondents to the first survey was conducted to follow-up on a few questions answered incorrectly and to focus on landowner opinions regarding cost-share assistance programs and land management activities. Overall, it appeared that five year performance contracts were the most chosen

contract type for respondents of all property sizes, earning mid/high annual incomes, and for all length of ownership time periods. Based on our findings, the publicly-funded assistance programs that should be allocated to the optimal ecosystem service locations are five and ten year performance contracts based on property size, length of ownership, and income level categories.

The spatial and statistical analysis results were successful, in that optimal locations and types of cost share programs were identified for each ecosystem service in order to prioritize the allocation of limited public resources. The patches of ecosystem target areas within the final target area map can be used as land management demonstration sites to reveal to surrounding landowners the benefits of participating in publicly funded cost-share assistance programs. However, the study has been limited by the generality of the GIS statewide wildlife data.

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CHAPTER I

INTRODUCTION

Land Management in the Edwards Plateau has attracted increasing public interest because over two million people in and around Austin and San Antonio depend on many of the biophysical services that rangelands on the Edwards Plateau provide, specifically high quality water (Dugas et al. 1998). In addition, society at large values other ecosystem services that these rangelands provide including wildlife habitat and carbon sinks (Bovey 2001). The Edwards Plateau is increasingly being subjected to land subdivision, land use changes, and habitat fragmentation. Fire suppression and overgrazing have led to increasing woody plant invasion and ecosystem homogenization resulting in declining biodiversity (Bovey 2001, McGinty and Ueckert 1997).

Because of these deleterious effects, land subdivision and land use change on ecosystem services, there is increasing public interest to provide incentives for private landowners (who dominate the landscapes across Texas) to implement land management practices that maintain or improve ecosystem services. There are land management practices, which could possibly enhance the three main ecosystem services, water yield, wildlife habitat, and carbon sequestration. In order to increase water yield, it might be beneficial for landowners to undertake extensive woody plant removal, especially juniper. Wildlife habitat could be heightened by selective removal of woody plants.

This thesis follows the style of *Rangeland Ecology and Management.*

Current hypotheses regarding carbon sequestration are that maintaining woody plant cover leads to more carbon sequestration and that areas suitable for maintaining woody plant cover are coincident with steeper slopes and canyons which golden-cheeked warbler inhabit.

There are two challenges that landowners must face when managing their land for the three ecosystem services. Currently, there are limited public funds for investing in improved land management practices on private land. There are also potential conflicts between programs aimed at enhancing ecosystem services. For example, if brush is removed to increase water yield, will carbon sequestration be reduced? In order to address these two challenges, a prioritization of both biophysical potentials and landowner interests for each type of ecosystem service needs to be developed.

Problem Statement

On private land, there are economical negative impacts on ecosystem services that require economic investments may not be maintained because landowners capture only part of the benefit of managing land appropriately but bear all of the costs for the benefit of society. Ecosystem services are considered a public good and are therefore under supplied without public investment. However, tradeoffs occur when making choices about investments of limited public funds in potentially conflicting programs aimed at improving competing ecosystem services. Landowner willingness to participate depends on their perception about commitments imposed by alternative legal instruments.

Objectives and Hypothesis

The first objective of the research was to create an overarching map for two counties in Texas depicting the best locations for government assistance (resources) to be allocated to landowners for managing private lands, in order to support three ecosystem services: water yield, wildlife habitat, and carbon sequestration. Attaining this objective required a three-phase approach (1) a GIS, spatial analysis of the potential for allocating public funds for each of the three ecosystem service, (2) a spatial evaluation of interest in participating in each of these three types of programs, and (3) evaluation of most preferred contracts for entering in programs.

Objective 1. Developing a layered potential map for prioritizing the allocation of limited public funds for the enhancement of three potentially conflicting land management objectives: increase water yield, improve wildlife habitat, and increase carbon sequestration.

H_1: Areas with slopes greater than 15% should represent a small portion of study area, which will benefit water yield using woody plant removal methods because brush management will be less costly on slopes greater than 15%. Wildlife species requiring reduced brush growth will also benefit with brush management to create openings for native grasslands to re-establish.

H_2: Riparian areas also represent a small portion of study areas, which provides habitat for wildlife to flourish, and riparian areas may assist in maintaining water quality.

H_3: Areas less than 15% slope and non-riparian represent the greatest overlap for biophysical conditions suitable for programs aimed at improving ecosystem services of interest. These areas would be the focal points for endangered species and as a default carbon sequestration because woody species would not be managed.

H_4: Landowner willingness to participate in programs is geographically clustered.

Objective 2. Determine the relative acceptability of alternative contracted instruments for entering into publicly funded land management programs, and the effect of level of cost sharing on landowner willingness to participate.

H_1: For contracts available to landowners, performance contracts and conservation easements are the most preferred options because landowners receive an economic incentive while not loosing part of their property rights.

Thesis Structure

The Thesis is organized into four chapters: (I) Introduction, (II) Literature Review, (III) Spatial Analysis, and (IV) Statistical Analysis.

CHAPTER II

LITERATURE REVIEW

Human population growth has increased throughout Texas, especially in west-central Texas and in the Edwards Plateau region, where the population currently stands at 2.1 million inhabitants, primarily due to population shifts from urban to rural areas. The population within this region is predicted to double by 2030 (Thurow et al. 2001).

The Edwards Plateau is an important hydrologic region in central Texas. It is the drainage area for the Edwards Aquifer, which provides drinking water to over two million people (Dugas et al. 1998), including the inhabitants of Austin and San Antonio, the 9th largest city in the United States (Thurow et al. 2001). Nevertheless, the storage capacity of the aquifer is insufficient to meet the increasing demand for water, unless methods are devised to increase water yield (Dugas et al. 1998).

By acting as catchments, rangelands contribute to the supply of surface and underground water. However, woody plants have been invading rangelands throughout the United States, negatively impacting the ecological functions of natural grasslands (Bovey 2001; McGinty and Ueckert 1997). Controlling brush may result in numerous benefits, such as an increase in the aquifer recharge rates in some cases (Hester et al. 1997; Bovey 2001; Wilcox 2002), improved livestock and wildlife habitats, enhanced aesthetics and recreational activities, and increased economic benefits to landowners (Bovey 2001).

Several cost-share assistance programs have been developed to help landowners manage brush on their land. The Environmental Quality Incentives Program (EQIP) is

administered by the Natural Resource Conservation Service (NRCS), and provides financial and technical assistance to agricultural producers wanting to enhance the environmental quality on their property (Environmental Quality Incentives Program 2004). The Conservation of Private Grazing Land Program (CPGL), also sponsored by the NRCS, provides technical support, but not financial assistance, to private landowners who want to improve the natural resources on their property, such as water quality, wildlife habitats, recreational activities, and aesthetics (Conservation of Private Grazing Land 2003). The Conservation Reserve Program (CRP), sponsored by the Farm Service Agency (FSA), is available to qualified agricultural producers who are willing to enter into a 10 – 15 year contract to protect sensitive lands and promote increases in water quality, decreases in soil erosion, and healthier wildlife habitats (Conservation Reserve Program 2003). In addition, the FSA administers the Grassland Reserve Program (GRP) to provide financial assistance to landowners for conserving and improving grasslands (Grassland Reserve Program 2003).

Characteristics of the Edwards Plateau

The rangelands of the Edwards Plateau cover twelve counties (Edwards, Kinney, Uvalde, Real, Kerr, Bandera, Medina, Bexar, Kendall, Comal, Hays, and Travis) that are crucial to the Edwards Aquifer water cycle (Eckhardt 2004). The composition of the 24,000,000-acre plateau and aquifer (Caesar 1991) includes 3 zones: a drainage, recharge, and artesian zone (Eckhardt 2004). The drainage or catchment region encompasses the north and west sections of the Edwards watershed (Dillon 1991) and covers 4,400 square miles of the hill country (Wu et al. 2001). With an elevation of

1,000 to 2,300 feet above sea level (Eckhardt 2004), the catchment area creates a drainage path for precipitation runoff to enter the recharge zone in the eastern and southern edges of the Plateau (Dillon 1991). The Edwards Aquifer recharge area encompasses 1,500 square miles of the plateau, and allows runoff to enter the aquifer via cracks occurring in the limestone substrate (Eckhardt 2004). The components in Medina and Uvalde County contribute the largest proportion of surface water supply to the artesian region (Eckhardt 2004).

Vegetative Characteristics

Historically, the plateau's vegetative characteristics consisted of a grassland savannah with woody brush predominately growing in steep canyons and riparian areas (Fuhlendorf et al. 1997; Bryan 1991; Scrifes and Hamilton 1993). The previously prevalent grasslands contribute to the water cycle by impeding overland flow and enhancing infiltration (Thurow 1985). Deep drainage also occurs more frequently under shallow-rooted grasses rather than deep-rooted woody vegetation (Polley et al. 1997).

However, plant communities within the Hill Country now consist primarily of juniper-oak savannahs with openings of short, bunchgrasses (Hester et al. 1997). Dominant woody species include Ashe Juniper (*Juniperus ashei),* redberry juniper (*Juniperus pinchotii),* live oak (*Quercus virginiana*), Vasey shin oak (*Quercus pungens* var. *vaseyana*), and honey mesquite (*Prosopis glandulosa*) (Rollins et al. 1988; Wu et al. 2001). The predominant herbaceous species consist of sideoats grama (*Bouteloua curtipendula),* curly-mesquite (*Hilaria belangeri*), Texas wintergrass (*Stipa leucotricha*), and threeawn (*Aristida purpurea*) (Rollins et al. 1988; Wu et al. 2001).

Juniper

Ashe juniper is an evergreen species dominating much of the Edwards Plateau (Lyons et al. 1998; Fuhlendorf, Smeins, and Taylor 1997) which occurs in clusters with oaks, Texas persimmon, and mesquite (Sullivan 1993). Ashe junipers reach a maximum height of 30 feet (9m), and mature between 10 to 20 years when the trees begin to produce seeds and shed bark (Sullivan 1993). The canopy doubles every ten years (McGinty 1994), but does not usually exceed twelve feet in diameter (Lyons et al. 1998). With their dense canopy and broad root system, Ashe junipers intercept large amounts of precipitation and draw up much soil water, thereby inhibiting rainfall from recharging groundwater (Sullivan 1993). Lyons et al. (1998) estimated that juniper canopies intercept 37% of annual rainfall and the leaf litter beneath the tree intercepts an additional 43% of yearly precipitation. However, Ashe juniper has potential economic values and uses; including the heartwood for fence posts (Sullivan 1993), and the oils for perfumes and insect repellant (Garriga 1998). However the labor costs for preparing the heartwood increases the price of Texas juniper oil, therefore diminishing its competitiveness with alternative, less expensive oils (Garriga 1998). The fence post market also suffers because longer-lasting steel fence posts out-compete juniper posts (Garriga 1998).

Redberry juniper is an evergreen dominating the northern and western portions of the Edwards Plateau (Lyons et al. 1998). This species matures at approximately 12 years of age (McGinty 1994; Ueckert 1997) and reaches a maximum height of 15 feet with the canopy not exceeding 12 feet in width (Lyons et al. 1998). The invasion of redberry

juniper can negatively impact the water cycle on grasslands, due to rainfall interception by the canopy (26% of yearly precipitation) and the tree's litter (40%) (Lyons et al. 1998; Ueckert 1997). Redberry juniper does not have the economic potential of Ashe juniper, but the trees have possible uses as fence posts (Sullivan 1993). Wildlife and livestock consume the berries produced by the tree (Everitt et al. 2001; McGinty and Ueckert 1997) and use the oak and juniper clusters as cover from weather (Sullivan 1993).

Even though juniper can negatively impact water yield, the trees serve important functions for wildlife on the Edwards Plateau (Sullivan 1993; Fuhlendorf, Smeins and Taylor 1997). The berries provide food for small mammals and birds between the months of November and April (McGinty 1994; Rollins and Armstrong 1997; Fuhlendorf, Smeins and Taylor 1997). White-tailed Deer (*Odocoileus virginianus texanus*) and livestock consume juniper foliage between January and March (Bryan 1991; Rollins and Armstrong 1997), but the low palatability of the forage does not supply a nutrionally adequate food source (Sullivan 1993). In addition, the broad canopy of Ashe juniper provides thermal and protective cover for mammals and birds (Lyons et al. 1998; Rollins and Armstrong 1997).

Oak

The two species of oak most abundant throughout the Edwards Plateau are shin oak and live oak. Both species are long-lived, semi-evergreen trees that lose and re-grow their leaves during the spring (USFS 2005, Bovey 2001). Landowners highly value oaks for their aesthetic characteristics and cover during the hot summer months (USFS 2005).

In addition, both species produce acorns (Bovey 2001; Kroll 1980) during the fall, an important source of protein, fat, and fiber for wildlife and livestock (USFS 2005), which are selected over junipers as a food source during the food stressed winter months (Vallentine 1960). Oaks also provide cover for wildlife and livestock from weather and predators (USFS 2005). However, an over abundance of large oaks can impede livestock handling and the growth of grasses (Vallentine 1960).

Other

Honey mesquite mixes with junipers and oaks to form thickets throughout the grassland and riparian areas of the Edwards Plateau (Steinberg 2001). Wildlife and livestock use mesquite as cover from weather and predation, and birds use the trees for nesting (Steinberg 2001). In addition, livestock and white-tailed deer consume the nutritional seeds during the summer and fall thereby creating a means for seed dispersal and continual spread of the grassland invader (Steinberg 2001). However, dense stands of mesquite interfere with livestock handling due to the thorny clusters formed by these trees (Steinberg 2001). Some experts believe mesquite does not appear to greatly affect water yield on the Edwards Plateau and its removal would not significantly increase the amount of water entering the Edwards Aquifer (Wilcox 2002; Desai 1992). One study found that both dense or open canopy throughfall of rain was very similar, and as trees grew taller throughfall increased while interception loss decreased (Desai 1992). Another study of mesquite trees in the Blackland Prairie region of Texas, found that the trees used more subsurface water than herbaceous plants, but after mesquite removal there was no change in evapotranspiration, runoff, or drainage because of the increased

productivity of other plant species (Weltz and Blackburn 1995). Land managers encounter difficulties when managing honey mesquite because of the plants ability to resprout. The most beneficial mesquite management method includes the use of broadcast and individual plant treatment using herbicides and/or proper grazing systems followed by prescribed burning (Steinberg 2001; Welch et al. 1985).

Wildlife Characteristics

White-tailed Deer

Juniper and oak species represent the majority of vegetative growth occurring in white-tailed deer habitats throughout the Edwards Plateau region (Halls 1984), protecting deer from weather (Bryan 1991) and predators, such as coyotes and bobcats (Halls 1984). Deer frequently travel in riparian areas with vegetative cover in order to remain hidden (Lyons and Ginnett 1998). In addition, deer prefer habitats providing an edge adjacent to forage and covered areas (Richardson 1999). White-tailed deer diets fluctuate seasonally between browse (roots, twigs, leaves of trees, etc.), forbs, and mast (hard fruits of trees such as acorns), but the majority of their diet consists of forbs and mast (Lyons and Ginnett 1998). Browse, forbs, and mast along with water and cover consists of the three main essential elements for White-tailed Deer habitats (Lyons and Ginnett 1998).

Grassland Birds

With an increase in brush density throughout Texas prairies, grassland bird populations have declined rapidly due to a decline in grassland-nesting habitats (Rosenstock and Van Riper 2001). The bobwhite quail (*Colinus virginianus*) is another

economically important wildlife species inhabiting the Edwards Plateau (Lockwood 2001, Lyons and Ginnett 1998). The habitat components necessary for a healthy quail population includes a variety of vegetation ranging from open canopies to close canopy woody plant species (Lockwood 2001; Lyons and Ginnett 1998). In general, quail require resting or loafing areas of live-oak mesquite savannas (Lockwood 2001; Rollins 2000), which consists of a maximum of 25% woody plant canopy cover at least one foot above the ground with little undergrowth vegetation and shorter herbaceous vegetation growing around the periphery (Lyons and Ginnett 1998). Travel areas scattered throughout their habitat is necessary and includes grasslands with short brush and bare ground for consuming seeds (Lyons and Ginnett 1998). During March and June, one breeding pair requires 250 acres of perennial grasses to provide cover for nests and young chicks, and forbs or canopies of smaller brush species to ensure a habitat for quail's food source - insects (Lyons and Ginnett 1998). In order to remain safe from predators, escape cover is needed near travel areas and roosting vegetation at a maximum of six inches tall (Lyons and Ginnett 1998). For management considerations, block patterns of travel and loafing areas are not beneficial for bobwhites. These areas need to be in strip patterns or scattered throughout the habitat (Lyons and Ginnett 1998), with brush occurring every fifty yards and with at least fifty square feet in area, woody vegetation at a maximum of twenty-five yards from grasslands, and land management not to exceed 90% of the habitat (Rollins 2000).

The rio-grande turkey or wild turkey (*Meleagans galloparo*) is another bird species in the Edwards Plateau region that requires diverse habitat (Lockwood 2001,

Lyons and Ginnett 1998) ranging from 370 to 1,360 acres in area (Lyons and Ginnett 1998). Dense canopies do not provide an adequate habitat; only 50% of woody plant species consisting of juniper and oaks is necessary to provide cover, mast, and roosting sites. (Lockwood 2001; Lyons and Ginnett 1998). The remaining 50% of the habitat should consist of herbaceous vegetation (Lockwood 2001; Lyons and Ginnett 1998) located in canopy openings, along roads, and on the edge areas between grasses and woodlands. Turkeys use herbaceous vegetation areas for breeding (4-8 inch grass heights), nesting with at least three feet tall grasses, and rearing their young (Lyons and Ginnett 1998). Three necessities for young turkeys include large amounts of insects and escape cover (Lyons and Ginnett 1998). In addition, during fall and winter seasons food and roosting, provided by live oak, hackberry, pecan, cedar, elm, cottonwood, and willow trees, are the two key factors for turkey habitats (Lyons and Ginnett 1998). For management there are four important considerations: ground-level water close to habitats, mast producing and roosting woody vegetation should remain (Rollins 2000) in at least in 50% of the habitat, openings should be at a maximum of half a mile across scattered throughout a 50% mixture of large and small trees, and a 50% mixture of brush and openings (Lyons and Ginnett 1998).

Endangered Species

Golden-cheeked Warbler

One bird species depending on Ashe junipers for survival is the endangered Golden-cheeked Warbler (*Dendroica chrysoparia*) (Damude 2005; McGinty 1994; Kroll 1980; Coldren 1998), which breeds and nests in Central Texas from Mid-March until

June, when it migrates to Southern Mexico, Guatemala, Honduras, and Nicaragua (Damude 2005). Each breeding pair requires three to six acres of nesting habitat, and a total habitat range of five to twenty acres (Damude 2005). Golden-cheeked warblers prefer a 50 – 100% closed canopy of woodlands (Damude 2005) consisting of a mixture of hardwoods and ashe juniper growing on slopes or in canyons (Damude 2005; Rollins and Armstrong 1997). This warbler species selects ashe juniper trees of at least 20 years in age and 15 feet tall for nesting because these trees produce the dominant nesting material, shredded bark (Morse 1989). By contrast, the oak trees provide a shrubby vegetative understory and a habitat for insects upon which the warblers feed (Kroll 1980). Limited water availability is not a constraint for these birds because they can travel long distances to obtain water and their insect diets provide adequate amounts of fluid (Coldren 1998). Unfavorable habitats for Golden-cheeked warblers consists of canopy cover less than 35% and sites composed mainly of junipers with less than 10% hardwoods (Damude 2005). Increases in human development density contribute to habitat loss threatening the survival of the species (Poole and Gill 1999), and population declines are also attributed to nest parasitism by Brown-headed Cowbirds (*Molothrus ater*). Despite the narrow habitat tolerance of golden-cheeked warblers (Bryan 1991) and the human population growth occurring on the Edwards Plateau (Thurow et al. 2001) the Texas Hill-Country consists of abundant slopes and dense mixed juniper-oak stands, which provide an excellent nesting and breeding habitat for the Golden-cheeked warbler (Hester et al. 1997).

