Brush, Water & Wildlife:

A Compendium of Our Knowledge

November 30 - December 1, 2000
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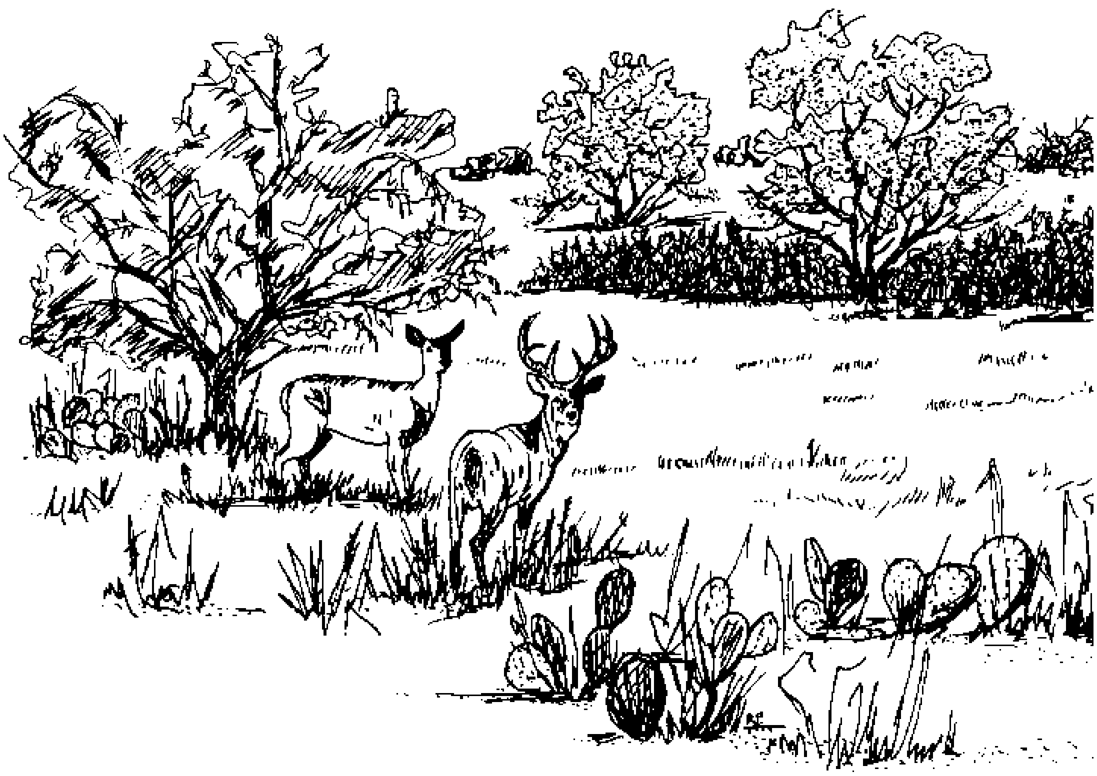

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FOREWORD

"A conference is just an admission that you want someone to join you in your troubles."
- Will Rogers

For those who have speculated that we would see a day when water was more valuable than oil, their prophesy is increasingly becoming true! Water issues are at the forefront of natural resource conservation in Texas. The future promises only increasing demand to satisfy society's thirst for urban needs, agriculture, and industry, while addressing environmental demands. Controlling brush on arid rangelands has become especially topical over the last 5 years to enhance water yield, and will continue to be as Texas seeks to quench the demand for water.

Brush control as a tool on rangelands can be an effective habitat management tool for many species of wildlife, especially the mid-successional species like white-tailed deer and bobwhite. However "wildlife" is a broad term, and just as clearing brush may benefit edge species, the resulting fragmentation may be onerous to other species (e.g., golden-cheeked warblers). Clearing brush can be positive for wildlife, provided one "knows when to say when." Generally, removing over 70% of the brush would not be recommended for enhancing wildlife habitat, yet clearing intensities exceeding 85% may be necessary before appreciable water benefits are realized.

Landowners who (a) enroll in brush clearing programs aimed at watershed enhancement, and (b) realize a significant economic impact from hunting leases need additional information about the effects of brush control on resident wildlife species. Similarly, as additional watersheds are being evaluated for expansion of the state-funded brush control program, legislators need background information on how wildlife habitat may be affected (positively or negatively) in different portions of the state.

This symposium was convened to assemble the state of the science relative to integrating wildlife concerns into brush management decisions, specifically as they relate to watershed management. Because such programs affect a variety of Texas' citizens, a number of viewpoints on the topic by various stakeholder groups are included.

Sir Isaac Newton's 3rd Law of Motion holds that to every action there is a reaction. I submit that Newton was an optimist. As a physicist, Newton saw the world in black and white; there was no gray. As an ecologist, I submit that to every action there are *many* reactions, some apparent, and some transparent. It is the goal of the Steering Committee that the various reactions are elucidated at this conference, and that such observations can be used to minimize conflicts among various stakeholder groups. Aldo Leopold suggested that *"the urge to comprehend must precede the urge to reform."* This symposium is a step towards comprehension.

The views presented herein do not necessarily reflect those of the Steering Committee or the sponsors.

– Dale Rollins, Chair
Steering Committee

WATER NEEDS FOR TEXAS

Honorable Tracy King, State Representative, Uvalde

When the issue of water, wildlife and brush are all discussed in the same conversation, it is usually difficult to separate what is truth based on extensive research, what is believed to be true and what someone wants to be true. This is particularly difficult for those of us who serve in the State Legislature and sometimes have the unenviable task of trying to mediate the often conflicting concerns of ranchers, recreational landowners, non-landowners, sportsmen, hunters, trappers, fishermen, conservationists, animal rights advocates, property rights advocates as well as many other legitimate stakeholders.

Most of the comments I make will be personal observations based on my experiences growing up around a ranch in southwest Texas, 6 years in the Texas Legislature and extensive discussions and reading on these subjects over the years. I am certainly not complaining because my wonderful wife, Cheryl, always reminds me that I asked for, campaigned for, raised money for and voted for the job. However it does illustrate the complexities that everyone involved with these issues needs to face.

Obviously the 3 areas of water, wildlife and brush are related and always have been. When my grandfather was ranching in Dimmit County in the first part of this century until about 1980, he did not spend much time worrying about the wildlife aspect of the equation. He was certainly worried about the tanks having enough water for the cattle. When he could, he cleared a little brush to improve the grazing because cattle were his cash crop.

He always relied on the deer lease to put groceries on the table, but it was not the bulk of his income. He basically had the same bunch of hunters for thirty or forty years and they did kill some very nice bucks but they were there to escape the city and primarily just to relax with their families. Over the years they became like family to us also. Of particular interest was that my grandfather did not limit their bag limits. When I was about 16 years old, and believed I was smarter than everybody else (after all I read every wildlife article available!), I asked him why he did not charge more, why he did not limit the number of deer they could kill and why he did a lot of things the way he did.

Of course he was very patient with me as grandparents are and answered my questions, but the answers I remember most vividly were his answers to the first 2 questions about the cost and the bag limits. First of all he said those hunters were known entities and they did not mind his restrictions on when they could come to the ranch and in fact they were only allowed there during deer season and one other weekend prior to the season to work on their blinds. Secondly, he told me that he did not own the deer and he was actually being paid for the right to enter the property or the right of trespass as we call it today. His thinking was that the people of Texas owned those deer and when they bought a hunting license they could kill the number of deer the license permitted.

I did not argue with him but I was sure he did not know what he was talking about because all the wildlife articles and information available in those days said to maximize your lease price, limit the hunters to one buck, kill every spike buck and a lot of does also. When my father took over the ranching operations he was one of the very first people in that area to do a game survey with a helicopter and was always looking for ways to improve the return on the ranch. We root-plowed in strips to preserve the deer cover and would probably have built a high fence if the money had been available and we could have justified the cost. In short, we got with the program of the day.

Now here we are 20 years later and I am in the Texas House of Representatives. During that time I have served on the Natural Resources Committee, the State Recreational Resources Committee and the Agriculture and Livestock Committee at different times. Those 3 committees, along with the Appropriations Committee, are the ones that deal with policy issues involving water, wildlife and brush in Texas.

Now I realize that my grandfather was right. Legally he did not own those deer on that ranch and his attitudes about the management of that resource may have been right given that set of facts. The reality is that every single wildlife specimen is the property of the people of Texas and there are serious legal and constitutional questions about the extent that individual landowners can manage those resources. However, to quote a state senator in south Texas: "The legislature does not always have the luxury of dealing with reality, we often can only deal with people's perception of reality." That is certainly the case in this issue.

The perception is that the landowner can manage the wildlife in whatever manner they see fit to improve their return on that resource. There is a great deal of money at stake in this issue and I don't look for that perception to change in the near future and perhaps that is okay. It seems very difficult for mankind to accurately predict the future because there is so many things we cannot control and change is inevitable. Change in public policy is often a result of the gradual shifting of public opinion or public perception.

The current focus on these issues in the Texas Legislature seems to be to encourage the removal of brush, particularly cedar, for the purpose of recharging water to aquifers and reservoirs. However, a "one size fits all" approach may not be appropriate for all parts of the state. When the issue of removing the brush in south Texas to recharge those aquifers arises, the issues become more complex because of questions about the removal of feed and cover for the wildlife that are so abundant and profitable in that area, and the lack of research on the rate of recharge to those aquifers. We in the legislature depend upon the expertise of people such as those at this conference to tailor general recommendations for various watersheds.

The current water plans being considered for Texas explore the need for additional water supplies for human, agricultural (irrigation) and industrial needs. The water needs of wildlife are pretty much left in the hands of the private landowners as it has been throughout Texas' history. This is appropriate because approximately 97% of land in Texas is privately held. The need to preserve private property rights makes some landowners hesitant to accept much help from the government for wildlife needs. The current emphasis on rainfall enhancement programs certainly is a valuable aid to wildlife management for the private landowners. The debate over the desirability of brush for wildlife management continues and if you read enough literature you will see several conflicting viewpoints. As I mentioned earlier the consensus that removal of cedar is beneficial for recharge is widespread. However some balance must be struck to accommodate habitat needs for various species of wildlife.

As I read over some literature preparing for this conference, I was struck by the shifting of attitudes on all these topics over the years by publications and authors that have been in the business a long time. At the end of the day, the more things change the more they stay the same. The debates over the role of private landowners and government with wildlife management, water conservation and supply, and brush control, will continue as long as we are blessed with the free and open society we have today.

SIMULATING THE EFFECT OF BRUSH CONTROL ON RANGELANDS

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Abstract: The Soil and Water Assessment Tool (SWAT) model was used to simulate the effects of brush removal on water yield in 8 watersheds in Texas for 1960 through 1998. Landsat7 satellite imagery (1999) was used to classify land use, and the 1:24,000 scale DEM was used to delineate the watershed boundaries and subbasins. After calibration of SWAT to existing stream gauges, brush removal was simulated by converting all heavy and moderate categories of brush (except oak) to open range (native grass). Removal of light brush was not simulated. The results of the Wichita River watershed simulations are presented. Water yield varied by subbasin, but all subbasins showed an increase in water yield as a result of removing brush. Economic analyses and wildlife habitat considerations will impact actual amounts of brush removed.

BACKGROUND

Recent droughts in Texas have brought attention to the critical need for increasing water supplies in some water-short locations, especially the western portion of the state. Brush infestation may contribute to a decrease in stream flow possibly due to increased evapotranspiration (ET) (Thurow 1998). Research has shown that ET is higher for brush dominated rangeland than for rangeland where brush was removed (Dugas et al. 1998). A study of the North Concho River watershed (Upper Colorado River Authority, 1998) indicates that removing brush may result in a significant increase in water yield.

During the 1998-99 legislative session, the Texas Legislature appropriated funds to study the effects of brush removal on water yield in 8 watersheds in Texas. These watersheds are: Canadian River above Lake Meredith, Wichita River above Lake Kemp, Upper Colorado River above Lake Ivie, Concho River, Pedernales River, watersheds above the Edwards Aquifer, Frio River above Choke Canyon Reservoir, and Nueces River above Choke Canyon. The feasibility studies were conducted by a team consisting of the Texas Agricultural Experiment Station (TAES), Texas Agricultural Extension Service (TAEX), U.S. Department of Agriculture Natural Resources Conservation Service (NRCS), and the Texas State Soil and Water Conservation Board (TSSWCB). The goals of the study are:

1. Predict the effects of brush removal on water yield in each watershed.
2. Prioritize areas within each watershed relative to their potential for increasing water yield.
3. Determine the benefit/cost of applying brush management practices in each watershed.
4. Determine effects of brush management on livestock production and wildlife habitat.

This paper focuses on the first 2 goals, and results are presented for the Wichita River watershed.

METHODS

SWAT Model Description

The Soil and Water Assessment Tool (SWAT) model (Arnold et al. 1998) is the continuation of a long-term effort of nonpoint source pollution modeling by the USDA-Agricultural Research Service (ARS), including development of CREAMS (Knisel 1980), SWRRB (Williams et al. 1985; Arnold et al. 1990), and ROTO (Arnold et al. 1995).

SWAT was developed to predict the impact of management (e.g. climate and vegetative changes, reservoir management, groundwater withdrawals, and water transfer) on water, sediment, and agricultural chemical yields in large un-gauged basins. To satisfy the objective, the model (a) is physically based; (b) uses readily available inputs; (c) is computationally efficient to operate on large basins in a reasonable time; and (d) is continuous in time and capable of simulating long periods for computing the effects of management changes. SWAT allows a basin to be divided into hundreds or thousands of grid cells or sub-watersheds. It can be used to look at long-term impacts of management (e.g., reservoir sedimentation over 50-100 years) and the effects of timing of agricultural practices within a year (e.g., crop rotations, planting and harvest dates, irrigation, fertilizer, pesticide application rates and timing).

Geographic Information System (GIS)

In recent years, there has been considerable effort devoted to using GIS to extract inputs (e.g., soils, land use, and topography) for comprehensive simulation models and display model outputs spatially. Much of the initial research was devoted to linking single-event, grid models with raster-based GIS (Srinivasan and Engel 1991; Rewerts and Engel, 1991). An interface was developed for SWAT (Srinivasan and Arnold 1993) using the Graphical Resources Analysis Support System (GRASS) (U.S. Army 1988). The input interface extracts model input data from map layers and associated relational databases for each subbasin. Soils, land use, weather, management, and topographic data are collected and written to appropriate model input files. The output interface allows the user to display output maps and graph output data by selecting a subbasin from a GIS map. The study was performed using GRASS GIS integrated with the SWAT model, both of which operate in the UNIX operating system.

Model Inputs

Development of databases and GIS layers was an integral part of the feasibility study. The data was assembled at the highest level of detail possible in order to accurately define the physical characteristics of each watershed.

Climate.--

Daily precipitation totals were obtained for National Weather Service (NWS) stations within and adjacent to the watersheds. Data from nearby stations were substituted for missing precipitation data in each station record. Daily maximum and minimum temperatures were obtained for the same NWS stations. A weather generator was used to generate missing temperature data and all solar radiation for each climate station.

Topography.--

The United States Geological Survey (USGS) database known as Digital Elevation Model (DEM) describes the surface of a watershed as a topographical database. The DEM available for the project area is the 1:24,000 scale map (U.S. Geological Survey 1999). The resolution of the DEM is 30 meters, allowing detailed delineation of subbasins within each watershed. Some of the 8 watersheds designated for study were further sub-divided for ease of simulation, resulting in 16 separate modeling jobs or watersheds. The boundaries of the 16 watersheds are shown in Figure 1.

The number of subbasins delineated in each watershed varied because of size and methods used for delineation, and ranged from 5 - 312 (Table 1). The subbasin numbers and location are shown for the Wichita River watershed in Figure 2.

Soils.--

The soils database describes the surface and upper subsurface of a watershed and is used to determine a water budget for the soil profile, daily runoff, and erosion. The SWAT model uses information about each soil horizon (e.g., horizon thickness, depth, texture, water holding capacity, dispersion, albedo, etc.).

The NRCS (USDA-Natural Resources Conservation Service) soils database used for this project was developed from 3 major sources:

1. The majority of the information is a grid cell digital map created from 1:24,000 scale soil sheets with a cell resolution of 250 m. This database is known as the Computer Based Mapping System (CBMS) or Map Information Assembly Display System (MIADS) (Nichols 1975) soils data. The CBMS database differs from some grid GIS databases in that the attribute of each cell is determined by the soil that occurs under the center point of the cell instead of the soil that makes up the largest percentage of the cell. This method of cell attribute labeling has the advantage of a more accurate measurement of the various soils in an area. The disadvantage is for any given cell the attribute of that cell may not reflect the soil that actually makes up the largest percentage of that cell.

2. Another NRCS soils database, the Soil Survey Geographic (SSURGO) is the most detailed soil database available. This 1:24,000-scale soils database is available as printed county soil surveys for over 90% of Texas counties. It was only currently available as a vector or high resolution cell database at the inception of this project for a few counties in the project area. In the SSURGO database, each soil delineation (mapping unit) is a soil which is described as a single soil series.

3. The NRCS soils data base currently available for all of the counties of Texas is the State Soil Geographic (STATSGO) 1:250,000-scale soils data base. The STATSGO database covers the entire United States and all STATSGO soils are defined in the same way. In the STATSGO database, each soil delineation of a STATSGO soil is a mapping unit made up of > 1 soil series. Some STATSGO soils are made up of as many as 20 SSURGO soil series. The dominant SSURGO soil series within an individual STATSGO polygon was selected to represent that area.

The GIS layer representing the soils within the project area is a compilation of CBMS, SSURGO, and STATSGO information. The most detailed information was selected for each individual county and was patched together to create the final soils layer. In the project area, approximately 2/3 of the soil data were derived from CBMS and the remainder was largely STATSGO data (only a very small percentage represented by SSURGO).

SWAT uses the soils series name as the data link between the soils GIS layer and the soils properties tabular database. County soil surveys were used to verify data for selected dominant soils within each watershed.

Land Use/Land Cover.--

Land use and cover affect surface erosion and water runoff in a watershed. The NRCS 1:24,000 scale CBMS land use/land cover database is the most detailed data presently available. However, for this project much more detail was needed in the rangeland category of land uses. The CBMS data does not identify varying densities of brush or species of brush - only the categories of “open” range versus “brushy” range.

Development of more detailed land use/land cover information for the watersheds in the project area was accomplished by classifying Landsat-7 Enhanced Thematic Mapper Plus (ETM+) data. The satellite carries an ETM+ instrument, which is an 8-band multi-spectral scanning radiometer capable of providing high-resolution image information of the earth's surface. It detects spectrally-filtered radiation at visible, near-infrared, short-wave, and thermal infrared frequency bands (Table 2).

Portions of 18 Landsat-7 scenes were classified using ground truth points collected by NRCS field personnel. The Landsat-7 satellite images used had a spectral resolution of 6 channels (the thermal band (6) and panchromatic band (Pan) were not used in the classification). The imagery was taken from 5 July 1999 - 14 December 1999 in order to obtain relatively cloud-free scenes during the growing season for the project areas. These images were radiometrically and precision terrain corrected (TNRIS Gordon Wells, personal communication).

Over 1,100 ground control points (GCP) were located and described by NRCS field personnel in November and December 1999. Rockwell precision lightweight Global positioning System (GPS) receivers were utilized to locate the latitude and longitude of the control points. A database was developed from the GCP's with information including the land cover, estimated canopy coverage, areal extent, and other pertinent information about each point. This database was converted into an ArcInfo™ point coverage.

ERDAS Imagine™ was used for imagery classification. The Landsat-7 images were imported into Imagine (GIS software). Adjoining scenes in each watershed were histogram matched or regression corrected to the scene containing the highest number of GCP's (this was done in order to adjust for the differences in scenes because of dates, time of day, atmospheric conditions, etc.). These adjoining scenes were then mosaiced and trimmed into one image that covered an individual watershed.

The ArcInfo coverage of ground points was then employed to instruct the software to recognize differing land uses based on their spectral properties. Individual ground control points were "grown" into areas approximating the areal extent as reported by the data collector. Spectral signatures were collected by overlaying these areas over the imagery and collecting pixel values from the 6 imagery layers. A supervised maximum likelihood classification of the image was then performed with the spectral signatures for various land use classes. The ground data were used to perform an accuracy assessment of the resulting image. A sampling of the initial classification was further verified by NRCS field personnel.

The use of remote-sensed data and the process of classifying it with ground truthing resulted in a current land use/land cover GIS map that includes more detailed divisions of land use/land cover. Although the vegetation classes varied slightly among all watersheds, the land use and cover was generally classified as follows:

Heavy Cedar - Mostly pure stands of cedar (juniper) with average canopy cover > 30%.

Heavy Mesquite - Mostly pure stands of mesquite with average canopy cover > 30%.

Heavy Oak - Mostly pure stands of various species of oak with average canopy cover > 30%.

Heavy Mixed - Mixture of brush species with average canopy cover > 30%.

Moderate Cedar - Mostly pure stands of cedar (juniper) with average canopy cover 10 - 30%.

Moderate Mesquite - Mostly pure stands of mesquite with average canopy cover 10 - 30%.

Moderate Oak - Mostly pure stands of various species of oak with average canopy cover 10 - 30%.

Moderate Mixed - Mixture of brush species with average canopy cover 10 - 30%.

Light Brush - Either pure stands or mixed with average canopy cover < 10%.

Open Range - Various species of native grasses or improved pasture.

Cropland - All cultivated cropland.

Water - Ponds, reservoirs and large perennial streams.

Barren - Bare Ground

Urban - Developed residential or industrial land.

Other - Other small insignificant categories

The accuracy of the classified image was 70 - 80%. Table 3 summarizes land use/land cover categories for each watershed in the project area.

A small area of the USGS land use/land cover GIS layer was patched to the detailed land use/land cover map developed using remotely-sensed data for the western-most (New Mexico) portion of the Upper Colorado River and Canadian River watersheds, which were not included in the satellite scenes for this study.

Thurow (1998) suggested that brush control is most likely to increase water yields in areas that receive at least 18 inches of average annual rainfall. Therefore, brush removal was not planned in areas generally west of the 18 inch rainfall isohyet (Figure 3). One exception is the Canadian River watershed, the majority of which is west of the 18 inch isohyet. Brush removal in the Canadian was simulated to the New Mexico state line.

Some areas in the Upper Colorado and Middle Concho watersheds do not contribute to stream flow at downstream gauging stations (USGS 1999). These areas have little or no defined stream channels, and considerable natural surface storage (e.g., playa lakes) which capture surface runoff. We used available GIS and stream gauge data to estimate the location of these areas, most of which are west of the 18 inch isohyet. Brush control was not planned in non-contributing areas (Figure 3).

In order to simulate the "brush removal" condition, the input files for all areas of heavy and moderate brush (except oak) were converted to native grass rangeland (good condition). Appropriate adjustments were made in growth parameters to simulate the replacement of brush with grass. All other calibration parameters and inputs were held constant.

It was assumed that all categories of oak would not be removed. In the Pedernales and Edwards watersheds, oak and juniper were mixed together in one classification. We assumed that the category was 50% oak and 50% juniper and modeled only the removal of the juniper.

The fraction of heavy and moderate brush (planned for removal) is shown by subbasin for the Wichita River watershed in Figure 4.

Model Calibration/Validation

Required inputs for each subbasin (e.g. soils, land use/land cover, topography, and climate) were extracted and formatted using the SWAT/GRASS input interface. The input interface divided each subbasin into a maximum of 30 virtual subbasins or hydrologic response units (HRU). A single land use and soil were selected for each HRU. The number of HRU's within a subbasin was determined by: (1) creating an HRU for each land use that equaled or exceeded 5% of the area of a subbasin; and (2) creating an HRU for each soil type that equaled or exceeded 10% of any of the land uses selected in (1). The total number of HRU's for each watershed was dependent on the number of subbasins and the variability of the land use and soils within the watershed. The soil properties for each of the selected soils were automatically extracted from the model-supported soils database.

Appropriate plant growth parameters for brush and native grass were input for each model simulation. It was assumed existing brush sites were in fair hydrologic condition (50 to 75% ground cover), and existing open range and pasture sites with no brush were in good hydrologic condition (> 75% ground cover). Precipitation interception, maximum leaf area index (LAI), leaf area development curve, base temperature, canopy height, albedo, potential heat units, and rooting depth were adjusted to accurately simulate the type of vegetation present in each watershed.

The calibration period was based on the available period of record for stream gauges within each watershed. Measured stream flow was obtained from USGS. A base flow filter (Arnold et al. 1999) was used to determine the fraction of base flow and surface runoff at selected gauging stations. Adjustments were made to runoff curve number, soil evaporation compensation factor, shallow aquifer storage, shallow aquifer re-evaporation, and channel transmission loss until the simulated total flow and fraction of base flow were approximately equal to the measured total flow and base flow, respectively.

RESULTS

Wichita River Watershed Calibration

SWAT was calibrated at 2 stream gauge locations:

(1) 07311700 (North Wichita River near Truscott)

(2) 07311800 (South Wichita River near Benjamin)

Results of the flow calibration for the Wichita River watershed are shown on Figures 5 and 6. Measured and predicted average monthly flows compare reasonably well with R^2 values of 0.56 for gauge

07311700 and 0.54 for gauge 07311800. At gauge 07311700 the measured monthly mean is 66.74 cubic feet per second (cfs) and predicted monthly mean is 64.63 cfs. At gauge 07311800 the measured mean is 41.32 cfs and predicted mean is 42.02 cfs.

At gauge 07311700 predicted average flow was less than measured (Figure 5). In July and August 1966, SWAT underestimated flow by a large amount, causing the cumulative lines of measured and predicted flow to diverge significantly. It is possible that large amounts of rainfall occurred in those 2 months that was not measured accurately at any of the climate stations. The measured and predicted lines for the remainder of the simulated period are parallel, with the predicted line approaching and nearly catching up to the measured line near the end of the simulation.

At gauge 07311800 average predicted flow for the simulation period is slightly higher than measured. The lines of cumulative measured and predicted flow diverge somewhat near the beginning of the simulation, but converge toward the end. Again, this may have been due to climate variability that is not reflected in measured data.

Wichita River Watershed Brush Removal Simulation

The increase in water yield (gallons per acre of brush removed) versus the fraction of moderate and heavy brush removed for each subbasin is shown in Figure 7. The amount of annual increase varies among the subbasins and ranges from 25,733 gallons per acre of brush removed per year in subbasin number 1 to 112,803 gallons per acre in subbasin number 26 (Figure 8). Variations in the amount of increased water yield are expected and are influenced by brush type, brush density, soil type, and average annual rainfall, with subbasins receiving higher average annual rainfall generally producing higher water yield increases. The larger water yields are most likely due to greater rainfall volumes as well as increased density and canopy of brush. This is evident in Figure 8 which shows the water yield increase by subbasin. The subbasins are numbered beginning with 1 in the western portion (lower rainfall) of the watershed and ending with 48 in the eastern portion (higher rainfall).

For the entire simulated watershed, the average annual water yield increases by 92 % or approximately 146,618 acre-feet. The average annual flow to Lake Kemp increases by 145,426 acre-feet. The increase in volume of flow to Lake Kemp is slightly less because of stream channel transmission losses that occur after water leaves each subbasin.