Black-capped Vireo

The Black-capped Vireo (*Vireo atricapillus*) is a second endangered bird species that inhabits mixed grassland/woodland areas in the Edwards Plateau (Damude 2005). This tiny songbird breeds in Central Texas, a small portion of Oklahoma, and Central Coahuila, Mexico from Mid-March/Mid-April to Mid-September, and spends the winter months on the western coast of Mexico (Damude 2005). The home range is comprised of two to four acres (Damude 2005) of scrub-oak growth (Graber 1961). Nesting habitats contain patches of approximately 30-60% shrub and tree cover growing near the surface (Damude 2005) with the maximum nest height reaching six feet (Grzybowski 1995). Their insect diet provides sufficient amounts of water, and does not restrict their nesting sites to areas without water (Graber 1961). The Black-capped vireo is classified as an endangered species because of vulnerabilities to the impacts of human activities, such as urbanization, improper brush management, and fire suppression. Additional threats consist of nest parasitism by Brown-headed Cowbirds and habitat loss caused by brush encroachment and intense herbivory of nesting sites by white-tailed deer and livestock (Damude 2005).

Causes and Effects of Woody Plant Increase

Within the United States' four billion hectares of land are considered either rangelands or pasturelands, and of this approximation one-third has undergone brush encroachment (Bovey 2001). Management goals need to incorporate brush control strategies for increasing the amount of water entering the aquifer from the cool and

warm season rainfall in order to meet the needs of the increasing populations of landowners, rural residents, urbanites, and wildlife inhabiting the Edwards Plateau.

The original herbaceous vegetation growing on the Edwards Plateau provided habitat and forage for wildlife and livestock (Dillard 2003). With the arrival of European settlers and their cattle in Texas 150 years ago, brush species began to spread onto the plateau's grasslands with a decrease in 90% of tall grasses, 30% of mixed prairies, and 80% of short-grasses (Wilkins et al. 2003). The woody plants out-competes herbaceous plants due to their taller canopy intercepting sunlight available to the understory vegetation (Thurow 1997), and by competing for the reduced amount of rain water that passes through the canopy and litter layers into the soil (Taylor and Fuhlendorf 2003). Based on such shifts, brush encroachment has been defined as "the increase in number and cover of woody plants across the landscape in which the brush already existed" (Hester et al. 1997).

Land Subdivision

Habitats on the Edwards Plateau are being effected negatively by land subdivision due to current growing urban populations in such cities as Austin, Kerrville, and San Antonio and rural land use increasingly changing from agriculture to aesthetic and recreational purposes (Wilkins et al. 2003; Lockwood 2001). Wilkins (2001) states that land fragmentation is one of four causes for increased difficulties for conserving natural resources on private lands. There are two types of fragmentation: ownership subdivision which is "dividing rural lands into smaller parcels that remain in rural use,"

and habitat fragmentation, defined as “progressive change in one type of continuous habitat coverage to a set of habitat patches or remnants (Wilkins 2001).”

In Texas 84-86% of land is privately owned. Recently land subdivision has increased with many medium sized ranches/farms (500 – 2,000 acres) dividing into smaller land-holdings (500 acres or less) (Wilkins et al. 2003). Throughout Texas 80% of ranches and farms are considered small properties (Wilkins et al. 2000), but large ownerships (2,000 acres or more) comprise most of the Edwards Plateau region (Wilkins et al. 2003). The lands of the plateau are being subdivided at a high rate. For example between 1992 to 2001 about 856,387 acres of native rangelands were lost (Wilkins et al. 2003). The primary downfall to large and medium landholdings fragmenting is the idea that small ownerships are more likely to change from native rangelands to non-native pastures (Wilkins et al. 2003). With accelerating smaller ownerships, native lands become increasingly scattered and too small sized to provide sufficiently large areas of habitat for wildlife (Wilkins et al. 2003).

Herbivory and Fire Suppression

The causes of woody plant invasion have been attributed to intense livestock grazing, dissemination of seed by livestock, fire suppression, elevated carbon dioxide levels, and climate changes (Rosenstock and Van Riper 2001; Wright et al. 1976; Scrifes and Hamilton 1993; Wilcox 2002; Bovey 2001; Smeins et al. 1997). Uncontrolled grazing by livestock contributed significantly to land cover changes in the hill country (Bryan 1991; Taylor and Fuhlendorf 2003; Smeins et al. 1997) which has led to a reduction in the competitive advantage of grasses over brush (Wink and Wright 1993).

The decline in short and mid-grass species in the landscape has caused decreases in infiltration rates, increased erosion, acceleration of the spread of woody vegetation (Taylor et al. 1993; Taylor and Fuhlendorf 2003), decreased wildlife and livestock habitats, and increased costs for livestock management (Taylor and Fuhlendorf 2003). Intensive grazing considerably reduced the fuel loads necessary for sustaining wildfires, an integral element for maintaining native grassland-savannas originally characterizing west-central Texas (Scrifes and Hamilton 1993). When natural fires were suppressed, woody plant seedling survival increased and brush encroachment accelerated (Scrifes and Hamilton 1993). Elevated carbon dioxide levels provide an additional explanation for increases in woody plants (Bovey 2001; Scrifes and Hamilton 1993; Owens 1997; Fuhlendorf 1999). Stomates begin closing when carbon dioxide levels increase, and the water stored within foliage permits plants with high carbon dioxide concentration to continue growing through drought and recover rapidly following dry periods (Polley et al. 1997). Since woody plants tend to be larger and, therefore, stores larger amounts of carbon dioxide than grass plants, brush adapts better to drought stresses (Polley et al. 1997). Water consumption by woody plants may exceed that of herbaceous vegetation, resulting in smaller amounts of deep drainage and disruption to the overall water cycle (Eckhardt 2004).

Water Cycle

In the Edwards Plateau, the distribution of rainfall determines the total amount of recharge entering the aquifer (Wilcox et al. 2003). The water balance equation, $P = ET + R + G + \Delta S$, assists in determining the amount of precipitation (P) used in each

component of the total water budget: evapotranspiration (ET), runoff (R), ground water recharge (G) and change in soil water (ΔS) (Hibbert 1983). Evapotranspiration involves the conversion of water turning from liquid to vapor via the interception and evaporation of rain by the plant canopy and litter layers, evaporation from bare soil, and transpiration by plants (Wilcox et al. 2003). On the Edwards Plateau, evapotranspiration accounts for 90-95% of the water balance because oaks (*Quercus sp.*) and junipers (*Juniperus sp.*) are characterized by high levels of interception, evaporation, and transpiration (Wu et al. 2001). Transpiration rates increase with the growth of such woody plants, due to junipers and oaks having denser leaf canopies, longer growing seasons, and extended lateral and longitudinal root systems compared to grasses (Wu et al. 2001). This is exhibited by difference in interception loss among plants: 70-80% interception rate for juniper, 46% for oak, and 11-18% for grasses (Wu et al. 2001). Thus, interception loss makes up 20-40% of the water budget, and occurs when precipitation evaporates at the canopy or litter layer without reaching the ground (Wilcox et al. 2003). In contrast, runoff, which consists of 5-10% of the water balance, determines the amount of recharge entering the Edwards Aquifer, and includes above ground, interflow, subsurface and groundwater flow (Wilcox et al. 2003). Infiltration rates above the Edwards Aquifer have decreased under the roots of woody vegetation, while increases in deep drainage has been reported when grassland root systems are reestablished (Thurow 1985).

Range managers classify the Edwards Plateau as a semi-arid rangeland, meaning intense rainfall occurs in small amounts and creates a serious problem for renewable aquifers when over consumption occurs (Thurow 1985). During the cool season

(October to April) the plateau experiences slow, steady rainfall, and the warm season (May to September) consists of storms with short, intense precipitation (Thurow 1985). Frequently, human water consumption from the Edwards Aquifer exceeds precipitation available to recharge the artesian zone (Jackson et al. 2001; Thurow 1997). It is estimated that by 2040 the demand for water in Texas will increase by 186% (Walker and Dugas 1999). Since rainfall determines the amount of water entering a renewable aquifer and water consumption presently exceeds the amount of precipitation available for storage, managing for increased water yield becomes a necessity (Jackson et al. 2001).

Carbon Sequestration

The environment needs continuous vegetative surface coverage in order to capture large amounts of carbon from the atmosphere (Robert 2001). Woodlands, savannas, shrublands, and grasslands encompass 40% of the world's surface, making these ecosystems a vital component for Earth's carbon sinks (Goodall and Davidson 2002). The rangelands of the United States also store large amounts of carbon in woody vegetation which accounts for approximately 18-34% of the country's total carbon sinks (Goodall and Davidson 2002). Carbon sequestration assists in promoting the sustainability of nutrient rich soils, which support healthy crops, reduce erosion, produce better forage for wildlife and livestock (Robert 2001), increases food production, increases infiltration rates, and increases water storage in the soil (Robert 2001). The intake of carbon dioxide by plants plays an important role in the climatic cycle and mitigating of global warming, since excess carbon accumulates in soils via above ground

vegetation (Schlesinger and Andrews 2000). In order to maintain carbon storage, land managers need to participate in controlled grazing, fire management and minimal fertilization for plant growth (Robert 2001). Erosion should also be avoided in order to reduce the loss of soil organic carbon (Robert 2001). While grasses and shrubs contribute significantly to the collection and storage of carbon in the soil, woody vegetation accumulates greater amounts of soil organic carbon, and therefore is a necessary component on the Edwards Plateau (Robert 2001). According Jackson et al. (2002), however, there is uncertainty of the actual amount of carbon storage increases when grasslands are invaded by woody vegetation.

Woody Plant Management

Managing brush encroachment presents landowners with difficulties because of tree height, adaptations, and quick growth and re-growth, but mechanical methods, herbicides, prescribed burning, and biological methods can be used to assist in controlling the speed of woody vegetation growth (Bovey 2001).

Mechanical (broadcast and individual)

The benefits of mechanical methods to control woody plants, such as increases in water yield and forage production, occur temporarily, but when followed with prescribed burning the advantageous effects continue for extended periods of time (Scrifes and Hamilton 1993). Handheld equipment, for grubbing, cutting, or girdling, present landowners with expensive and laborious control methods, but larger equipment, such as roller chopping, shredding, and chaining and to a lesser extent bulldozing, mechanical

grubbing, and railing, can provide a more cost effective and less time consuming means of managing brush encroaching on rangelands (Bovey 2001).

Since fire alone kills only young brush species, there are three beneficial mechanical methods used in coordination with prescribed burning that assist with the management of undesirable woody brush: roller chopping, shredding, and chaining (Richardson 1999). Roller chopping consists of top removal of brush species, and has many advantages for controlling Ashe juniper on the Edwards Plateau (Richardson 1999), such as thinning the dense canopy, providing fuel for burns, creating better natural cover, forage and browse for wildlife (Lyons and Ginnett 1998), and providing a quick method for landowners (Bovey 2001). This method disturbs the soil, which presents a means for increasing rainfall infiltration (Welch et al. 1985). Due to only temporary woody plant control results of chopping, burning within three to five years is a necessary follow-up treatment (Richardson 1999; Bovey 2001). Shredding, also involves the process of top removal, which increases the availability of browse and forbs for deer and livestock (Richardson 1999). Unless used along with prescribed burning, shredding rarely controls root or stem sprouting plant species (Richardson 1999; Bovey 2001). The benefits of shredding last a maximum of five years and repetitive use creates thickets of shrub and woody vegetation (Richardson 1999). Chaining entails thinning of undesirable brush remaining in diameter from four to eighteen inches (Welch et al. 1985), and presents a means of mechanical treatment that is inexpensive (Bovey 2001). With this method, maximum canopy reduction is approximately 20% (Richardson 1999), and in one case grass production may increase by 240 kg/ha less than two months after

chopping (Bryan 1991). The vegetation consumed by wildlife improves nutritionally and becomes more abundant (Richardson 1999). Chaining produces temporary results when used alone (Bovey 2001) but provides abundant fine fuels for burning (Welch et al. 1985).

By using techniques such as roller chopping, shredding, and chaining in combination with prescribed burning, dense tree canopies can be managed to allow naturally occurring shrubs and herbaceous vegetation to grow and provide suitable habitat for various wildlife species inhabiting the Edwards Plateau (Damude 2005). Management during fall and winter (September – February) should not harm the endangered bird species nesting and breeding in west-central Texas during spring and summer, but should enhance their reproductive success due to healthier habitats (Damude 2005). Because golden-cheeked warblers tend to avoid sites where an overabundance of juniper trees crowd out hardwood species, removal of young junipers from preferred areas should occur (Damude 2005). Brush control methods should not create widespread edges between nesting and livestock locations due to the negative influence of nest parasitism and predation by brown-headed cowbirds (Fullbright 1996).

Herbicides

Encroaching brush can also be controlled with the use of herbicides, which can be divided into two broad categories: broadcast and individual plant treatments. Broadcast applications have been declining in popularity and are increasingly being replaced by individual plant treatments. This shift is due to land subdivision of large properties into smaller landholdings, better protection of endangered species, and the

greater cost effectiveness of individual treatments relative to broadscale treatments (McGinty and Ueckert 1997). In addition, compared to mechanical control methods, herbicides applications can be less expensive, may have fewer negative impacts on the environment, and can control some woody plant species better (Bovey 2001).

Individual treatments provide a beneficial way to manage hard to kill vegetation and consist of foliage spraying, basal spraying, cut surface and injection, and cut stump (Bovey 2001). Foliar spraying provides best results when used during spring or summer application and when plants are growing and leaves have reached maturity but before thickening occurs (Bovey 2001). Basal sprays and cut surface/injection can be used to control woody plants throughout the year for plants with stem diameters reaching 13 cm, but cut surface/injection presents landowners with higher costs and labor demands (Bovey 2001). After mechanical methods, cut stump herbicide methods can be used to decrease re-sprouting (Bovey 2001).

Herbicide treatment of woody vegetation is beneficial depending on the species and type of chemicals used. The best herbicides to use for managing juniper includes basal and soil treatment of bromacil, hexaszinone, tebuthiuron, and picloram and foliar treatment with glyophosphate. Chemicals used when managing juniper with intermediate results, consists of foliar spraying of dicamaba and picloram (Bovey 2001).

Prescribed Burning (cool season and warm season)

A natural means for managingwoody brush encroachment is with the use of prescribed burning (Bovey 2001). The goals of prescribed burning include: suppressing brush, improve abundance and palatability of forage for wildlife and livestock,

increasing wildlife habitat, and reducing the amount of pests affecting both livestock and wildlife (White and Hanselka 1991). Since fires cannot sustain themselves without sufficient amounts of fuel, burning should be used in conjunction with effective grazing methods (Smeins and Fuhlendorf 1997), mechanical, chemical, and biological methods (Ansley and Taylor 2000; Bovey 2001; Scrifes and Hamilton 1993). Burning presents landowners and managers with a cost effective means of maintaining the results produced by mechanical techniques (Bovey 200; Welch et al. 1985). However, prescribed burning can be dangerous (Ansley and Taylor 2000), and intense summer fires should be used with caution to avoid increased erosion, runoff, and destruction of valuable forage for wildlife (White and Hanselka 1991). Fires of low intensity provide an adequate amount of heat to promote herbaceous growth but do not destroy all surface litter, which prevents increased runoff and erosion (Wright et al. 1976). In addition, with the continual increases in population growth, land subdivision, and ownership of lands and without the proper education or experience about burning, fires can pose a safety threat (Ansley and Taylor 2000) for animals and humans inhabiting the Edwards Plateau and who depend on water from the aquifer.

Biological Methods

Another inexpensive and beneficial way to manage brush is with the use of biological control methods, such as selective herbivory by livestock (Bovey 2001), but land managers/owners need proper education and experience with biological control in order to avoid damaging their land and desirable vegetation (Taylor et al. 1997).

The rangeland of the Edwards Plateau benefits in a variety of ways by having livestock present, but this depends on the type of grazing system landowners use and the density of livestock involved in these systems (Thurow 1985). Three grazing methods positively contributing to the management of woody vegetation on the plateau include high intensity, low frequency (HILF), moderate grazing, and rotational grazing (Thurow 1985). These three techniques allow infiltration rates to remain constant which does not negatively affect the water yield, the healthy condition of litter and vegetative cover remains stable, and if drought occurs herbaceous vegetation re-establishes quickly (Thurow, 1985). The negatives effects of livestock grazing arise with excessively high stocking rates, which have the ability to severely reduce herbaceous plants and exacerbate the brush encroachment problem. High stocking rates destroy the naturally occurring vegetation, increase runoff and erosion, reduce the amount of rainfall available to enter the aquifer, and enhance the competition over food and shelter between livestock and wildlife (Taylor et al. 1993). When stocking rates remain at moderate to low levels, livestock assist landowners in managing woody vegetation by promoting new grass growth and providing increased forb growth for wildlife (Kerr WMA: Management Program 2004).

An additional biological technique, already in use in some portions of the Edwards Plateau, incorporates the use of goats, which have the potential to reduce the rate of woody plant invasion (Taylor and Fuhlendorf 2003). When woody vegetation grows at an excessive rate, goats can be used in combination with other management techniques to slow the brush encroachment process and reduce the costs of mechanical

or herbicide methods (Taylor et al. 1997; Taylor and Fuhlendorf 2003). Stocking goats at a low or medium levels can reduce the negative effects of livestock and wildlife that consume the desirable herbaceous plants by reducing competition between herbaceous and woody vegetation (Taylor and Fuhlendorf 2003). Although goats consume undesirable woody vegetation, they also browse desirable plants, which increases the competitive advantage of undesirable woody plants over herbaceous vegetation (Taylor et al. 1997, Taylor and Fuhlendorf 2003). In addition, when goats share a habitat with deer, competition for forage can occur due to a preference by both species for the same browse and forbs (Taylor and Fuhlendorf 2003). The best time to use goats for brush management should be when woody vegetation are seedlings and more palatable and desirable herbaceous vegetation is limited (Taylor et al. 1997; Taylor and Fuhlendorf 2003). Landowners and land managers must use strict grazing systems to control the amount of vegetation browsed by goats. On the Edwards Plateau the maximum stocking rate should not be less than fifteen acres per goat (Taylor and Fuhlendorf 2003).

Similar Studies

A previous spatial analysis study was conducted by Brody et al. (2004) regarding the environmental perceptions of randomly selected San Antonio, Texas residents towards the pollution of two watersheds: Salado and Leon Creek. A survey was conducted within the city to determine what types of influences affect the perceptions of survey participants. The survey responses were incorporated into geographic information systems in order to determine if spatial clustering of respondent perceptions towards the two watersheds occurred at certain locations throughout the city of San Antonio and if

clustering exists why it occurs. The study provided areas in which respondents concerned with pollution are clustered in areas of high population and close to both creeks. This study's results can assist in targeting certain locations with the creation of environmental policies regarding pollution of two watersheds in San Antonio, Texas (Brody et al. 2004).

There have also been several past studies conducted using mail or interview structured surveys regarding the perceptions of landowners towards land management practices and cost-sharing contract preferences. Tays (2001), Amestoy (2002), Olenick et al. (2005), and Narayana (2003) have each conducted mail survey techniques within and around the Edwards Plateau region to determine various landowner perceptions pertaining to respondent willingness and interests in cost-share assistance and brush management programs. An additional landowner perception study was conducted by Sanders (2005) using an interview technique within the Leon River Watershed (Bell, Coryell, Hamilton, and Comanche counties) to understand the relationships among landowners and the characteristics of landowners to participate in conservation programs.

Current Study

This study is being conducted in order to compensate for the tradeoffs that have to be made for the ecosystem services being analyzed: increasing water yield, protecting wildlife habitat, and protecting endangered species habitat/improving carbon sequestration. What is meant by tradeoff is that when one of these services is managed (positively affected) then another service might be negatively impacted. For example,

when managing land in order to increase water yield, the invasive juniper trees are removed wich has the potential to disrupt the habitat of golden-cheeked warblers, possibly black-capped vireos, and the carbon sequestration cycle. Another example could be the protection of golden-cheeked warbler habitat, old growth mixture of juniper and oak trees, which could decrease the amount of water available to recharge the Edwards Aquifer and possibly impact other wildlife species requiring mid-successional brush growth or herbaceous vegetation habitats. By identifying optimal areas for each ecosystem service and understanding the perceptions of landowners regarding cost share assistance the tradeoffs should be less of a negative impact on water yield, wildlife habitat, and endangered species/carbon sequestration.

CHAPTER III

SPATIAL ANALYSIS

The Edwards Plateau region of Bandera and Kerr counties acts as a water catchment area for water draining into and recharging the Edwards Aquifer. There are two major metropolitan centers (Austin and San Antonio) that rely heavily on the catchment for recharge of the Edwards Aquifer, which supplies much of their water needs. An issue facing these two counties is increasing brush encroachment, primarily juniper, which effects not only the ability of the area to act as an effective catchment, but also to provide suitable habitat for several game and two endangered wildlife species.