SUMMARY

The Soil and Water Assessment Tool (SWAT) model was used to simulate the effects of brush removal on water yield in 8 watersheds in Texas for 1960 through 1998. Landsat7 satellite imagery from 1999 was used to classify current land use and cover for all watersheds. Brush cover was separated by species (cedar, mesquite, oak, and mixed) and density (heavy, moderate, light). After calibration of SWAT to existing stream gauge data, brush removal was simulated by converting all heavy and moderate categories of brush (except oak) to open range (native grass). Removal of light brush was not simulated.

In the Wichita River basin, simulated changes in water yield varied by subbasin, with all subbasins showing increased water yield as a result of removing brush. Water yield increases ranged from 25,733 gallons per acre of brush removed per year in subbasin number 1 to 112,803 gallons per acre per year in subbasin number 26. The average annual increase in flow to Lake Kemp was 145,426 acre-feet.

For this study, we assumed removal of 100 % of heavy and moderate categories of brush (except oak). Removal of all brush in a specific category is an efficient modeling scenario. However, other factors must be considered in planning brush treatment. Economics and wildlife habitat considerations will impact the specific amounts and locations of actual brush removal.

The hydrologic response of the watershed is directly dependent on receiving precipitation events that provide the opportunity for surface runoff and ground water flow.

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Table 1: Subbasin Delineation

WATERSHED	NUMBER OF SUBBASINS
Canadian River	312
Wichita River	48
Upper Colorado River	71
Main Concho River	37
Middle Concho River	28
Spring & Dove Creeks	23
South Concho River	18
Pecan Creek	13
Pedernales River	35
Nueces River	113
Frio River	70
Upper Frio River	23
Sabinal River	11
Seco Creek	13
Hondo Creek	5
Medina River	25

Table 2. Characteristics of Landsat-7 Imagery

Band Number	**Spectral Range**(microns)	**Ground Resolution**(meters)
1	.45 to .515	30
2	.525 to .605	30
3	.63 to .690	30
4	.75 to .90	30
5	1.55 to 1.75	30
6	10.40 to 12.5	60
7	2.09 to 2.35	30
Pan	.52 to .90	15

Swath width:	185 kilometers
Repeat coverage interval:	16 days (233 orbits)
Altitude:	705 kilometers

Table 3. Land Use Categories and Percent Cover

	Percent Cover					
Watershed	Heavy & Mod. Brush (no oak)	Oak	Light Brush (no oak)	Open Range & Pastureland	Cropland	Other (Water Urban,Barren,etc)
Canadian *	69	0	4	5	18	4
Wichita	63	4	15	9	7	2
Upper Colorado*	41	3	21	14	20	1
Main Concho	40	5	19	10	26	< 1
Middle Concho *	46	2	36	2	11	3
Spring & Dove	61	3	25	8	3	< 1
South Concho	55	3	26	11	4	1
Pecan	70	4	20	4	2	< 1
Pedernales	25	50	7	16	1	1
Nueces	62	18	19	< 1	1	< 1
Frio	58	17	18	1	5	1
Upper Frio	60	22	17	1	< 1	< 1
Sabinal	60	22	16	1	1	< 1
Seco	65	24	10	1	< 1	< 1
Hondo	59	24	15	1	1	< 1
Medina	56	24	18	1	1	< 1

*Percentage of watershed where brush removal was planned

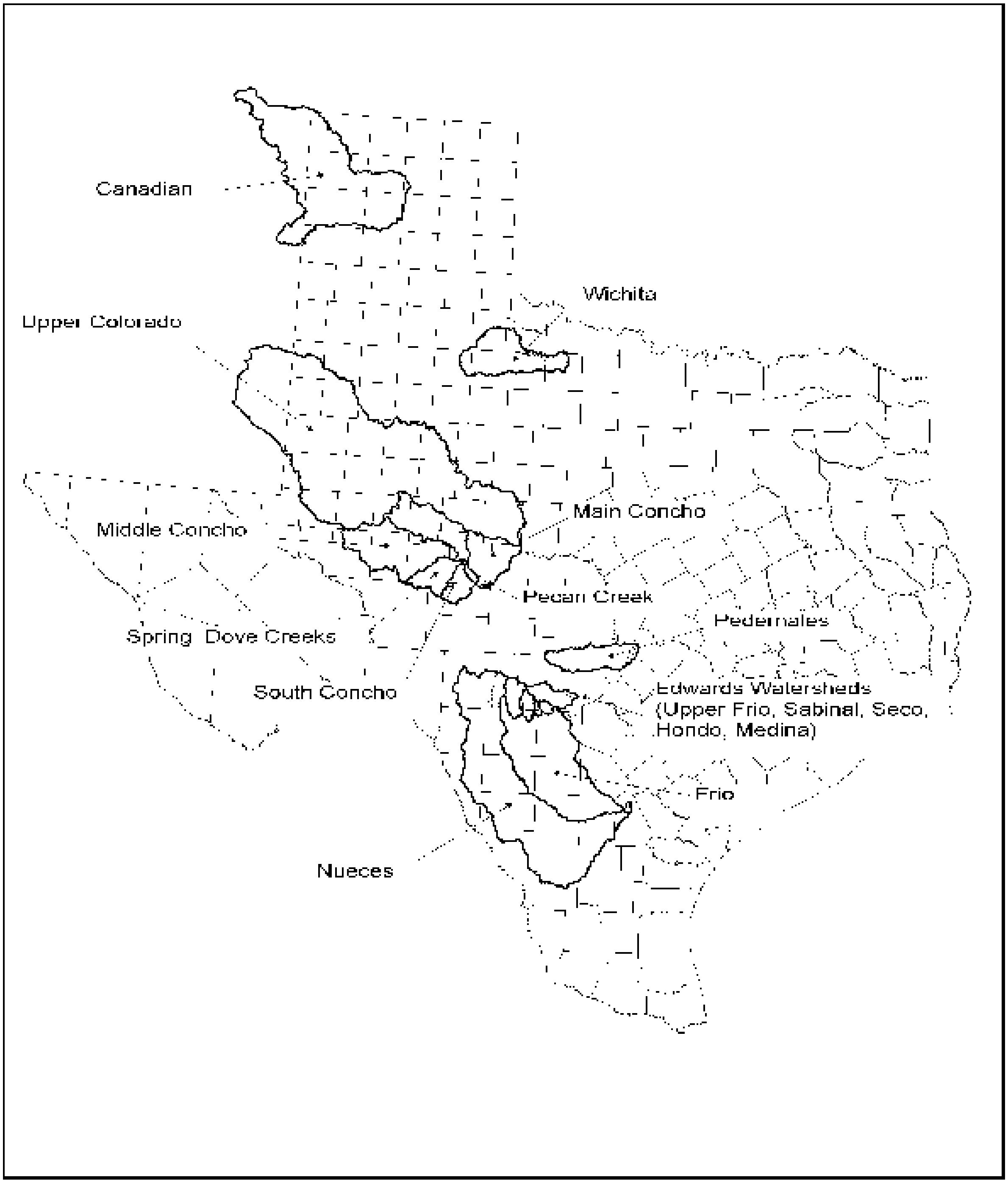

Figure 1. Watersheds included in the study area.

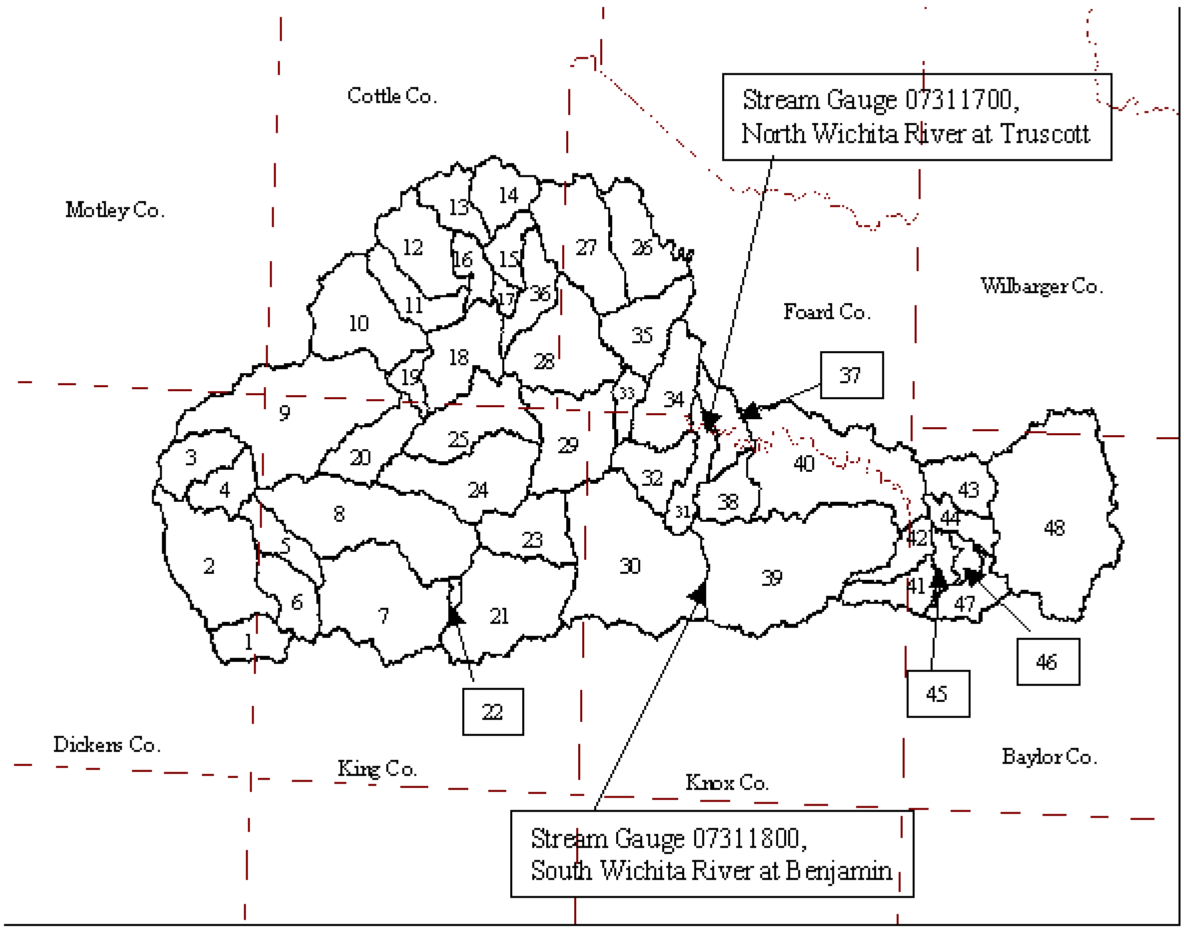

Figure 2. Wichita River watershed subbasin map.

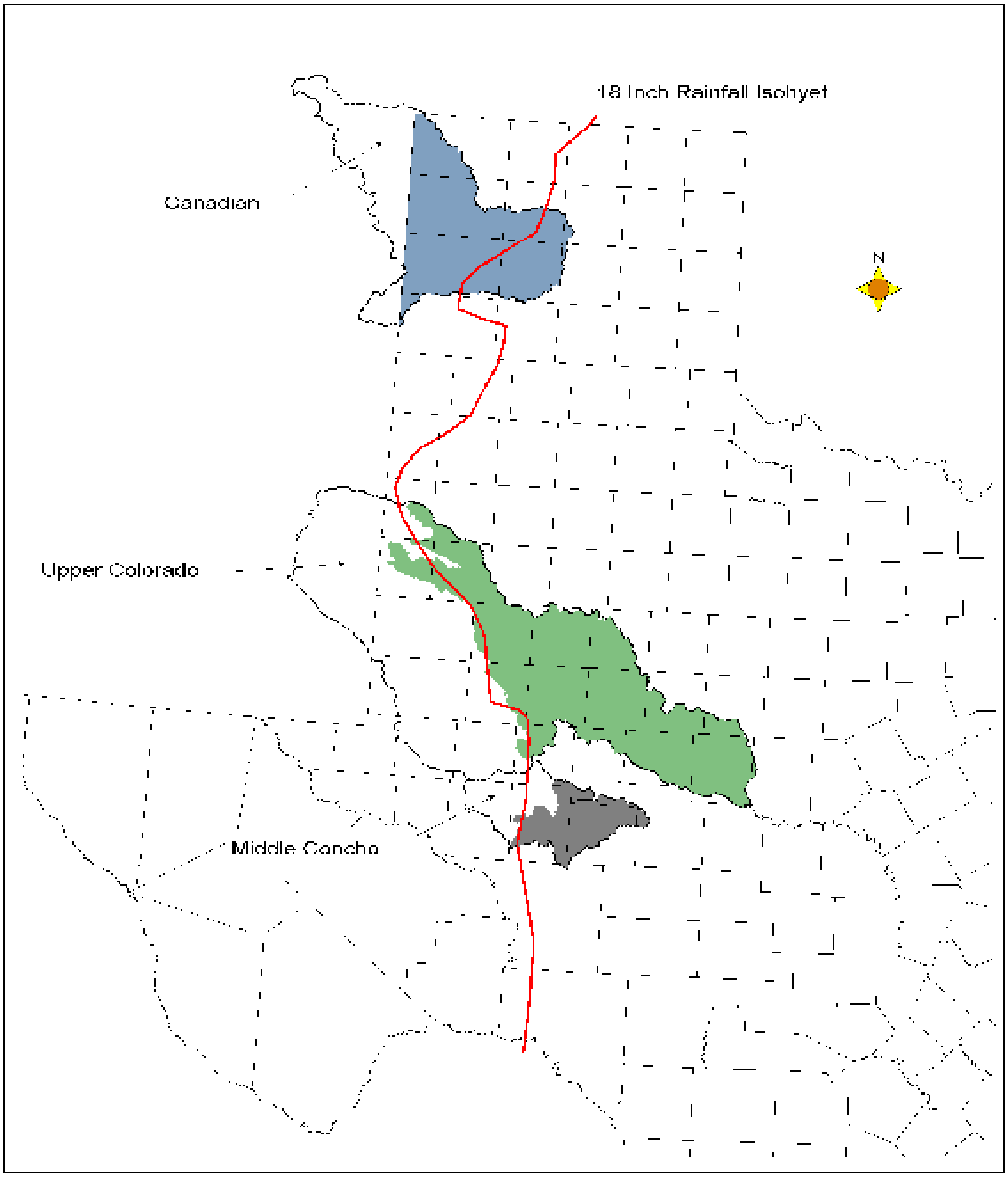

Figure 3. Areas where brush removal was not evaluated (non-shaded portions of each watershed).

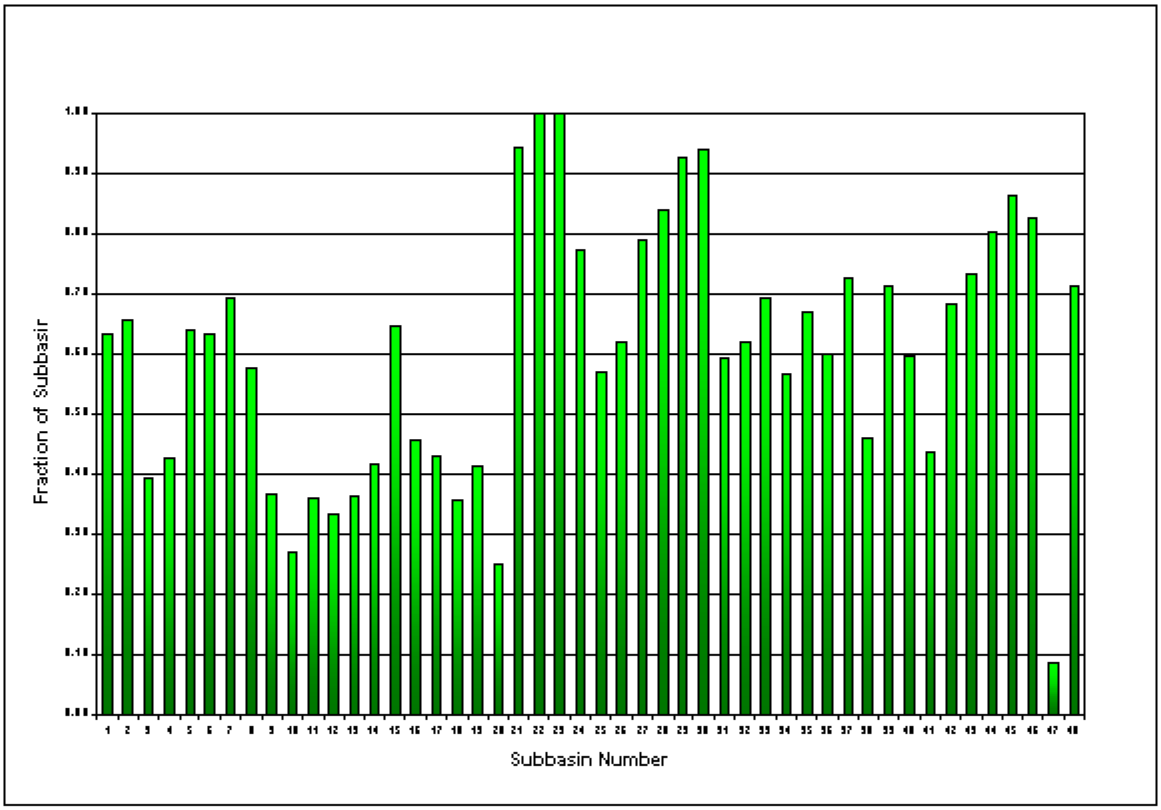

Figure 4. Fraction of each subbasin containing heavy and moderate brush planned for removal in the Wichita River Watershed.

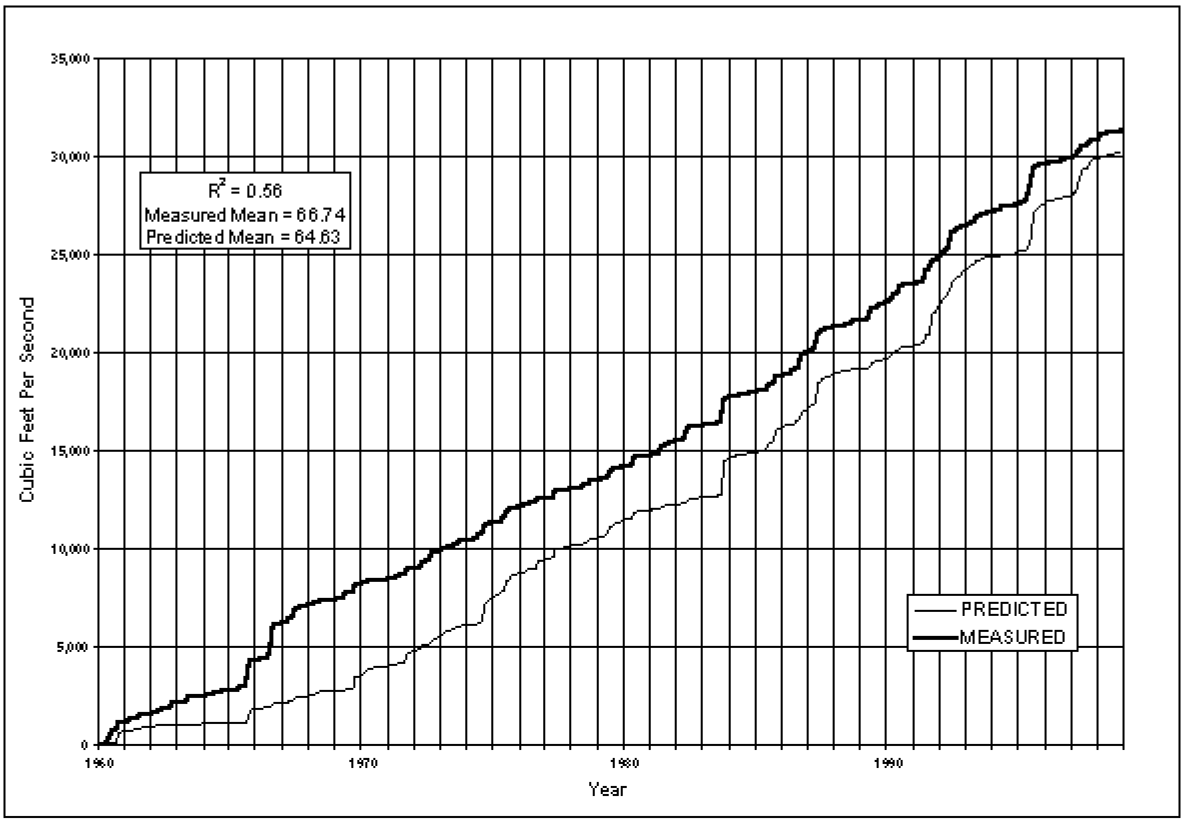

Figure 5. Cumulative monthly average measured and predicted stream flow at gauge 07311700 (Truscott), Wichita River Watershed, 1960 through 1998. Monthly statistics are shown in box.

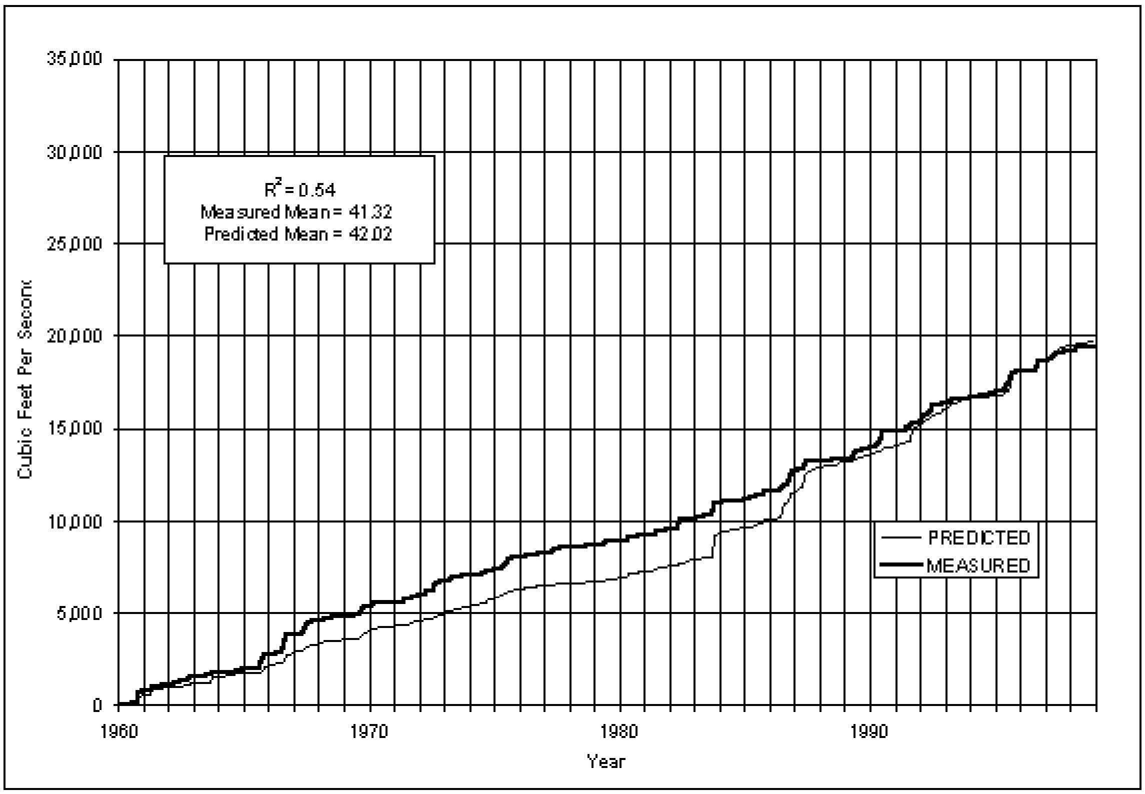

Figure 6. Cumulative monthly average measured and predicted stream flow at gauge 07311800 (Benjamin), Wichita River Watershed, 1960 through 1998.

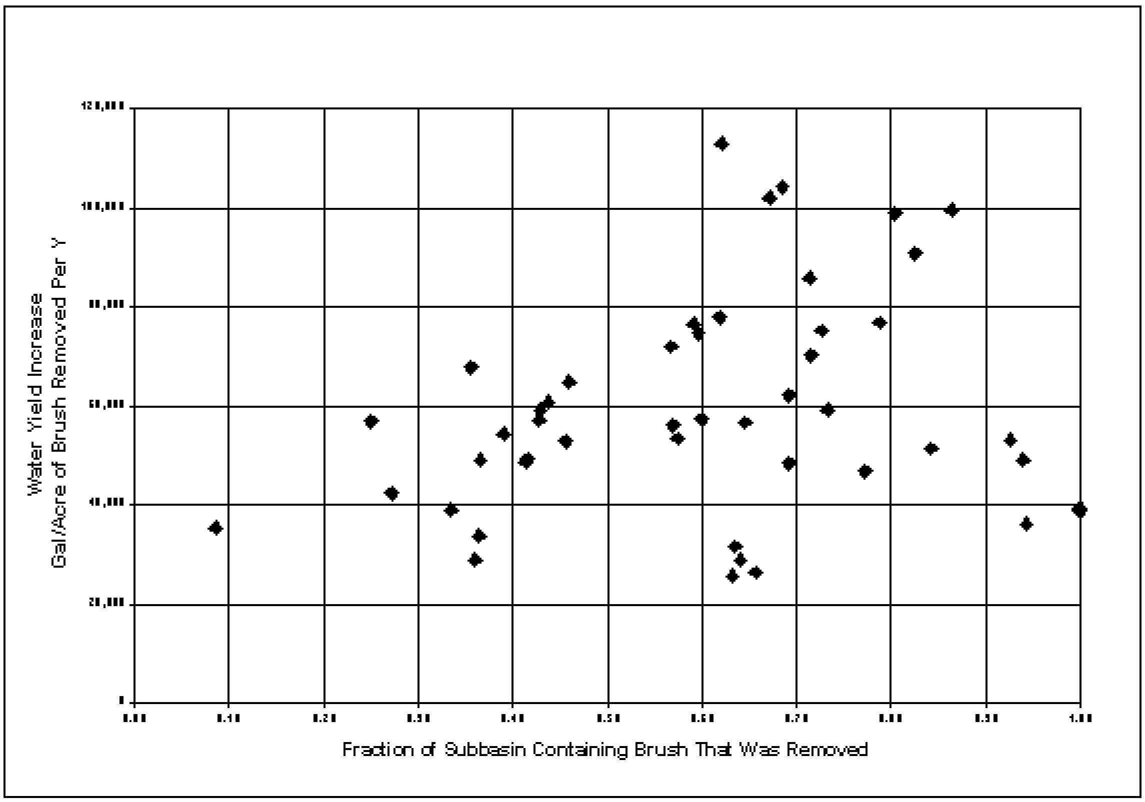

Figure 7. Increase in water yield per unit area of brush removed versus fraction of subbasin containing brush that was removed, Wichita River watershed, 1960 through 1998. Each point represents one subbasin (Figure 2).