Private property owners finance land management practices to improve ecosystem services, which ultimately benefits the public at little or no cost. Yet, landowners in the area are not able to effectively manage the spread of woody plant on their property because of the high cost involved and the lack of public assistance available for programs to offset land management cost. It is important to understand the perceptions of the landowners towards land management programs and to locate areas with highest biophysical potential, in order to efficiently allocate limited public funds to assist with effective land management that enhances ecosystem services, such as increasing water yield, protecting wildlife habitat, and sequestering carbon.

Methods

A spatial analysis was conducted using Geographic Information Systems (GIS) methods to prioritize locations within Bandera and Kerr counties (Figure 1) in terms of

their potentials for enhanced water yield (brush management), improved wildlife habitat, and endangered species protection plus atmospheric carbon dioxide (CO_2) sequestration programs. Wildlife habitat and landcover data were downloaded in raster format from the recently completed United States Geological Survey (USGS) 2004 Texas Gap Analysis website (USGS 2004). Gap analysis data is a broad set of data depicting the status of wildlife species and their habitats within the landscape (Jennings and Scott 1997). This data was created to help individuals manage land more efficiently (Jennings and Scott 1997). Bandera and Kerr County data, which included the shape of the county, urban areas, subdivision locations, and landowner parcels, were acquired from the Bandera County and Kerr County tax appraisal offices. In addition, a highway location shapefile was downloaded from the Texas Natural Resource Information System (TNRIS) website (http://www.tnris.state.tx.us/DigitalData/data_cat.htm), a shapefile of major rivers of Texas was downloaded from the Texas Water Development Board (TWDB) website (http://www.twdb.state.tx.us/mapping/gisdata.asp), and the digital elevation model (DEM) data for the two counties was obtained from the Texas A&M University Spatial Sciences Laboratory. The data projection used for the spatial analysis was Universal Transverse Mercator (UTM) Zone 14N North American Datum (NAD) 1983, which was the original projection of the GIS data from both Bandera and Kerr Counties' tax appraisal office. The spatial analysis consisted of two components: (1) biophysical and (2) landowner.

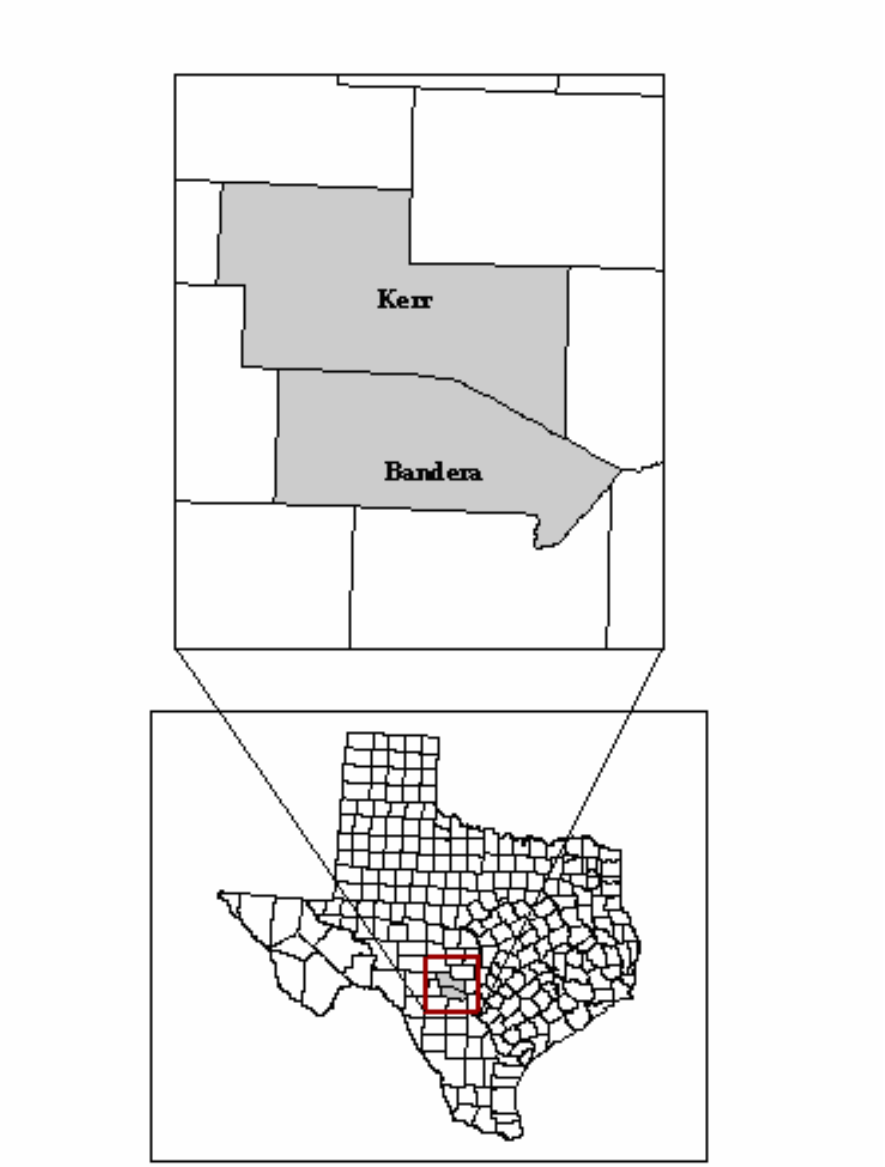

Figure 1. Location of counties for spatial analysis to prioritize potential for enhanced water yield, wildlife habitat, and endangered species plus carbon sequestration programs.

Biophysical Component

The purpose of the biological component of the spatial analysis was to create three key maps reflecting: (1) the overlap of five wildlife species, (2) wildlife species overlap with rivers and slopes, and (3) wildlife species overlap with high human impacted areas. Once these maps were created, the generated spatial data were combined to create an overarching biophysical components map used to identify the best locations for three biophysical potentials categories: water yield, wildlife habitats, and endangered species/carbon sequestration. The wildlife species upon which the wildlife habitat potential map was based included White-tailed deer (*Odocoileus virginianus texanus*), Rio Grande Turkey (*Meleagans galloparo*), Bobwhite Quail (*Colinus virginianus*), and two endangered songbirds: Golden-cheeked Warbler (*Dendroica chrysoparia*) and Black-capped Vireo (*Vireo atricapillus*).

The development of a species overlap map was the first step in the biophysical spatial analysis. The GAP Analysis raster data downloaded for each wildlife species were for the entire state of Texas, but Kerr and Bandera counties were the only data sections needed for this study. Wildlife rasters for the counties were created using ArcGIS Spatial Analyst: Raster Calculator. This was achieved by selecting a mask option for the shape of both counties to set the environment in the spatial analysis. In addition, in the raster calculator the following equation was used for each wildlife raster separately in order to create wildlife raster files for each species in the shape of only Bandera and Kerr counties.

(wildlife raster X 1) (1)

*1 multiplies the wildlife raster against itself in order to create a raster in the shape of both counties using the chosen county shape mask option.

The last step for the first biophysical components map was to calculate the species overlap, also using the raster calculator within spatial analyst. The equation used to overlap the five wildlife species within the counties was

spoverlpfinal = [counties_bobwhite] + [counties_wtdeer] + [counties_turkey] + [counties_bcv] + [counties_gcw] (2)

This provided an overall visual representation of the greatest concentration of wildlife within both counties.

The second map, wildlife species overlap with rivers and slopes was created using map one's species overlap raster (spoverlpfinal), the major rivers of Texas shapefile, and the county DEMs. The river data for the entire state of Texas was clipped to include only the portions of the major rivers within Bandera and Kerr counties using ArcToolbox Analysis Tools: proximity – clip option. The slope description for the counties was created using Spatial Analyst: Surface Analyst – slope, using the percentage option. Once the slope percentage raster was created it was reclassified into two manual breaks of zero (slope less than 15%) and one (slope greater than 15%). The biophysical components map showing rivers and slopes assisted in determining the best locations to increase water yield and preserving endangered species habitat/sequestering carbon.

The third biophysical spatial analysis map, wildlife species with unsuitable habitat, was created in order to identify the areas within both counties that were

unsuitable for wildlife habitats and carbon dioxide. The state highway data was clipped to include only the portions of the major highways within Bandera and Kerr counties using ArcToolbox Analysis Tools: proximity – clip option. The landcover raster from the USGS GAP Analysis data was used to determine the land uses within Bandera and Kerr counties. A land cover raster was created in the shape of the counties using the raster calculator and selecting a mask option in the shape of both counties.

(bothldcover = [landcover] *1) (3)

The "bothldcover" raster was reclassified into ones and zeros, with one representing unsuitable/high impact areas (bare soil, cropland, and urban areas) and zero representing all other land uses. In order to determine the best overall locations for the three parameters (increase water yield, protect wildlife habitat, and improve endangered species/carbon sequestration), a final biophysical map was created by combining the data from the three previously described biophysical components maps: species overlap, rivers, slope, highways and unsuitable habitats.

Landowner Component

The purpose of the landowner components spatial analysis was to create three potential maps using responses to selected questions from a landowner survey conducted in July 2004: (1) "If adequate compensation were provided, how interested do you think you would be in programs aimed at increasing each of the following type of land management activities?" (land management activities), (2) "If adequate compensation were provided, approximately what percent of your land do you think you would be willing to include in programs aimed at each of the following objectives?" (percent of

land), and (3) “Approximately what minimum level of cost share would you require to participate in any cost-sharing land improvement program?” (minimum level of cost share) (see Appendix A). The survey results are based on responses from 40 Kerr and 35 Bandera participants. Once the maps were created the resulting digital data maps one and two were combined and compared to map three in order to identify the locations landowners are more willing to participate in cost-share programs aimed at three land management objectives (increase water yield, wildlife habitats, and carbon sequestration) for the least amount of cost-share assistance.

The first step before analyzing the survey questions was to delineate the survey participant properties from the entire set of county tax appraisal parcels for each county. First, a new polygon shapefile was created for each county with two attribute table fields: owner_name and prop_id (survey number), and using ArcGIS Editor, the survey participant parcels were selected in order to create the new polygon shapefile. In order to use spatial analysis for each question, a centroid shapefile was created from the survey participant parcels shapefiles. Two fields, X_Field and Y_Field, were added to the attribute tables of both counties’ participant parcels. The x and y coordinates were calculated using the Visual Basic for Application (VBA) scripts found in ArcGIS Desktop Help entitled Making Field Calculations: Adding the XY coordinates of the centroid of a polygon layer to a new field (for a more detailed explanation of the VBA script see Appendix B). The last step before analyzing the three selected survey questions was to add the Bandera and Kerr survey excel database files for percent of land, land management activities, and minimum level of cost share to the new centroid

shapefiles. This was done by adding the survey responses database file tables to ArcMap and joining the tables to the centroids attribute tables based on the field identification field. In order to create one shapefile comprising data for both counties collectively, ArcToolbox Data Management Tools (Generalization): Dissolve function was used.

The question chosen for the first landowner components map was the land management activities for which compensation might be provided - "If adequate compensation were provided, how interested do you think you would be in programs aimed at increasing each of the following types of land management activities?" (Appendix A). The question choices being spatially analyzed were (3) allow brush to flourish on slopes greater than 15%, (5) remove brush and seed grasses, and (6) develop buffer strips along streams. Responses to item (5) were used to analyze interest in improving water yield, items (5) and (6) for wildlife habitat, and item (3) for endangered species habitat and carbon sequestration. The question choices for B1 were a ranking of 3 to –3 (3 = very interested, 0 = neutral, -3 = very disinterested), with two additional choices: NA (not applicable) and DK (don't know). For the GIS attribute data the answer choices were assigned a number from 1 to 8 (Table 1).

Table 1. GIS ranking scale for land management activity response choices.

Answer Selection	GIS Assigned Number Value
3	1
2	2
1	3
0	4
-1	5
-2	6
-3	7
NA/DK/No Response	8

Based on Philip and Watson, Inverse Distance Weighted (IDW) program was chosen as the surface analysis method for each of the three question choices because this method analyzes data that is "locationally dependent" and because the returned surveys totaled a small number (75 respondents), the power chosen for the IDW was the common value of two which allows points at farther distances to have an influence on the point being analyzed. The IDW point value chosen was five in order to include the five closest points surrounding each centroid being analyzed. After the IDW analyses were run for each question choice, the data was reclassified into eight manual breaks (Table 1). This was followed by the creation of a land management activities wildlife raster using "Spatial Analyst: Raster Calculator" to add response choices for statements 5 and 6 for the land management activities.

(B1_water + B1_buffer) (4)

With all three parameter rasters created, again using “Raster Calculator” all three parameter rasters were added in order to create a final hot spot map for land management activities.

(B1_water + B1_wildlife + B1_endanger) (5)

The second landowner components map, percent of land respondents would be willing to enroll in a cost-sharing program, was based on six subcomponents of “If adequate compensation were provided, approximately what percent of your land do you think you would be willing to include in programs aimed at each of the following objectives?” (Appendix A): (1) total woody plant removal, (2) selective woody plant removal, (3) protect woody plants, (4) protect riparian areas, (5) improve wildlife habitat, and (6) protect endangered species habitat. The three parameters analyzed were water yield (respondent subcomponents 1 and 4), wildlife habitat (respondent subcomponents 2 and 5), and endangered species protection/carbon sequestration (respondent subcomponents 3 and 6). The attribute fields being analyzed using IDW were averaged together for each of the three parameters by creating three new fields (water, wildlife, and endanger) within the centroid shapefile attribute table. For each new field the values were calculated from the question choices with common parameters. For example, the values for the new water field were the averaged percentage values from question choices 1 and 4. Within ArcMap spatial analyst: surface analysis IDW (power: 2 and point: 5) was computed for each of the three-parameter fields, and then reclassified (Table 2).

Table 2. GIS reclassification for minimum level of cost share.

Parameter	Reclassification Values
Water	0 - 20%
	20 - 40%
	40 - 60%
	60 - 80%
	80-100%
Wildlife	0 - 20%
	20 - 40%
	40 - 60%
	60 - 80%
	80-100%
Endangered Species & CO_2	0 - 20%
	20 - 40%
	40 - 60%
	60 - 80%
	80-100%

The overall B2 hot spot identification map was created using spatial analyst: raster calculator and adding all three-parameter inverse distance weighted rasters together.

(water_B2 + wildlife_B2 + endanger_B2) (6)

The final landowner components map was based on responses to question B3, which provided information about minimum cost-sharing necessary for participation in a program (Appendix A), with the previously listed items and parameter assignments as land management activities. The attribute fields being analyzed using IDW were averaged together into one column for each of the three parameters (water yield, wildlife habitat, and endangered species/carbon sequestration) by creating three new fields (water, wildlife, and endanger) within the centroid shapefile attribute table. For each

new field the values were calculated from the response choices with common parameters. For example, the values for the new water field were the average percentage values from question B2 subcomponents 1 and 4 (i.e. the equation typed into the Calculated Values textbox were

$$(1 + 4) / 2 \quad (7)$$

Using ArcMap spatial analyst, surface analysis inverse distance weighted (power: 2, point: 5) was computed for each of the three parameter fields, and then reclassified into five manual breaks: 0-20%, 20-40%, 40-60%, 60-80%, and 80-100%. The overall B3 hot spot identification map was created using spatial analyst: raster calculator and adding all three parameter IDW rasters together.

$$(water\_B3 + wildlife\_B3 + endanger\_B3) \quad (8)$$

Research Results

Biophysical Component

The goal of the biophysical components portion of the GIS spatial analysis was to create one map depicting the biophysically optimum locations within Bandera and Kerr counties to focus cost-share program expenditures for improved water yield (brush management), wildlife habitat, and endangered species protection/carbon sequestration for private landowners (Figure 2).

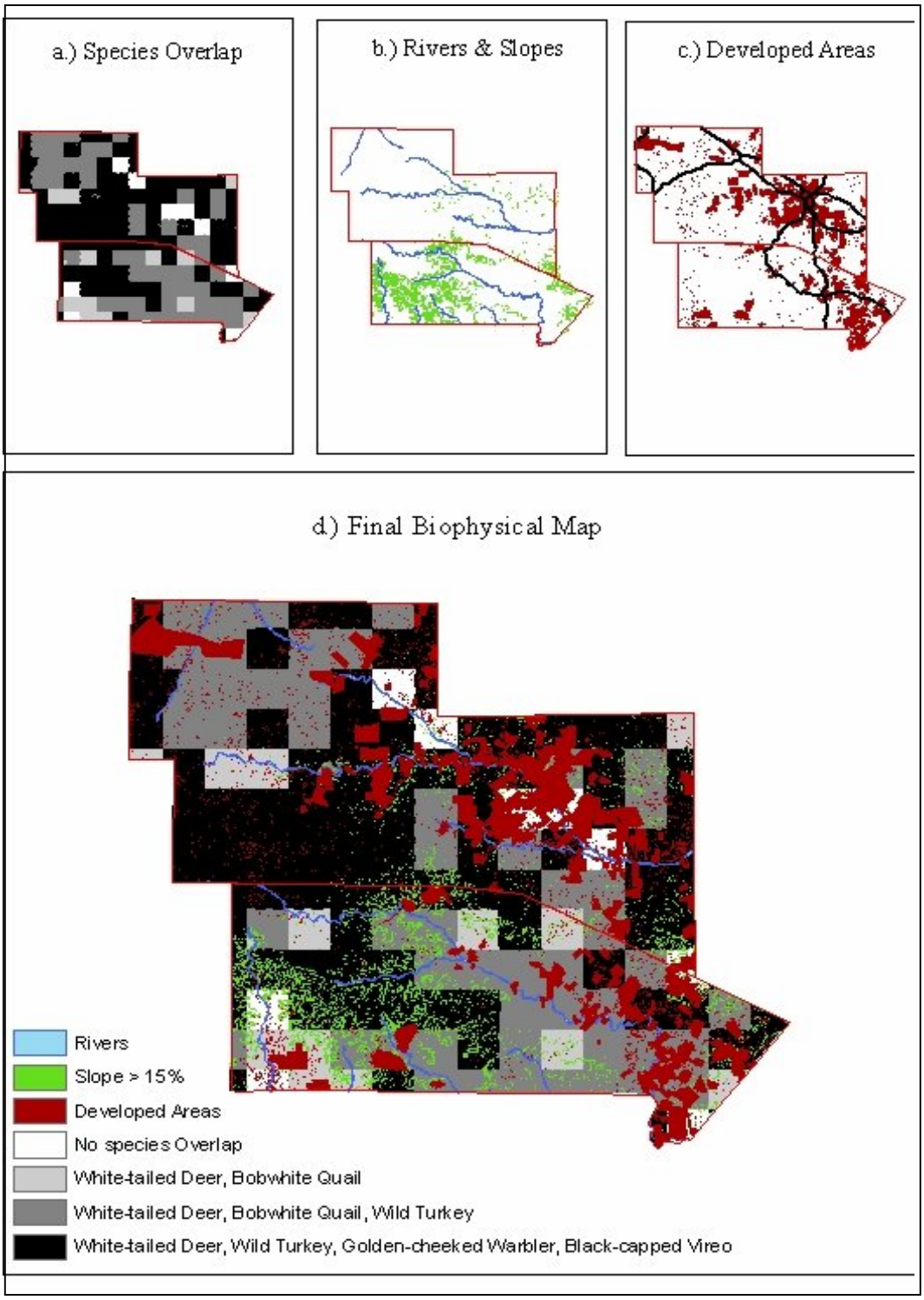

Figure 2. Biophysical components map (a. species overlap, b. rivers and slopes, developed areas).

The first map, showing species overlap (Figure 2a), depicts the amount of habitat overlap between the five chosen wildlife species (white-tailed deer, bobwhite quail, wild turkey, golden-cheeked warbler, and black-capped vireo). The highest level of species habitat overlap discovered within the two county area is a level four, which is the overlap of white-tailed deer, wild turkey, golden-cheeked warbler, and black-capped vireo, occurring throughout both counties with concentrations in southwest Kerr and northwest to central Bandera. Level three overlap consisted of white-tailed deer, wild turkey, and bobwhite quail and is concentrated in northwestern Kerr and central-eastern Bandera. A level two overlap between white-tailed deer and bobwhite quail in western Kerr and sporadically throughout Bandera. Within the county there are minimal areas in northern and eastern Kerr and southwestern and southeastern Bandera where habitat for none of the species occur.