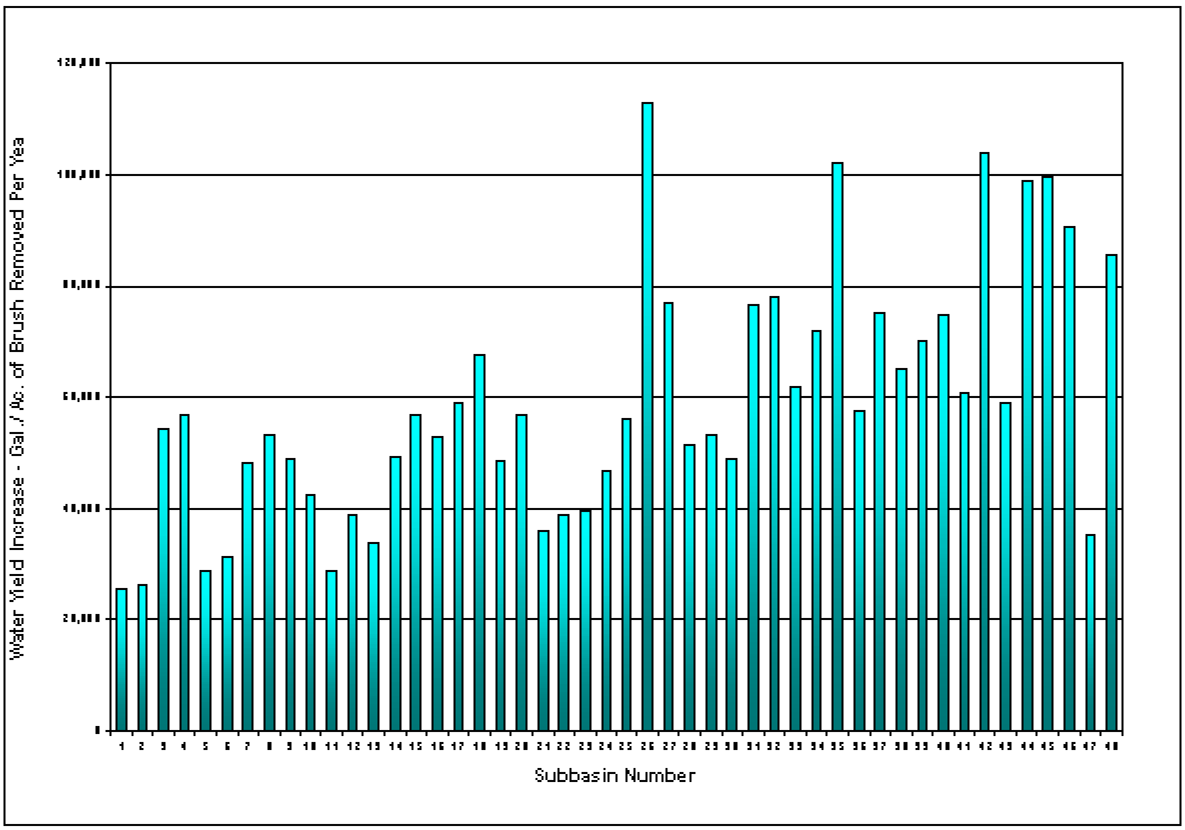

Figure 8. Increase in water yield by subbasin, Wichita River watershed, 1960 through 1998.

THE NORTH CONCHO RIVER BRUSH CONTROL PROJECT: SIMULATION OUTPUT, ECONOMIC ANALYSIS AND IMPLEMENTATION

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In 1985, the Legislature authorized the Texas State Soil and Water Conservation Board (TSSWCB) through local Soil and Water Conservation Districts to conduct a program that includes cost share assistance for the "selective control, removal, or reduction of noxious brush such as mesquite, salt cedar, or other brush species that consume water to a degree that is detrimental to water conservation." The first project to be funded under this bill was the North Concho River Watershed Brush Control Project, which was funded during the 76th Legislative Regular Session that began in January 1999. This paper will describe the steps taken from initiation through initial implementation.

In August 1997 the Upper Colorado River Authority (UCRA) held a meeting that included the Texas Agricultural Experiment Station (TAES), Texas Agricultural Extension Service (TAEX), Texas Water Development Board (TWDB), TSSWCB, Texas Parks and Wildlife Department (TPWD) and landowners in the North Concho River Watershed to develop a plan for conducting a feasibility study to estimate the cost and potential benefits of controlling brush to enhance water yield in the watershed. A landowner oversight committee was established to ensure that all landowner concerns were addressed. Partial funding for the feasibility study was obtained from TWDB and the project began.

The UCRA was assigned the task of documenting the historical hydrologic condition of the watershed and profiling the geology of the watershed. It was decided that the effect of controlling brush on projected water yield could best be estimated using a hydrologic simulation model and that TAES and the NRCS had the necessary technical expertise to accomplish this task. TAES also performed the economic analysis once simulated water yields were known. TAEX was given the task of organizing many public meetings to ensure that all involved were informed and had an opportunity for input into the process. The final public meeting to present the results of the feasibility study was presented in October 1998, a fast 14 months after the first meeting to discuss the project was conducted. Because of concerns over potential negative impacts on wildlife as a result of the proposed large-scale brush project, another public meeting was held in Austin, TX in January, 1999. That meeting pointed out the need for this symposium to define the state of our knowledge on the interaction between brush and wildlife.

The remainder of this paper will describe the assumptions and output of the bio-physical model used to predict the effect of brush control on water yield; the economic analysis used to determine the cost and benefits that would be expected if the brush control was conducted; and how the project was actually implemented.

STUDY SITE

The North Concho River watershed is a 950,000 ac. area that heads out in southeastern Howard County at the northern limit of the Edwards Plateau where this resource region joins the High Plains. Tributaries that come together to form the North Concho River head out in cretaceous limestones of the Edwards Group. The North Concho River is in the Upper Colorado River planning region. Its course includes portions of Howard, Glasscock, Sterling, Coke and Tom Green Counties, and, for this study, terminates at O. C. Fisher Reservoir. The broad valley of this watershed has predominantly a clay loam range site often covered with moderate to heavy amounts of mesquite. The uplands that form the boundary of the watershed are shallow hill range sites, normally dominated by redberry juniper (*Juniperus pinchotii* Sudw.). Four different situations were simulated for the North Concho

River watershed: 1) present condition; 2) removal of all brush including heavy mesquite, moderate mesquite and heavy juniper and replacing it with grass; 3) removal of heavy mesquite only and replacing it with grass; and 4) removal of heavy juniper only and replacing it with grass.

HYDROLOGIC MODELING

Model Description

The Soil and Water Assessment Tool (SWAT) was the bio-physical hydrologic simulation model selected to estimate the effect of brush control on water yield. SWAT is a distributed-parameter, continuous-time surface hydrology simulation model developed to assist managers in assessing water supplies and non-point source pollution (Arnold et al. 1993, 1994, 1998). It simulates the surface and near-surface hydrology of watersheds that vary from a few hectares to several thousand square kilometers. When the feasibility study was conducted SWAT was the only surface hydrology model that was linked to a Geographic Information System (GIS). This GIS linkage provides an efficient mechanism to run the model and account for the spatial diversity of large rangeland watersheds. Watersheds are divided into sub basins, model inputs (e.g., soils, slope, land cover, etc.) are provided by the GIS, and water is routed within and between sub basins.

SWAT has been validated against measured stream flow for the Lower Colorado River watershed (Arnold and Srinivasan 1998), 3 Illinois watersheds (Arnold and Allen 1996), the Trinity River (Srinivasan et al. 1998), and the upper portions of the Seco Creek watershed (Srinivasan and Arnold 1994). In most cases, simulated stream flow was within 20 % of measured.

The North Concho River watershed was divided into over 200 subbasins. Required inputs for each subbasin (e.g. soils, land use/land cover, topography, and climate) were extracted and formatted using the SWAT/GRASS input interface. The SWAT model was calibrated to measure flow at 2 USGS stream gauging stations: Sterling City (Gauge 08133500) and Carlsbad (Gauge 08134000). Both weather data and stream gauge data were available for the period 1949 - 1996. Two periods of time, 1949 - 1961 and 1962 - 1996, were chosen for calibration of the SWAT model for stream flow because measured stream flow changed drastically in 1961 - 1962. Calibration for these 2 periods had to account for a total discharge that was almost 5- times greater in the earlier period, while precipitation was 25% lower compared to the post-1961 period. Calibration for the 1949 - 1961 period was done by re-classifying the areas with heavy brush and heavy juniper as moderate brush and all moderate and light brush areas as open rangeland. This resulted in a reduction in the amount of leaf area. SWAT was then calibrated for flow by adjusting the runoff curve number and available soil water capacity until the predicted flow matched the measured flow at the 2 USGS stream gauges. The reduced stream flow during the 1962 - 1996 period was thought to be caused primarily by an increase in channel transmission loss caused by a drop in the shallow aquifer associated with the river bed as well as an increase in amount of brush. The current land use/land cover map from the satellite imagery was used for this simulation. The following assumptions were made: *the open rangeland and brush were in fair condition, the shallow aquifer was severely depleted, channel transmission loss and required minimum shallow aquifer storage were high, and the re-evaporation from the shallow aquifer was high.* Flow calibration for this period was accomplished with the same adjustments in runoff curve number and soil available water capacity as the 1949 - 1962 simulation. Ten cubic feet per second of water was withdrawn from the river for irrigation when available. See Upper Colorado River Authority (1998) for complete calibration details for the North Concho River.

Simulated water yields

The simulated current conditions and predicted changes in the water yield and stream flow are presented in Table 1. Without brush control, the simulated water lost to evapotranspiration (ET) was 98% of the precipitation. These simulated percentages of precipitation lost to ET were similar to field measurements for mesquite (Carlson et al. 1990 and Weltz and Blackburn 1995). Removal of all brush reduced ET by 0.8 inches or about 4 % less precipitation was used for ET. Brush control was predicted to increase stream flow by 33,515 ac. ft. compared to the current condition. A significant amount of this increase is a result of reducing river and tributary transmission loss of water. The reduced transmission loss would be hypothesized to occur because following brush control the alluvial aquifer that provides base flow to the river would eventually be recharged. After this aquifer is recharged the efficiency with which run off that enters the river channel is transported down stream will be greatly increased. However, it is estimated that it could take up to 10 years following brush control for the alluvial aquifer to be recharged and the increased yield occur.

ECONOMIC ANALYSIS

The objective of the economic analysis was to estimate the minimum total cost for the state-funded portion of brush control, so that this amount could be used to calculate the cost per ac.-ft. for the increased stream flow that SWAT predicted would result from brush control. The assumptions used to for the analysis were that ranchers would pay for the cost of brush control up to the amount of value they received from the improvement and the state would pay the remaining cost in return for the benefit of additional water for off site uses. To perform this analysis several task had to be accomplished.

1. Determine a series of brush control practices and their associated cost for each brush type to reduce canopy cover in the treated area to 3 - 8% for the 10-year time frame of the feasibility study.

2. Estimate the potential increased carrying capacity and the anticipated present value of the additional production that would result from brush control.

The appropriate brush control practices and the effect on carrying capacity were determined by consulting with range management experts from TAES, TAEX, and NRCS. While it was recognized that the objective of reducing brush cover could be accomplished with a variety of brush control methods, the recommended practices were the ones that based on this expert opinion would accomplish the objective at the least cost. A series of 7 brush management practices were determined that represented different treatment scenarios for mesquite and juniper at heavy, moderate and light levels of infestation. Two methods were used for heavy juniper depending upon topography. The same expert opinion was used to estimate the effect of brush control on additional forage production and livestock carrying capacity. Because of differences in climate, soils and livestock carrying capacity, different increased production rates were used for the northwest and southeast halves of the watershed. Rancher focus group meetings for each half of the watershed were held to develop livestock enterprise budgets so the net present value of the increased livestock production as a result of brush control could be calculated. Based on these inputs, 14 different cost share rates in which the state paid for the cost of brush control that was above the benefit received by the rancher were calculated. The calculated state share of brush control cost ranged from 31% for 2-way chaining of juniper in the southeast portion of the watershed to 77% for tree dozing of juniper in the northwest and averaged 62% across all brush types.

The estimated total cost for treating all 438,000 acres of the brush in the water shed was $12 million. This is a cost of $52.65/ac.-ft. of added water as a result of brush control, which compared favorably to the $160/ac.-ft. the city of San Angelo pays to have water delivered from O.H. Ivie reservoir. These results undoubtedly made a significant impact on the decision of the 76th Texas State Legislature to appropriate $7 million for brush control in this watershed.

IMPLEMENTATION

The North Concho Brush Control project was funded through the TSSWCB, which had to interpret the feasibility study, authorizing legislation, and appropriations bill to develop guidelines for administering the funds. It was determined that the 14 cost share rates calculated in the feasibility study were operationally too complex to administer and a single cost share rate of 70 % was settled on. To encourage rangeland conservation an additional 5% cost share was added for producers who deferred grazing for 90 days during the growing season following brush control. The brush control best management practices that were recommended for meeting canopy reduction goals in the feasibility study proved to be too restrictive for the diverse situations (e.g., proximity to herbicide susceptible crops) that were encountered when the program was implemented. Allowed herbicide treatments for aerial spraying of mesquite are restricted to 1/4 lb. Remedy + 1/4 lb. Reclaim per ac. for control of mesquite and approved Brush Busters methods for individual plant treatment of mesquite and juniper. However, a variety of mechanical methods for the control of both mesquite and juniper are approved. This is in contrast to the feasibility study, which only considered chemical treatments or fire for mesquite control. The maximum cost for mechanical brush control that is allowed by the program is $70/ac., i.e., the state will pay a maximum of $49/ac. for mechanical control. However, most landowners are finding that the cost of contracted mechanical control is closer to $100/ac. and brush sculpting to enhance wildlife habitat can increase the cost of mechanical control to $125/ac. Thus, the actual cost share on much of the mechanically-controlled areas is in the 50 - 70% range.

The current status of the North Concho Brush Control Program is shown in Figure 1. Of the approximately 950,000 ac. in the watershed, landowners have made request for enrollment in the program on 61 % of the area (576,400 ac.). Plans have been completed on 375,200 ac. or 65 % of the area requested for enrollment, and of the planned area, 57 % will be treated to control brush. This indicates that in a voluntary program such as this one that landowners are about equally concerned with increasing their livestock carrying capacity as they are in protecting wildlife habitat. Approximately $7 million in state funds have been obligated for brush treatment at an average cost of $37/ac. for the initial treatment. This compares to a calculated cost of about $27/ac. in the feasibility study for an initial treatment and 1 or 2 follow-up treatments. The difference is caused by the greater allowance for mechanical brush control treatments and a higher allowable cost for individual plant treatments than was used in the feasibility study. The cost of follow-up treatments is unknown and are contingent upon appropriation of additional funds by the legislature.

The effect of the differences between this project as it was actually implemented and the feasibility study are not known. The results of the feasibility study were based on controlling all eligible ac. in the watershed and it is apparent that the actual amount of brush to be cleared will probably be less than half of the amount identified as infested. Greater use of mechanical treatments affects not only the cost of brush control but also the expected water yields because mechanical methods increase surface roughness and thus reduce runoff. The ultimate affect on increased water yield will also be influenced by the spatial distribution of the brush that is treated. However, it would be reasonable to expect that, based on the factors discussed above, water yield will be at least half the amount that was estimated in the feasibility study, and the cost will be at least twice the estimated cost. Nonetheless even if this project yields half the water at twice the price it may ultimately be considered a success because even these reduced projections will result in a doubling of river flow at a cost that is less than the cost of water from O.H. Ivie reservoir.

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Table 1. SWAT predicted effect of brush control on water yield and stream flow in the North Concho River watershed using 1992-1996 Climatic data.

	Rain fall (inches)	ET (inches)	Deep Perc. (ac. ft.)	Water Yield (ac. ft.)	Channel Loss (ac. ft.)	Other** Losses (ac. ft.)	Flow to O.C. Fisher (ac. ft.)	Increase in Flow (ac. ft.)	Area of Brush Removed (sq. mile)	Unit Flow Increase (ac. ft./sq. mi)
Present Condition	19.97	19.60	407	32,750	-24,805	-72	7,873	0	0	0
Remove All Brush	19.97	18.80	1,189	54,833	-10,291	-3,154	41,388	33,515	571	59

** Other losses includes difference between beginning and ending soil water/shallow aquifer storage, loss to snow sublimation, loss to surface evaporation in streams and rivers, etc.

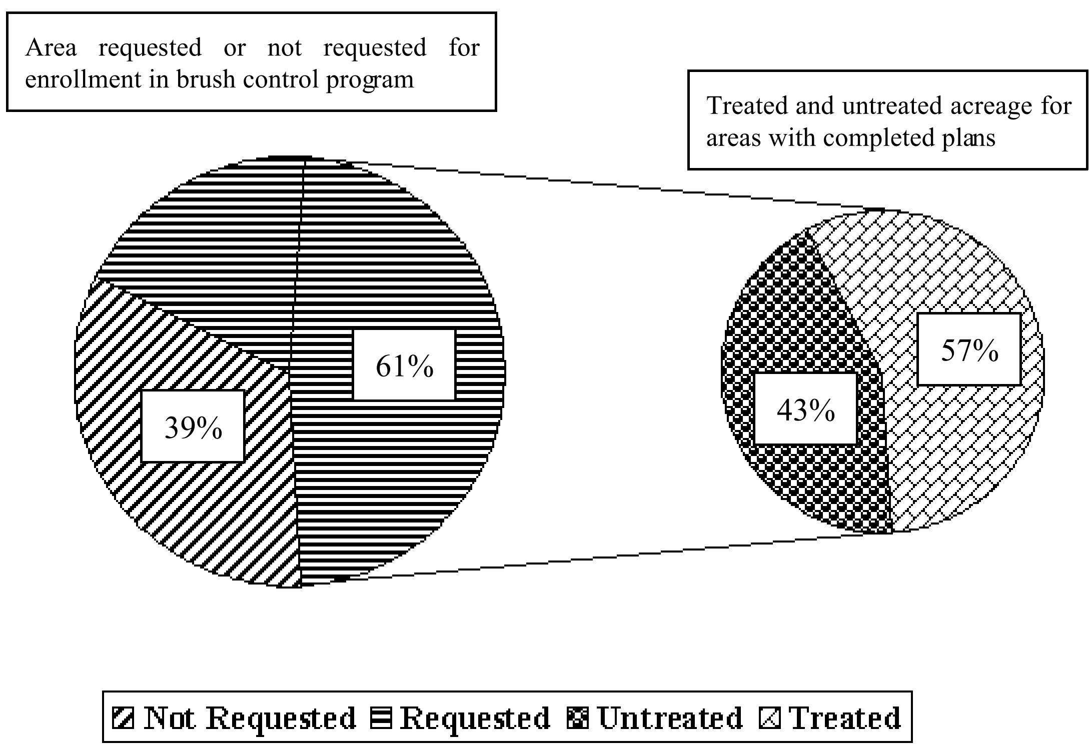

Figure 1. Distribution of land area in the North Concho River watershed among requested and not requested for enrollment in the brush control program and between areas to have brush treated or not treated.

BRUSH CONTROL FOR WATER YIELD - INCORPORATING LANDOWNER INPUT

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In 1998, the Texas Legislature, through the Texas State Soil and Water Conservation Board (TSSWCB) authorized a feasibility study to determine the costs and benefits of controlling brush to yield additional surface water in the North Concho River, northwest of San Angelo. The feasibility study done in the North Concho combined independent hydrological and economic studies to determine the cost of increased water.

The methods and results of the 1998 North Concho River Feasibility Study (NCRFS) have been published and were discussed in previous papers (Bednarz et. al., Walker) presented at this symposium. Those combined studies estimated the cost of added water at $49.75 per ac.-ft., as averaged over the entire North Concho basin (Bach and Conner 1998). No studies of individual subbasins within the main basin were performed, and no differences for subbasins were recommended for funding of any subsequent project.

In response to the NCRFS, the Texas Legislature, in 1999, appropriated approximately $6 million to begin implementing the brush control program on the North Concho. A companion Bill authorized feasibility studies on 8 additional watersheds across Texas. The 8 watersheds range from the Canadian, located in the Texas Panhandle to the Nueces which encompasses a large portion of the South Texas Plains (Figure 1). In addition to including a wide variety of soils, topography and plant communities, the 8 watersheds have average annual precipitation zones from 16 - 35 inches and growing seasons from 178 - 291days.

The studies of these 8 watersheds were performed in a nearly identical manner to the manner used in the 1998 study. These studies were conducted primarily between February and September, 2000, with results on the feasibility of controlling brush for water yield presented at public meetings in the watersheds in September and October, 2000. Final information was available to the Legislature in November, 2000, and this information will be considered in the January, 2001 Texas Legislative Session to determine if any or all of the projects merit funding.

The overall goal of these projects is to increase the stream flow and water availability in lakes and aquifers for use as a supply of public water which can be used for multiple purposes. The first stage of the projects has been to determine the feasibility of brush control for increased water yield on a basin by basin basis. New for the 2000 feasibility studies is the study of feasibility on a sub-basin by sub-basin basis within the watersheds.

In order to meet this goal and to conduct these studies, several objectives were formulated:

1. Estimate the potential change in stream flow of rivers and annual recharge to the local underground aquifer (if applicable) if large-scale brush control projects were conducted in the watershed.

2. Prioritize areas within watersheds (subbasins) relative to their estimated contribution to stream flow and/or aquifer recharge.

3. Quantify changes in water yields associated with removal and management of brush (by type/density categories) in the 8 watersheds.

4. Estimate the costs of participation in such a project by both private landowners and the state (cost-share) for implementing a brush control program by subbasin for each watershed.

The focus of this paper is not on the hydrological aspects of brush control for water yield, nor is it on the biological, meteorological and geological data sources and how they were collected, compiled, and analyzed. The focus is on how agency, public, and landowner concerns, affairs, and information were gathered and used to estimate the economic feasibility of such an undertaking.

PARTICIPANTS AND CHRONOLOGY OF INPUT AND INTERACTION

Agencies

The legislature appropriated funding for the feasibility studies to the Texas State Soil and Water Conservation Board (TSSWCB) who, in turn, contracted with the Texas Agriculture Experiment Station (TAES), and Extension Service (TAEX) to conduct the studies. Other participants included the Texas Parks and Wildlife Department (TPWD), local Soil and Water Conservation Districts (SWCD), the USDA Natural Resource Conservation Service (NRCS), and various river authorities and groundwater control and/or conservation agencies.

Following the manner of the North Concho River Feasibility Study, initial meetings were held for agency participants and/or expert staff in each of the watersheds. These meetings were held in February and March, 2000. They were held in Amarillo, Vernon, San Angelo, Stonewall, and Uvalde. The purpose of these meetings was to answer questions amongst the staff members and to decide who would act as an agency principal for each of the eight watershed studies. Different agencies took different leads, depending on the watershed.

Public or Stakeholders

Shortly after these meetings were held and agency principals stepped forward to lead the local organization of the studies, public hearings called Public Stakeholder meetings were held in each of the watersheds. In several cases, more than one meeting was held to ensure the opportunity for many landowners/ranchers to attend and give valuable information relating to the projects. These meetings were to explain exactly how the studies would be done, who and what was needed to help, and when the results would be finished and what would be done with the infomation. Speakers at these meetings explained the biophysical and economic modeling processes as well as how careful planning should be implemented to protect wildlife resources. The location of these meetings and the watersheds which were included in their particular explanations are shown in Table 1. The attendance at these meetings was between 50 and 100 at each, with the exception of the meetings held at Tilden and Laredo, which approximately half that number. A main purpose of the meetings was to answer the public's questions and allow for anyone in attendance to offer comments or express concerns with the projects. These meetings were held in April and May, 2000.

Landowner / Rancher Focus Groups

Initial Data Collection.--

At the close of the stakeholders meetings, the agency principals were notified to organize and set up meetings with representative producers from each of the watershed areas. These meetings were called Focus Group Meetings, with purpose to gather primary information on what types of brush could be controlled with what practices, what were the costs of control, how plant communities would benefit, and how production practices were implemented. These meetings were held in June and July, 2000.

In several of the watersheds, an excellent effort on the part of the agency principals led to separate meetings with local agency specialists and landowner/ranchers. This allowed for a very functional cross-checking of information, whereby estimates could be categorized as either conservative or liberal, which led to more precise information. These meetings were the source of the majority of the data collected for the brush control treatments, and comprised most of the information used in the economic analyses.

Questioning and discussion in these meetings yielded six primary categories of information. Those categories were:

1. The brush types and their characteristic growth form, etc. Table 2 lists the categories for each watershed.

2. Brush control practices and their relative effectiveness on the targeted species.

3. The cost of acceptable control practices for each type and density category of brush. Table 3 details the control practices and costs for the Wichita Watershed as an example.

4. The before and after brush control livestock grazing capacities of each affected plant community. Table 4 shows the before and after brush control grazing capacities for the different brush type-density categories for the eight watersheds.

5. The effects of brush control on wildlife-based enterprises. The focus groups indicated that the only economic impact on wildlife-related revenue from brush control would be slight increases in wildlife lease revenue. These effects were minimal, and only in areas with heavy brush canopies if quail were important in the area or if some amounts of brush control were necessary to implement improved wildlife management(access, food plots, senderos, fence construction, etc).

6. The costs and revenues of the livestock enterprises used on lands having brush within the study areas. Table 5 provides an example of this type of information for a portion of the Upper-Colorado Watershed. The information for these budgets came primarily from TAEX budgets for the regions of the watersheds and was adjusted by the use of rancher input for local specifics.

Modeling Results - Return Visits.--

The information gained from the Focus Groups was organized and entered into the Economic Analysis Model (ECON) at Texas A&M University. The ECON model is part of the Grazinglands Analysis (GLA) Software developed by the Ranching Systems Group at Texas A&M in the early 1990's. The ECON model reports costs and revenues for management options based on changes in production inputs. In the case of the brush control analysis, the primarily affected dependent variable is the grazing capacity of a theoretical 1,000 - acre area in terms of acres per animal unit. An example of the results of the ECON analysis for the Upper-Colorado Watershed are shown in Table 6.

Since a 1,000 - acre management unit was used, benefits needed to be converted to a per acre basis. To get per acre benefits, the accumulated net present value of $11,895 shown in Table 6 must be divided by 1,000, which results in $11.90 as the estimated present value of the per acre net benefit to a rancher. The resulting net benefit estimates for all of the type-density categories for all watersheds for the rancher-landowner are shown in Table 7.

If ranchers are not to benefit from the state's portion of the control cost, they must invest in the implementation of the brush control program an amount equal to their total net benefits. The total benefits that are expected to accrue to the rancher from implementation of a brush control program are equal to the maximum amount that a profit maximizing rancher could be expected to spend on a brush control program (for a specific brush density category).

Using this logic, the state cost share is estimated as the difference between the present value of the total cost per acre of the control program and the present value of the rancher participation. Present values of the state cost share per acre of brush controlled are shown in Table 7.

The results of the analyses, including the state versus landowner/rancher cost share, were discussed with the same rancher Focus Groups upon completion. In some of the study areas, very little was changed, and in others, changes forced complete re-runs of the ECON model. Any adjustments and considerations noted by the Focus Groups were included as needed adjustments, then the information again returned to the Focus Groups in each watershed. The meetings with returned results and adjustments were all complete by the end of August, 2000.

Public or Stakeholders Final Meetings.--

When all the economic data had been collected, corrected, modeled, and reported to the focus groups, a final step was to find the value of added water by combining the economic results with the hydrological information provided by those who modeled those processes. This was done by finding the total amount of added water which was expected to be yielded by the removal of brush, by acre, over ten years, discounting that value for time-availability, and dividing that number (in acre feet) by the present value of the state's share of cost for the brush control programs. An example for the Pedernales Watershed is shown in Table 8.

This final combined information was presented to a second series of public stakeholder meetings. The key information of interest to most of those interested in the feasibility studies was the percentage of rancher cost-share for the brush removal projects and the total cost of added water, in dollars per acre-feet. These figures would allow ranchers to determine the amounts of acreage that they would like to enroll in the program as well as discover how well the projects compare not only to each other, but to alternative avenues for supplying water for public use. These meetings represented the final interaction with the public, landowners, and agency for the purposes of collecting information and feedback. These meetings were completed during the period of the final week in August through the second week in October, 2000.

RESULTS

The results of the 8 feasibility studies have been included in final reports to the TSSWCB and will shortly to be considered by the Texas Legislature. The information collected in the studies, as analyzed and presented for consideration, is a part of the individual reports published for each of the watersheds. Information from the feasibility studies is only part of the reports. The local SWCBs and River Authorities were able to add information they felt was important to the consideration of the projects for their areas. All agencies and the public were able to contribute to this local effort by working with their local SWCB. These concerns were not part of the focus of this study, but are noted to be very important to participants in specific watersheds.

Literature Cited

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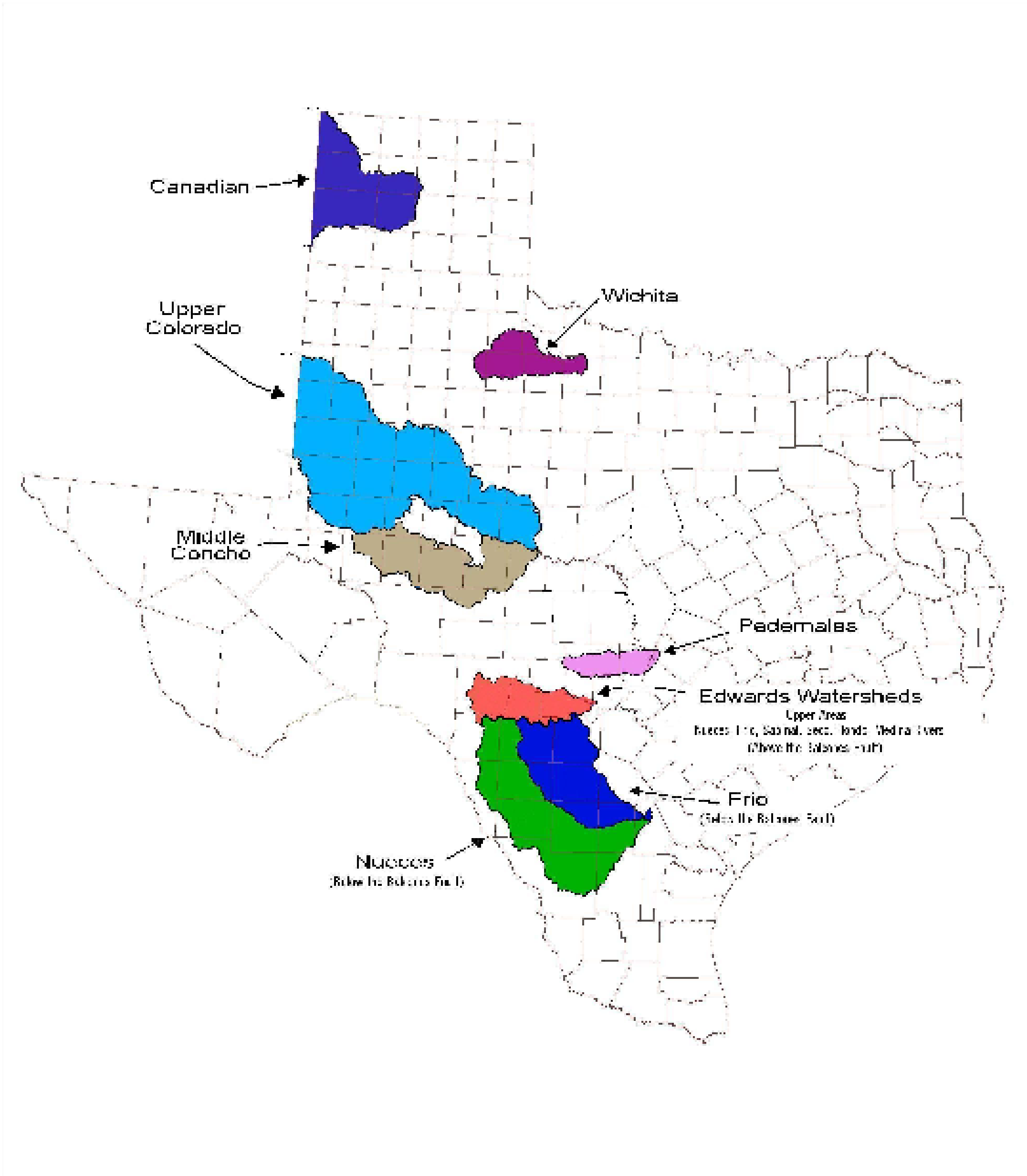

Figure 1. Map of Texas with the eight watersheds which were involved in the *Brush Control for Water Yield* feasibility studies.

Table 1. Locations of initial public hearings, called *stakeholder meetings*.

Meeting Location	Watershed
Amarillo	Canadian
Benjamin	Wichita
Colorado City	Upper Colorado
Ballinger	Upper Colorado
Mertzon	Middle Concho
Stonewall	Pedernales
Bandera	Edwards Aquifer
Uvalde	Frio
Pearsall	Frio
Tilden	Nueces
Laredo	Nueces

Table 2. Brush type-density categories in the eight watershed feasibility studies

	Brush Type-density Category					
Watershed	Heavy Cedar	Heavy Mesquite	Heavy Mixed	Moderate Cedar	Moderate Mesquite	Moderate Mixed
Canadian		X	X		X	X
Edwards Aquifer	X	X	X	X	X	X
Frio	X	X	X	X	X	X
Middle Concho	X	X	X	X	X	X
Nueces	X	X	X	X	X	X
Pedernales	X	X	X	X	X	X
Upper Colorado	X	X	X	X	X	X
Wichita	X	X	X	X	X	X

Table 3. Water yield brush control program methods and costs by type-density category[1]

Heavy Mesquite Aerial Chemical			
Year	Treatment Description	Cost/Unit	Present Value
0	Aerial Spray Herbicide	25.00	25.00
4	Aerial Spray Herbicide	25.00	18.38
7	Choice Type IPT or Burn	15.00	8.75
			$ 52.13

Heavy Mesquite Mechanical Choice			
Year	Treatment Description	Cost/Unit	Present Value
0	Tree Doze or Root Plow, Rake and Burn	150.00	150.00
6	Choice Type IPT or Burn	15.00	9.45
			$159.45

Heavy Cedar Mechanical Choice			
Year	Treatment Description	Cost/Unit	Present Value
0	Tree Doze, Stack and Burn	107.50	107.50
3	Choice Type IPT or Burn	15.00	11.91
6	Choice Type IPT or Burn	15.00	9.45
			$ 128.86

Heavy Cedar Mechanical Choice			
Year	Treatment Description	Cost/Unit	Present Value
0	Two-way Chain and Burn	25.00	25.00
3	Choice Type IPT or Burn	15.00	11.91
6	Choice Type IPT or Burn	15.00	9.45
			$ 46.36

Heavy Mixed Brush Mechanical Choice			
Year	Treatment Description	Cost/Unit	Present Value
0	Tree Doze, Stack and Burn	107.50	107.50
3	Choice Type IPT or Burn	15.00	11.91
6	Choice Type IPT or Burn	15.00	9.45
			$ 128.86

Table 3. (Continued) Wichita water yield brush control program methods and costs by type-density category

Heavy Mixed Brush Mechanical Choice			
Year	Treatment Description	Cost/Unit	Present Value
0	Two-way Chain and Burn	25.00	25.00
3	Choice Type IPT or Burn	15.00	11.91
6	Choice Type IPT or Burn	15.00	9.45
			$ 46.36

Moderate Mesquite Mechanical or Chemical Choice			
Year	Treatment Description	Cost/Unit	Present Value
0	Aerial Spray Herbicide	25.00	25.00
7	Choice Type IPT or Burn	15.00	8.75
			$ 33.75

Moderate Cedar Mechanical or Chemical Choice			
Year	Treatment Description	Cost/Unit	Present Value
0	Chemical or Mechanical – Burn Choice	45.00	45.00
7	Choice Type IPT or Burn	15.00	8.75
			$ 53.75

Moderate Mixed Brush Mechanical or Chemical Choice			
Year	Treatment Description	Cost/Unit	Present Value
0	Chemical or Mechanical – Burn Choice	45.00	45.00
7	Choice Type IPT or Burn	15.00	8.75
			$ 53.75

[1] Example from the Wichita River watershed

Table 4. Grazing Capacity in Acres per AUY Before and After Brush Control by Brush Type-Density Category

	Brush Type-density Category & Brush Control State											
	Heavy Cedar		Heavy Mesquite		Heavy Mixed Brush		Moderate Cedar		Moderate Mesquite		Moderate Mixed Brush	
Watershed	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-
Canadian	-	-	30	20	37	23	-	-	25	20	30	23
Edwards Aquifer	60	30	35	20	45	25	45	30	25	20	35	25
Frio – North	50	30	36	24	36	24	40	30	32	24	32	24
Frio – South	-	-	38	23	35	23	-	-	30	23	30	23
Mid Concho	70	35	38	25	50	30	52	35	32	25	40	30
Nueces – North	50	30	39	27	39	27	40	30	35	27	35	27
Nueces – South	-	-	41	26	38	26	-	-	33	26	33	26
Pedernales	45	28	28	15	40	22	38	28	24	15	34	22
Upper Colorado – East	56	24	32	18	48	21	44	24	28	18	36	21
Upper Colorado – West	70	35	38	25	50	30	52	30	32	25	40	30
Wichita	50	25	32.5	20	38.5	20	40	25	25	20	32.5	20

Table 5. Investment analysis budget: cow-calf production[A]

Partial Revenues[1]

Revenue Item Description	Quantity	Unit	$ / Unit	Cost
Calves	382.5	Pound	.80	306.00
Cows	111.1	Pound	.40	0
Bulls	250.0	Pound	.50	0
			Total	306.00

Partial Variable Costs[2]

Variable Cost Item Description	Quantity	Unit	$ / Unit	Cost
Supplemental Feed	480.0	Pound	0.10	48.00
Salt & Minerals	27.0	Pound	0.20	5.40
Marketing	1.0	Head	6.32	6.32
Veterinary Medicine	1.0	Head	15.00	15.00
Miscellaneous	1.0	Head	12.00	12.00
Net Replacement Cows[3]	1.0	Head	35.28	35.28
Net Replacement Bulls[4]	1.0	Head	3.09	6.09
			Total	128.09

[A] Example budget from Ivie watershed – Upper Colorado river basin.

Note: This budget is for presentation of the information used in the investment analysis only. Values herein are representative of a typical ranch in the Upper Colorado River Basin, Lake Ivey Watershed. The budget is based on 1 cow-calf pair per animal unit. Variable costs listed here include only items which change as a result of implementing a brush control program and adjusting livestock numbers to meet changes in grazing capacity. Net returns cannot be calculated from this budget, for not all revenues and variable costs have been included, nor have fixed costs been considered.

[1] Revenues for calves are calculated by finding the actual sales weight per cow, as based on a combined male and female calf sale weight of 450 with no retained heifers, and adjusted for weaning percentage (calves weaned per cows exposed). No salvage revenue is listed for sales of cull bulls and cows, for net replacement costs are used in the investment analysis. Those net replacement costs are listed under the variable cost items.

[2] Variable costs which are not affected by the investment decision are not included in the investment analysis. These include changes in variable costs for equipment and/or facilities, (ie. a 15% increase in carrying capacity resulting from any investment decision does not requite a 15% increase in variable costs for fencing, a barn, nor stock trailer(s) or other vehicles).

[3] Net replacements for cows are figured by using purchase price ($700) divided by useful life (9 years) minus normal salvage value ($400) divided by useful life, adjusted for 2.5% death loss.

[4] Net replacements for bulls ($1,500) are done in the same manner (6 years) ($625), divided by the number of cows per bull (25).

Table 6. GLA-ECON model report – ten year net present values generated by brush control[1]

Year	Animal Units	Total Increase In Sales	Total Added Investment	Increased Variable Costs	Cash Flow	Annual NPV	Accumulated NPV
0	0.0	0	0	0	0	0	-
1	4.2	1423	2800	520	-1897	-1757	-1757
2	9.8	3557	3500	1171	-1113	-955	-2711
3	10.1	3557	0	1171	2387	1895	-817
4	10.3	3557	0	1171	2387	1754	937
5	10.6	3557	0	1171	2387	1624	2562
6	10.8	3913	0	1171	2742	1728	4290
7	11.1	3913	0	1171	2742	1600	5890
8	11.4	3913	0	1171	2742	1482	7371
9	11.6	3913	0	1171	2742	1372	8743
				Salvage Value:	6300	3152	11895

Note: Includes carrying capacity changes with current management.
Run based on 1,000 acre representative ranch.

[1] Example from the Upper Colorado – west watershed, moderate cedar control

Table 7. Landowner and state shares of brush control costs by crush type-density category by watershed

	Brush Type-density Category											
	Heavy Cedar		Heavy Mesquite		Heavy Mixed Brush		Moderate Cedar		Moderate Mesquite		Moderate Mixed Brush	
Watershed	Rancher Benefits	State Costs	Rancher Benefits	State Costs	Rancher Benefits	State Costs	Rancher Benefits	State Costs	Rancher Benefits	State Costs	Rancher Benefits	State Costs
Canadian	-	-	10.37	40.33	10.44	54.93	-	-	8.95	26.10	10.48	23.43
Edwards Aquifer	43.52	138.5	52.12	98.49	45.61	105.00	23.27	93.75	20.81	43.71	23.88	40.64
Frio – North	30.69	79.81	39.76	90.18	39.76	84.57	10.44	92.29	23.43	60.56	23.43	60.56
Frio – South	-	-	38.71	75.95	41.6	72.32	-	-	21.07	55.57	21.07	62.92
Mid Concho	16.59	78.30	15.66	57.46	16.35	78.54	11.79	53.10	10.49	41.76	9.91	54.98
Nueces – North	30.69	79.81	34.49	95.45	34.49	89.84	10.44	92.29	19.73	64.26	19.73	64.26
Nueces – South	-	-	35.69	79.02	36.53	77.40	-	-	17.14	59.50	17.14	66.85
Pedernales	31.86	108.56	40.61	88.77	33.31	96.07	25.74	54.68	21.22	49.20	21.22	49.20
Upper Colorado – East	14.90	69.99	17.22	60.62	16.35	83.54	11.32	58.57	12.07	42.68	10.92	58.97
Upper Colorado – West	16.76	42.14	15.89	57.23	15.07	64.82	11.90	32.99	10.55	29.84	10.25	34.64
Wichita	18.79	68.82	18.70	87.09	21.80	65.81	15.13	38.62	12.05	21.70	19.09	34.65

Note: rancher benefits and state costs are in $ /ac.

Table 8. Cost Per Acre-Foot of Added Water From Brush Control by Sub-basin[1]

Subbasin	Total State Cost ($)	Average Annual Increase (Gallons)	Average Annual Increase (Acre/Feet)	Additional 10 Year Water (Acre/Feet)[2]	State Cost Per Acre/Foot of Added Water ($)
1	938379.39	3,509,934,604	10771.59	84039.97	11.17
2	1076826.7	3,830,330,157	11754.85	91711.35	11.74
3	862557.2	1,173,085,471	3600.07	28087.72	30.71
4	579534.36	1,203,434,375	3693.20	28814.38	20.11
5	1063687.5	2,613,606,806	8020.86	62578.79	17.00
6	416425.3	2,078,427,110	6378.46	49764.73	8.37
7	1503135.6	2,142,472,577	6575.01	51298.20	29.30
8	231102.24	143,029,849	438.94	3424.63	67.48
9	172041.49	969,947,825	2976.66	23223.91	7.41
10	731119.03	3,499,761,808	10740.37	83796.40	8.72
11	55839.216	82,369,342	252.78	1972.21	28.31
12	923234.38	3,339,561,545	10248.74	79960.65	11.55
13	124894.59	45,832,580	140.66	1097.39	113.81
14	495537.1	1,120,243,861	3437.90	26822.51	18.47
15	450494.89	482,484,548	1480.69	11552.35	39.00
16	595143.09	224,459,965	688.84	5374.35	110.74
17	0	0	0.00	0.00	0.00
18	78285.356	552,188,395	1694.60	13221.30	5.92
19	22506.288	54,225,936	166.41	1298.36	17.33
20	409738.01	2,606,809,374	8000.00	62416.03	6.56
21	0	0	0.00	0.00	0.00
22	534242.78	3,290,299,232	10097.56	78781.14	6.78
23	398726.56	686,889,242	2107.99	16446.50	24.24
24	451531.88	1,530,495,204	4696.92	36645.35	12.32
25	353602.6	803,690,121	2466.43	19243.12	18.38
26	310622.73	2,113,161	6.49	50.60	6139.23
27	341117.23	1,352,300,667	4150.06	32378.76	10.54
28	27700.888	1,858,684	5.70	44.50	622.45
29	488733.87	1,073,272,439	3293.75	25697.85	19.02
30	274075.84	476,201,733	1461.41	11401.92	24.04
31	304869.05	324,609,923	996.19	7772.28	39.23
32	269065.96	1,515,842,097	4651.95	36294.50	7.41
33	102060.22	300,394,705	921.88	7192.49	14.19
34	1689484.7	2,445,623,566	7505.34	58556.69	28.85
35	820034.68	24,635,822	75.60	589.87	1390.20
TOTALS	17096351			1041550.82	

Average:	16.41

[1] Example is from the Pedemales watershed.

[2] Figure is the 10 year discounted additional water. Water supply was discounted for time availability.

INTEGRATING WILDLIFE CONCERNS INTO BRUSH MANAGEMENT DESIGNED FOR WATERSHED ENHANCEMENT

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Abstract: Wildlife, e.g., northern bobwhites (*Colinus virginianus*) and white-tailed deer *(Odocoileus virginianus*), are ecologically and economically important considerations when contemplating brush management in Texas. Brush control can be either an asset or liability for wildlife habitat, usually depending on whether the needs of wildlife are considered *a priori*. Important factors to consider include site factors (e.g., brush community, topography), wildlife species of interest, clearing intensity, method of brush control, and subsequent grazing management. Conflicts between wildlife and water needs will likely focus on clearing intensity. Clearing brush at levels recommended for water enhancement (e.g., > 90% cleared) over large areas (e.g., watershed level) will likely have detrimental impacts to quail and deer. Suggested clearing guidelines for quail and deer are presented. Research is needed to quantify such trade-offs and to determine overlap between high yield sites for water and wildlife.

The increasing economic and aesthetic importance of wildlife-based recreation is fostering a paradigm shift relative to landowner attitudes toward brush in Texas. Over the last 50 years, this evolution of thought has gone from "brush eradication" in the 1940s to one of "brush control" in the 1960s to an era of "brush management" in the 1980s. Brush "management" connotes the idea of managing brush-infested rangeland for multiple uses, including forage, watershed, wildlife habitat, and recreation. Recently, the Texas Agricultural Extension Service developed the "Brush Sculptors" program which heralds the continued evolution of brush management (Rollins et al. 1997). Brush Sculptors promotes the planned, selective control of brush as a means of enhancing wildlife habitat.

In some areas of Texas, rural land values are tied more closely to recreational enterprises (e.g., hunting) than traditional ranching enterprises. This trend of the "(wildlife) tail wagging the (livestock) dog" is poised to persist for some time. As it does, wildlife considerations will become increasingly important in determining land management strategies, especially relative to brush control.

Brush isn't necessarily a "4-letter word" for Texas ranchers. Indeed, the same brush that complicates livestock handling, competes with grass, and reduces the state's underground water, also dictates the habitability of most Texas rangelands as wildlife habitat. But, vast, dense stands of brush are not conducive to livestock, watersheds, or (most species of) wildlife (Rollins and Armstrong 1997).

Ralph Waldo Emerson once asked "and what is a weed but a plant whose virtues have yet to be discovered?" As despicable as mesquite (*Prosopis glandulosa*) may be with your cowboy hat on (i.e., livestock perspective), it must be acknowledged for its contributions as a food and cover species for bobwhites and other wildlife (Nelle 1997). Similarly, prickly pear (*Opuntia* spp.) is a hindrance to livestock grazing, but its thorny lairs enhance nest survival for bobwhites (Slater 1996).

In this paper, I will address concerns over brush management as it is applied relative to watershed enhancement, and the implications thereof for "game" species, i.e., deer, quail, and turkey (*Meleagris gallopavo*). Other authors will address nongame and endangered species concerns. As mentioned previously, brush control per se can be positive, negative, or neutral for wildife habitat, depending on several factors. Previous reports (Hailey 1978, Guthery 1986, Koerth 1996, Fulbright and Guthery 1996, Guthery and Rollins 1997, Rollins et al. 1988) have addressed the role of brush management in deer and quail management in Texas. The Brush Sculptor symposia proceedings (Rollins et al. 1997; available online at *http://texnat.tamu.edu*) addresses many of the concerns of managing Texas rangelands for wildlife.

BRUSH CONTROL AND WILDLIFE

Some key points to ponder relative to brush control and wildlife include:

1. brush is a key habitat component;
2. vast, dense stands of brush are not conducive to water, wildlife, or livestock;
3. brush control can be an effective habitat management technique within limits;
4. clearing intensity is the pivot point around which the arguments will center;
5. several factors affect wildlife response to clearing (e.g., site factors, treatment method);
6. post-treatment grazing management impacts wildlife response;
7. rangeland products cannot be *maximized* simultaneously;
8. trade-offs should be quantified and compromises sought based on landowner's goals and society's needs.

Probably the 2 most contentious issues for wildlife managers focus on (1) clearing intensity, i.e., how much of the site's brush will be cleared, and (2) the scale of implementation (e.g., 400 acres or 400 square miles?). What are the minimum thresholds of brush necessary to maintain wildlife on the site? Are these compatible with clearing intensities sought by water managers?

First, we need to address some confusion over "brush cover." Brush cover can be quantified at 2 spatial scales (Fulbright 1997). The first scale is the percent *canopy cover* of brush at a particular site. Percent canopy cover at the site scale is measured by estimating the amount of ground surface beneath the canopy of shrubs, i.e., how much of the ground would be shaded on a clear day at noon. In a mesquite or juniper community, a canopy of 50% is "thick" brush. The second scale is the *landscape scale* or the percent of the landscape that supports a cover of woody plants somewhat irrespective of the canopy cover at the site. The percent of the landscape that supports a cover of woody plants is measured by determining the percentage of a given area dominated by woody plants versus the amount dominated by grasses and forbs; i. e., the amount of woodland versus grassland.

Confusion arises when these two parameters are considered substitutes. A 50% canopy cover of brush over a ranch is not the same as having a brush problem on 50% of the ranch. Similarly, when one suggests that he has "cleared 80% of the ranch", does he mean he has removed 80% of the 50% canopy (i.e., a 10% canopy remains) or has he applied a herbicide to 80% of his property, which means he may have reduced canopy cover by perhaps 50%? Confused yet?

I suggest the use of "clearing intensity" to describe the amount of the pasture to which a specific treatment is applied. In terms of mechanical control (e.g., chaining), if we chain 80% of the pasture, then we conclude that we cleared 80% of the site. However, within the 20% of the acreage left uncleared we would probably leave those pockets of heaviest brush on the site to maximize "usable space" (Guthery 1997) by our wildlife species of interest. Fulbright (1997) suggested that such "honeyholes" (i.e., thick pockets of brush where a deer "feels" secure) consist of dense brush (> 85% canopy cover).

The concept of "cover thresholds" suggests that animals have a minimum amount of brush that is required on the landscape to make that site habitable. Clearing above such thresholds results in "lost" space on the landscape. Rollins et al. (1988) studied white-tailed deer response to 4 clearing intensities (30, 50, 70 and 80%) of mechanical brush removal (i.e., chaining). They suggested that 50 - 70% of the brush could be cleared while enhancing habitat for deer given the conditions of their study (e.g., scale of treatment about 400 acres in size).

Clearing thresholds are not absolute. Some of the factors that affect wildlife response to a given level of clearing include (a) species of wildlife concerned, (b) topography, (c) brush community before and after clearing, (d) method of brush control implemented, (e) hunting pressure, (f) scale of treatment. Whether Rollins et al. would have observed the same results in flatter country at larger scales of treatment (e.g., 10,000 acres) is speculative.

LANDOWNER GOALS

Landowners in Texas can be identified somewhere along a continuum of goals depicted in Figure 1. Landowners in "Class I" are interested exclusively in livestock, with no compensation in management decisions made for wildlife's sake. Ranchers in this group often exhibit "brush vendettas" and may go well beyond the point of diminishing returns in an attempt to clear the ranch of brush. At the right end of the scale are the "Class V" ranchers, a new breed of landowners in Texas, whose motivation for land ownership is strictly wildlife-based. Livestock are considered taboo, and with the recent passage of "Proposition 11", this landowner can maintain his "ag use valuation" for ad valorem taxation purposes without a head of livestock on the place. Those ranchers in between the endpoints have varying interests in livestock and wildlife. "Class II" ranchers have livestock as their primary motivation, but are also interested in wildlife. "Class IV" is the opposite to Class II, with wildlife being the primary motive for ownership and livestock secondary. While the Brush Sculptor's philosophy can benefit landowners along the continuum, those in Classes III and IV are most likely to use these technologies.

Let me share some observations based on my 15-year tenure of working with Texas ranchers relative to brush and wildlife matters. The composition of ranchers around the state (Class I-IV) varies across Texas. Ranchers in south Texas and the Edwards Plateau are further to the right (i.e. perhaps a 2.5 score, indicating they are more interested in wildlife as a land management factor) than their neighbors in the Rolling Plains (perhaps a 1.5 score), but the escalating trend to the right (i.e., more interest in wildlife) is statewide.

A landowner's attitudes toward wildlife (either from commercial or personal motivations) are likely to influence his (a) willingness to participate in cost-share programs aimed at watershed enhancement, and (2) the degree to which he will clear brush at the levels conducive to enhancing water yields (i.e., > 90%).

Now, we must interject other stakeholders into our landowner-wildlife equation. The growing demand for water from Texas' rangelands will likely impact landowner decisions relative to brush control. Thus, a landowner must analyze the actions and reactions of brush management as they affect not only "his" needs, but also society's.