Map two, showing rivers and slopes (Figure 2b), assisted in identifying the areas for focusing attention on water yield and endangered species protection/carbon sequestration. Areas with a slope greater than 15% are automatically designated endangered species habitat and carbon sequestration space because intensive brush management on steeper slopes is practically not possible and economically unsound. Surprisingly, a large part of Bandera County consists of slopes greater than 15%, excluding the northwest corner and central eastern portions of the county. Conversely, a lower proportion of Kerr County consisted of slopes greater than 15%, with the majority concentrated in the eastern part of the county. Therefore, Bandera may not be a cost-effective target area for cost-sharing programs aimed at improved water yield through

brush clearing, but central and western Kerr county appear to be prime areas for juniper control because of slopes being less than 15% and major rivers being located in these areas.

The third map, unsuitable Areas (Figure 2c), depicts the areas of species overlap along with the unsuitable areas (urban centers, subdivisions, highways, bare soil, and cropland) within both counties for all three parameters. The two major cities in the study area are Kerrville and Bandera, both located in the eastern portions of the counties which are nearest the metropolitan cities of Austin and San Antonio. The highways are concentrated in the eastern portions as well, with slightly more highways in the northern part of Kerr County. The subdivisions, bare ground, and cropland are scattered randomly throughout both counties. The best locations for wildlife are situated in south central and west Kerr and western Bandera, for endangered species and carbon sequestration the optimal locations appear to be in southwest Kerr and northwest/central Bandera.

The final map (Figure 2d) is a combination of the data from the three previous maps. It depicts the areas with highest potential for improved water yield, wildlife, and endangered species/carbon sequestration programs aimed at improving water yield through brush management. Water yield would be optimal in northwest Kerr County and areas nearest the highways that are not suitable for wildlife, on slopes less than 15%, and near the major rivers. Bandera does not have suitable sites for woody plant (mainly Ashe juniper) control because the majority of the optimal areas within the county are composed of slopes greater than 15%, which would make woody plant removal not only

very expensive but ecologically unsound. The optimal locations for improving wildlife habitat are the level three and four species overlap areas, riparian areas, and locations without substantial human disturbance. The optimal locations appear to be western Kerr and central to northwest Bandera counties. The optimal locations for protecting endangered species habitat and carbon sequestration are the locations with level four species overlap, slopes greater than 15%, and locations that are distant from human disturbances, which are located in southwest Kerr and central to western Bandera. A bubble depiction of the optimal locations within each county for the three parameters is shown in Figure 3, with the areas in blue identifying the locations for water yield, green for wildlife, red for endangered species/carbon sequestration.

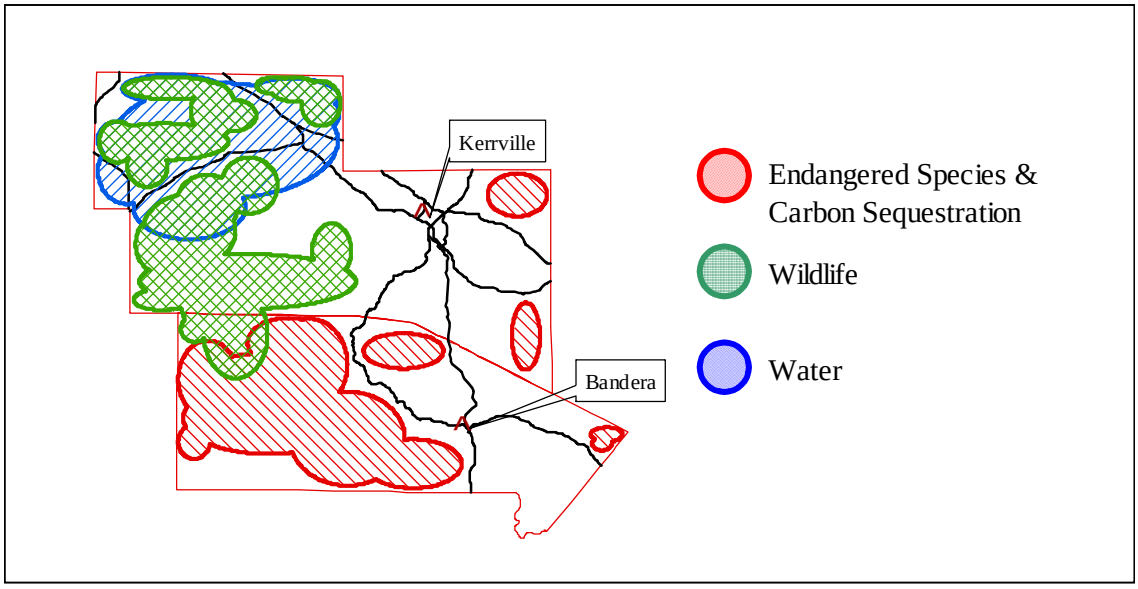

Figure 3. Final biophysical component target area map.

Landowner Component

The second component of the spatial analysis for focusing cost-share programs was conducted to create hot spot maps for depicting landowner interest in applying land management activities for improving water yield, wildlife habitat, and endangered species habitat/carbon sequestration; percent of land they would be willing to commit to such activities; and minimum level of cost share they would require to participate. From the July 2004 supplemental survey in order to identify the locations within Bandera and Kerr counties with the highest amount of landowner interest in cost-sharing programs for the lowest amount of public funds required.

The first map (Figure 4) identifies the locations where landowners would be most interested, in increasing the following types of land management activities: (3) allow brush to flourish on slopes greater than 15%, (1) remove brush and seed grasses, and (2) develop buffer strips along streams. The first map (Figure 4a) created for increase in water yield was based on removal of woody plants and seeding grasses because the dense canopy and deep root systems of invasive brush species, such as juniper, may intercept more rainfall and use more water from the soil than native grassland type species in some cases (Hester et al. 1997, Bovey 2001, Wilcox 2002). The hot spot map created for this objective suggests that the majority of landowners are willing to remove brush and seed grasses throughout most of both counties, except for a few small areas in western Kerr and central/southern Bandera. A second map (Figure 4b) was created for the improvement of wildlife habitat by selectively removing brush, seeding grasses, developing grazing buffer strips along streams. This map depicts northwest, northeast,

and central Kerr and west and southeast Bandera as the locations of greatest landowner interest. The map of landowner interest in the third objective (Figure 4c), endangered

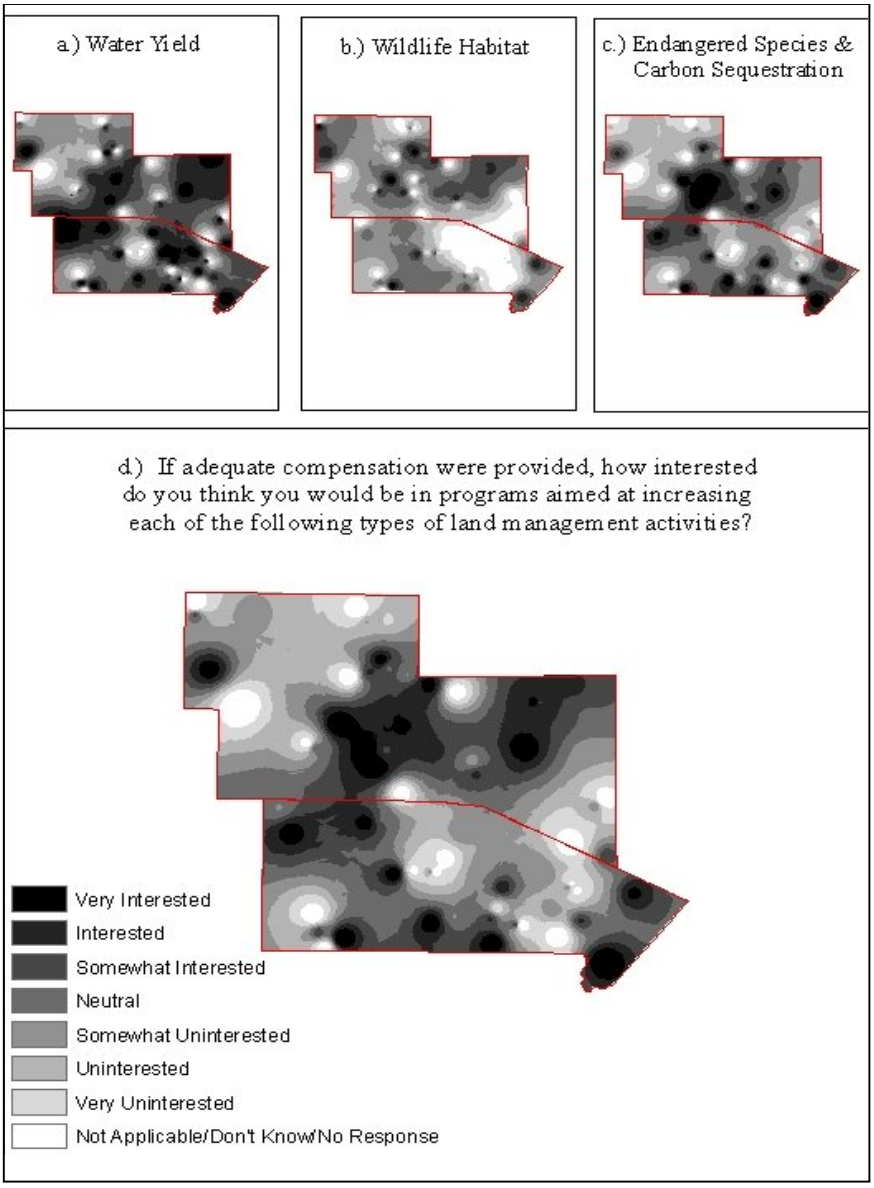

Figure 4. Landowner components map for land management activities.

species/carbon sequestration, suggest that interest was greatest in the northwest, central and northeastern portions of Kerr County and in the south-central and eastern edges of Bandera County. When the three parameter maps were superimposed the areas of highest potential for landowner participation in cost- sharing programs were concentrated in the central region of Kerr and the central to northwest areas and southeast portions of Bandera counties.

The second landowner components map (Figure 5) analyzed the proportion of their property that landowners would be willing to incorporate into three potential cost-share programs focusing on six land management objectives (Appendix A). The first objective, increased water yield (Figure 5a), was analyzed using responses regarding: selective woody plant removal and protect riparian areas. There are surprisingly small areas within counties, central and east Kerr and northwest Bandera, in which landowners are willing to include 60-100% of their land into land management activities aimed at increasing water yields. The majority of both county respondents are not willing to include land in water yield management activities (0-20%). The second objective, wildlife habitat improvement (Figure 5b), resulted in a very different spatial pattern. The analysis of responses regarding selective woody plant removal and improve wildlife habitat revealed landowners are more willing to participate in management activities to improve wildlife habitat than increase water yield throughout Kerr and northern Bandera. The remaining two management options, protect woody plants and protect endangered species habitat, were used to identify the potential for protection of endangered species and carbon sequestration (Figure 5c). The percent of land map

identified a dramatic difference between the landowner interests in Kerr and Bandera counties. The majority of Bandera landowners are not willing to incorporate land into management activities that enhance endangered species and carbon sequestration (0-20%), with a few exceptions on the county's northeastern and southwestern border.

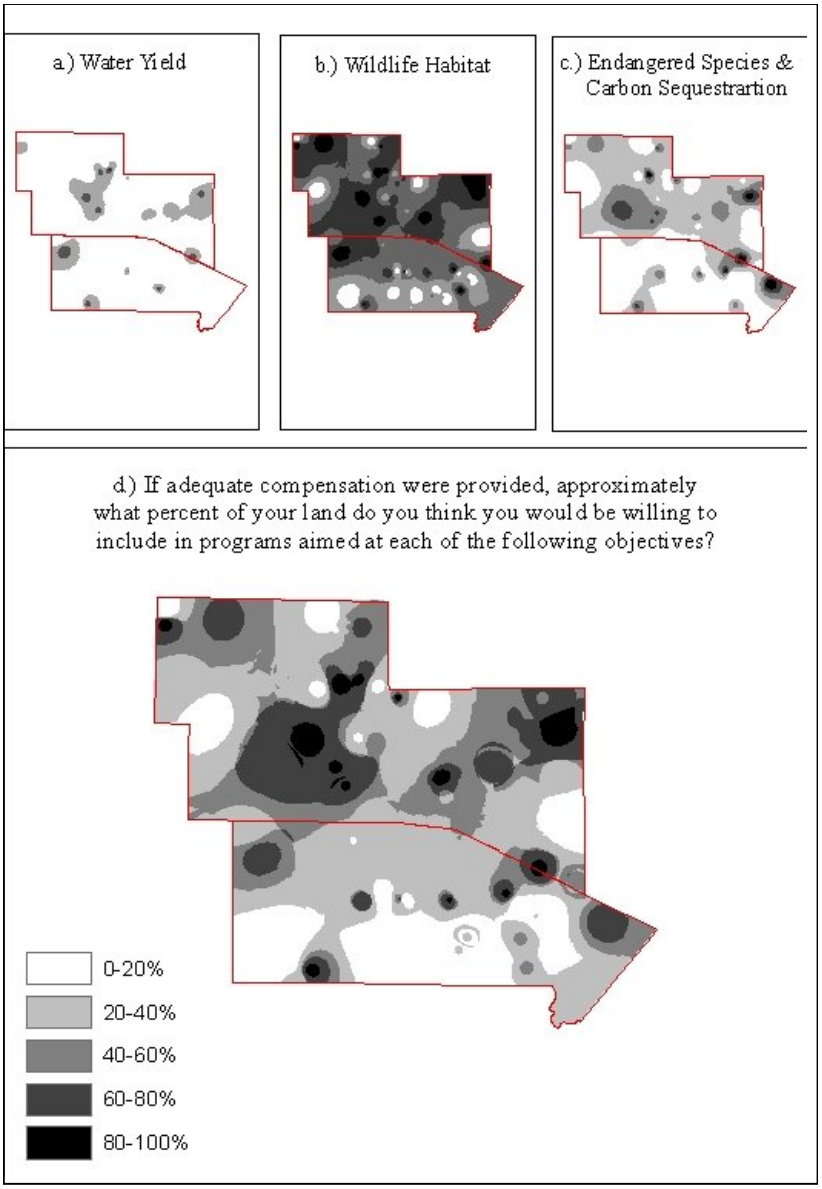

Figure 5. Landowner components map for percentage of land respondents are willing to include in programs aimed at land management objectives.

On the other hand, Kerr County consisted mostly of high landowner participation (40-80%), with central and north-eastern regions of the county having the largest percentage of land included in management objectives. The overall combined map for all three objectives revealed a much higher percentage of land in cost-share program objectives in Kerr County than Bandera, evidenced in the high percentage regions spread throughout Kerr's northwest, central, and northeastern regions compared to Bandera's percentages being concentrated on the northwestern and northeastern borders of the county (Figure 5d).

The last issue that was analyzed spatially was the minimum level of cost-sharing landowners would require participating in six alternative land improvement programs (Appendix A). Level of cost-sharing need to participate in water yield improvement interests was determined using two response objectives: total woody plant removal and protect riparian areas. The result was encouraging with the majority of both counties requiring no more than a 20% level of cost-share assistance to participate in land management programs aimed at improving water yield (Figure 6a). There are only a few patches within both counties (east Kerr and scattered throughout Bandera) requiring levels higher than 20%. For wildlife habitat improvements, the results were less encouraging with most landowners requiring levels between 20-40% and throughout most of the study area (Figure 6b). The last set of programs aimed at protecting endangered species and carbon sequestration have low levels of cost-share requirements in the western areas of both counties, with a larger number of landowners in Bandera (west and central regions) willing to accept 0-20% cost-share levels (Figure 6c). For

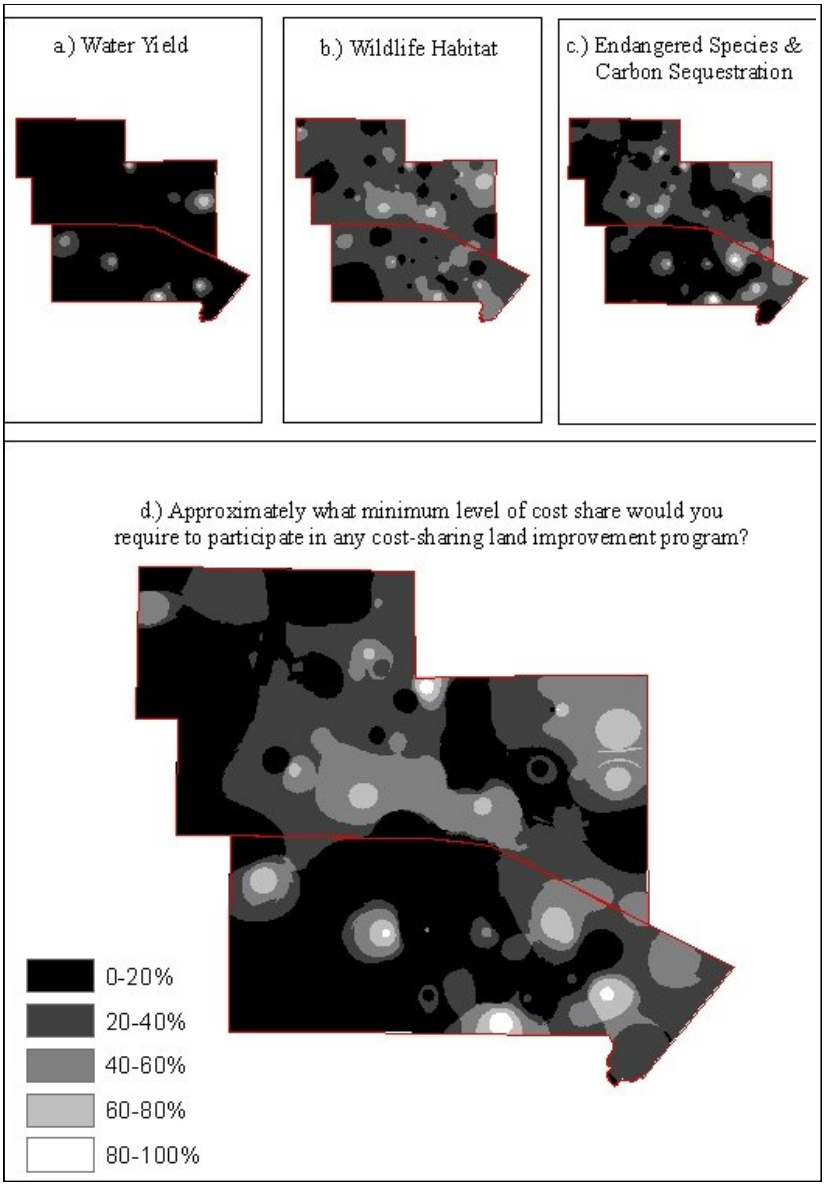

Figure 6. Landowner component map for minimum level of cost share assistance to participate in any land improvement programs.

both counties only a minute portion of property owners require cost-share levels above 40%, predominately found in the eastern portions of both Kerr and Bandera counties. When all three maps were combined (Figure 6d), the lowest minimum level of cost-share required by landowners (0-20%) became concentrated in western Kerr county and

west/central Bandera county, and the higher levels of cost-share requirements (40-100%) were concentrated in central/eastern Kerr and eastern Bandera counties.

When comparing the map depicting the areas most accepting of the minimum level cost-share assistance with the land management activity maps, there are distinct locations for allocating cost-share assistance that were identified (Figure 7). The areas for landowner assistance entailing the least amount of government expenditures is in one large region in western Kerr County and one large patch in the western half of Bandera County (depicted in red on the map). By contrast, the overall best locations within the counties for high landowner interests in land management activities aimed at improving water yield, wildlife habitat, and endangered species protection plus carbon sequestration are in northern and southern Kerr County and northeast and southwest Bandera County.

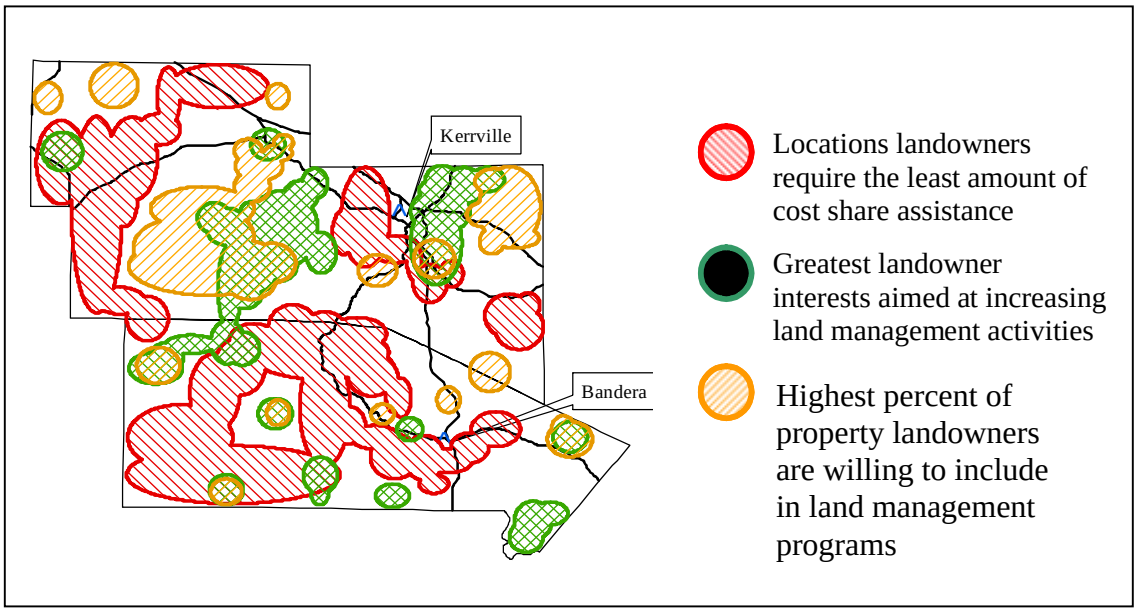

Figure 7. Final landowner component target area map for land management activities, percent of land for land management activities, and minimum level of cost share.

Conclusion

The optimum locations within Bandera and Kerr counties for cost-share assistance programs is easily visible when the two target area maps for biophysical and landowner components are combined into one overall target area map (Figure 8). Two options were created for each ecosystem service, with the blue (water; 10,241 acres), green (wildlife; 19,545 acres), and red (endangered species/carbon sequestration; 29,777 acres) representing the optimal locations where each ecosystem service and two spatially analyzed survey questions overlap. These dark bubbles are the locations in which limited cost-share assistant programs should first be focused to incorporate both high biophysical potential and high level of landowner interests at relatively low cost.

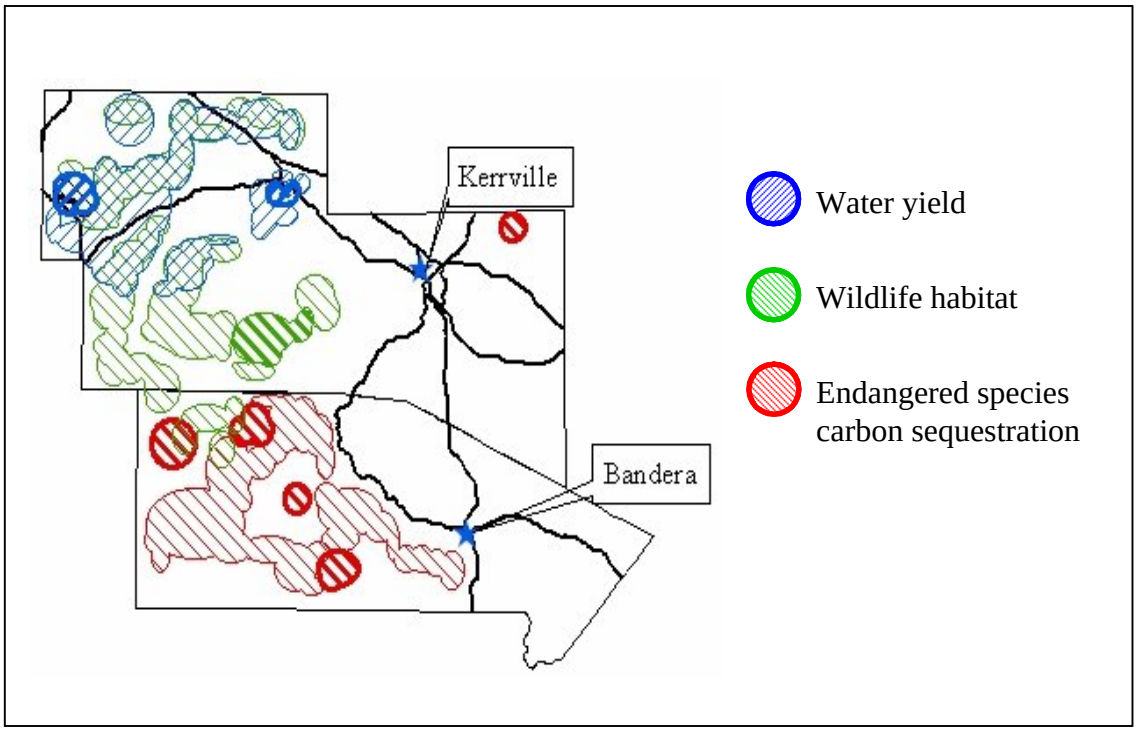

Figure 8. Final target area map for increasing water yield, protecting wildlife habitat, and protecting endangered species/carbon sequestration areas. The dark color categories are regions of two survey questions overlapping with one ecosystem service, and the light colors indicate areas where one ecosystem service and one question overlap.

If additional publicly funded assistance is available there is a second option. The light colored blue (79,678 acres), green (111,480 acres), and red (118,158 acres) areas are the second option indicating the locations where each ecosystem service overlaps with one spatially analyzed survey question. There were not any locations within both counties where each of the ecosystem services overlapped with three overlapping survey questions.

When the biological and landowner maps were combined, the management areas for increased water yield (brush management), wildlife habitat, and endangered species protection/carbon sequestration declined dramatically in both counties. Water yield and wildlife management areas are surprisingly concentrated in the same northwest regions of Kerr County because these are the locations where landowners are more willing to become involved in land management activities for the least amount of cost-share assistance (between 0-40%). Furthermore, northwest Kerr is the focal point for water yield and wildlife because slopes are less than 15%, wildlife requiring management of brush within their habitats are centered in this location, riparian areas are present, and there are major human disturbances within this region. The endangered species conservation areas are located within central and western Bandera County because these areas are also regions landowners are most willing to participate in land management activities for the least amount of required cost-share assistance (0-40%). The endangered species/carbon sequestration patches are most suitable due to the slopes being greater than 15%, less anthropogenic impacts, and present riparian areas. The end result of the biological components and landowner opinions spatial analysis, the combined target area

map, will aid government agencies in prioritizing the allocation of funds for landowner assistance programs within Bandera and Kerr Counties which are aimed at improving water yield (brush management), wildlife, and endangered species/carbon sequestration on private property.

The optimal locations apparent on the final target area map could be used as demonstration sites in which the respondents will participate in publicly funded cost share programs. Respondent participation should have a ripple effect on surrounding property owners in order to increase the number of landowners participating in assistance programs to benefit ecosystem services within Bandera and Kerr counties.

CHAPTER IV

STATISTICAL ANALYSIS

Bandera and Kerr counties are part of the Edwards Plateau region, which act as a water catchment area for water draining into and recharging the Edwards Aquifer. There are two major metropolitan centers (Austin and San Antonio) to the east and southeast of Bandera and Kerr counties that rely heavily on the Edwards Aquifer for much of their water needs. An issue facing these two counties is the increasing brush encroachment, primarily juniper, which effects not only the ability of the area to act as an effective catchment, but also to provide suitable habitat for several game and two endangered wildlife species.

Private property owners finance land management practices to improve ecosystem services, which ultimately benefits the public at little or no cost. Yet, landowners in the area are not able to effectively manage the increasing woody plant growth occurring on their property because of the high cost involved and the lack of public assistance available for programs to offset land management cost. It is important to understand the perceptions of the landowners within the two counties towards land cost-sharing programs, in order to efficiently allocate limited public funds to assist with the effective management of ecosystem services, such as increasing water yield, protecting wildlife habitat, and sequestering carbon.

A mail survey was conducted to determine the perceptions of landowners towards publicly supported land management programs. Three central questions were the focus of the study: (1) Are landowners with larger property sizes and higher annual

incomes more likely to participate in programs aimed at improving brush management and wildlife protection; (2) If compensation were provided, to what extent are landowners more willing to participate in selective woody plant removal, protecting riparian areas, improving wildlife habitat, and protecting endangered species habitat; and (3) What type of cost-sharing contracts are most preferred.

Methods

A mail survey was conducted in April of 2003, within the counties located in the Western Edwards Aquifer Area, Texas, dealing with landowner opinions regarding ecosystem services and cost-share programs. The mailing list for selected landowners owning at least 50 acres was acquired from the County Appraiser Office in each county and a total of 600 landowners were randomly selected for the survey, with 248 (41%) responding (Olenick et al. 2005).

In July 2004, a supplemental mail survey of respondents in the first study was conducted in Medina, Uvalde, Real, Kerr, and Bandera counties to follow-up on a few ambiguous questions in the previous survey and to focus on landowner perceptions about government cost-share assistance programs and participation in land management activities. Availability of GIS data was greatest for Bandera and Kerr counties, the statistical analysis of the survey data was restricted to these two counties, in order to connect the GIS spatial analysis results reported in chapter III to the statistical results. The procedure used to administer the surveys was Dillman's (2000) four phase method: (1) A packet containing the survey questionnaire, a cover letter explaining why responses are important and a link to the results from the prior survey, and a stamped

return envelope were mailed on August 23, 2004; (2) Thank you/reminder postcard on September 2, 2004; (3) A second copy of the survey questionnaire was mailed to non-respondents on September 20, 2004; and (4) A final reminder/thank you card was mailed to non-respondents September 30, 2004. The data were analyzed using the Statistical Package for the Social Sciences (SPSS). Statistical techniques included descriptive frequency distributions (valid percentage reported), crosstabulation (X^2, p-value significant at 0.05), analysis of variance for bivariate analyses (F-statistic, p-value significant at 0.05), and independent sample t-test to compare independent sample means (t-value, p-value significant at 0.05).

Research Results

The supplemental survey was sent to all 247 landowners who responded to the April 2003 survey. Out of the 116 survey questionnaires sent to Bandera and Kerr counties, 79 (68%) were completed and returned.

Landowner Characteristics

The average property size of respondents was 672 acres (SEM = 290, 95% CI = 591) for Bandera and 1,156 acres (SEM = 428, 95% CI = 864) for Kerr, with the overall mean property size counties equaling 940 acres (SEM = 270, 95% CI = 537) (Table 3). Even though Kerr has a larger mean property size than Bandera, there appears to be no significant differences between each county's average property size (t = -0.89, p = 0.11).

Table 3. Comparison of respondents' properties in Bandera and Kerr Counties rounded to the nearest acre.

Acres Owned	Mean	Std. Error	95% CI
Bandera	672	290	591
Kerr	1156	428	864
Total	940	270	537

A frequency analysis and crosstabulation were conducted in order to determine the primary nature of respondent properties. The most frequent property use undertaken by respondents in both counties was mixed livestock and wildlife (Figure 1). The most frequent property uses by Bandera County respondents were mixed livestock and wildlife operation (27.3%), mainly livestock production (18.2%), mixed livestock operation and crop (15.2%), mainly wildlife operation (9.1%), primary residence (9.1%), mixed wildlife operation and crop (6.1%), mixed wildlife operations and crop (6.1%), long-term investment (6.1%), other (6.1%), and tourist operation (3%). The property uses in Kerr County includes mixed livestock and wildlife operation (42.9%), mainly wildlife operation (21.4%), primary residence (16.7%), mainly livestock production (9.1%), other (4.8%), mixed wildlife operation and crop (2.4%), and long-term investment (2.4%) (Figure 9). Based on the crosstabulation, the variables seem to be statistically similar between both counties ($X^2 = 13.785$, $p = 0.088$).

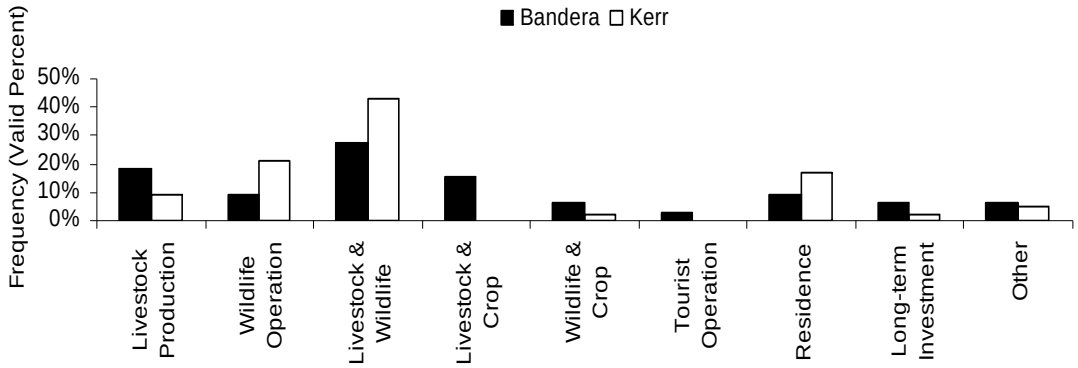

Figure 9. Frequency (valid percent) of primary nature of landowner properties.

The importance of six land management objectives on private property (improve grass and forb cover, increase open savanna, increase brush cover, reduce brush cover, protect or improve riparian areas, and increase stream flow) were answered on a scale ranging from +3 (very important) to –3 (very unimportant) and analyzed using ANOVA and independent-sample t-test. The analysis of variance verified that there are significant differences ($F = 96.85$, $P < 0.000$) between overall responses regarding the importance of the six land management objectives. The most negatively viewed land management objective was increasing brush cover (–1.83, SEM = 0.17, 95% CI = 0.34). The remaining five land management objectives were positively viewed, with improving grass and forb cover having the highest average importance level of 2.58 (SEM = 0.10, 95% CI = 0.19) (Figure 10, Table 4). The independent-sample t-test provides evidence that there are no statistically significant differences between counties about the importance of land management objectives (Table 5).

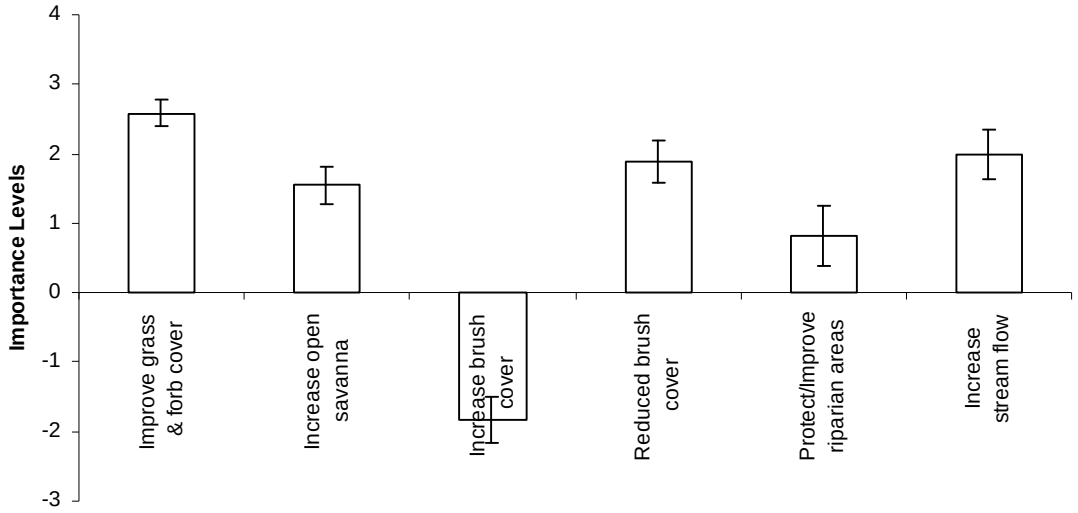

Figure 10. Importance of land management objectives on respondent properties (error bars show 95% CI).

Table 4. Overall perceived importance of land management objectives on respondents' properties.

Land Management Objectives	Mean	Std. Error	95% CI
Improve grass & forb cover	2.58	0.10	0.19
Increase open savanna	1.55	0.14	0.27
Increase brush cover	-1.83	0.17	0.34
Reduced brush cover	1.89	0.15	0.30
Protect/Improve riparian areas	0.82	0.22	0.43
Increase stream flow	1.99	0.18	0.35
Total	1.20	0.10	0.18

Table 5. Independent-sample t-test for differences in importance of land management objectives on respondents' properties in Bandera and Kerr counties.

Land Management Objectives	Mean Values		t	p
	Bandera	Kerr		
Improve grassa & forb cover	2.546	2.610	-0.330	0.742
Increase open savanna	1.613	1.500	0.402	0.689
Increase brush cover	-2.097	-1.605	-1.528	0.131
Reduce brush cover	1.909	1.875	0.111	0.912
Protect or improve riparian areas	0.679	0.921	-0.520	0.606
Increase stream flow	1.774	2.158	-1.060	0.294

The percentage cover of plant types occupying landowner properties was estimated by each respondent and analyzed using ANOVA and an independent-sample t-test. The difference in the proportion of plant cover types within Bandera and Kerr counties varied significantly ($F = 38.87$, $P<0.001$). The most dominant plant cover types within both counties are open grasslands (24.9%, SEM = 2.2%, 95% CI = 4.40%), mainly live oak (9.1%, SEM = 1.7%, 95% CI = 3.30%), mainly juniper (cedar) (26.0%, SEM = 3.1%, 95% CI = 6.30%), mixed live oak/juniper (31.2%, SEM = 3.5%, 95% CI = 7.00%)(Figure 11, Table 6). There appears to be no differences between plant cover types throughout Bandera and Kerr counties (Table ***7).***

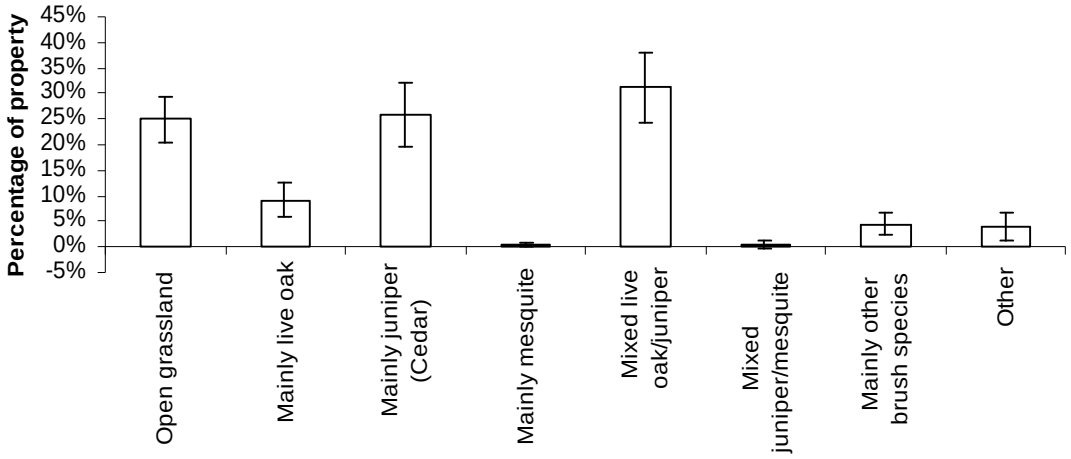

Figure 11. Percentage cover of plant types occupying respondent properties (error bars show 95% CI).

Table 6. Plant cover types occupying respondent properties.

Plant Cover Types	Mean	Std. Error	95% CI
Open grassland	24.9%	2.2%	4.40%
Mainly live oak	9.1%	1.7%	3.30%
Mainly juniper (Cedar)	26.0%	3.1%	6.30%
Mainly mesquite	0.4%	0.2%	0.50%
Mixed live oak/juniper	31.2%	3.5%	7.00%
Mixed juniper/mesquite	0.5%	0.3%	0.70%
Mainly other brush species	4.4%	1.0%	2.10%
Other	4.1%	1.3%	2.70%
Total	12.6%	0.9%	1.70%

Table 7. Independent-sample t-test for the percent plant cover types found on respondent properties.