APPRECIATING BRUSH

As such complex decisions are evaluated, I encourage landowners to develop an "*appreciation*" for brush. I refer to 2 connotations of "appreciate". First, the idea of "*to judge with heightened awareness*" and secondly to "*be critically or sensitively aware of.*" An appreciation for brush may require a new way of thinking. Incorporating water concerns into our management equation means we must strive to clear brush to the degree possible while maintaining adequate brush cover to meet our wildlife goals. Thurow (1997) recommended clearing intensities > 85% in order to generate water from west Texas rangelands. In order to assess how such intensities of brush clearing affect wildlife, we must understand how brush is important for our species of interest (defined in this paper as deer, quail, and turkey).

Cadenhead's Corollary

One of my axioms for wildlife managers is that the 2 keys for range managers are (a) know your plants and (b) know how to manipulate them. These underpinnings work for cows or quail, lambs or larks, steers or deer.

Several years ago, while on a tour in Wheeler County, I was extolling the virtues of various forbs and grasses as forage for bobwhites, wild turkeys or white-tailed deer When one fellow had digested all he could, he pulled up some sandburs (*Cenchrus incertus*) and thrust them up to me and asked indignantly "just what good are these for quail?" En guard! Just when I thought he'd caught me in a contradiction, Extension range specialist J.F. Cadenhead of Vernon rescued me when he answered "they slow down bird dogs, don't they?" Touche'!

"Cadenhead's Corollary" cautions us not to judge a plant's contribution to wildlife by its food value alone; a point worth remembering for aspiring Brush Sculptors. Land managers should learn to recognize the specific values of various species (or individual plants within a species) for their target species of wildlife.

Shelter

The term shelter (i.e., cover) may connote any of the following habitat needs: thermal, escape, nesting, loafing, screening, etc. Each of these will be discussed in more of a qualitative than quantitative manner.

Thermal cover allows animals to compensate for temperature extremes. To this end, junipers are probably much more valuable for thermal cover in winter than in summer and in colder climates than in warmer ones (Leckenby 1977). The popularity of junipers (e.g., eastern redcedar; *Juniperus virginiana*) as windbreak plantings is suggestive of their value for winter cover. Relative to summer thermal relief (e.g., shade), other species of deciduous trees probably allow for more air flow and shade than do junipers (Johnson and Guthery 1988).

Escape cover is rather generic and can probably be satisfied by any species of brush of sufficient density. Cedar (*Juniperus* spp.) "breaks" and mesquite thickets certainly qualify as dense cover suitable for escape purposes for deer and other wildlife. The relative need and value of escape cover varies with factors like topography, human disturbance (e.g.,hunting), brush density, and wildlife species in question. Rollins et al. (1988) attempted to quantify cover thresholds for white-tailed deer on Ashe juniper (*J. asheii*) range in Kerr County. Series of 20-acre clearings were established with progressively smaller "strips" of brush between the clearings to identify how much escape cover was necessary for deer. Their findings suggested that as much as 70 percent of the range could be cleared mechanically (e.g., chaining) without adversely affecting deer use of habitats or deer populations within two years of treatment.

Food value

Browse is the leaves and tender twigs which are eaten. Browse is a mainstay in the diet of game species such as white-tailed deer, mule deer, bighorn sheep and many exotic hoofstock (Nelle 1997). The fruits and/or seeds of woody plants are extremely important to many species of wildlife. Fleshy fruits (often called berries or soft mast) are used heavily by hoofstock (e.g., deer, hogs); carnivores (e.g., coyotes, fox); songbirds (e.g., bluebirds, robins); and game birds (quail, turkey). Non-fleshy fruits (i.e., nuts or hard mast) are also important to many of the same species of wildlife. A listing of shrubs and trees of central and south Texas, and their value as browse and fruit, is provided by Nelle (1997).

Brush control, especially via mechanical means or fire, usually enhances nutrition for white-tailed deer, at least for a short period of time (Waid et al. 1984). The regrowth of plants like shinoak and elbowbush are more palatable after top removal. Similarly, deer use of relatively unpreferred shrubs like lotebush increases after a fire.

EFFECTS OF BRUSH CONTROL ON WILDLIFE

Vast, dense stands of brush are not conducive to wildlife, watershed, or livestock management. Ideally, enough brush should be cleared to increase water yield, forage production, and handling ease for livestock, but maintain sufficient cover for wildlife. As mentioned earlier, such cover thresholds are species- and habitat-specific. The impacts of brush control on wildlife depend upon how much brush is cleared (intensity and acreage), how it is cleared (e.g., mechanically, goats), and the subsequent management on the cleared land (i.e., grazing management). Impacts to wildlife may be both acute (e.g., forage response) and chronic (e.g., habitat fragmentation).

Obviously clearing too much brush (or too large an area) could negatively impact deer, but the other extreme (clearing too little) is also troublesome, albeit for different reasons. Small, isolated clearings (e.g., 2 acres) are subjected to intensive grazing pressure by wild and domestic herbivores. The repeated browsing on plants like sumacs and oaks will eventually kill these species. Regardless of the intensity and scale of clearing, herd and grazing management are important for maintaining healthy plant populations.

Brush is generally controlled by mechanical, chemical, biological, or pyric means, either singly or in combination. Mechanical treatments like grubbing or chaining generally increase forage production, at least temporarily. Annual forbs respond to the ground disturbance caused by mechanical treatments. Further, browse availability generally increases by topkilling such species as shinoak (*Quercus* spp.) and liveoak (*Q. virginiana*). Similarly, burning tends to promote the growth of annual and perennial forbs and also enhances browse availability and/or palatability. Chemical means (i.e., herbicides) offer more economical treatments and have the advantage that the standing dead brush still serves as screening cover.

Deer

Rangelands dominated by brush can be tailored to enhance habitat for white-tailed deer by designing brush manipulation to achieve the appropriate structure, spatial arrangement, and dispersion of brush (Fulbright 1997). One approach involves clearing small (about 20 acres), irregularly-shaped patches scattered throughout the landscape. Fulbright (1997) recommend such clearings should total 40% of the landscape in south Texas, with relatively wide corridors of brush between patches that total 60% of the landscape should remain. Areas of tall, dense, diverse brush with canopy cover over 40% should be interspersed throughout the landscape. Brush in and along natural drainage areas and large, single-stemmed mesquites should not be disturbed.

The biggest concern for deer relative to mechanical treatments is the scale of the clearing operation. Ideally, brush should be cleared in order to promote forage availability up to the point that cover (rather than food) becomes the limiting factor. As clearing size exceeds some threshold value (e.g., 50 acres), wildlife use of some portions (i.e., the center) of the clearing decreases. Smaller clearings have proportionately more edge, thus less habitat is"lost." For optimum use by white-tailed deer, clearing size should be no larger than 40 acres.

The optimum percent canopy cover of woody plants for deer habitat varies among regions. In west Texas, woody plant canopy cover averaged 43% in areas with low deer densities compared to 63% in areas with high deer densities (Wiggers and Beasom 1986). In south Texas, deer densities were greatest in areas with 43 to 60% canopy cover of brush (Steuter and Wright 1980). Greatest deer use during summer occurred on areas with 60 to 97% canopy cover of brush.

In south Texas, mature bucks preferred areas with canopy cover 85% and with dense screening cover (Pollock et al. 1994). Brush management planning should focus on having areas with 85% brush canopy cover interspersed within the landscape. Brush management is not recommended for white-tailed deer habitat improvement on areas with <60% canopy cover of woody plants in South Texas (Fulbright 1997).

Gee et al. (1991) suggested that the optimum percentage of wooded area for deer in the Cross Timbers of Oklahoma and Texas is 40-60% of the landscape, with patchy, irregularly shaped openings <200 yards wide composing the remainder of the landscape.

An important function of woody plants in deer habitat is providing screening cover for concealment. Brush must be >1 yard tall to serve as screening cover. Mature bucks prefer areas with taller screening cover. Mature bucks in south Texas heavily used areas where average seasonal canopy height was 16 feet and did not use areas with brush <15 feet tall (Pollock et al. 1994). Mature bucks select taller screening cover regardless of the amount of herbaceous vegetation present. One advantage of treating with herbicides is that the standing dead brush continues to serve adequately as screening cover. Dense screening cover that inhibits travel, such as whitebrush (*Aloysia lyciodes*) thickets, may receive little use by deer (Bozzo et al. 1992). Creating travel corridors (i.e., "senderos") via shredding, dozing, or chemically within these thickets may increase use by deer (Fulbright 1997).

Drainages (i.e., creeks and draws) are especially important wildlife habitats on most landscapes. Deer densities are often greatest in drainage areas and brush management is strongly discouraged within and along drainage areas. In west-central Texas, bottomland habitat contained higher deer densities than all other habitat types (Darr and Klebenow 1975). Deer densities were almost 6-fold greater in bottomland habitats than in upland savannas. Chaining bottomland habitats reduced deer densities by >50%, with densities decreasing as the amount of area chained increased. The taller vegetation along drainage areas is of major importance for deer because it provides preferred loafing and bedding sites (Inglis et al. 1986).

The Brush Sculptor's goal should always be to maintain, if not increase, plant species diversity. Species like chittam, hackberry, and granjeno should be spared in most situations. Steuter and Wright (1980) reported that sites with <50% woody canopy cover were used more heavily by deer if brush composition was more diverse.

Disadvantages of herbicides are that forbs preferred by deer suffer "forb shock" for up to 2 years after application, depending on the herbicide and rates used, and related site factors (e.g., soil type). Two to 4 years may be required for forbs to grow back in abundance similar to what existed before herbicide application. Deer may make very little use of treated areas until forbs return to their original abundance (Beasom and Scifres 1977).

Management plans for using brush control to improve habitat for white-tailed deer should address these general concepts (adapted from Fulbright 1997):

1. Clear small (about 20 acres) irregularly shaped patches across the landscape. These clearings should total 40 to 60% of the landscape. "Stringers" of brush should connect clearings and suffice as travel corridors across the landscape. Generally the bottomlands may be thinned but should not be "cleared."

2. Areas of older, taller, denser, and more diverse brush species composition should be interspersed throughout the landscape to provide "honeyholes." Such areas may range from 5 - 50 acres in size.

3. Avoid disturbing brush in and along natural drainage areas.

4. Use the brush control method best suited to the habitat. Root plowing is generally not recommended because of its long-term effects on brush species diversity.

5. Do not plant exotic grasses such as old world bluestems and buffelgrass.

6. Use wildlife-friendly retreatment options (e.g., individual plant treatments, prescribed fire).

Quail

Populations of game birds maximize when individuals can use any part of a pasture at any time. Although intended for bobwhites, this recommendation undoubtedly holds well for any species that is a target of management. Lehmann (1984) believed each and every square inch should be usable each and every day of the year. This philosophy has been called maximization of space-time (Guthery 1997); the philosophy serves as the basis for the patterns applied in brush management.

The habitat component that usually dictates quail use of the available habitat tends to be the availability of suitable loafing and escape cover. Grant Huggins of the Noble Foundation refers to the proper threshold for quail as the 50:50 rule, i.e., there should be a covert offering 50 square feet of brush cover spaced every 50 yards. I use a similar rule of thumb that involves a softball. Usable space for quail will be met if you can throw a softball (in the air, roll doesn't count!) from one quail covert to the next. Suitable quail "houses" (i.e., coverts) include lotebush, sandplum, littleleaf sumac, algerita, elbowbush, and other plants with similar growth forms.

Guthery and Rollins (1997) developed the following guidelines for brush control relative to bobwhites:

1. no point in the pasture is further than 25 yards from woody cover,

2. no more than 90% of the pasture is treated, and

3. no woody cover object is less than 75 square feet in area.

Actually, the above prescription probably is conservative for bobwhites. We might be able to accept points up to 75 yards from woody cover, but such a configuration would be more sensitive to grazing. Also, the prescription is quite arbitrary. Thirty-two yards from woody cover, 82% treated, and 150 square feet probably are equally useful guidelines.

There are some other guidelines in managing brush for game birds.

1. Preserve mottes instead of singletons. Wild turkeys, quail, and deer are more likely to occur in areas with mottes.

2. Save patches of taller, mature brush. Taller brush is important on semiarid rangelands because of the cooler temperatures it creates during hot days and seasons (Johnson and Guthery 1988).

3. Preserve wild turkey roosts and travel corridors (strips of woody cover) radiating from the roosts (Scott and Boeker 1977).

4. Identify and preserve the integrity of "honeyholes", i.e., special sites like sandplum or chittam thickets.

INTEGRATED APPROACH

In recent years, my colleague A. McGinty and I have developed an integrated approach for sculpting brush that involves both chemical and mechanical means. For mesquite-dominated habitats, we first delineate the areas that we wish to clear. If quail are a management objective, selected multistemmed mesquites are marked for "half-cutting) (Rollins 1997*a*) usually at a spacing of about 5 - 10 trees per ac. Generally we initiate the clearing by using the "Brush Busters" individual plant treatments (foliar spray; see *http://texnat.tamu.edu* for additional details) targeting all mesquites < 7 feet tall. Once these trees are controlled, mechanical means (e.g., grubbing) are employed to remove the larger trees we have designated for removal. Removal may be done in "clearings" or simply thinned (i.e., leave every fifth mesquite). Generally only mesquite and junipers are removed, depending on the site. Hackberry (*Celtis reticulata*), chittam (*Bumelia lanuginoides*), and other preferred species are not cleared. Follow-up treatments with either Brush Busters or prescribed burning will be needed every 5 - 7 years depending on the site.

Regardless of the method selected, communication with the contractor before and during the clearing operation is imperative (Rollins 1997*b*). Good aerial imagery and computer applications are now available to facilitate planning efforts. Misunderstandings (i.e., clearing more brush than what the landowner had intended) may limit habitability of a site for some time. Traditional methods of using flagging tape work fine, and new technology like GPS-mapping will soon be available to facilitate such communications.

RESEARCH NEEDS

There are many grey areas relative to the recommendations herein. Accordingly, additional research is needed to clarify and refine some of the generalizations. Specific items that need to be addressed include:

1. deer and quail response to various intensities and scales of clearing over most of the watersheds targeted for expansive brush control; such efforts should monitor population responses beyond just the initial treatment period.
2. define cover thresholds for various situations, clearing methods, and grazing regimes
3. develop and validate models for predicting wildlife responses that can be integrated with existing watershed models
4. evaluate "high yield" water and wildlife sites in a spatial sense, i.e., are the deer honeyholes high or low yield sites for water?
5. develop Geographic Information Systems to facilitate implementation of brush clearing plans.

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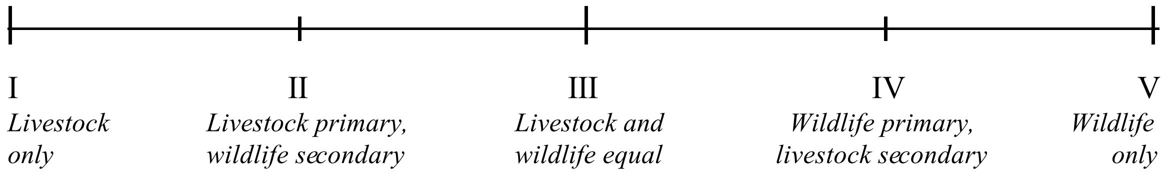

Figure 1. Landowner interest in livestock versus wildlife goals dictates the managers thought about brush.

BRUSH MANAGEMENT AND WILDLIFE DIVERSITY, NONGAME CONSIDERATIONS

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Abstract: Landowners and managers are becoming increasingly aware of the economic and intrinsic values of nongame species on their properties. Consideration of wildlife diversity should be of prime importance to any land manager when planning the implementation of any management practice. With today's technology, more and more people are knowledgeable of the cumulative effects of land practices and the impacts to surrounding properties and the wildlife dependant on those lands. Land managers must realize the importance of planning any management practice such as brush control, and the need to have realistic and obtainable goals with measurable impacts over the long term. Encouraging habitat diversity using proven management practices on all lands will promote wildlife diversity and utilization with long-term benefits well into the future.

Management practices have long been implemented to benefit livestock and game species. Many of these practices such as prescribed burning on native range also benefit nongame species by increasing plant diversity and food availability. On the other hand, there have been many practices in the past and still continue that are detrimental to wildlife habitats. An example from my field experience is the unmanaged browsing by goats or overgrazing by cattle on absentee-owned lands. Absentee landowners wanting to maintain their agricultural tax base allow local ranchers to graze unchecked, many times resulting in the degradation of the land. Certainly not all situations of this sort result in this outcome, but all of us know of examples throughout the state where this has occurred.

The passing of Proposition 11 in 1995 allows landowners to retain their agricultural property tax valuation while changing their land use practices to an active wildlife management endeavor. This has had a positive effect on the recovery of wildlife habitat, while allowing some relief from the tax burden that may otherwise be overwhelming to some landowners. Proposition 11 could be considered a tool to be used in the recovery of habitat when drought, overgrazing or other influences have impacted a property. Texas Parks and Wildlife Department personnel are available to assist landowners with the aspects of Proposition 11 and other wildlife management practices through the technical
guidance program.

NONGAME

Let us proceed now under the assumption that everyone is in favor of maximizing wildlife diversity on his or her property or at the very least giving some thought to wildlife other than game species when considering any management activities. For the sake of discussion we will use the term nongame to mean all wildlife not classified as game animals or endangered species. This includes all the reptiles and amphibians, birds, and mammals. Invertebrates should be given consideration when addressing unique situations such as caves and direct impacts on streams or rivers. They play vital roles in the ecosystem, for our discussion we will deal with impacts on vertebrate nongame species.

There are close to 950 terrestrial vertebrates in the state of Texas, of which close to 90% are considered nongame wildlife. Texas now supports 618 bird species, both resident and migrant, more than any other state in the U.S. Therefore, Texas is known as the number one destination for the leading outdoor activity in the U.S. : bird watching. With an estimated 70 million participants, there is a tremendous opportunity to develop nature tourism on private properties. Not every landowner is going to be willing to open their gates to a flood of tourists, but as with any other management activity, every possible impact and utilization must be considered.

Resident and migratory birds need brush and trees to rest, feed, roost , nest and rear offspring in. Brush is said to provide the best shelter from storms for birds. Many times the trees nearest a permanent source of water are the most desirable for nesting birds. In dry habitats, the first 20 feet of woody vegetation beside a water source may carry as many as 80 % of bird nests in the area.

Small, nongame species of mammals, reptiles, and amphibians feed on insects, plant material and each other. Although most of these species are not entirely dependant on brush for their existence, all benefit from good range management and diversity of habitat. If there is a healthy, diverse habitat, it will most likely support reasonable populations of small nongame species without the need for intense management or the concern that well planned brush control will adversely affect populations.

BRUSH MANAGEMENT AND NONGAME RESPONSE

Much of the rangeland in the state is covered by dense stands of low growing, thorny shrubs that may limit livestock production because of reduced herbaceous forage. Large acreages of brushy rangeland have undergone treatment to curtail woody plant encroachment and increase forage production for domestic livestock. In the past, most range improvement efforts in Texas were directed at clearing pastures of brush through mechanical means, followed by conversion to tame pasture. Only in recent years have the habitat requirements of wildlife species been considered in brush management programs. The concept of brush management recognizes the potential value of some quantity of woody plants in range management. The development of this concept is closely tied to the realization that wildlife is an economic asset and that management objectives should accommodate the habitat needs of wildlife.

If you desire brush management, the quantity of brush you should remove will depend upon your brush characteristics and management goals. It means setting management objectives based on an inventory of range resources, the identification of problems, and the economic and environmental analysis of alternative solutions. Those management objectives must consider all aspects affected by brush management, such as nongame responses and livestock and wildlife management. Most successful wildlife management programs maintain 40 - 60% of the land in brush cover. Brush removal at any intensity decreases total bird density but increases species diversity. As clearing increases, tree-foraging species are replaced by ground- foraging species of birds. Very little research has been conducted in Texas on the response of reptiles and amphibians to brush control methods. Common sense will allow that the removal of bird nesting habitat will remove a food source for reptiles, and loss of escape cover for both reptiles and amphibians.

BRUSH CONTROL METHODS AND NON-GAME

Brush control methods include mechanical, fire, chemical and biological methods. There is seldom any one best method of brush management for a particular ranch or pasture. Brush management is usually more effective and economical when a combination of methods is integrated over a period of several years. It has been my experience in the Hill Country that a combination of mechanical control with the use of an agri-ax on a skid loader followed by a prescribed burn 3 - 7 years later to control cedar and regrowth cedar is one of the most cost effective means while minimizing damage to habitat.

On the Gulf Coast, the control of Chinese tallow trees is best achieved by a combination of herbicide application and follow-up shredding to control seedling growth. Herbicide treatment alone is used in South Texas to control mesquite with annual treatment of regrowth necessary in most instances. As stated before, the brush control method chosen depends on the individual ranch or pasture, size of area to be treated, species to be controlled, topography, economics, and personal desires of the manager.

SUMMARY

All wildlife species need shelter for protection from the elements, nesting materials, and cover to hide from predators or as predators. Brush also provides feeding areas, roosting cover, erosion control and enhancement of water quality. Experts agree that a 40 - 60 percent ratio of clearing to brush standing is accepted as a goal to shoot for. Most will agree that a mosaic pattern of clearing is most beneficial for wildlife. Brush should be left along waterways and drainages (riparian areas), around tanks and lakes and windmills and as corridors between stands of brush or timber.

Brush management objectives should be clearly defined on paper using topographic maps or infrared imagery. Landmarks should be identified on maps and goals listed for all persons involved in the operation. Decisions should never be left solely to the equipment operator or herbicide applicator. No one knows the property better than the landowner or manager.

The objective of the landowner, past ranch history, vegetation present, soil types and species present should all be considered when brush control is proposed. When planning any management decisions on the land a few things should be remembered:

1. Exotic or introduced species have no place on the landscape.
2. Small cleared areas in mosaic patterns across the landscape are desired over straight-line large scale clearing.
3. Consideration should be given to leaving the large established trees and associated understory to create "mottes".
4. Leave as much brush associated with water sources as possible.
5. Leave snags and dead trees in place and cut brush in small piles or scattered where cut.
6. Refrain from burning large piles of brush to reduce sterile ground creation.
7. Use cut brush to create shelter, nesting cover, erosion control, protection for seedling establishment and hedgerows.
8. Leave brush standing on slopes when interspersed with hardwoods until the last of the clearing operations.
9. Use a proven control method for your region and for the species you are controlling. Make visits to previously controlled sites to evaluate your potential success.

LANDOWNER INCENTIVE PROGRAM

It is the goal of the Landowner Incentive Program (LIP) to provide direct financial and technical assistance to landowners interested in conserving rare species and habitats on their property. It is the first program of its kind in the nation in which government funds were used to directly help landowners improve rare species habitat and populations. The LIP was conceived in 1997 with strong support from concerned Texas landowners. In 1999 the Governor's Office and the State Legislature likewise demonstrated their whole-hearted backing of this program by appropriating state funds to help meet this challenge.

For further information on this program please contact:

Landowner Incentive Program, Texas Parks and Wildlife Department, 4200 Smith School Rd., Austin, Texas 78744-3292

(512) 389-4799
-or-
(800) 792-1112 ext 4799

RESULTS OF "ECOSYSTEM MANAGEMENT" ON THE KERR WILDLIFE MANAGEMENT AREA

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Abstract: As a result of an integrated system of population and habitat management designed to mimic ecological processes, both the black-capped vireo (*Vireo atricapillus*) and golden-cheeked warbler (*Dendroica chrysoparia*) populations on the Kerr Wildlife Management have increased. This paper discusses the historical and present management practices that have contributed to increased numbers of these birds.

The Edwards Plateau is home for two endangered species of birds - The black-capped vireo (BCV) and the golden-cheeked warbler (GCW). They are both neotropical migrants.

BLACK-CAPPED VIREOS

Black-capped vireos overwinter in western Mexico. They migrate to the Edwards Plateau in April to nest and rear their young. BCV are basically brushland birds, often constructing nests just 3 feet off the ground in "mottes" of low brush. These mottes of low brush are readily created through a combination of management practices such as (1) rotational grazing systems utilizing cattle at proper stocking rates, (2) using prescribed fires and mechanical brush control, and (3) white-tailed deer and exotic deer harvest to balance browsing animals to available brush species. Black-capped vireos avoid areas of regrowth cedar, preferring more open areas mixed with brush mottes. Therefore, management should be for a more open mid succession brushy savanna. A major threat to black-capped vireo habitat is excessive browsing of woody plants and the formation of "browse lines". Browse lines are the rule and not the exception throughout the Edwards Plateau. Browse lines can be created by domestic livestock, and exotic species, or native white-tailed deer. BCV were placed on the endangered species list in 1987.

GOLDEN-CHEEKED WARBLERS

Golden-cheeked warblers winter in Central America and migrate to the Edwards Plateau in the spring. GCW prefer vegetatively mature areas that have relatively tall, closed canopies. In the Edwards Plateau, closed canopies are most often associated with mature cedar breaks. Within these "cedar breaks", GCW prefer areas that have deciduous hardwood trees (trees that drop their leaves in winter). They feed heavily on insects associated with Spanish oaks, elms, and cherry trees. GCW can do well in areas with as little as 10% cedar; however, they still require that closed canopy. Closed canopy can be defined as canopy cover greater that 50%. They also prefer average stand heights of 13 feet are taller. They **do not** prefer the more dry upland sites with monocultures of cedar and liveoak. Preferred deciduous trees are usually associated with drainages, steeper slopes, and canyon areas. GCW were placed on the endangered species list in 1990.

FRAGMENTATION

Both GCW and BCV are colony nesters who migrate to the Edwards Plateau each spring establishing 4-8 acre territories which are defended from other males of their species. These territories are usually adjacent to each other forming loose colonies. Within these territories, males sing to attract mates, build nests, and rear young. Both males and females assist in the rearing of young. Larger colonies of birds tend to be more stable over time than smaller colonies. Therefore, it is important to populations of these birds that relative large blocks (500+ acres) of land be left to ensure that colonies (populations) remain comparatively stable. In the absence of a single large block, smaller blocks (50 - 200 acres) of habitat in close proximity (1/4 to 1/2 mile) to other small blocks are acceptable. They have been found in as small as 5-ac. areas. Populations in these smaller habitat areas are less stable and are dependent on nearby larger blocks for recruitment of excess males and females. Often birds will accept less than ideal habitat conditions in order to be close to the main colony in order to attract mates.

COWBIRDS

Cowbirds (*Molothrus ater*) are also migratory, arriving in the spring and leaving in October. Prior to European settlement, cowbirds followed buffalo (bison) and fed on seeds and insects exposed by buffalo disturbance. Because buffalo are very mobile, cowbirds were never in one place long enough to raise young. Over time, they developed a habit of laying their eggs in other birds nests (nest parasitism) and letting the other bird (host species) raise their young. The problem for the host species is that cowbird chicks often hatch before their own young and the host quits incubating its own eggs and raises the cowbird chick. If the "other bird's" eggs do hatch, cowbirds are usually larger than their host and can easily out-compete their nestmates for food. Nest parasitism nearly always results in nest failure for the host species. From a ***population*** viewpoint, this was not a big problem for the host if nest parasitism only happened once every few years. The host species would have time to produce young and replenish the population. With the removal of the buffalo, cowbirds readily shifted to feeding around cattle. Cattle were confined by fences and did not migrate. Cowbirds being very mobile and migratory often overwinter in or near gain fields which furnish stable food sources. The result was that cowbird numbers increased dramatically and the same populations of BCV or GCW were being parasitized annually. Without new recruitment, populations of BCV and GCW began to decline and were eventually placed on the endangered species list.