Plant Cover Types	Mean		t	p
	Bandera	Kerr		
Open grassland	1.255	0.444	1.566	0.124
Live oak	1.090	0.512	1.025	0.310
Juniper	1.236	0.676	1.008	0.318
Mesquite	1.037	0.409	1.107	0.273
Live oak & juniper	1.348	0.474	1.695	0.097
Juniper & mesquite	1.033	0.415	1.088	0.281
Other brush species	1.063	0.456	1.073	0.288
Other	1.055	0.456	1.056	0.296

Land Management Characteristics

Landowners were asked, “within the past five years, what types of land management practices have been used on your property?” (Figure 12). Both, Bandera and Kerr county respondents are involved in broad scale mechanical methods (Bandera 50.0%, Kerr 39.0%) individual plant treatment using mechanical methods (Bandera 44.1%, Kerr 65.9%), prescribed burning (Bandera 29.4%, Kerr 19.5%), individual plant treatment using herbicide (Bandera 29.4%, Kerr 17.1%). By contrast, a high percentage of respondents were not involved in: prescribed burning (Bandera 70.6%, Kerr 80.5%), broadcast herbicide (Bandera 92.1%, Kerr 97.6%), individual plant treatment using herbicide (Bandera 70.6%, 82.9%), broad scale mechanical methods (Bandera 50.0%, Kerr 61.0%), individual plant treatment using mechanical (Bandera 55.9%, Kerr 34.1%), contour plowing (Bandera 91.2%, Kerr 97.6%), minimum till cultivation (Bandera 88.2%, Kerr 87.8%), and other (Bandera 97.1%, Kerr 95.1%). According to the crosstabulation analysis and the chi-square values, the land management practices adoption patterns were similar between the counties, except for individual plant treatment using mechanical methods ($X^2 = 3.564$, $p = 0.059$) (Table 8).

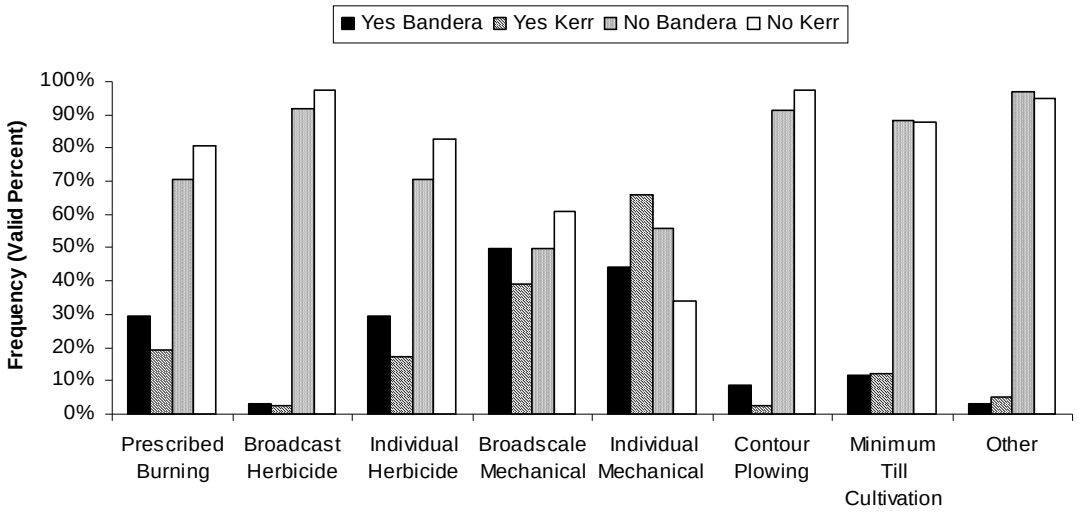

Figure 12. Types of land management practices conducted on respondent properties within the past 5 years.

Table 8. X^2 values for land management practices within the past 5 years.

Land Management Practices	P-value	X^2
Prescribed Burning	0.318	0.999
Broadcast Herbicide	0.893	0.018
Individual Herbicide	0.204	1.614
Broadscale Mechanical	0.340	0.909
Individual Mechanical	0.059	3.564
Contour Plowing	0.221	1.501
Minimum Till Cultivation	0.954	0.003
Other	0.670	0.182

Respondents were asked what percentage of their property has been managed using seven land management practices within the past five years. The difference between mean percentage of land area subjected to various land management practices differs significantly ($F = 13.08$, $P < 0.001$) (Figure 13, Table 9). Broad scale mechanical methods (14.41%, SEM = 2.91%, 95% CI = 5.80%), and individual plant treatment

using mechanical methods (9.53%, SEM = 2.01%, 3.99%), appear to be used much more widely from the other practices in both counties. Minimum till cultivation (2.16%, SEM – 1.37%, 95% CI = 2.73%), broadcast herbicide (1.51%, SEM = 1.06%, 95% CI = 2.12%), individual plant treatment using herbicide (1.22%, SEM = 0.44%, 95% CI = 0.88%), contour plowing (0.47%, SEM = 0.27%, 95% CI = 0.54%), and other practices (0.72%, SEM = 0.39%, 95% CI = 0.79%) appear to be applied to much smaller portions of land. With one exception, the proportions did not vary significantly between counties; the use of broad scale mechanical appeared to be somewhat greater in Kerr (18.80%) than in Bandera (8.38%) (t = -1.901, p = 0.061) (Table 10).

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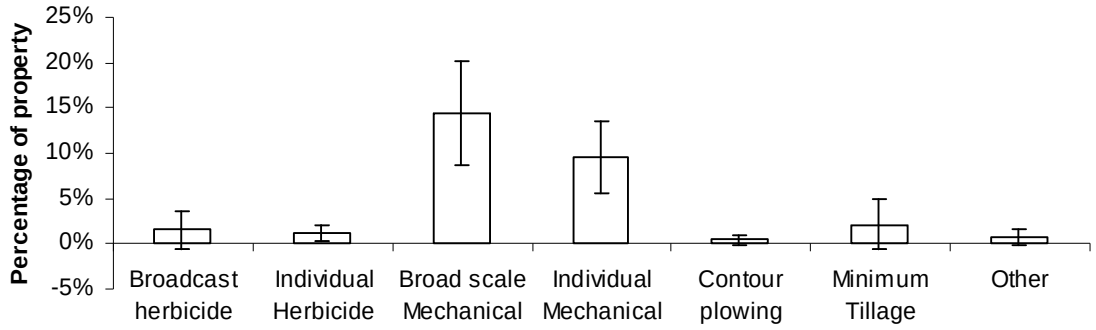

Figure 13. Percent of property currently undergoing or has undergone land management practices during the last five years.

Table 9. Percent of property currently undergoing or has undergone land management practices during the last five years.

Land Management Practices	Mean	Std. Error	95% CI
Broadcast herbicide	1.51%	1.06%	2.12%
Individual Herbicide	1.22%	0.44%	0.88%
Broad scale Mechanical	14.41%	2.91%	5.80%
Individual Mechanical	9.53%	2.01%	3.99%
Contour plowing	0.47%	0.27%	0.54%
Minimum Tillage	2.16%	1.37%	2.73%
Other	0.72%	0.39%	0.79%
Total	4.29%	0.61%	1.19%

Table 10. Independent-sample t-test for the percentage of property undergoing or having undergone the following land management practices.

Land Management Practices	Mean		t	p
	Bandera	Kerr		
Broadcast herbicide	0.00%	2.61%	-1.430	0.160
Individual herbicide	0.47%	1.77%	-1.661	0.102
Broadcast mechanical	**8.38%**	**18.80%**	**-1.901**	**0.061**
Individual mechanical	11.28%	8.25%	0.744	0.459
Contour plowing	0.31%	0.59%	-0.511	0.611
Minimum tillage	3.88%	0.91%	0.921	0.363
Other	1.25%	0.34%	1.004	0.322

Landowner Interests in Cost-share Programs

Survey participants were asked to use a scale of +3 (very interested) to –3 (very uninterested) to indicate their level of interest in various types of cost-share contracts if adequate compensation were provided. Using ANOVA, overall levels of interest among contracts were found to vary significantly ($F = 18.65$, $P < 0.001$). The two most chosen answer choices were 5-year Performance Contract and "I would not be prepared to enter into any contract," while the remaining contract types were negatively viewed by landowners in Bandera and Kerr counties (Figure 14, Table 11). In addition, the

difference in landowner interest level averages across the two counties was tested using independent sample t-tests. The only significance difference occurred for contracts that transfer to new owners with Bandera respondents being less interested (-1.731) than Kerr participants (-0.485) ($t = -2.358$, $p = 0.022$) (Table 12).

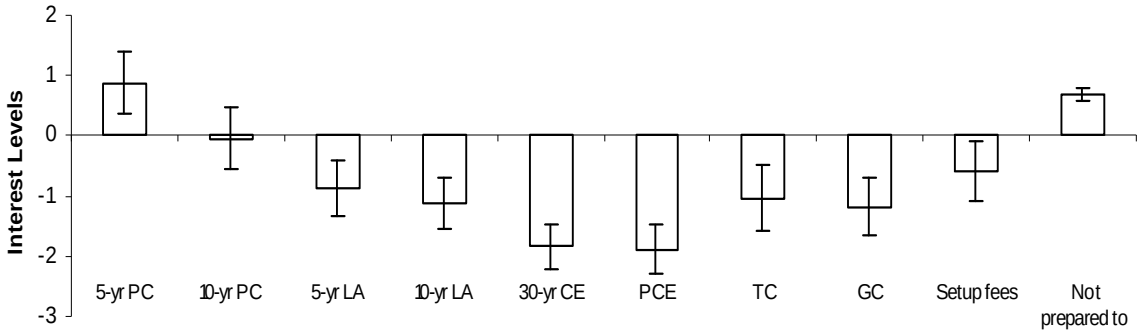

Figure 14. Types of cost-share contracts respondents would be most willing to participate in if adequate compensation were provided on a scale of +3 (very interested) to –3 (very uninterested) (error bars show 95% CI). (5-yr PC: 5 year Performance Contract, 10-yr PC – 10 year Performance Contract, 5-yr LA – 5 year Lease Agreement, 10-yr LA – 10 year Lease Agreement, 30-yr CE – 30 year Conservation Easement, Perpetual CE – Perpetual Conservation Easement, TC – Contracts that transfer to new owners if land is sold, GC – Group Contract, Setup fees- Contracts with set up fees based on property size, Not prepared to enter – I would not be prepared to enter into any contract)

Table 11. Types of cost-share contracts respondents would be most willing to participate in if adequate compensation were provided on a scale of +3 (very interested) to –3 (very uninterested.

Types of contracts	Mean	Std. Error	95% CI
5-year Performance Contract	0.88	0.26	0.53
10-year Performance Contract	-0.05	0.26	0.51
5-year Lease Agreement	-0.86	0.23	0.46
10-year Lease Agreement	-1.12	0.21	0.43
30-year Conservation Easement	-1.84	0.19	0.38
Perpetual Conservation Easement	-1.89	0.21	0.41
Transferable Contract	-1.03	0.27	0.54
Group Contract	-1.19	0.24	0.48
Contracts with setup fees	-0.59	0.25	0.51
Not prepared to enter into contract	0.68	0.06	0.11
Total	-0.67	0.08	0.16

Table 12. Independent sample t-test for landowner interests towards specific types of contracts.

Types of Contracts	Mean		t	p
	Bandera	Kerr		
5yr Performance Contract	0.808	0.939	-0.246	0.807
10yr Performance Contract	-0.192	0.059	-0.484	0.630
5yr Lease Agreement	-0.692	-1.000	0.634	0.529
10yr Lease Agreement	-1.154	-1.091	-0.145	0.885
30yr Conservation Easement	-2.039	-1.677	-0.936	0.353
Perpetual Conservation Easement	-2.080	-1.750	-0.787	0.435
Contracts transfer to new owners	**-1.731**	**-0.485**	**-2.358**	**0.022**
Group Contract	-1.192	-1.182	-0.022	0.983
Contract with fees	-0.560	-0.606	0.090	0.929
Not willing to enter into any contract	0.710	0.650	0.526	0.600

If adequate compensation were provided, the survey participants were asked what their interest level would be (+3 = very interested to –3 = very disinterested) in programs aimed at increasing each of the following six types of land management activities: minimum/no-till farming practices, cropland retirement, allow brush to

flourish on slopes greater than 15%, allow brush to flourish over entire property, remove brush and seed grasses, and develop buffer strips along streams. Overall mean response values differed significantly ($F = 20.55$, $p < 0.001$). There was only one land management activity for which respondents answered negatively, which was allowing brush to flourish on the entire property (-1.83, SEM = 0.26, 95% CI = 0.52) (Figure 15, Table 13). The remaining management activities were viewed either neutrally or positively. Based on the independent t-test values, the interest levels for the six land management activities did not vary significantly between the two counties (Table 14).

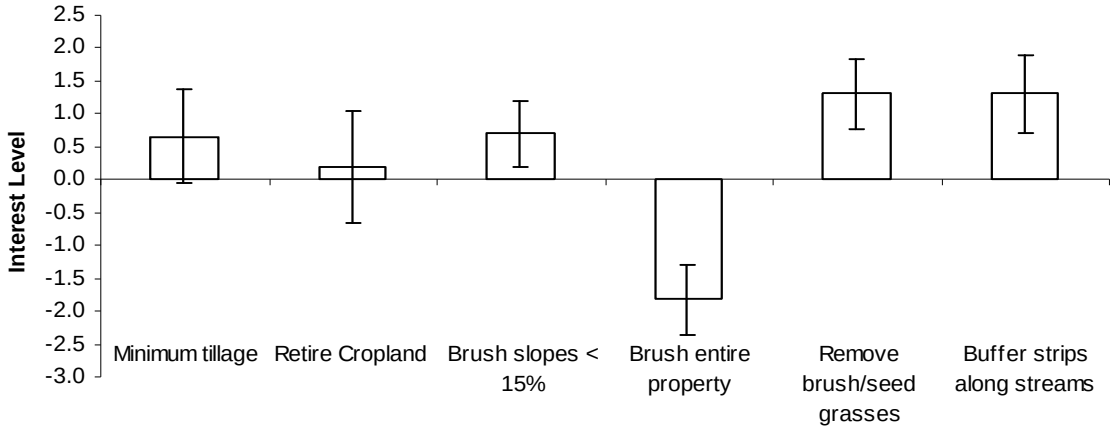

Figure 15. If adequate compensation were provided, the survey participants were asked what their interest level would be (+3 (very interested) to –3 (very disinterested)) in programs aimed at increasing each of the following six types of land management activities (error bars shows 95% CI).

Table 13. If adequate compensation were provided, the survey participants were asked what their interest level would be (+3 (very interested) to –3 (very disinterested)) in programs aimed at increasing each of the following six types of land management activities.

Land Management Activities	Mean	Std. Error	95% CI
Minimum tillage	0.66	0.35	0.72
Retire Cropland	0.18	0.41	0.85
Brush slopes < 15%	0.70	0.24	0.49
Brush entire property	-1.83	0.26	0.52
Remove brush/seed grasses	1.30	0.26	0.52
Buffer strips along streams	1.31	0.30	0.60
Total	0.32	0.14	0.28

Table 14. Independent sample t-test showing each land management activity is un-related and independent from each other.

Land Management Activity	Mean		t	p
	Bandera	Kerr		
Minimum/No tillage	0.727	0.611	0.157	0.876
Cropland retirement	1.000	-0.059	1.090	0.289
Allow brush (slope < 15%)	0.864	0.542	0.654	0.517
Allow brush over entire property	-2.077	-1.630	-0.861	0.393
Remove brush and see grasses	1.214	1.368	-0.295	0.769
Buffer strips along streams	1.688	1.000	1.153	0.257

Survey respondents were also asked, if adequate compensation were provided to landowners, approximately what percentage of their land they would be willing to include in programs aimed at each of the following objectives: total woody plant removal, selective woody plant removal, protect woody plants, protect riparian areas, improve wildlife habitat, and protect endangered species habitat? There was a high percentage of land (76.32%) that respondents would not be willing include in programs aimed at the land management objectives. However, there were significant differences in mean response values ($F = 15.44$, $p < 0.001$) with selective woody removal (49.32%,

SEM = 4.66%, 95% CI = 9.31%), improve wildlife habitat (62.85%, SEM = 4.90%, 95% CI = 9.79%), and protect endangered species (45.47%, SEM = 13.76% 95% CI = 27.46%) providing the highest percentages for land management programs (Figure 16, Table 15). The proportion of land that respondents would be willing to include in programs aimed at the six land management objectives did not vary significantly between Kerr and Bandera counties (Table 16).

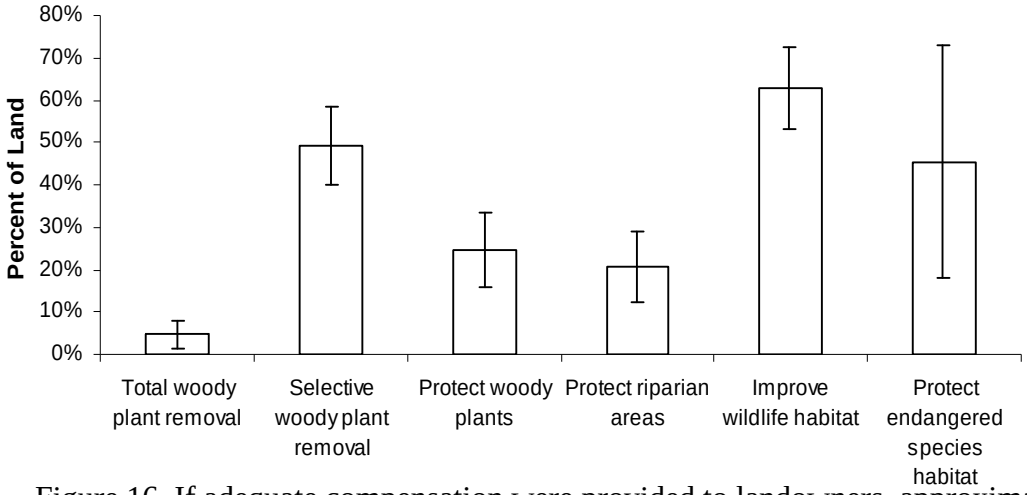

Figure 16. If adequate compensation were provided to landowners, approximately what percentage of the land would property owners be willing to include in programs aimed at each of the following objectives?

Table 15. The percentage of the land property owners would be willing to include in programs aimed at each of the following objectives.

Land Management Objectives	Mean	Std. Error	95% CI
Total woody plant removal	4.68%	1.69%	3.38%
Selective woody plant removal	49.32%	4.66%	9.31%
Protect woody plants	24.62%	4.32%	8.61%
Protect riparian areas	20.81%	4.16%	8.31%
Improve wildlife habitat	62.85%	4.90%	9.79%
Protect endangered species habitat	45.47%	13.76%	27.46%
I am not willing	76.32%	4.91%	9.78%
Total	41.17%	2.66%	5.23%

Table 16. Independent t-test for the percentage of land respondents would be most willing to include in cost-share assistance programs.

Land management objectives	Mean		t	p
	Bandera	Kerr		
Willing	78.13%	75.00%	0.312	0.756
Total woody plant removal	4.00%	5.50%	-0.426	0.672
Selective woody plant removal	52.00%	49.83%	0.229	0.820
Protect woody plants	29.67%	21.78%	0.888	0.378
Protect riparian areas	25.67%	17.92%	0.903	0.370
Improve wildlife habitat	73.83%	57.19%	1.754	0.084
Protect endangered species habitat	38.33%	3.94%	1.137	0.260

Survey participants were asked if they are currently participating the Environmental Quality Initiative Program (EQIP), Conservation Reserve Program (CRP), Wildlife Habitat Incentive Program (WHIP), and other federal or state funded program, with three answer options for each program: “Never participated,” “Have participated,” and “Am participating.” The answer choice most frequently chosen for Bandera participants was never participated for all four program choices. But, Bandera participants have participated for EQIP (3.8%), CRP (10.3%), WHIP (3.6%), and other programs (14.3%), and are participating for EQIP (10.7%) and other programs (7.1%).

Similarly, the majority of Kerr county respondents have never participated in any of the listed programs, with few participants having participating in EQIP (2.6%), CRP (5.3%), and other programs (4.8%), and a small proportion currently participating in EQIP (2.6%), WHIP (2.7%) and other programs (4.8%) (Figure 17). The crosstabulation analysis shows that there were no significant differences across both counties (EQIP X^2 = 0.779, p = 0.677), CRP X^2 = 0.050, p = 0.823, WHIP X^2 = 1.662, p = 0.436, and other X^2 = 0.438, p = 0.803).

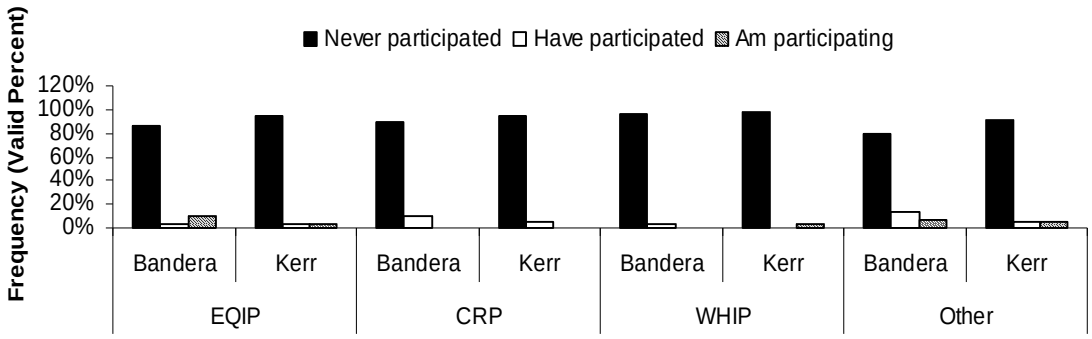

Figure 17. Federal or state funded land improvement programs in which landowners have never participated, have participated, or are currently participating. (EQIP: Environmental Quality Initiative Program, CRP: Conservation Reserve Program, WHIP: Wildlife Habitat Incentive Program)

Landowners were asked what the minimum level of cost-share they would require in order to participate in any cost-sharing land improvement programs. The results for the ANOVA suggest significant differences in levels of necessary compensation for different programs (F = 3.81, p = 0.002) (Figure 18, Table 17). The smallest percentage requested was for total woody plant removal (15.81%, SEM = 5.17%, 95% CI = 10.55%), and the highest amount required was for selective woody plant removal (43.81%, SEM = 3.39%, 95% CI = 6.78%). The proportions of cost-share

assistance required for landowners to participate in land improvement programs did vary significantly for total woody plant removal with Kerr (58.33%) greater than Bandera (11.25%), protect woody plants with Kerr (57.06%) greater than Bandera (23.62%), protect riparian areas with Kerr (54.50%) greater than Bandera (22.50%), and protect endangered species habitat with Kerr (57.20%) greater than Bandera (24.81%) (Table 18).

Figure 18. Minimum level of cost-share required for landowners to participate in land improvement programs.

Table 17. Minimum level of cost-share required by landowners.

Land Improvement Programs	Mean	Std. Error	95% CI
Total woody plant removal	15.81%	5.17%	10.55%
Selective woody plant removal	43.81%	3.39%	6.78%
Protect woody plants	35.98%	5.20%	10.47%
Protect riparian areas	35.83%	4.89%	9.85%
Improve wildlife habitat	42.00%	3.58%	7.15%
Protect endangered species habitat	40.38%	5.01%	10.05%
Total	37.56%	1.85%	3.64%

Table 18. Independent t-test for minimum required cost-share assistance.

Land Improvement Program	Mean		t	p
	Bandera	Kerr		
Total woody plant removal	**11.25%**	**58.33%**	**-3.040**	**0.005**
Selective woody plant removal	38.71%	48.75%	-1.487	0.143
Protect woody plants	**23.62%**	**57.06%**	**-3.828**	**0.000**
Protect riparian areas	**22.50%**	**54.50%**	**-3.614**	**0.001**
Improve wildlife habitat	35.31%	48.48%	-1.869	0.067
Protect endangered species habitat	**24.81%**	**57.20%**	**-3.590**	**0.001**

The last question related to types of contracts respondents would most likely enter into if cost-share programs were developed for four types of land management objectives: removal of woody plants, improvement of wildlife habitat, protection of endangered species, and protection of riparian areas. The pattern of preference for contract types for each program is similar pattern in each county. The three most chosen options for all 4 categories were 5-year Performance Contracts, 10-year Performance Contracts, and not willing to participate (Figure 19). The least chosen contract types were the two lease agreements and two conservation easement types. There were two program types for which the patterns varied significantly between the counties: remove woody plants (X^2 = 13.201, p = 0.022) and improve wildlife habitat (X^2 = 10.479, p = 0.063) (Table 19).

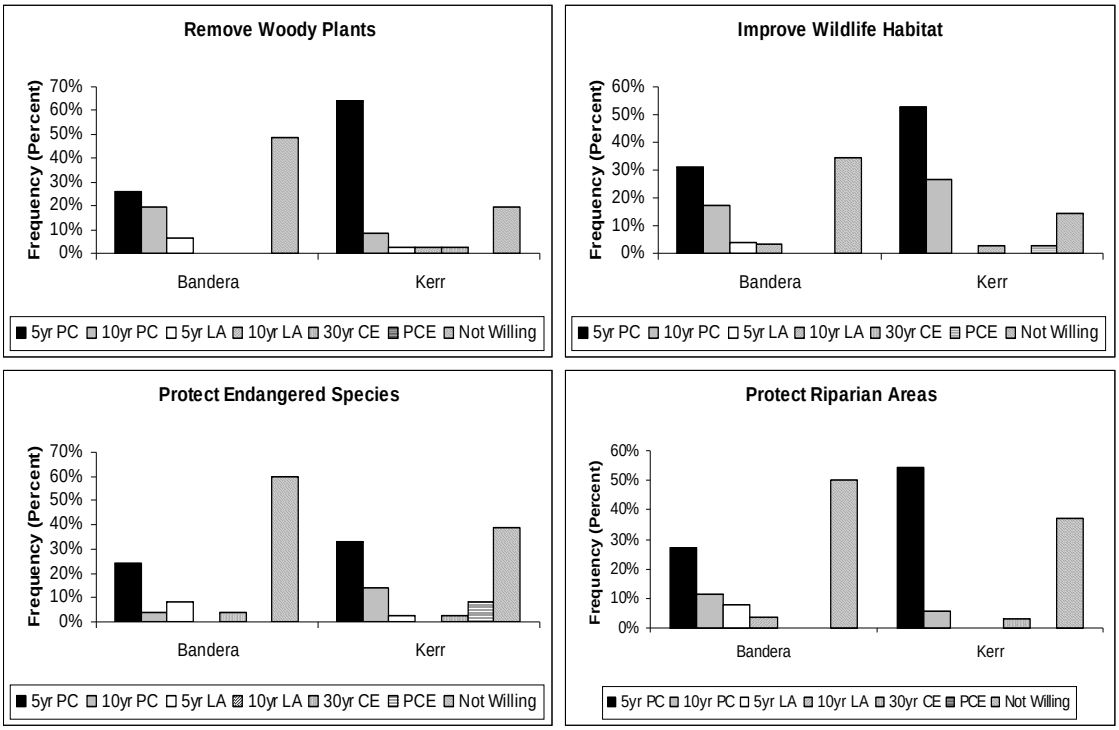

Figure 19. Contract types chosen if cost-share programs were developed for four categories: removal of woody plants, improvement of wildlife habitat, protection of endangered species, and protection of riparian areas.

Table 19. X^2 values for the types of programs respondents would most likely participate in.

Types of Programs	X^2	p
Remove woody plants	**13.201**	**0.022**
Improve wildlife habitat	**10.479**	**0.063**
Protect endangered species	6.254	0.282
Protect riparian areas	8.598	0.126

To determine whether or not preferences for contract type varies significantly across property size, respondents were categorized into above and below median property size groups (202 acres). The interest level of landowners towards ten alternatives was compared to the cost-share contracts across property size groups (Figure

20). The preference for 5-year Performance Contract did not differ substantially between the small (0.59) and large (1.10) property size interest levels. The 10-year Performance Contract had a larger portion of large property owners (0.14) being more interested than small properties (-0.23). The remaining contract types were responded to negatively with little interest by both small and large property sizes. The respondents that were not prepared to enter into a contract were evenly distributed for the small and large properties (small = 0.66, large = 0.69). From the distribution of respondent answers towards contract types by property size, 5-year Performance Contracts are the best option for properties smaller than 202 acres, and 5-and 10-year Performance Contracts are the best options for properties larger than 202 acres. With one exception, the interest levels did not vary significantly across property size groups; large properties (-0.72) appeared to have a higher interest in ten year Lease Agreements than small properties (-1.55) (Table 20).

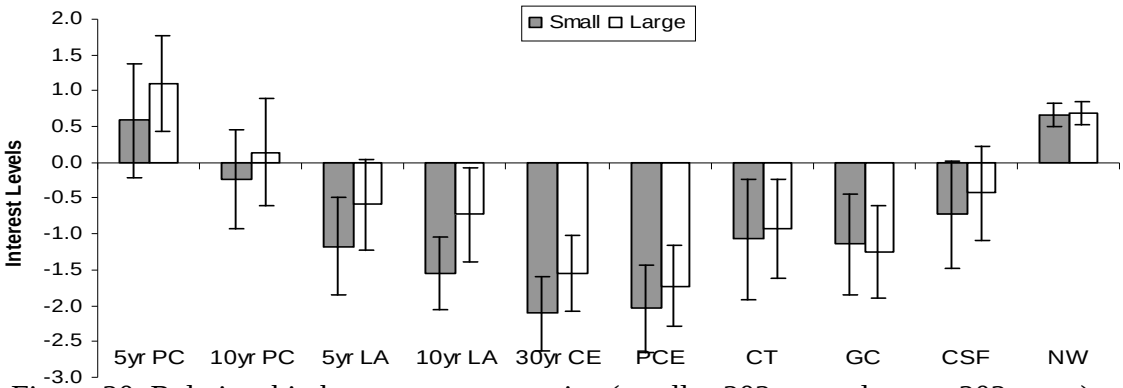

Figure 20. Relationship between property size (small < 202 acres, large > 202 acres) of landowner respondents and their preference for types of cost-share contracts (5 yr PC – 5 year Performance Contract, 10 yr PC – 10 year Performance Contract, 5 yr LA – 5 year Lease Agreement, 10 yr LA – 10 year Lease Agreement, 30yr CE – 30 year Conservation Easement, PCE – Perpetual Conservation Easement, CT- contracts transferred when property sold, GC – group contracts, CSF – contracts with set-up fees, and NW– landowners not willing to participate in contracts).

Table 20. Effect of property size on the types of contracts chosen.

Types of Contracts	Mean		t	p
	Small	Large		
5yr Performance Contract	0.59	1.10	-0.972	0.335
10yr Performance Contract	-0.23	0.14	-0.712	0.480
5yr Lease Agreement	-1.17	-0.59	-1.241	0.220
10yr Lease Agreement	**-1.55**	**-0.72**	**-1.959**	**0.055**
30yr Conservation Easement	-2.11	-1.55	-1.453	0.152
Perpetual Conservation Easement	-2.04	-1.72	-0.741	0.462
Contracts transfer to new owners	-1.07	-0.93	-0.249	0.805
Group Contract	-1.14	-1.24	0.213	0.832
Contract with st-up fees	-0.72	-0.43	-0.576	0.576
Not willing to enter into any contract	0.66	0.69	-0.251	0.803

The effect of property size groups on the preference for performance contracts for four different land management objectives was also determined. All four land management objectives for both small and large properties are more willing to participate in 5- then 10-year Performance Contracts (Figure 21). The property size did not substantially effect the types of contracts chosen for each land management objective, with the patterns between property size groups being statistically similar for all four types of programs (Table 21).

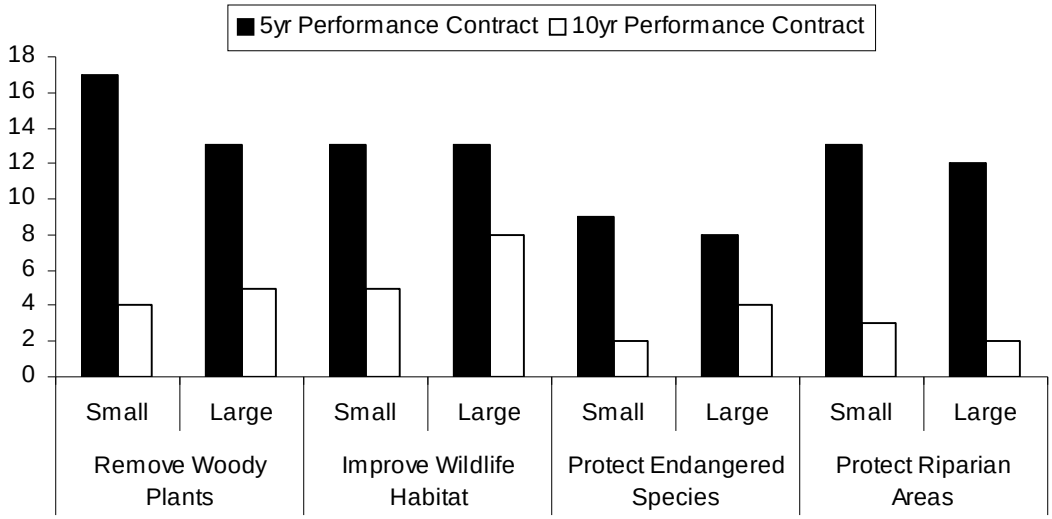

Figure 21. Relationship between property size (S – small, >202 acres; L – large, <202 acres) of landowner respondents and contracts preferred for different land management objectives: remove woody plants, improve wildlife habitat, protect endangered species, and protect riparian.

Table 21. X^2 values for the types of programs property size groups would most likely participate in.

Types of programs	X^2	p
Remove woody plants	5.073	0.407
Improve wildlife habitat	2.692	0.747
Protect endangered species	4.250	0.513
Protect riparian areas	1.600	0.809

The period of property ownership was also examined as a variable that might affect the interest levels of landowners concerning alternative contract options. Interest in the 5-year performance contract was not correlated with all length of ownership categories: less than 3 years equaled 1.400 (SEM = 1.122, 95% CI = 1.717), 3-25 years was 0.341 (SEM = 0.564, 95% CI = 1.14), and more than 25 years equaled 1.402 (SEM

= 0.474, 95% CI = 1.064) (Figure 22, Table 22). Ten-year performance contracts were also uncorrelated with less than 3 years (mean = 0.800, SEM = 1.114, 95% CI = 2.42) and more than 25 years of ownership (mean = 0.518, SEM = 0.568, 95% CI = 0.969), but the ownership category 3-25 years responded negatively to ten-year performance contracts (mean = -0.393, SEM = 0.486, 95% CI = 1.044). The confidence intervals for the less than three years length of ownership category is highly variable because of a small sample size (n = 5). The remaining cost-share improvement programs received negative responses in each of the three lengths of land ownership categories.

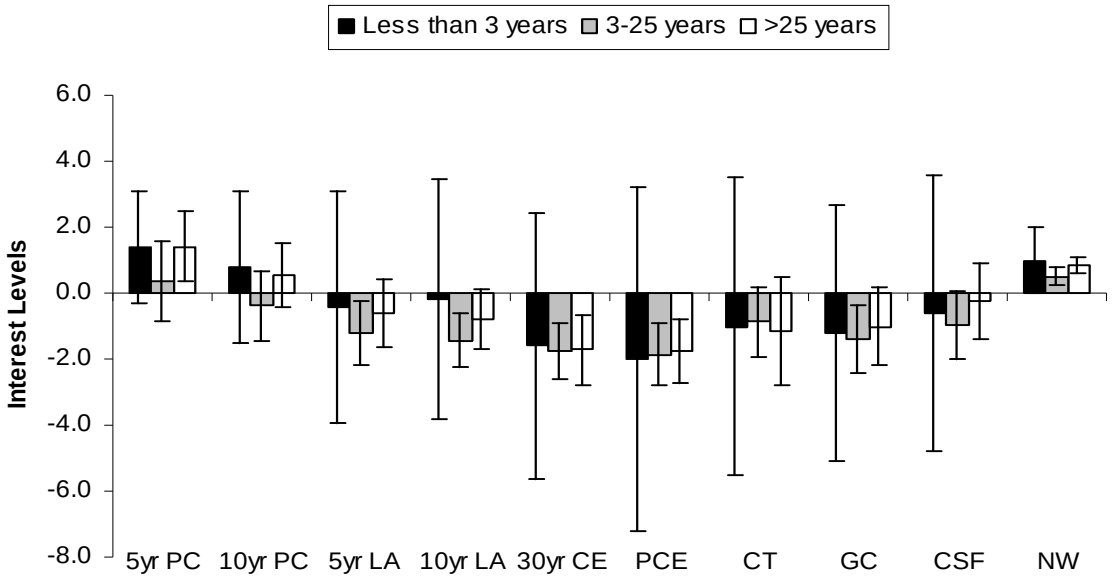

Figure 22. Comparison of the length of time a property has been owned compared to landowner interests in participating in different contract types (5yr PC – 5 year Performance Contract, 10yr PC – 10 year Performance Contract, 5yr LA – 5 year Lease Agreement, 10yr LA – 10 year Lease Agreement, 30yr CE –30 year Conservation Easement, PCE – Perpetual Conservation Easement, CT – contracts transfer if property is sold, GC – group contracts, CSF – contracts with set-up fees, and NW – not willing to enter into any contract).

Table 22. Comparison of length of property ownership to the types of contracts chosen.

Types of Contracts	Length of Ownership	Mean	Std. Error	95% CI
5yr Performance Contract	Less than 3 years	1.400	1.122	1.717
	3-25 years	0.341	0.564	1.214
	>25 years	1.402	0.474	1.064
10yr Performance Contract	Less than 3 years	0.800	1.114	2.292
	3-25 years	-0.393	0.486	1.044
	>25 years	0.518	0.568	0.969
5yr Lease Agreement	Less than 3 years	-0.400	1.122	3.517
	3-25 years	-1.215	0.449	0.966
	>25 years	-0.607	0.447	1.004
10yr Lease Agreement	Less than 3 years	-0.200	1.241	3.645
	3-25 years	-1.429	0.385	0.828
	>25 years	-0.813	0.402	0.906
30yr Conservation Easement	Less than 3 years	-1.600	0.872	4.020
	3-25 years	-1.750	0.389	0.840
	>25 years	-1.715	0.450	1.057
Perpetual Conservation Easement	Less than 3 years	-2.000	1.000	5.182
	3-25 years	-1.857	0.435	0.938
	>25 years	-1.770	0.429	0.976
Contracts transfer to new owners	Less than 3 years	-1.000	1.265	4.512
	3-25 years	-0.877	0.496	1.068
	>25 years	-1.143	0.720	1.639
Group Contract	Less than 3 years	-1.200	0.970	3.892
	3-25 years	-1.422	0.957	1.032
	>25 years	-1.000	0.511	1.161
Contracts with set-up fees	Less than 3 years	-0.600	1.288	4.177
	3-25 years	-0.950	0.478	1.029
	>25 years	-0.245	0.502	1.140
Not willing to enter into a contract	Less than 3 years	1.000	0.000	-1.000
	3-25 years	0.512	0.119	0.249
	>25 years	0.827	0.109	0.241

For 5- and 10-year performance contracts, the greater amount of total annual household income the more likely landowners are interested in performance contracts. (Figure 23, Table 23). Respondents within the income ranges of $50-100K (mean = 0.635, SEM = 0.810, 95% CI = 1.937) and greater than $100K (mean = 1.364, SEM = 0.352, 95% CI = 0.731) were interested in the 5-year Performance Contract, while the

income level less than $50K all contracts negatively (mean = -0.417, SEM = 0.796, 95% CI = 2.693). The highest income level (greater than $100K) also appeared interested in 10-year Performance Contracts (mean = 0.609, SEM = 0.376, 95% CI = 0.779), while the less than $50K (mean = -1.067, SEM = 0.630, 95% CI = 2.105) and $50-100K (mean = -0.810, SEM = 0.666, 95% CI = 1.581) were disinterested in this contract. The confidence intervals for the less than $50K income category is highly variable because of a small sample size (n =3). The best overall income class to focus assistance would be the higher income levels with 5- and 10-year Performance Contracts, followed with 5-year performance contracts for mid-level income levels.