MANAGING A SYSTEM

The Kerr Wildlife Management Area (Kerr WMA) is a 6,493 acre research and demonstration area owned and operated by the Texas Parks and Wildlife Department. It is located 25 miles west of Kerrville, in the Edwards Plateau Ecological Region of Texas. The Kerr WMA was purchased in 1950. Initially, the goal was to understand relationships between white-tailed deer and livestock. Over the years, a system of management has evolved which attempts to utilize and integrate various management tools into a system that strives to mimic ecological processes, duplicate population numbers, and create habitat patterns that occurred prior to European settlement. Prior to settlement, these processes and events occurred on a large scale. The Kerr WMA has been attempting to recreate similar events on a smaller scale. The philosophy behind the system is that plants and animals on the WMA evolved under a particular environmental system and should benefit if that system is recreated. Management, therefore, is for a system and not for a particular species. For systems management to be successful, systems not only need to be biologically sound, they must also be economically and socially viable.

For the past 16 years, the Kerr WMA has been utilizing an integrated system of range, wildlife, livestock, and prescribed fire management. The use of these tools has been integrated to control/mimic fundamental ecological processes. A combination of a 28-pasture, 1-herd, short duration grazing system stocked with cattle only is used to mimic vegetative grazing impacts and rest periods created by bison (*Bison bison*) herds. Proper deer harvest is used to balance white-tailed deer (*Odocoileus virginianus*) populations to available food supply.

Prescribed fire is used to control regrowth cedar (*Juniperus ashei*). In pre-European settlement, wild and man-made fires were frequent. These fires sculptured the landscape removing cedars in areas that burned frequently. Mature cedars were left in areas that did not burn frequently such as steep canyons, shallow soiled areas, and overgrazed areas around rivers and steam.

Mechanical brush control has also been used to control mature juniper while leaving blocks of cedar in strategic areas. A basic white-tailed deer management recommendation is to leave 20-35% juniper cover for white-tailed deer. If this cover is strategically left along drainages, on the steeper slopes, or in canyon areas, it will ensure golden-cheeked warbler habitat. In addition to the brush strips, on the Kerr WMA, a 400-acre block of mature juniper was left as a "relict site" and is currently furnishing a "stable" colony for GCW. A cowbird trapping program is being used to balance cowbird numbers to existing bird populations. All of these tools have been used to mimic some of the original ecosystem processes.

Under this system, fire and large mammal impact have been used as tools to create plant diversity and manipulate structure. Large animal impact is controlled through the use of fencing and rotational grazing systems. Pastures within these systems are used to control time and space impacts of livestock grazing. Prescribed fires have been used to control under utilized plant species such as cedar while at the same time increasing the establishment of the more desirable species.

Plant diversity has increased from approximately 65 species of plants found on August vegetative transects in 1966 to over 90 by 2000. By balancing white-tailed deer numbers to available vegetation, adult male deer (4.5+ years old) weights have increased from an average of 79 pounds (field dressed weights) to over 118 pounds with some individuals reaching 140 pounds. Proper stocking rates in conjunction with short duration grazing has increased livestock weaning weights. Weights have increased from 430 pound calves to 560 pound calves. The endangered BCV has increased from 27 territories in 1985 to over 400 in 2000 (Figure 1). Golden-cheeked warblers have also increased from 18 territories in 1984 to 56 in 1999 (Figure 2) and are found in brush strips left for white-tailed deer. These species have increased because habitat was created through management of large animal impact and fire, as well as, mechanical means. They also increased due to cowbird trapping efforts to restore the balance of cowbirds (a nest parasite) to host species.

SPECIFIC MANAGEMENT GUIDELINES

Because both the BCV and GCW are endangered species, management practices for these 2 birds falls under the review of the U.S. Fish and Wildlife Service (USFWS). Two leaflets have been published by the Texas Parks and Wildlife Department dealing with the management of BCV and GCW. Management practices in both have been approved by the USFWS. The leaflets are available through Texas Parks and Wildlife and are reprints of a book on endangered species. The citation for this book is:

Campbell, L. 1995. Endangered and Threatened Animals of Texas - Their Life History and Management. Texas Parks and Wildlife Press, Austin, Texas. 130 pp.

If you have concerns about your management practices, you should contact your local Texas Parks and Wildlife biologists, NRCS personnel, or Extension Service person.

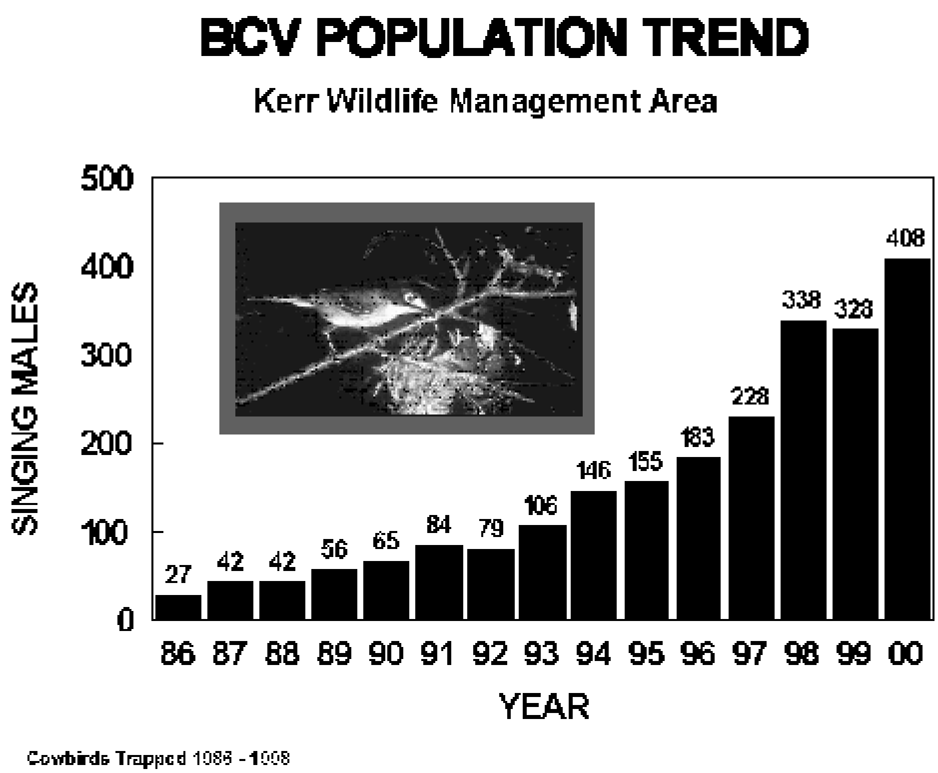

Figure 1. Black-capped vireo population trends on the Kerr Wildlife Management Area.

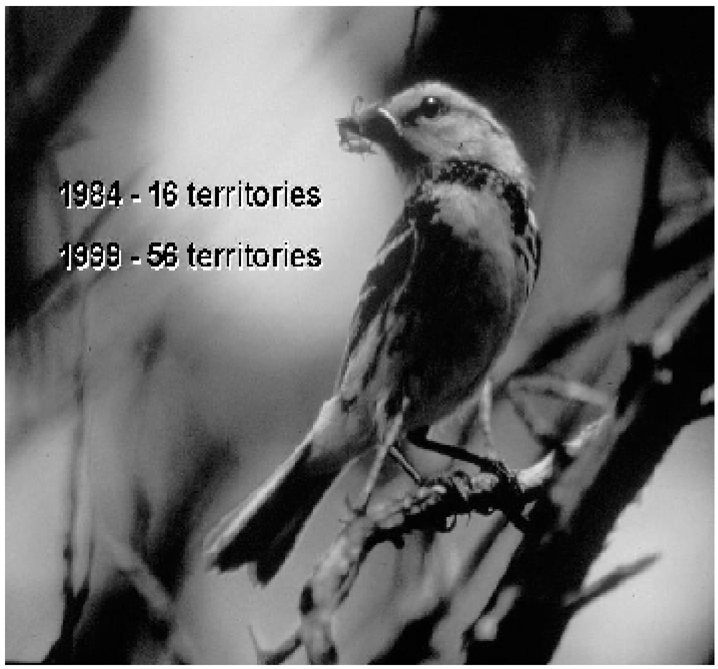

Figure 2. Golden-cheeked warbler populations 1984 and 1999

ACHIEVING GOALS THROUGH BRUSH MANAGEMENT

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Water management, brush management, and wildlife management, go hand in hand. Each management practice can be done without consideration for the other. However, when one is done alone the others suffer. To maximize the total return on rangeland, we must use balance and common sense. Even with the right balance of brush management, water management and wildlife management, the producer is destined for failure if there is not a sound range management plan in effect. Many times, we as ranchers or wildlife enthusiasts pick one over the other and never think of the end result. Goals and priorities must be set before any brush control is started. The very best thing a landowner can do is to spend time on the land. Saddle up old paint, gas up the four wheeler, go for a long walk, learn from the land, livestock, and wildlife. If you pay attention to those lessons you are well on your way to a plan that fits your priorities while minimizing the adverse effect on your range management project.

I am not an expert on brush control or wildlife management and never will be; however, I make it a point to listen to as many experts as possible. Taking some advice, and leaving some advice. I try to take the good advice from all those who have lived through many hardships and experiences. Advice, plus common sense, makes a pretty good combination and fits our program. History of ranches in our area can help determine the future if we learn what worked and what did not. The history of the Mims Ranch gives a glimpse of past stocking rates on 16,640 acres:

100 rams	800 goats
4500 ewes	20 brood mares
400 cows	several saddle horses

Stocking rates were high but the carrying capacity was unknown.

Our ranch is located in the area 25 miles north of San Angelo, Texas. We are in the North Concho Watershed and have completed 1 year of brush control as part of the North Concho River Watershed Project. To this date, we have cleared about 60% of 4,012 acres and left the other 40% in wildlife strips of various patterns. I was on one of the rancher committees that helped determine the monetary benefit of brush control. I was shocked to learn the different opinions of ranchers on the committee. Some ranchers said they could double their stocking rate if all mesquite and cedar was removed from their ranches. Others said they would not participate in brush removal because of the detrimental effect it would have on hunting and real estate values. We wanted to maintain our wildlife numbers, remove enough brush to return to the stocking rates of 30 years ago, and reduce the need for supplemental feeding.

The North Concho Watershed Project is 1 of few projects that help ranchers as well as cities. The key to the success of this project, is to clear enough acreage to maintain the brush control for years to come. The benefits of this watershed project, will be to increase the flow of the North Concho River and therefore, give the city of San Angelo, more available water. Ranchers will benefit by overall increase in forage production.

The first step in the process of brush control and wildlife management, is to set goals. The first goal was a given: to increase ground water and increase the flow rate of the North Concho River. From the ranching side, our goals were:

1. To increase forage production and return to carrying capacity of 30 years ago
2. To increase ground water and raise water tables
3. Increase visibility for livestock gathering; therefore reducing labor costs.

From the wildlife side, our goals were:

1. Maintain approximately 1 deer for every 25 acres
2. Increase body size and quality of antlers on white-tailed deer

3. Maintain and increase quail habitat
4. Provide adequate, open areas for quail hunters, with dogs.

By combining these goals, we found common ground and room for compromise. By removing mesquite and cedar only, we should achieve an increase in forage equality and production. We also will maintain adequate cover between designated wildlife strips, by leaving all plants beneficial to wildlife. Visibility will increase; therefore, reducing labor cost for livestock gthering. With grazing rotation, and an abundance of seed produced, there will be an increase in quail population. With these very basic goals in place, we turn our attention to methods of brush removal. With the selective nature of brush control, we focused on mechanical control. The list of mechanical control options included:

1. Department of Correction crews for small cedar and mesquite control.
2. Skid-steer loaders:
    a. With tree shear/chemical treatment
    b. With grubber attachment
3. Rubber tire loaders with grubber attachment
4. Track loader with grubber attachment
5. Bulldozer with grubber attachment
6. Excavator with grubber attachment.

Over an 8-month period, I observed each of these mechanical brush control methods. The Department of Correction crews were efficient in grubbing seedling cedar and mesquite. They can be very efficient on follow-up treatments. Next, I observed skid-steer loaders with the grubber attachment. I found they were effective on seedling, cedar and mesquite. Skid-steer loaders with tree shear/chemical treatment seem to work very well on blueberry cedar. However, on redberry cedar and mesquite, I was not satisfied with the kill rate, after 4-months' treatment. Rubber-tire loaders, with a grubber attachment, achieved good results on all sizes of mesquite and cedar. However, they seem to be slower than track-type loaders. Track loader seem to be the most efficient and achieve good results. Excavators with grubber attachments, achieve good results. With a good operator, this would probably be my first choice. The initial cost and limited use, was a concern. Bulldozers with grubber attachment, achieve good results, but were not as efficient as track loaders and did more damage to the ground than excavators. After weighing all our options, carefully, we decided to use bulldozers with grubber attachments. The bulldozers are not the most efficient, and damaged the ground more than some of the other choices. However, we made our choice, based upon many other uses of the dozer, e.g., raking, blading pasture roads and fire guards, and constructing dirt tanks.

Brush control should never have a set pattern. What looks good from an airplane may be all wrong for wildlife. The pattern that is good for the south side of the pasture may be wrong for the north side of the pasture. Before any equipment is moved in, you must listen to what the land and wildlife are telling you. Even if you have spent your entire life on a place and know it very well, you must still take time to observe wildlife patterns. While observing, I notice travel patterns of deer and turkey. Start from a source of water and move in a circle about 100 yards out, marking any trail that shows any heavy wildlife use. Each of these areas becomes wildlife strips and many times lead to known honeyholes. Width of these strips vary depending on density of brush. Most strips are at least 300 feet wide; however, if I can stand in the middle of a strip and not see the clear areas, I consider the strip wide enough. Strips are interconnected, so cleared areas will not exceed 20 acres. The areas between the strips are cleared of mesquite and cedar, only leaving plants beneficial to wildlife. We then rake all downed trees into windrows. The windrows are positioned across the cleared areas in the opposite directions from the wildlife strips, breaking the line of sight for the deer; thus giving an added feeling of security.

One of the ideas behind the North Concho River project, is to increase percolation of water. Percolation is increased when water is slowed over a given area. The windrows keep the water from rushing directly to the creeks and rivers; therefore reducing the amount of silt entering the creeks, rivers, and eventually the lake. The theory is when percolation increases, ground water increases, therefore springs are rejuvenated, creating a year round flow of cleaner water reaching the lakes. Erosion is slowed by windrows when placed across sloping areas and benefit quail by adding low cover and a variety of seeds deposited when water is slowed or held. Soil is deposited behind the windrows, therefore creating a different plant culture. For example: shorter grasses are replaced by taller grasses, thus providing additional cover for quail.

In pastures with no definite wildlife travel patterns, I leave brush strips which may run from southeast to northwest. Each of these strips are connected to brush strips along creeks. On the opposite side of the creek, the brush strips will run southwest to northeast. I do the same along roads which might split the pasture. Cleared areas, between strips, (Usually no larger than 20 acres), seem to be much less, when strips change angles every couple of 1000 feet. This makes the deer feel more comfortable and also keeps hunters happy because of the optical illusion created by the angles. Buffer strips are left along any roads to add to the effect.

After the amount of brush control is achieved, a sound range management program must be followed, or all is lost. The control pasture must be deferred for at least 90 days during the growing season. Once again, the rancher must let the land tell him the next step. The amount of ground cover, amount of seed produced, amount and type of forage should determine when deferment ends. Deferment gives the land time to heal after mechanical brush control, and also gives wildlife an opportunity to benefit from the many forbs produced without competition. Brush control without a good grazing rotation system, will be extremely detrimental to all wildlife. Wildlife need a good food supply and adequate cover. Take one, or both away and they will go elsewhere. Proper brush control can increase food supply and maintain adequate cover; therefore benefitting both wildlife and livestock for years to come. Livestock are like my son eating Oreo cookies. Allow him free access to the bag and all the good stuff will disappear. Allow livestock free access to the range and all good grasses will disappear, leaving only the undesirable forage. Rotational grazing allows the good grasses to restore themselves and also forces livestock to use some of the undesirable grasses to create improved range conditions.

Without wildlife and livestock, the family rancher will soon be placed on the endangered species list. Ranching is changing very fast and water will be the determining factor in the future. Cities will someday win the battle for water rights, so we must develop ways to be more efficient with water utilization in the livestock industry. Brush control can benefit the rancher, wildlife, and the cities by increasing the availability and quality of water, while providing some of the best recreation found anywhere.

"I Believe"

I believe *a man's greatest possession is his dignity*
and that no calling bestows this more abundantly than ranching.
I believe *that hard work and honest sweat*
are the building blocks of a person's character.
I believe *that ranching, despite its hardships and disappointments,*
is the most honest and honorable way a man can spend his days on this earth.
I believe *ranching nurtures the close family ties*
that make life rich in ways that money can't buy.
I believe *my children are learning values that will last*
a lifetime and can be learned in no other way.
I believe *ranching provides education for life*
and that no other occupation teaches so much about birth, growth,
and maturity in such a variety of ways.
I believe *many of the best things are indeed free:*
the splendor of a sunrise, the rapture of wide open spaces,
the exhilarating sight of your land greening each spring.
I believe *true happiness comes from watching*
your crops ripen in the field, calves frolicking in the pasture,
your children growing tall in the sun,
your whole family feeling the pride
that springs from their shared experience.
I believe *that by my toil I am giving more to the world*
than I am taking from it, an honor that does not come to all men.
I believe *my life will be measured ultimately*
by what I have done for my fellow man,
and by this standard I fear my judgment.
I believe *when a man grows old and sums up his days,*
he should be able to stand tall and feel pride in the life he has lived.
I believe *in ranching because it makes all this possible.*
-Author Unknown-

THE HUNTING OUTFITTER'S PERSPECTIVE

GREG SIMONS, Wildlife Systems, P.O. Box 5121, San Angelo, TX 76902

Abstract: Hunting income has become an important component of ranching enterprises that are profit oriented. As a professional outfitter who contracts hunting rights on numerous ranches scattered throughout Texas, there are various issues that are typically outside of my control but can impact my interests on a particular property, 1 of which is brush control. Relative to my concern on properties I have leased, there are three primary issues at stake when discussing brush control and these are "marketability," "harvestability," and "habitability." Two "wild cards" which do influence these 3 mentioned issues are size of properties and high fences. As a rule of thumb, I would much prefer to lease and conduct hunts on a property that is "too brushy" than 1 that is "too open." Wildlifers who are involved with brush control programs are well advised to live by the carpenter's old adage: "Measure twice, cut once."

The outfitting business can often be a weird and challenging way to make a living. There are many variables outside of an outfitter's control which can and do affect the spirit of a hunting camp and the quality of the hunt, some of which include temperamental game movement, weather conditions, hunter's ability, and luck, to name a few. As an outfitter who does not own the land that I am involved with, there are other activities and issues outside of my control, such as land practices dictated by the landowner or landlord. Brush control is 1 of these landowner practices which I occasionally deal with, and this activity can very much impact my ability to successfully operate a hunting program on a particular property. Due to increasing pressure for landowners to maximize hunting income in order to realize a profitable ranching portfolio, my lease fees for hunting rights continue to swell, which in turn has forced me to become more critical of various ranching activities which affect the hunting program. Brush control is indeed an activity that can profoundly impact a hunting program.

Relative to brush control and outfitting, I have identified a handful of issues that are affected by this relationship. Though there are indeed some "gray" or debatable aspects of these issues, I will share with you some opinions based on my observations that relate to outfitting and brush control. These issues primarily deal with white-tailed deer (*Odocoileus virginianus*) and northern bobwhites (*Colinus virginianus*), which are the 2 game species in Texas which yield the greatest hunting income levels in areas typically involved in brush control. These issues include "marketability", "harvestability", and "habitability". Two "wild card" variables, which can influence these three issues, are size of property and high fences.

MARKETABILITY

The ability to effectively promote and market a hunting program is ultimately going to influence the profitability or value of a hunting property. Land features or habitat characteristics can often be a determining factor on how marketable a property is, particularly when it is under a season lease program.

Under a lease program, a business deal between the landowner/lessor and hunters is typically negotiated after the prospective hunters have had a chance to inspect the property. The perception from the hunters on how "gamey" a place appears to be adds greatly to value of the lease. As a rule of thumb, properties that are "excessively" brushy will typically yield a higher lease value than those that appear to be "excessively" open. Lack of brush cover can reduce the value of a hunting lease by several times. In areas that provide good whitetail and bobwhite hunting, the key is having the "right mix" of cover characteristics, which can appeal to both deer and quail enthusiasts. Properties characterized by a good mix of "quail country" and "deer country" generally yield top lease prices when marketed properly.

Package hunting programs do not always fit into the aforementioned scenario regarding marketing. Unlike season lease hunters, prospective clients shopping for a package hunt are generally not influenced much by visual land features, as they will typically rely more on past success statistics, references, referrals, etc. Thus, cover characteristics are not directly a large factor when it comes to marketing a package-hunting program. However, if the quality and/or quantity of game are impacted by the result of brush control, this activity will indirectly affect marketing success at a later time; more on this matter under "habitability."

HARVESTABILITY

An issue that is commonly overlooked relative to brush control and brush cover is what I consider to be a factor I call "harvestability". I have been involved with several properties that supported either good whitetail numbers or good quail numbers, but due to various reasons, including brush cover, the ease at which these areas could be hunted was not conducive to efficiently harvesting available animals. This can be a costly relationship as I do feel that it is one matter to produce or grow game populations, and it is yet another matter to be able to efficiently harvest animals from these populations. I feel both production and harvest are important when it comes to long range success of a hunting program. Harvest efficiency is particularly important under package hunting programs where prospective clients have a tendency to evaluate their options based on past harvest statistics.

Harvestability of white-tailed deer relative to brush cover can be a complicated matter. Those areas that are most difficult to harvest whitetails are not always areas characterized by vast stands of heavy brush. I have found that whitetails can often be more predictable when they are forced to use few openings as opposed to having unlimited openings scattered about their habitat. With the use of baiting via feeders and feeding along right-of-ways, deer that live in these brushy environments can be manipulated to the extent of being vulnerable to hunting.

Some of the most challenging circumstances I have dealt with relative to harvestability and brush cover, involves relatively flat country that is characterized by thick brushy areas over the landscape with a scattering of small openings interspersed within these brushy environs. From a habitability standpoint, whitetails tend to thrive under these conditions, but these habitat types tend to disperse animals, which can sometimes complicate matters from a hunting standpoint. However, I would rather hunt an area that has some open areas as opposed to an area where visibility does not exist anywhere on the property. Finding the proper balance relative to this issue is not easy.

On relatively large properties, I believe you can often get by with having what some people would consider too open of country for deer, particularly if this type of country is under a package hunting program where you are dealing with small groups at a given time. Whitetails have proved that they can thrive in open country as long as hunting pressure does not push them from these areas or does not exploit them through over-harvest. Whitetails in open country do tend to be more sensitive to hunting pressure. That is why package hunts work well under these circumstances, which can be illustrated by the following scenario. An open area that has an adequate buck population to support a harvest of 30 bucks will be "impacted" greater by having 30 season lease hunters who could all show up at one time as opposed to a package hunt where you have five groups of six hunters hunting at different times. In theory, the total buck harvest may be the same at the end of the season, but with 30 season lease hunters on this open country, there is a greater risk of pushing deer onto neighboring lands and/or witnessing deer that become harder to hunt due to hunter exposure.

Huntability of quail is perhaps more important than with deer. We recently had the opportunity to conduct quail hunts on a 10,000-acre property in South Texas which could be described as very brushy with most open areas being limited to senderos. This property had a huge quail population, and we were indeed able to harvest a fair number of birds by "jump shooting" over feed. Our hunters, however, expressed disappointment because the terrain did not lend itself to a traditional quail hunt over dogs where we could conveniently hunt birds in a leisurely fashion. Thus, this is a case where the huntability issue was impacted dramatically by brush cover, but this is also a case where this problem could be addressed through proper brush control.

HABITABLITY

Habitability is an aspect of brush control that can impact an outfitter's interests in a property. More will be discussed on this specific topic is greater detail by others involved in this symposium, and habitability relative to brush control is indeed an important topic in itself.

Rather than elaborate fully on this topic, let me say I would much rather deal with a property that is "too brushy" as opposed to one that is "too open." It is my observation that game populations do indeed have a tendency to thrive better in brushy areas. Even if these brushy areas are more difficult to hunt, I would rather deal with this issue than to deal with a situation where game numbers are sparse due to lack of brush cover. I am of the opinion that brush generally favors habitability of game populations and brush control should be approached with this understanding.

THE WILD CARDS

Property Size.--

Huge properties do have a tendency not to fit the mold of my personal concerns on brush control. This issue was briefly discussed under "Huntability," and I do believe that size of property, particularly if a high fence does not exist, should be taken into consideration when evaluating brush control plans. As a rule, the smaller a property is, the more critical the brush component becomes. Small, open properties tend to be more sensitive to hunting pressure and tend to be more influenced or impacted by neighboring properties' activities.

I have seen huge properties in both North and South Texas that are relatively open but support large game populations. I rarely see low-fenced, small, open properties that harbor good game populations. Much of the explanation for this relationship is most likely due to habitability requirements of game species, but I am sure that these smaller, open properties tend to be more sensitive to hunting pressure and animals can essentially be pushed from these areas and/or exploited.

Thus, it is my observation from on outfitting standpoint that the brush component of the landscape becomes less critical on very large properties. All things considered, however, I still favor a property that has "too much" brush over one that "lacks" brush.

High Fence.--

Another factor that greatly influences my opinion on these matters is high fences, particularly regarding white-tailed deer. If a property is completely surrounded by a high fence, the brush component becomes less critical, especially from the standpoint of pushing deer onto neighboring properties and the potential consequences of such. I have seen several situations where smaller high-fenced properties that are relatively open successfully develop strong deer populations. Under high fenced conditions, security cover via brush becomes somewhat less important from a management standpoint. Even with this said, I still favor brushier properties even when there is a high fence in place, as I do feel brush adds to habitability quality, and I also feel that brush can add to the overall recreational quality of the deer hunting experience.

SUMMARY

As more emphasis continues to be placed on hunting income in order to realize a profitable ranching enterprise, brush control will become a greater issue. We are already at a stage where hunting income and hunting lease prices often exceed grazing income or grass lease prices. Those who make a living off the land may need to reevaluate their perception of brush and brush control.

From an outfitting standpoint, I prefer a property that tends to have too much brush over one that has little brushy cover. From a hunting standpoint, brush control activities should be tailored to not only address habitability requirements of those game species under management but should also be done in a fashion that compliments harvestability issues and also adds to aesthetic pleasure of recreational clients. A brush control plan that successfully addresses all of these described needs cannot be formulated into a model concept that fits all occasions, as each property is different, as is each situation. I will compare brush control to the old adage that carpenters live by:

"measure twice, cut once". As land stewards, we would all be well advised to practice this philosophy when dealing with issues such as brush control.

THE LAND ENHANCEMENT SERVICES' PHILOSOPHY FOR SCULPTING BRUSH

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Abstract: Economic incentives derived from wildlife enterprises have allowed landowners to consider the needs of wildlife in their land management decisions. Brush sculpting is a new "school" for dealing with brush on rangelands. Using the brush sculpting philosophy, Land Enhancement Services has refined a 5-step process to work with landowners to help them achieve their goals for their property. This process takes into account numerous factors involved in land resource management.

Landowners have been dealing with brush on rangelands across Texas for decades. *Brush sculpting* is the term currently used to describe the selective removal of undesirable brush in a technique that is favorable to wildlife. Wildlife has become a major consideration on properties across the state. Economic impacts from wildlife are evident in rural economies, real-estate values as well as for individual landowners. As a result, landowners are encouraged to consider wildlife in decisions involving the management of their land resources. With wildlife being considered in management decisions, there are a variety of issues that need to be addressed before any action is taken. Techniques used in brush sculpting consider various and numerous factors in land resource management. So that habitat for wildlife is created as well as the landowners' goals are accomplished.

There is an old saying: "*If you fail to plan then plan to fail!*" This quote summarizes Land Enhancement Services' philosophy for brush sculpting. This philosophy provides landowners with a comprehensive approach for sculpting brush to meet a variety of needs on individual properties. Proper planning is the key for successful brush sculpting. With this philosophy, there is a 5-step process for planning brush sculpting projects. First, identify individual landowners' goals and objectives for their property. Second, identify projects and map them using Geographical Information Systems (GIS). After the plans are identified, they can be reviewed by individuals with technical knowledge and experience to ensure they will achieve the landowners' goals. Then physical tasks with the proper equipment will be performed. Finally, prescribe follow-up treatments will be implemented to maintain and extend the life of the completed projects. By following these steps, unique habitat can be created to enhance rangelands to achieve landowners' goals. Each step needs to be completed, or the final product will not achieve the landowners' goals.

To demonstrate this process, 2 hypothetical examples of potential ranch situations will be used as identified by: Land Owner 1 (LO1) and Land Owner 2 (LO2). Each ranch will have unique features along with diverse owners. These examples are generalized; they are being presented to demonstrate the process and the amount of variability that may occur.

The first step in the planning process requires project managers to spend time with landowners to gain an understanding of their goals and objectives for their property. The goals need to be both qualitative and quantitative. Initially, LO1's main goal is to have a ranch for quail, while LO2 wants to operate a livestock enterprise. These goals are broad and need to be defined better. To narrow down these goals there are numerous questions to be addressed.

In LO1's case the first question is: Do you want to have quail or hunt quail? Having quail for hunting is important for his property. Will the hunting be on a recreational or a commercial level? The ranch's primary use will be for family and friends to hunt quail. How will the birds be pursued? LO1 uses bird dogs and a truck outfitted for hunting quail.

In LO2's case potential questions begin with: What type of livestock? Cattle. What type of operation? Cow-calf. Is there a grazing system selected? Rotational. Is there adequate fencing? Partially. Several pastures are established; others need some work. With these questions answered there is ample information to move onto the next step.

Now we need to identify potential projects that may improve the ranch to meet the landowners' goals. These projects can deal with a variety of issues, such as the availability of water in the field, ranch road system or the densities of brush across the landscape. Once individual projects have been identified, they can then be input into GIS. After they are loaded, the exact location can be determined along with the sizes and estimated costs for each project. With this information the landowner can prioritize each project. In LO1's case he may want to reduce the amount of brush in 3 areas of the ranch, then put in .85 miles of all-weather roads. He may also want to construct four ponds of various sizes across the ranch in accordance with the watershed.

For LO2's plans, he has finalized the layout for his pasture system. Some lanes need to be cleared for the fence lines and roads. After the fence lines are in, he wants to remove some invading brush from his established pastures. Finally, he would like to treat 6 areas of 20 ac. each for planting improved forage. These projects can be planned over the course of several months or years. Now that the projects are prioritized and budgeted, the plans can be taken to the next step.

The third step is to have the plans reviewed by individuals with technical knowledge and experience. This is done to ensure that the projects are completed and the landowner has improved the ranch to meet his goals. If the plans create new problems or do not achieve the ranch goals, then the plans will be revised. In LO1's projects there are 2 recommended changes. In LO2's plan there is one change that should be made. The three areas that were proposed for reducing brush were examined. It was determined that another site on the ranch had a more diverse brush community and would create better quail habitat if sculpted. Additionally, 1 of the proposed sites for a pond was tested, and there was not enough clay present. This area will need to have another method for making water available.

After reviewing LO2's plan, it is determined that the 20 ac. clearings for improved forage are not large enough. Therefore, the plan is revised for four areas of 30 ac. to be treated. Once the plans have "technical approval", the projects can begin.

The work will be performed in the "physical phase." The proper equipment should be utilized in order to produce the highest possible quality product. For LO1's plans, the amount of brush to be treated may allow for individual plant grubbing instead of having to root plow a large area. A root plow is an angled blade that is pulled behind a large bulldozer, 12 - 18 in. below the soil surface to shear the roots from the plant. There are a variety of grubbers designed to cut individual plant's roots. Grubbing does not have as dramatic an effect as root plowing. This is because the root plow's blade cuts through 8 - 10 feet of soil at a time; the grubber's blade is smaller and is generally used on 1 or 2 plants at a time. The pond dams should be cored to prevent water from seeping under them in the future. This calls for the topsoil to be removed from the dam site and be replaced with clay. When treating the 30 ac. areas in LO2's plan, do the sites need to be cleaned to farm quality or can they be left in range quality? If the sites are going to be farmed, a root rake should be utilized to remove woody debris from the soil. If not for farming, this may be an unnecessary procedure. In a range situation, it may not be necessary to remove the woody debris from the soil. Once the physical work is completed, there is only one step remaining.

The final step is determining follow-up procedures to maintain and extend the treatment life of the completed projects. If there is no future input for the projects, the brush will return and the work that was performed may be lost. The ongoing maintenance should also be reviewed by technical personal. Follow-up recommendations for LO1's projects may include: spot treatment of invading brush in treated areas, some type of soil disturbance to encourage forb growth for the production of a food source for quail, use of a maintainer on the all-weather roads, and the elimination of brush off the pond dams so that holes or cracks do not develop causing the dams to leak.

Recommendations for LO2's projects could include: treating brush in fence lines and spot treating brush in his established pastures as well as the woody vegetation encroaching in the 30 ac. areas.

When all these steps are correctly applied using the resources available, a high- quality product can be created through brush sculpting. If one of the steps is omitted, the landowners' goals may not be achieved. By using this sculpting process, diverse goals are met for individual landowners, and the end result is positive.

LAND FRAGMENTATION IN TEXAS: WHAT ARE THE IMPLICATIONS?

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Abstract: Driven by changes in the demand for rural lands, the ownership sizes in many areas of Texas are increasing in number and decreasing in size. This trend may result in fragmented habitats, and landscapes that are more difficult to effectively manage for wildlife and other natural resources. The most apparent trend is a recent loss of mid-sized ownerships (500-2000 acres), accompanied by a substantial increase in numbers of smaller ownerships, with ownership consolidation perhaps occurring in some areas. Land fragmentation rates do vary according to proximity to population centers and the desirability of land for recreation. The implications of land fragmentation are not completely understood, but the phenomena should be considered when devising programs for effectively managing brush, water, and wildlife.

The participants of a recent working symposium on *Private Land Stewardship and Conservation* held at Texas A&M University identified ***land fragmentation*** as 1 of 4 major issues impacting the conservation of natural resources on private lands in the US. This issue was a consensus among 48 participants from across the country, many of whom were representatives of private landowner groups. So, what is land fragmentation? And, just why might the phenomena be receiving so much attention? The purpose of my presentation here is to provide some background on fragmentation, and to give an update on the fragmentation trends in Texas. Finally, I will review some of the potential implications of fragmentation on brush, water, and wildlife management.

WHAT IS FRAGMENTATION?

In the context of land and natural resources management, fragmentation is usually meant to describe 1 of 2 trends - ownership fragmentation or habitat fragmentation. While the first of these may lead to the second, they may operate independently. Likewise, habitat fragmentation might occur independent of ownership fragmentation. In identifying fragmentation issues, some have tended to treat both of these under the broader headings of *land fragmentation* or *landscape fragmentation.*

Ownership Fragmentation

Ownership fragmentation is routinely thought of as the division of rural lands into smaller parcels that remain in rural use. Ownership fragmentation may result in rural parcel sizes too small to maintain the economy-of-scale for efficiently practicing traditional farming, ranching, and forestry operations.

Because many wildlife management activities require a landscape perspective, when ownerships become fragmented, managing wildlife habitats may become more difficult. Simply put, **the smaller your property, the more your operation is influenced by your neighbor's decisions**. As important is the fact that certain management practices lose both efficiency and effectiveness when applied to small ownerships. The costs of prescribed fire or aerial herbicide application, for example, can become prohibitive on smaller acreages. Likewise, the ability to influence land management decisions across a large portion of a local watershed can become infeasible in a landscape of fragmented ownerships.

Habitat Fragmentation

The term habitat fragmentation is used to describe the progressive change in one type of continuous habitat coverage to a set of habitat patches, or remnants. Fragmentation of a landscape produces remnant patches of important habitats surrounded by a matrix of different land uses (Saunders et al. 1991). Some land uses can result in fragments of otherwise high-quality habitats that are simply too small to provide the needs for some native wildlife species that otherwise might occur in that habitat. For example, habitat remnants are not useful for a particular bird species if they are smaller than the minimum territory for that species (Moore and Hooper 1975). Habitat fragmentation may encourage non-native or invasive species that compete with native species. Some native species may suffer from increased predation and loss of mating choices as habitat remnants shrink and the proportion of edge to interior habitats increase. In general, these impacts are called *fragmentation effects*, and they result from *habitat fragmentation*, or what some call *ecosystem fragmentation*. Species respond different to habitat fragmentation depending upon life history, available competitors, dispersal abilities, and composition of the habitat matrix (Whitcomb et al. 1981).

TRENDS IN TEXAS

Rural Land Ownership Status

At present, rural lands in Texas account for approximately 144 million acres. At the latest accounting (1997), these lands were divided among approximately 194,000 landowners (US Department of Agriculture 1999). About 77% of these ownerships are less than 500 acres (Fig. 1), but approximately 81% of the total acreage is owned by the remaining 23%.

Average ownership sizes vary across Texas, according to proximity to population centers and historical land uses. If one were to consider the state as being roughly divided by Highway 281 (Wichita Falls to McAllen), we find that smaller ownerships are concentrated in the eastern portion of the state. Of course, this is also where the vast majority of the state's population resides. Average ownership sizes in the counties of the eastern portion of the state are generally less than 500 acres, and the averages tend to increase as one travels westward. With the exception of El Paso County, counties in the Trans Pecos have average ownership sizes exceeding 10,000 acres.

Land conversion trends

Although the focus of this account is on the fragmentation of rural lands (i.e., rural lands divided, but remaining rural), it is necessary to at least consider the rates of land conversion from rural to urban use. Texas lost 2.6 million ac. of rural land to urban development from 1982 to 1997. Even though this rate of rural land conversion led all other states for that period, viewed in the context of our total land area (about 167 million acres), this conversion rate might not seem so alarming. However, many residents in the fastest growing areas of the state may not appreciate any calming influence of these statewide statistics. Land conversion is most prevalent in the vicinity of the states major metropolitan areas (Dallas-Fort Worth, Houston, San Antonio, and Austin) and along the connecting Interstate highway system.

Land fragmentation trends

Recent competition for rural lands has resulted in an overall increase in the numbers of rural ownerships. In the five years between 1992 and 1997 the number of rural ownerships in Texas increased by 7%, while average ownership size decreased from 725 to 676 acres (Fig. 1, US Department of Agriculture 1999). During this period, average rural ownership sizes decreased in 74% of Texas' 254 counties. Because ownership patterns in different parts of the state were likely responding to slightly different market pressures and agricultural economies, the use of statewide averages to gauge trends in ownership size may be misleading. In fact, some of the more relevant changes may be masked by the use of these averages.

Overall, the state experienced a loss in mid-sized ownerships (500 to 2,000 acres), while ownership numbers in all categories < 500 acres increased - and there was a slight increase in those ownerships >2,000 acres (Fig. 2). The 1992-97 increases in ownership sizes >2,000 acres suggests that ownership consolidation (the opposite of fragmentation) might be occurring in some areas of the state. When ranked according to the increase in ownerships <500 acres, the top 10% of "fragmented counties" experienced a net loss only in the 500-1000 acre ownership size class (Figure 3a). Even in those counties where consolidation might be occurring (i.e., top 10% based on an increase in >2,000 acre ownerships), the smaller ownerships continued to increase while mid-sized ownerships (500-2000 acres) experienced net losses (Fig. 3b).

These data suggest that ownership consolidation may have occurred simultaneous with ownership fragmentation, perhaps even in the same county.

However, from these data, one cannot reliably determine whether the increase in ownership numbers >2,000 ac. might be occurring within that category. Even though these data beg for a more spatially-explicit analysis, the evidence points out a strong trend toward a widespread gain in smaller ownership classes (<500 ac.), at the overall expense of mid-sized ownerships (500-2,000 ac.). These figures further suggest that some counties might have realized some ownership consolidation at the same time as fragmentation was occurring.

WHAT DRIVES FRAGMENTATION?

If we consider the motivations behind the acquisition of rural lands in Texas, we find that that agricultural production is no longer the primary reason for buying land (Fig. 4). The production-oriented landowner that once dominated our land market has been replaced by land "consumers" - those that are primarily interested in hunting, fishing, and other outdoor recreation, as well as scenic values, and other amenities that are not customarily considered when calculating the productive value of land. As a result we are likely experiencing a fundamental shift in the ownership, land use, and tenure patterns of private rural landowners. This phenomenon has social, economic, political, and ecological consequences - not all of which we can predict. We can predict, however, that as the market value for rural lands exceeds its productivity value, we should expect a shift toward a bimodal distribution in ownership sizes - in other words, a loss in mid-sized ownerships with an increase in both small and large ownerships (Pope 1985).

As recognized by Pope (1985), the market value of the surface rights to Texas rural lands are largely a function of ***productive value*** and ***consumptive values***. The productive value of land is normally described as the discounted present value of the future incomes expected from commodity production (*e.g.*, agriculture or forestry). The consumptive value of rural land is not as easily defined - but in general it is the value placed on land according to aesthetic and recreation appeal. Consumptive values vary with land's proximity to major population centers; and factors such as incomes, availability of credit, and personal preferences (Pope 1985).

According to Pope's model, if an increase in consumptive demand is accompanied by a declining agricultural economy, then some agricultural landowners may actually increase their ownership sizes to gain a greater economy-of-scale for their farming and ranching enterprises - a business decision.

Ownership fragmentation tends to occur when consumptive demands for rural farm and ranch lands exceed the per acre productive values of those lands. Highly desirable lands tend to be broken into smaller parcels that can be sold at a much higher price per acre than the original ownership. New buyers, not being limited by considerations of income from agricultural productivity, can afford to pay prices that exceed the land's value for agricultural uses. In 1998, for example, the average agricultural productivity value of rural land was only 16% of the total market value. New buyers with off-farm incomes have little need for large land acreages in order to experience rural living. As a result, lands are subdivided to maximize per-acre returns.

OWNERSHIP FRAGMENTATION MAY OCCUR INDEPENDENT OF URBAN SPRAWL

At times, it is assumed that ownership fragmentation is simply a part of the overall loss of rural lands to urban sprawl, or that loss of rural land unavoidably follows ownership fragmentation. Although these commonly occur together, the 2 can be unrelated. For example, the owner of one 2800 ac. property might subdivided into eight 350 ac. properties, each purchased by separate landowners. Under this scenario, we still have 2800 ac. of rural land - that is still 2800 ac. of wildlife habitat, and still 2800 ac. that might require some form of brush management. This scenario is not uncommon in many areas of Texas where rural land is sought for its recreational values - and is not adjacent to a metropolitan center. Due to growth patterns in some areas of Texas, however, the phenomena of ownership fragmentation and rural land conversion does seem to be simultaneous (e.g., the Hill Country counties of Kendall, Hays, and Williamson).

WHEN DOES OWNERSHIP FRAGMENTATION CAUSE HABITAT FRAGMENTATION?

Ownership fragmentation results in habitat fragmentation when the diverse management practices of several landowners results in a landscape where habitat remnants are too small and too far apart to support the life history requirements for the species. Even adaptable species such as white-tailed deer can suffer reductions in overall carrying capacity and fawn survival if certain habitat components (e.g., fawning cover) are spatially isolated due to poor coordination among neighboring landowners in fragmented landscapes.

Habitat fragmentation occurs at different scales for different species. In general, habitats are considered fragmented when the entirety of the habitat needs for a species are isolated to the extent that the costs of moving among the habitat patches required for meeting basic requirements exceeds the overall benefits derived by the species.

Ownership fragmentation alone does not degrade native wildlife habitats. In fact, in landscapes heavily dominated by a single agricultural practice, the increased habitat diversity resulting from a variety of new management objectives may actually increase the overall utility of the habitat for some desirable species. For example, in some areas of Texas, the replacement and/or reversion of large expanses of 1 habitat structure toward a series of habitat patches with variable vegetative structure may actually improve the habitat for selected species such northern bobwhites (*Colinus virginianus*) (Kuvlesky 1990).

IMPLICATIONS OF LAND FRAGMENTATION

The implications of land fragmentation for managing brush, water, and wildlife in Texas are complex. I assume that much of this symposium will center on resolving the potential for conflicting management objectives of brush management for water production *versus* brush management for wildlife. Land fragmentation adds yet another dimension to this challenge.

I have addressed here only a summary review of some of the potential issues associated with fragmentation. One thing is for certain: much of Texas' rural landscape is changing - not only physically and ecologically, but socially. Many of the potential effects are yet unknown. One of our larger challenges is to gain an increased understanding of what drives the land use decisions of new landowners, and how their collective decisions ultimately influence natural resources across a fragmented rural landscape. Realizing the potential problems posed by land fragmentation is less complicated than devising solutions. As natural resource managers, here are some of the questions we must address:

1. Is it possible (or even advisable) to take action that would reverse the trend toward ownership fragmentation in Texas?
2. What is the real relationship (if any) between ownership fragmentation and habitat fragmentation, and how does this vary across different ecological regions?
3. How do we most effectively coordinate the management activities of private landowners in fragmented landscapes to avoid habitat fragmentation?
4. For water management, how do we meet the threshold requirements for brush management in a landscape of multiple small ownerships with conflicting management objectives?
5. And finally, how do we grapple with natural resource conservation issues in rural communities in an atmosphere of "culture clash" between newcomers and longer-term landowners?

ACKNOWLEDGEMENTS

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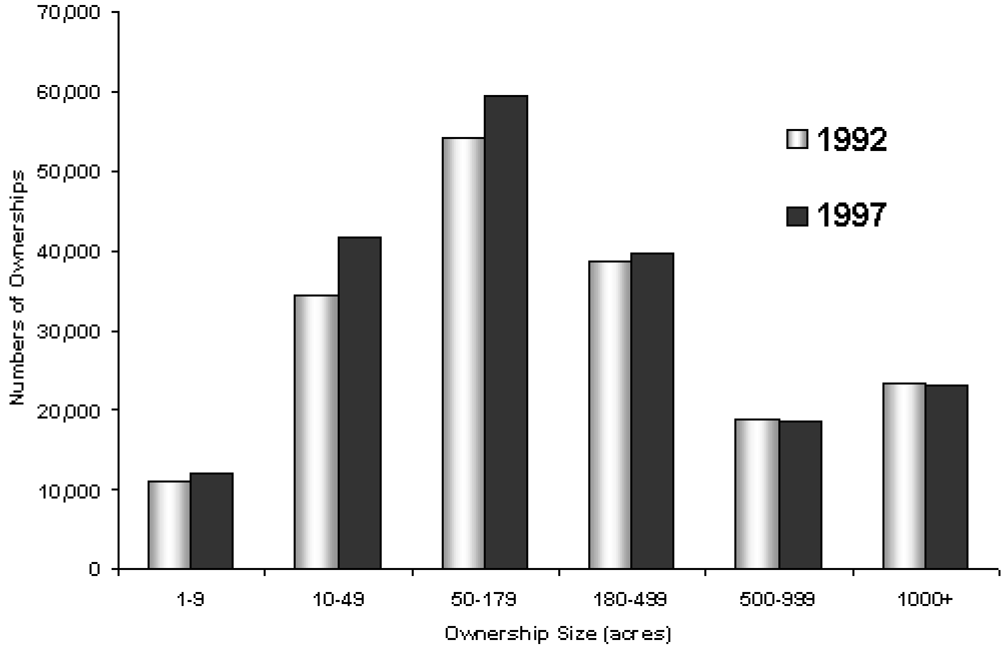

Figure 1. Ownership size distribution for 144 million acres of rural lands in Texas, 1992 and 1997.

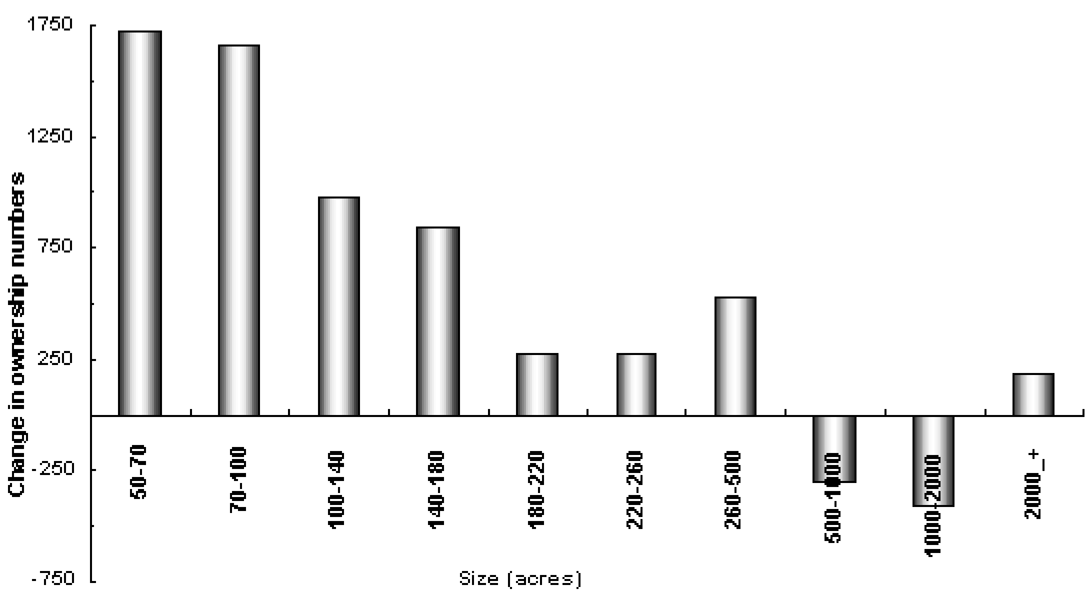

Figure 2. Statewide change in ownership numbers by size class (acres), Texas, 1992-1997 (Data source: Census of Agriculture 1992 and 1997, USDA National Agricultural Statistics Service).

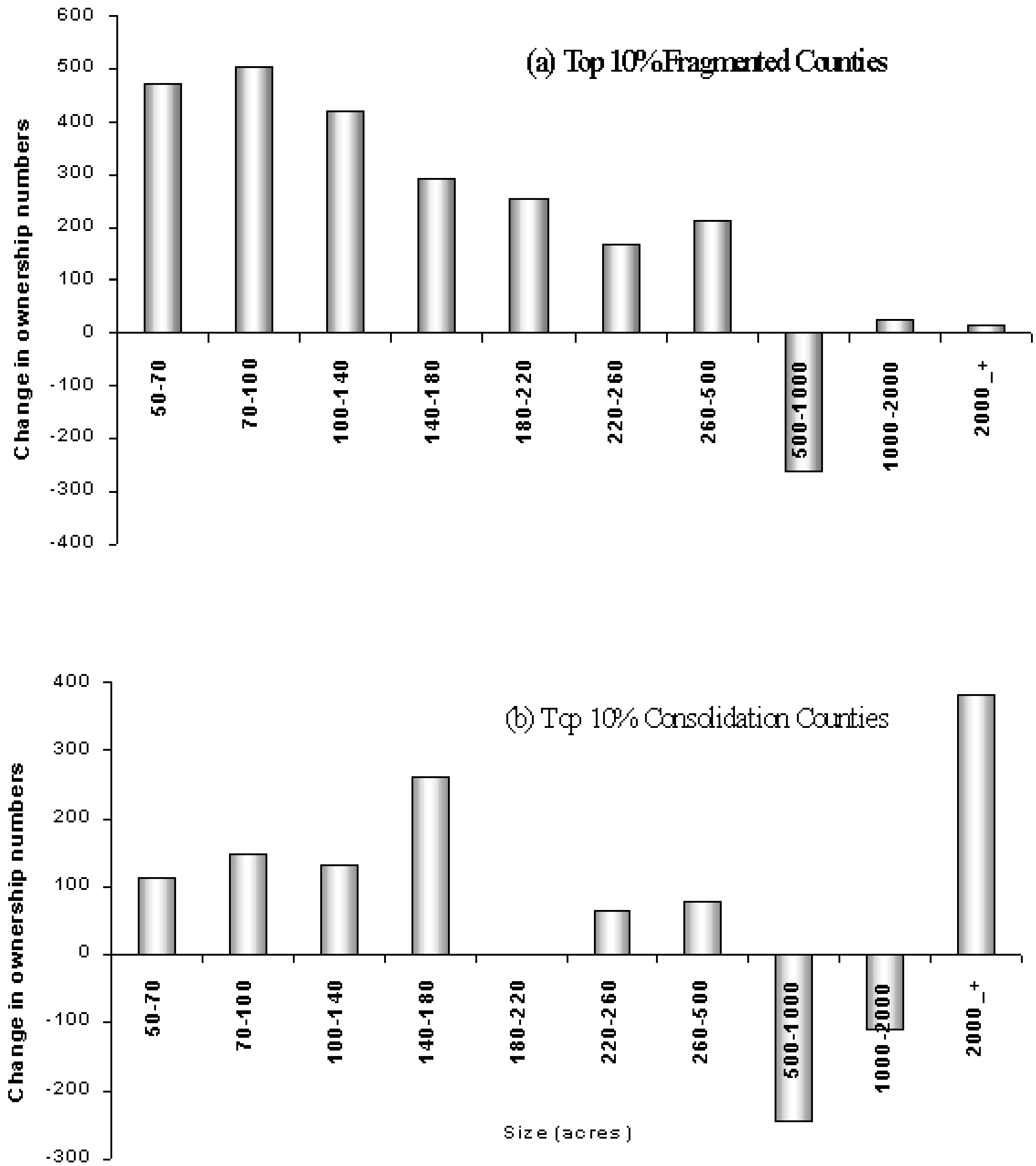

Figure 3. Change in ownership numbers by size class, 1992-1997, for (a) top 10% of Texas counties according to gains in 50-500 ac. ownerships; and (b) top 10% of Texas counties according to gains in 2,000+ ac. ownerships (Data source: Census of Agriculture 1992 and 1997, USDA National Agricultural Statistics Service).