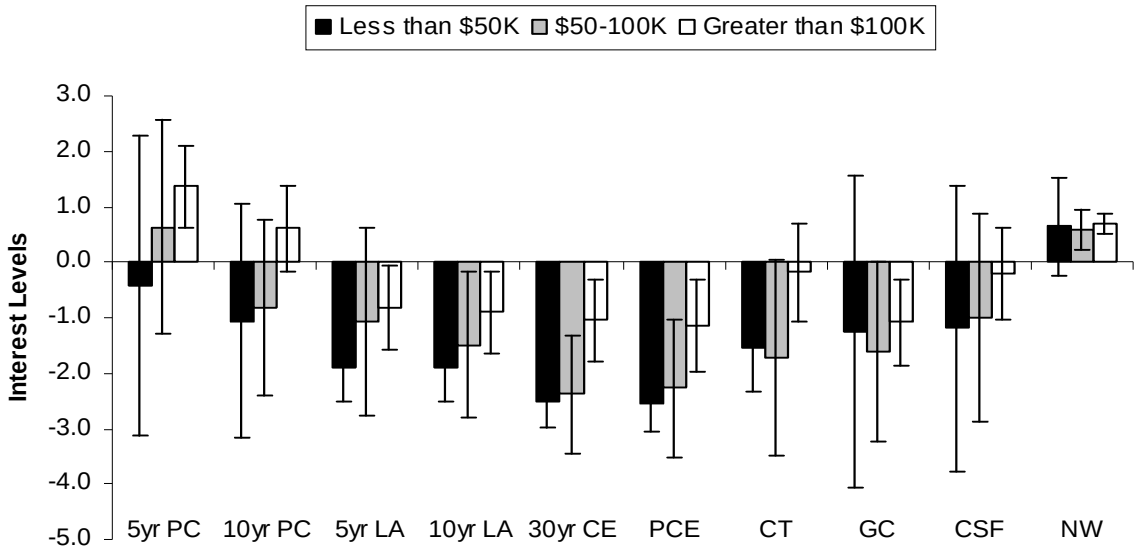

Figure 23. Comparison of the total household annual income compared to landowner interests in participating in different contract types (5yr PC – 5 year Performance Contract, 10yr PC – 10 year Performance Contract, 5yr LA – 5 year Lease Agreement, 10yr LA – 10 year Lease Agreement, 30yr CE –30 year Conservation Easement, PCE – Perpetual Conservation Easement, CT – contracts transfer if property is sold, GC – group contracts, CSF – contracts with set-up fees, and NW – not willing to enter into any contract).

Table 23. Comparison of total annual household income to the types of contracts chosen.

Types of Contracts	Total Annual Income	Mean	Std. Error	95% CI
5yr Performance Contract	Less than $50K	-0.417	0.796	2.693
	$50-100K	0.635	0.810	1.937
	Greater than $100K	1.364	0.352	0.731
10yr Performance Contract	Less than $50K	-1.067	0.630	2.105
	$50-100K	-0.810	0.666	1.581
	Greater than $100K	0.609	0.376	0.779
5yr Lease Agreement	Less than $50K	-1.900	0.267	0.603
	$50-100K	-1.072	0.713	1.696
	Greater than $100K	-0.818	0.358	0.745
10yr Lease Agreement	Less than $50K	-1.900	0.267	0.603
	$50-100K	-1.493	0.551	1.312
	Greater than $100K	-0.909	0.360	0.748
30yr Conservation Easement	Less than $50K	-2.500	0.212	0.477
	$50-100K	-2.385	0.436	1.066
	Greater than $100K	-1.048	0.355	0.741
Perpetual Conservation Easement	Less than $50K	-2.550	0.217	0.491
	$50-100K	-2.278	0.508	1.237
	Greater than $100K	-1.143	0.392	0.818
Contracts transfer to new owners	Less than $50K	-1.550	0.353	0.799
	$50-100K	-1.723	0.715	1.765
	Greater than $100K	-0.174	0.425	0.881
Group Contract	Less than $50K	-1.250	0.791	2.810
	$50-100K	-1.611	0.663	1.627
	Greater than $100K	-1.087	0.377	0.781
Contracts with set-up fees	Less than $50K	-1.184	0.740	2.574
	$50-100K	-1.000	0.771	1.879
	Greater than $100K	-0.217	0.402	0.834
Not willing to enter into a contract	Less than $50K	0.652	0.243	0.886
	$50-100K	0.600	0.160	0.362
	Greater than $100K	0.704	0.090	0.184

Conclusion

The characteristics of survey respondents were the first aspect of the surveys to be analyzed and consisted of the average property size, primary nature of property, land management objectives, and percentage of plant cover. The average property size is relatively large for both counties (940 acres), with Kerr having a slightly larger property

average (1156 acres) compared to Bandera (672 acres). The primary nature of the respondent properties within the counties are livestock production, wildlife operations, livestock and wildlife, and primary residence, which allow the survey responses to be gathered from a variety of perceptions within the study area. The most important land management objectives to survey participants were improving grass and forb cover, increasing open savanna, decreasing brush cover, protecting/improving riparian areas, and increasing stream flow. The majority of respondents' properties are composed of open grasslands, mainly juniper (cedar), and/or mixed oak and juniper. The land management objectives for managing these plant cover types are important for improving wildlife habitat, increasing water yield, and increasing the sequestration of carbon. The resulting survey respondent characteristics for this study are similar to previous studies conducted by Amestoy (2002), Narayanan (2003), and Olenick et al. (2004).

Land management characteristics were the second aspect to be analyzed for both Bandera and Kerr counties. The land management practices participated in most frequently by survey participants were mostly broad scale mechanical methods and individual plant treatment using mechanical methods, with a small portion participating in individual plant treatment using herbicides and prescribed burning. The land management survey results are consistent with Amestoy (2002). The practices used on the largest percentage of property within the counties were broad scale mechanical methods and individual plant treatment using individual mechanical methods. These two

land management practices appear to be the optimal programs to focus cost-share assistance for improving the desired respondent land management objectives.

The level of landowner interests toward publicly funded cost-share assistance programs appeared to be highest for both 5- and 10-year Performance Contracts, which is consistent with past studies by Narayanan (2003) and Olenick et al. (2004). When asked what types of program objectives respondents would most likely participate in if adequate compensation were provided the following objectives were chosen for several questions: woody plant removal, increasing wildlife habitat, protecting endangered species habitat, and protecting/conserving riparian areas. When comparing property size, 5-year performance contracts were preferred by both small and large properties, but large properties were also willing to participate in ten year performance contracts. Similarly, when comparing the length of property ownership with types of contracts chosen, the 5-year performance contract was chosen by all three ownership categories. However, the 10-year performance contract was chosen by the less than 3 years and 3-25 years ownership groups. Respondents' income levels also affected the types of programs preferred, with the lower income level not willing to participate in any contracts, mid-level income category only participating in 5-year performance contracts, and the highest income bracket participating in both 5- and 10-year performance contracts.

Overall, respondents seem to want to manage their property for important ecosystem services, such as increasing water yield, protecting wildlife habitat, and increasing carbon sequestration, if offered either a 5- or 10-year performance contract. If government agencies would like landowners to be committed to lengthier contract types,

then maybe they should create new contract method types for each landowner characteristic (property size, length of ownership, and income level), such as stage type performance contracts divided into different 5/10-year stages. Possibly, one staged performance contract for managing a landowner's property and following staged performance contracts for maintaining property in the managed vegetative state. Another alternative to increase participation in publicly funded assistance programs would be to create special contract types which includes overall respondent preferences and the preferences presented by each property size, length of ownership, and income level category.

CHAPTER V

SUMMARY AND CONCLUSION

The geographic information systems spatial analysis that was conducted for Bandera and Kerr counties consisted of two components: (1) biophysical and (2) landowner interests. These components resulted in an overarching map depicted the optimal locations to allocate government assistance to landowners for managing their property to support three ecosystem services: water yield, wildlife habitat, and carbon sequestration. The optimal locations for allocating cost-share assistance to landowners would be in the dark red, green, and orange areas depicted in the final spatial analysis map; the combination of the biophysical and landowner interests spatial analyses. The area with highest potential for increasing water yield by removing brush, primarily Ashe juniper, appears to be in northwestern Kerr County, and the most favorable location for protecting wildlife habitat is south-central Kerr County. The highest potential site for protecting endangered species and increasing atmospheric carbon sequestration are the steeper slope areas of northwest Kerr County and several scattered locations within in west-central Bandera County.

A statistical analysis of the April 2003 and supplemental 2004 survey responses was conducted in order to determine landowner opinions regarding ecosystem services and cost-share programs. The contract type most selected by small and large property groups by all three length of ownership categories, and mid- and high total annual income levels was the five year performance contract. The second highest cost-share program chosen were ten year performance contracts by small and large properties, the

less than 3 year and more than 25 year ownership groups, and high income levels. The management practices landowners would most likely participate in with these assistance programs appear to be broad scale mechanical and individual plant mechanical methods in order to improve grass and forb cover, increase open savannas, decrease brush cover, protect/improve riparian areas, and increase stream flow.

If government agencies would like landowners to be committed to lengthier contract types, then maybe they should create new contract method types, such as staged performance contracts with 5-10 year phases for land management practices and proper land maintenance techniques. Another alternative to increase participation in publicly funded assistance programs would be to create customized contract types that incorporate overall respondent preferences as well as preferences expressed by each property size, length of ownership, and income level category.

Future Research Needed and Study Limitations

In the future, an additional spatial analysis using actual wildlife sample points would be beneficial for creating an optimal wildlife habitat map, since the wildlife GAP Analysis data was statewide and very general. For example, USGS data grouped golden-cheeked warblers and black-capped vireos within the same habitat, but there are differences in habitat preferences by these both species. Black-capped vireos prefer mid-successional growth while golden-cheeked warblers prefer a mix of old growth juniper and oak. The GAP analysis statewide data can also have flaws because the wildlife habitats are based solely on vegetative classifications and does not include other landscape characteristics, such as the age and height of vegetation, topography, and/or

soil types. The GAP analysis, also, does not analyze the human population densities and impacts on habitat quality. In addition, with the GAP analysis data being statewide and the rest of the GIS data being at a local scale the spatial units differed between each wildlife shapefile and the remainder of the biophysical data. The creation of more detailed data on a county-by-county basis using GAP analysis techniques would be beneficial for managing at a local scale.

Because many survey respondents did not perceive most of cost-share assistance programs presented in the survey as being desirable, programs aimed on educating landowners about the benefits of lengthier types of contracts and conservation easements should be created. Also, many landowners do not participate in non-mechanical woody plant management practices. An increased number of educational workshops aimed at informing landowners about the benefits of other land management practices would also be helpful for property owners wanting to properly manage their property.

By determining the optimal locations for increasing water yield, protecting wildlife habitat, and improving carbon sequestration and knowing the preferences of landowners within Bandera and Kerr counties should assist government agencies in the allocation of limited land management resources. Also, the highest potential areas on the final target area map would operate as demonstration sites for surrounding landowners. Respondents will participate in publicly funded cost share programs for water yield, wildlife habitat, and endangered species/carbon sequestration and produce a ripple effect on surrounding property owners in order to increase the number of landowners

participating in assistance programs to benefit ecosystem services within Bandera and Kerr counties.

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APPENDIX A

SURVEY QUESTIONNAIRES

These questions were extracted from the April 2003 survey:

A2. Of the acres listed in the previous question, what is the acreage for which you make LAND IMPROVEMENT DECISIONS?

Number of acres…….._____Acres

A4. What is the primary NATURE OF YOUR PROPERTY? (CHECK ONLY ONE BOX)

Mainly livestock production…… □
Mainly a wildlife operation…….. □
Mainly crop production…… □
Mixed livestock and wildlife operation……... □
Mixed livestock operation and crop……. □
Mixed wildlife operation and crop …….. □
Tourist operation (e.g., dude ranch, bed and breakfast, etc.)……... □
Primary residence or weekend hideaway…… □
Long-term investment…….. □
Other (Please describe: _____)……... □

A7. How important is each of the following LAND MANAGEMENT OBJECTIVES on your land?

	+3	+2	+1	0	-1	-2	-3
Improve grass and forb cover……..	□	□	□	□	□	□	□
Increase open savanna (trees interspersed by grassland)……...	□	□	□	□	□	□	□
Increase brush cover……	□	□	□	□	□	□	□
Reduce brush cover…….	□	□	□	□	□	□	□
Protect or improve riparian areas……	□	□	□	□	□	□	□
Increase stream flow……..	□	□	□	□	□	□	□

B1. To the best of your ability, please estimate what percentage of your property is currently occupied by each of the following PLANT COVER TYPES? (ENSURE YOUR ANSWERS TOTAL TO 100%).

Open grassland……___%
Mainly live oak……..____%
Mainly juniper (Cedar)……____%
Mainly mesquite……..____%
Mixed live oak/juniper……...____%

Mixed juniper/mesquite…….____%
Mainly other brush species…….____%
Other land cover (Please specify_____)……____%
TOTAL 100 %

D1. If you were to participate in a cost-share land improvement program, how interested do you think you would be in the following TYPES OF CONTRACTS? (CHECK THE BOX THAT BEST REFLECTS YOUR INTEREST IN EACH CONTRACT: +3 = Very interested, +2 = Interested, +1 = Somewhat interested, 0 = Neutral, -1 = Somewhat disinterested, -2 = Disinterested, -3 = Very disinterested)

	+3	+2	+1	0	-1	-2	-3
5-year Performance Contract……...	□	□	□	□	□	□	□
10-year Performance Contract…….	□	□	□	□	□	□	□
5-year Lease Agreement……...	□	□	□	□	□	□	□
10-year Lease Agreement…….	□	□	□	□	□	□	□
30-year Conservation Easement……...	□	□	□	□	□	□	□
Perpetual Conservation Easement ……...	□	□	□	□	□	□	□
Contracts that transfer to new owners if land is sold…...	□	□	□	□	□	□	□
Group contract that includes several landowners…….	□	□	□	□	□	□	□
Contracts with set up fees based on property size……...	□	□	□	□	□	□	□
I would not be prepared to enter into any contract……...	□						

D3. Have you previously or are you currently participating in any of the following FEDERAL OR STATE FUNDED LAND IMPROVEMENT PROGRAMS? (CHECK ONLY ONE BOX PER ROW.)

	Never participated	Have participated	Am participating
Environmental Quality Initiative Program (EQIP)……	□	□	□
Conservation Reserve Program (CRP)……...	□	□	□
Wildlife Habitat Incentive Program (WHIP)……	□	□	□
Other (Please specify_____)…….	□	□	□

E3. For how long have you or your family owned this property? (CHECK ONLY ONE BOX)

Less than 3 years……□
3-10 years……..……□
11-25 years……□
More than 25 years (single generation)……□
More than one generation……..□
I manage but don't own the property……□

E7. Please check the category that best represents your total household income before taxes in 2002? (Include net property income, income from wages, salaries, non-farm businesses, rental payments, investments, retirement accounts, and any other major income sources).

Less than $25,000……...…… □
$25,001-$50,000……..……..…… □
$50,000-$75,000…….…… □
$75,001-$100,000…… …….. □
Greater than $100,000……..…….. □

July 2004 Supplemental Survey Questionnaire: Landowner Perceptions About Brush Cover, Ecosystem Services and Publicly Funded Cost-Share Land Management Programs

SECTION A – PROPERTY LOCATION AND LAND MANAGEMENT PRACTICES

A1. In what county is your property primarily located? (CIRCLE ONLY ONE)

Bandera Kerr Medina Real Uvalde Other:_____

A2. What is the zip code where your property is centered?

Zip Code…… _____

A3. What is the distance and direction from the nearest state/county cross road? (PLEASE SPECIFY THE ROAD NUMBER OR NAME)

_____

A4. If possible, please provide the coordinates for your property. (THIS WILL HELP US MORE EASILY UNDERSTAND SPATIAL VARIATION IN LANDOWNER INTEREST IN COST-SHARING PROGRAMS).

Coordinates_____

A5. Which of the following types of management practices have you used on your land in the last five years? (PLEASE CHECK ALL THAT APPLY)

Prescribed burning……...……. □
Broadcast herbicide application to control brush (including aerial application)……...□
Individual plant treatment using herbicides to control brush (e.g., Brush Busters approved methods)…….□
Broad scale mechanical methods to control brush (e.g., shredding, roller chopping, chaining, etc.)……...…… □
Individual plant treatment using mechanical methods to control brush (e.g., mechanical shears, etc.)…….□
Contour plowing……...….□
Minimum till cultivation……..…….□
Other (Please describe_____)……..□

A6. Approximately what percent of your property is currently undergoing or has undergone any of the following land management practices during the last five years?

Broadcast herbicide application to control brush (including aerial application)……___%
Individual plant treatment using herbicides to control brush (e.g., Brush Busters approved methods)…….___%
Broad scale mechanical methods to control brush (e.g., shredding, roller chopping, chaining, etc.)…….___%
Individual plant treatment using mechanical methods to control brush (e.g., mechanical shears, etc.)…….___%
Contour plowing……..…… ___%
Minimum till cultivation…….___%
Other (Please describe_____)…….... ___%

SECTION B – COST SHARING PROGRAM PARTICIPATION

B1. If adequate compensation were provided, how interested do you think you would be in IN PROGRAMS aimed at increasing each of the following types of land management activities? (CHECK THE BOX THAT BEST REFLECTS YOUR INTEREST LEVEL: +3 = Very interested, +2 = Interested, +1 = Somewhat interested, 0 = Neutral, -1 = Somewhat disinterested, -2 = Disinterested, -3 = Very disinterested, NA = Not Applicable, DK = Don't know)

	+3	+2	+1	0	-1	-2	-3	NA	DK
(1) Minimum/no-till farming practices……...…	□	□	□	□	□	□	□	□	□
(2) Cropland retirement…….....□	□	□	□	□	□	□	□	□	
(3) Allow brush to flourish on slopes greater than 15%…….....	□	□	□	□	□	□	□	□	□
(4) Allow brush to flourish over entire property……..……....…….□	□	□	□	□	□	□	□	□	□
(5) Remove brush and seed grasses.……..…	□	□	□	□	□	□	□	□	□
(6) Develop buffer strips along streams……..…..□	□	□	□	□	□	□	□	□	□

B2. If adequate compensation were provided, approximately what percent of your land do you think you would be WILLING TO INCLUDE in programs aimed at each of the following objectives? (PLEASE DO NOT LEAVE BLANKS – write 0% if you are not interest in a specific program type)

Total woody plant removal……..___%
Selective woody plant removal…….___%
Protect woody plants…….___%
Protect riparian areas (buffer areas along streams and other water bodies)…… ___%
Improve wildlife habitat…….___%
Protect endangered species habitat……..___%

I am not willing to incorporate any of my land in cost-sharing programs…….☐

B3. Approximately what MINIMUM LEVEL OF COST SHARE would you require to participate in any cost-sharing land improvement program? Your response will not influence the actual level of cost-share of future land improvement programs. (PLEASE DO NOT LEAVE BLANKS – check the NI box if you are not interest in a specific program type)

		NI
Total woody plant removal…….	___%	☐
Selective woody plant removal……..	___%	☐
Protect woody plants……..	___%	☐
Protect riparian areas (buffer areas along streams and other water bodies)..	___%	☐
Improve wildlife habitat…….	___%	☐
Protect endangered species habitat……	___%	☐

In answering the final question, please refer to the following definitions of three types of contractual agreements.

- Performance Contract: The landowner is partially/fully compensated for his/her costs of participating in a land improvement program after meeting predetermined performance criteria.
- Lease Agreement: In participating in a program aimed at restoring land, landowner gives up all/part of his/her land use right in exchange for annual payment.
- Conservation Easement: Landowner receives a lump sum payment in exchange for the transfer of part of his/her use rights to all or part of their land. Conservation easement contracts are usually longer than performance contracts or lease agreements.

B4. Which of the following CONTRACTS would you most likely enter if cost-share programs were developed for the following four categories of land management objectives? (CHECK ONLY ONE BOX PER COLUMN. You should check a total of FOUR BOXES; ONE IN EACH COLUMN.)

	Remove woody plants (brush)	Improve wildlife habitat	Protect endangered species	Protect riparian areas
5-year Performance Contract…….	☐	☐	☐	☐
10-year Performance Contract…….	☐	☐	☐	☐
5-year Lease Agreement…….	☐	☐	☐	☐
10-year Lease Agreement……..	☐	☐	☐	☐
30-year Conservation Easement…….	☐	☐	☐	☐
Perpetual Conservation Easement …….	☐	☐	☐	☐
I would not be prepared to enter into any contract…….	☐	☐	☐	☐

APPENDIX B

X & Y COORDINATES ESTIMATE PROCEDURAL METHOD

FOR COUNTY PARCEL SHAPEFILE

In order to calculate the x-values, within each county's parcel shapefile right click on the X_Field and choose Calculate Values, check advanced on the calculation box, type the following VBA script in the first text box:

```
Dim dblX As Double
Dim pArea As IArea
Set pArea = [Shape]
dblX = pArea.Centroid.X
```

and in the second text box type dblX for the X_Field name. And, in order to calculate the y-values, right click the Y_Field and choose Calculate Values, check advanced, type the following VBA Script in the first text box:

```
Dim dblY As Double
Dim pArea As IArea
Set pArea = [Shape]
dblY = pArea.Centroid.Y
```

and in the second text box type dblY for the Y_Field name. Export the coordinate data from the attribute table into a separate excel XY .dbf file, and import the .dbf table into ArcMap, choose display XY data, project the data (UTM Zone 14N NAD83), and export the data into permanent XY centroid shapefiles for each county.

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