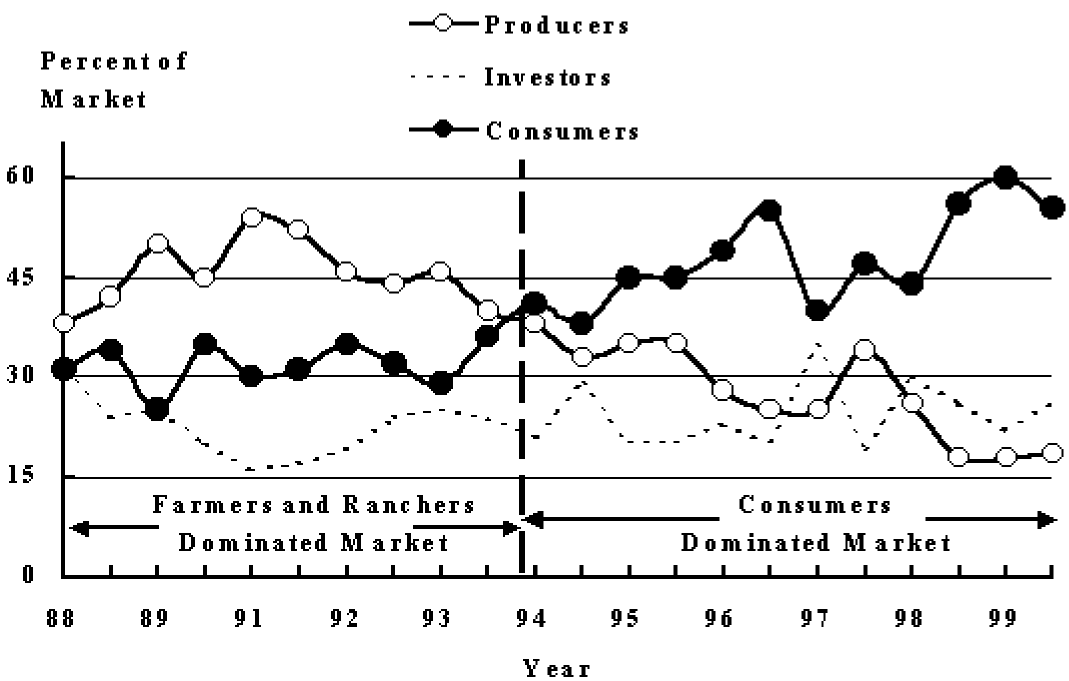

Figure 4. Proportion of Texas rural land buyers characterized annually by one of 3 major motivations for land purchase (see text for definitions of categories), 1988-2000 (C. Gilliland, unpublished data, Texas A&M Real Estate Center).

CHANGES IN RURAL LAND OWNERSHIP, STEWARDSHIP AND IMPACTS ON LAND VALUE

BILLY SNOW,

Abstract: This article is based on my observations of changes throughout the Texas Hill Country over the past two decades. It is influenced by the multitude of brokers, realtors, land traders, estate executors and other appraisers with which I deal with daily. The Texas Hill Country has been known as one of the major livestock producing areas (principally sheep and goats) for many decades. It has also been looked to as one of the major recreational areas of the state due to its abundant wildlife resources and highly desirable habitat for whitetail deer (*Odocoileus virginianus*) and turkey (*Meleagris gallopavo*). This has been largely attributable to the live oak (*Quercus ??*), shin oak (*??*), mountain juniper (*??*) and other desirable forbs, legumes and woody plants found throughout the region. This paticular "green belt" area of the state with its spring fed creeks and rivers has long been one of the "unique" areas enjoyed my literally thousands of tourists, travelers, kids at summer camps, hunters and outdoor naturist.

A large portion of this area was originally held in relatively large holdings by families who were true stewards of the land. Cultivated ground was limited, ranches were typically diversified in agricultural enterprises and brush control a constant battle. Brush control to many of the old timers was a simple solution of how heavy to "goat" pastures to achieve the desired browse line, keep shin oak and young cedar in check. Numerous years of hunting "trophy bucks" only, coupled with a population explosion of deer numbers principally attributable to the elimination of screw worms, resulted in a decreased gene pool and animal numbers and size that made many landowners take stock and re-evaluate what it was they truly wanted to raise and market.

The exploitation of the Hill Country land market began in earnest in the early 1970's with the completion of Interstate 10 in western Kerr County. Accessibility and time/distance travel relationships were greatly enhanced. Beginning in the late 1970's - 1985, this market saw one of the fastest pace appreciation rates ever experienced. Due to a thriving economy (inflation-driven) the desire to own land for hunting and recreational purposes was aided by a highly leveraged banking economy. This period also saw one of the most profuse conversions of productive ranches into consumptive use with development or subdivision of large ranch holdings into “ranchettes” or small-acreage homesite/ recreational tracts. The crash or bust that occurred in late 1985 saw numerous banks go under. Lenders, were the largest land owners and a soft market during the following 4-5 years, until the inventory of real estate was absorbed, resulted in a stabilized market with values almost back to where they existed in the late 1970's.

By 1990, the market has stabilized, and a very slow but gradual increase in land values was seen to emerge. The buyers through the early part of the 1990's were generally people who had remained liquid with strong financial statements. A large percentage of these buyers could be typified as "old money" seeking a storehouse for wealth and enjoying recreational pursuits as well. With the mid to late 1990's, a new generation of "stock market" wealth, seeking diversification had emerged. The profile of current ranch purchasers will generally fall into one of 2 categories. The first is professionals that have sufficient discretionary income to own their own ranch/hunting preserve versus leasing these services. Second are the sellers that are avoiding capital gains via a 1031 exchange. With the current tax laws for like-kind exchanges, numerous transactions observed are at a premium but are palatable compared to the tax hit they would have incurred. The number of cash buyers (no financing required) is astonishing.

What characteristics or physical attributes of properties is driving the current market? For the most part, live water is the number one attribute being sought. Deer-proof fencing follows with a close second and a "manicured" land clearing program is third. Many of these new purchasers have the income and financial resources to do what they desire with the property. Building improvements (primary residence or lodge) being the first order of priority or construction, is advantageous. There is such a backlog for construction services, that a premium is often paid to forego the time delays.

How conservation minded are these new buyers and what sort of land stewards do they make? For the most part, these buyers have rural beginnings in their backgrounds and have made their own money to enjoy this lifestyle. They typically are well educated with business backgrounds. They will make economic decisions based on whether it translates to maintain or enhance value of their long term investment. The recreational benefit can almost be considered the "interest earned" on their investment during the holding period. Recent analysis of market rents and transactions show a relatively low (1 - 3% cash on cash) returns annually due to lease prices in comparison to cost per ac. These investors anticipate long term appreciation at resale to net them an 8 - 10% internal rate of return overall. This relatively safe, long term (5 - 10 year) investment while enjoying recreational pursuits will generally last at maximum 20 years or 1 generation. How do these factors affect current land management with regards to conservation and wildlife?

Wildlife is probably the foremost concern with these buyers. Texas Parks & Wildlife and private game biologist are probably working more game management programs now than ever before. Game herds size, buck to doe ratios and dietary needs are having positive effects on considerably large number of acres. This is being accomplished primarily through deer-proof fencing and management and keeping numbers in balance with available forage.

Clearing and brush control is extremely costly and mechanical due to availability of labor and costs. So much of the Hill Country has become virtually choked with cedar that range conditions have been severely impaired. The current breed of landowner has the resources to properly conduct (over a long period) clearing and conservation measures that will be rewarded in price received or return on investment. The primary goal is to educate these land owners to assist them in making prudent decisions.

INTEGRATED MANAGEMENT FOR WATER, BRUSH AND WILDLIFE ON TEXAS RANGELANDS

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Abstract: Rangelands in Texas produce a multitude of benefits to landowners and citizens. More water, brush, wildlife, livestock or other benefits can be produced from rangelands by changing the landscape: 1) to increase water runoff, storage and/or percolation to aquifers; 2) to reduce detrimental impacts of management on desired brush species and/or allow natural succession to occur; 3) to promote a suitable mix of brush, grass and forbs in mosaics of different densities to provide cover, food, and water for select wildlife species or natural landscapes for natural populations of wildlife species; 4) to promote grass production with proper mixes of forbs and/or brush to meet diet requirements of livestock species grazed, or 5) to promote other values, e.g.. scenic quality through promotion of wildflowers. Each benefit has certain requirements from the landscape that can be increased by manipulating components of the natural system. Healthy rangeland ecosystems can be sustainable if managed within their respective "carrying capacities" for each product or combination, i.e., high quality water, livestock, wildlife products and other benefits and products or combinations. However, natural ecological processes must be maintained without accelerated loss of limited resources, ie., water, soil, nutrients and biodiversity. Unlike an agronomic system, the rangeland resource depends on natural ecological functions to maintain itself and produce benefits within a "carrying capacity". More water, more brush, more wildlife, etc. cannot be attained simultaneously from the same landscape nor the resource sustained as a natural ecosystem. An integrated approach to rangeland resource planning and management is needed to 1) **always** sustain the rangeland resource and 2) within the carrying capacity optimize water, brush, wildlife, and other benefits and 3) without detrimental impacts on other ecosystems or citizens.

AN ECOSYSTEM PERSPECTIVE FOR BRUSH MANAGEMENT PLANNING

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Abstract: An ecosystem approach to planning requires integration of physiographic, climatic, edaphic and biological components of natural systems in the planning process. It recognizes the influences of these components on decision-making and, conversely, recognizes the influences of management decisions on all system parts. It is the most logical, effective and efficient way to plan and implement brush management. The key words are integrated and planning. Steps in the planning process for brush management should include 1) setting of enterprise objectives, 2) conducting a comprehensive inventory of natural and other resources to identify resource potentials and factors preventing obtainment of goals, 3) matching technically feasible treatments alternatives with specific problems, 4) estimating resource requirements and production impacts (developing costs and benefit information), 5) performing economic analysis, and 6) selecting a plan, implementing the plan, monitoring the results and cycling "real time" information back into the planning process. There are two particularly critical issues in planning brush management. One is to plan all elements, brush management, grazing management and wildlife management simultaneously. The other is to understand that the best conceived and executed plan cannot overcome lack of follow-up brush management and grazing management. The result of not implementing these practices will be failure to meet the expected level of improvement.

THE PLANNING FUNCTION OF MANAGEMENT

Planning is the first function of management (Fig.1). It is basically decision-making; that is, choosing from alternative courses of action. All planning begins with setting objectives, i.e., a vision of how we want things to be at some future time. Brush management plans, like all plans, become the blueprint or road map that "plots the course" between where we are today and the goal we want to reach. Thus, plans should provide a rational approach for meeting enterprise objectives. The integrated part of planning simply means that all components of the resources important to meeting management's goals are included in the planning process. In most cases, these components include livestock and wildlife, as well as aesthetic or recreational amenities that may involve physical structure of the vegetation and location on the landscape. The bottom line - if you do not develop an integrated brush management system, a plan with a long-term strategic view to range improvement - chances are you will dramatically reduce the potential for biological or economic success, or both.

INTEGRATING BRUSH MANAGEMENT WITH OTHER ENTERPRISE OBJECTIVES

The goal of brush management is often to encourage desirable forage plants in order to increase livestock carrying capacity or to modify vegetation composition to enhance wildlife habitat. In some areas, brush management may also be used to manipulate vegetation for the purpose of increasing water yield from rangelands. The record is clear that these are realistic expectations from the use of current brush control technologies. Just as clear, however, is the fact that improper grazing management after brush treatments can undermine any improvement goal and result in failure (Scifres 1980). For instance, optimum response from many brush management procedures requires closely timed deferments from grazing which may be achieved through planned grazing systems, restructuring of livestock herds, and/or use of land outside the system (Stuth and Scifres 1985). The way land is grazed after treatment affects the response of plants and the time required to realize benefits of treatments, whether they are increased forage production, enhancement of wildlife habitat or increased water yield. Proper use and rest allow desirable plants to gain vigor and competitive position with less desirable plants. The optimum approach is to plan brush, grazing and wildlife simultaneously in order to identify opportunities and constraints associated with possible combinations of alternative treatments.

The ease with which brush management strategies can be integrated with planned grazing systems over a given time depends on the physical and logistical characteristics of the grazing system. The arrangement of watering locations, the shapes of pastures, the placement of fences, and the locations of corrals and roads may limit treatment alternatives. Other factors such as the number of pastures; the graze/rest sequences used; the flexibility in moving livestock; the ability of forage to absorb short-term heavy grazing; the sensitivity of the range to stocking rate; and the portion of the ranch committed to a structured grazing system will all interact and affect compatibility of grazing systems with long-term brush management strategies (Stuth and Scifres 1985). When grazing management and brush management are planned simultaneously, it is critical that they be compatible. If either part of the system is given priority, the other must be adjusted to fit within the context of the overall management program (Hanselka et al. 1996.)

Wildlife species have different habitat requirements that must be accommodated in a brush management system, particularly if objectives include income derived from hunting leases (Holechek 1981). Some wildlife prefer areas of dense brush. Some must have open areas. Most species prefer vegetation patterns in which there are both brush and open areas. Seldom is an entire ranch treated with brush management at one time. When a certain portion of a ranch is scheduled for range improvement, the first step involving wildlife management should be to determine the importance of that segment to the wildlife habitat on the ranch as a whole. Size of area, proportion of the total ranch area and the importance of this area's contribution to ranch wildlife habitat before treatment all affect wildlife/brush management strategies. A cover mosaic should create patterns that allow the treated segment to carry its own populations of wildlife, to contribute to diversity and interspersion of the habitat in the surroundings, and to favor wildlife observations (bird-watching, etc.), hunting or other activities. Brush treatment should be conservative, relative to proportion of total area cleared, when managing white-tailed deer (*Odocoileus virginianus*) in a region where adjacent land already lacks adequate cover or where the brush being treated acts as a shelter in a more open regional habitat. Conversely, if the treated area is part of a large region of mature brush thickets, treatment can be more aggressive (Inglis 1985). In order for brush treatments to be beneficial to both wildlife and livestock, the following should be considered, 1) size and pattern of the area to be treated, 2) management options available, 3) application methods, 4) timing of applications and 5) the presence of endangered species.

INVENTORY - FINDING THE RIGHT "STARTING PLACE"

Determining the most technically, economically and ecologically efficient plan for reaching brush management objectives is a major and often complex challenge on natural landscapes. Effectively dealing with this challenge requires a comprehensive inventory of ecosystem resources. The inventory should support and validate the basis for the objectives you have set. There should be a "feed-back loop" between objective setting and the inventory process. After the resources have been inventoried relative to their current state and potential, the objectives should be reevaluated relative to their congruency with the resources. The inventory should provide baseline data about the soil, water, vegetation and physical resources on the ranch. It should provide a comparison of present production to potential, and identify problems constraining achievement of goals. The inventory should allow matching problems with the best technology for solving them. It should aid in projecting post- treatment responses and rate of change. These projections, in turn, should facilitate economic assessments of alternate management strategies. In short, if plans bridge the gap between where we are and where we want to go, resource inventory gives us the starting place from which to measure progress toward goals. "You can't tell how far you have gone unless you know where you started!"

The inventory should also identify important landscape attributes, such as archaeological sites and important habitats for nature-based tourism that may be important to the enterprise. An assessment of wildlife habitat and how it relates to current and planned vegetation modifications is also a significant element of the inventory. Lastly, the inventory should locate existing facilities, such as water locations and other structures that impact wildlife and livestock distribution. All of the things furnished by inventory should be spatially referenced to facilitate decision-making. The primary reason for resource inventory is to provide information for integrated planning where the interactions of livestock, wildlife, vegetation and ecological site management can be considered at the same time.

Because inventory of large areas of natural resources requires considerable expertise and can be a time-consuming process, it may be overlooked by planners. In such cases, the capability to make accurate projections of the influence of proposed management scenarios is reduced or lost. This reduces the capability to assess both the biological and economic implications of decisions before the fact, and, in turn, reduces management efficiency. Being able to compare the economic feasibility of alternate courses of action before making a financial commitment should be a high priority goal of management.

USING AN ECOSYSTEM APPROACH TO THE INVENTORY PROCESS

An inventory of components of natural ecosystems should include the differences in landscapes significant to decision-making based on soils, topography, and vegetation. It should provide for analysis of range landscapes at the most practical level for meeting management objectives. This means segregating the landscape into areas for consideration of improvement practices that are matched to their specific needs. Above all, it should facilitate efficiency, both technical and economic, in the planning process.

What are the components required for a comprehensive, ecologically-based resource inventory? Good quality aerial photographs of an appropriate scale are essential. A scale of 1:30000 or less with high contrast black and white or infrared is desirable for range landscapes. Digital map images that can be downloaded into GIS, such as Arc-View or the new WEBGLA natural resources planning software, facilitate the planning process by providing spatial capabilities. USGS quadrangle sheets with topographic information are helpful.

Where the intensity of planned land use includes grazeable cropland, pastureland or hayland, standard soil survey data is essential. Soil surveys delineate landscapes into different soil mapping units and provide detailed information about each profile, including capabilities and limitations, as well as productivity potential under different uses. For lower intensity uses, such as rangeland, standard soil survey is highly desirable as a means to correlate soils with ecological sites.

THE VALUE OF ECOLOGICAL SITES AND SITE DESCRIPTIONS IN THE PLANNING PROCESS

When completed, there will be likely be over 600 ecological site descriptions for Texas rangelands (Sanchez 2000). These site descriptions are the "encyclopedias" for natural landscapes, providing planners with an ecosystem perspective for decision-making. They describe each site and the factors making it unique to other areas of the landscape. They provide a comprehensive review of the climatic factors associated with sites, including precipitation (mean annual and monthly), temperature distribution, humidity, wind, frost-free days and other useful data. Site descriptions also discuss influencing water features, such as wetlands, and soil data, including parent material kind and origin, depth, texture, available water holding capacity, drainage and permeability classes (NRCS 2000).

Plant communities common to sites and the ecological dynamics that result in transitions between steady states are described and a diagram representation of transitions and states is provided (Fig. 2). These descriptions include community dynamics and the influence or absence of fire, brush management, grazing management and seeding on vegetation composition within states and across thresholds between states. Ecological site dynamics are extremely important to brush management planning, as they identify the mechanisms of change, when and how it occurs, and when it begins to influence opportunity to reverse trends with the least inputs (Fig. 3.)

Ecological site descriptions include the composition of different plant types, grasses and grasslike plants, forbs, shrubs and vines, and trees for the historic plant community. They also list the individual plant species contained within each plant type. Air-dry production data is provided for the site, both for plant types and for individual species and groups of species within the types.

The historic plant community described for an ecological site is an approximation of the natural (or climax) plant community found on the site in the absence of abnormal disturbances and physical site deterioration. Historic plant communities have been reconstructed for many years by studies of relict areas, evaluation of different degrees of grazing use, ecological research dealing with soils and plant communities, and botanical records and historical accounts. The value of historic plant communities within site descriptions is to indicate potential of the site in both aspect and relative production of plant types, species and groups of species. Few, if any, of us here today have seen ecological sites in Texas that represent the historic plant communities. It is important for planners to have this vision of landscapes to relate to current and planned plant compositions.

Each of the other plant communities that occur within states are shown in site descriptions, as well as an estimate of the community annual production by plant type and percent deviation from the historic plant community. A plant growth curve that provides an estimate of the percent of total annual production from the site by months is also available for each community. These data are especially helpful in identifying seasonal influences on site yield important to livestock and wildlife management decisions.

Ecological site descriptions also provide preference values of the vegetation associated with the site for a variety of animal users, such as cattle, goats, white-tailed deer, bobwhite quail (Colinus virginianus) and others that may be important. Site interpretations contained in the descriptions include the animal community, hydrology functions, recreational uses, wood products and others. It is obvious how these data would also support decision-makers in determining brush control methods and placement on landscapes.

Ecological sites are a fundamental part of natural resource inventory. They are the products of the environmental factors that influenced their development. They are a distinctive kind of landscape that differs from other kinds in their potential to produce native plants. These separations of parts of the landscape have very practical applications. For example, the efficacy of brush control technologies can be related to site characteristics, such as soil texture. Relative internal rates of return on investment in brush control may also change dramatically between ecological sites receiving the same treatment (Fig. 4.) Unless they are severely influenced by abnormal events, ecological sites do not change. Certainly, the vegetation composition changes, as represented in the diagram showing states and transitions (Fig. 1 and 2). However, vegetation will respond to secondary succession and/or intervention with "activation energy" if the climax soil profile has not been severely degraded.

MORE SPECIFIC INFORMATION IS REQUIRED ON WOODY PLANTS AND WILDLIFE

The inventory should also include very specific information on woody plant composition. This can be accomplished with a variety of methods, including line transects that measure canopy intercept by individual species, or "belt" transects that can provide both canopy cover and density data. It may also be important to record woody plant height and other attributes, such as average basal diameter, which can affect control technologies. Woody plant densities are also important for selection of broadcast versus individual plant treatments.

A part of the inventory should be an assessment of current and projected wildlife populations so that planners are cognizant of the influence of brush management on habitat and subsequent wildlife quantity and quality. Brush manipulation can negatively impact important wildlife species, or it can be used as a positive influence for habitat improvement. For example, both foliar and soil applied herbicides can be used in variable rate patterns of application to create mosaics of diverse vegetation types and enhance habitat (Scifres and Koerth 1986). High utility areas can be identified from aerial reconnaissance or with aerial photographs. If digital images are available, coordinates for designs can be loaded into GPS units on application equipment to allow precise patterns of application on the landscape.

Determining the relative percent composition of woody plants by individual species allows more precise planning for control technologies. It also allows more accurate determination of the response to expect from different practices that could be used based on technical efficacy. For example, it will be possible to predict if a secondary species will become a future problem based on responses to the initial treatment selected. The release and spread of pricklypear (*Opuntia spp.*) following some mechanical practices, or the increase in non-susceptible understory species following chemical control of oaks (*Quercus spp.*) or mesquite (*Prosopis glandulosa*) are well known examples of such problems.

Additional information accrued in the inventory process should include the percent of years that are > 20 % above, 20 % below and within 20% of the annual average precipitation calculated from historical averages. Changes in herbage and browse production associated with each of these percentages should also be determined to show growth potential of forage resources and for assessment of risk (economic analysis) associated with improvement technologies

USING THE RESOURCE INVENTORY FOR BRUSH MANAGEMENT DECISIONS

Once ecological sites and response units are determined and adequate information is accrued on the woody plant component of vegetation, the following questions can be answered:

1. Is there a brush problem (is brush the most limiting factor to increasing herbaceous forage production, providing habitat amenities or other goals for the site)?
2. Which species is(are) creating the problem?
3. Which species are desirable for livestock or wildlife nutrition?
4. Which species contribute to special habitat requirements [deep shade, loafing/bedding areas, pricklypear for javelina (*Tayassu tajacu*), etc.]?
5. What are the technically feasible brush manage-ment alternatives?
6. What will the area look like 5, 10, 15 years after treatment?
7. What kind of maintenance treatments and frequency will be required to keep the most desirable combinations of plants on the landscape?

The answers to these questions allow decision-makers the means to determine where in the landscape that certain habitats are most conducive to different animal species and/or watershed characteristics and aesthetic values. Landscapes can be "sculpted" (Rollins 1997) to provide the best combination of components to meet objectives. In short, the inventory process using ecological site descriptions provides a sound basis for planning and implementation of brush management decisions. However, ecological sites are not necessarily the final divisions of natural landscapes that influence planning decisions.

Many sites are large and not utilized equally by livestock or wildlife for a variety of reasons, the most common of which is water distribution. Other constraints or influences on animal movements within sites include brush cover, steep escarpments or gullies, prevailing wind direction and animal preferences (edge area, etc.) (Stuth 1991). Areas within sites may have undergone previous treatments that cause them to be significantly different from other portions of the site. Any of these factors, alone or in combination, can cause areas within sites to respond differently to management. Such areas are designated as response units and delineated as polygons within ecological sites. The primary reason for developing response units is to adjust range carrying capacity by discounting forage value for livestock. However, response units can also have significant influence on the technical and economic success of brush management treatments, including selection and placement of initial treatments and selection and timing of maintenance treatments. Response units should be shown on GIS overlays and area calculated for use in planning specific brush management strategies.

MATCH BRUSH MANAGEMENT TECHNOLOGIES WITH THE SPECIFIC PROBLEM

Seldom will there be only a single technically feasible alternative to consider in planning a brush management program. The diversity of woody species and control technologies available makes it difficult to be sure that all of the correct possibilities have been considered. Moreover, different treatments that may be equally effective in controlling the target species could well have significant economic differences (cost of herbicides or how soon benefits can be expected based on posttreatment response). There may also be differences in how these same treatments affect secondary woody species and, therefore, the expected posttreatment vegetation as it relates to wildlife habitat or brush maintenance requirements (Hamilton et al. 1981).

Recognition of these difficulties in selecting from the array of technologies available for brush management led to the development of EXSEL, a computer-based expert system for brush and weed control technology selection (Hamilton et al. 1993). EXSEL allows users to interact with databases that match appropriate mechanical, chemical, and burning practices with specific brush or weed problems. The user inputs information required to characterize a brush or weed problem within the environment of a specific landscape and furnishes data on soils and geographic region. EXSEL is particularly helpful in assisting users to match herbicides, rates, mixtures and application techniques with brush and weed problems. Additionally, the program provides posttreatment response information that projects changes in the vegetation and when these can be expected to occur. These projections help planners to "see" the shifts in vegetation composition that will occur and match these with desired habitat attributes. EXSEL is available for use free of charge on the Internet at *http://cnrit.tamu.edu/rsg/exsel/*.

PROJECT VEGETATION RESPONSES OVER TIME AFTER TREATMENTS

We refer to the tools used to visualize future shifts in vegetation following application of an integrated brush/wildlife/grazing management program as response curves. Response curves are an attempt to project a two dimensional change in vegetation magnitude (how much it will change) and time (when the changes will occur.) They may be the most important element of decision-making related to the economic realities of investments. Information needed to construct response curves can be derived from a combination of brush management research, demonstrations, personal experiences, and experiences of others. Texas A&M Research and Extension Centers and NRCS offices located throughout the state provide excellent sources of information for developing treatment responses.

USE ECONOMIC ANALYSIS TO SELECT BEST TREATMENT SCENARIOS

Man and his domestic livestock are components of the ecosystem and, in many cases, livestock represent the primary means of economic survival. Therefore, how planned changes in vegetation following brush management will affect economic potential of livestock products over time will often have profound influence on decisions. Response curves assist in development of cash flows by projecting benefits from brush treatments over time in the planning horizon. These benefits are then compared to increased costs of brush control applications to produce the annual net cash flows associated with the project. Benefits from brush treatments include increases in livestock yields, as well as cost reductions, such as variable costs associated with livestock operations. Benefits of treatments can also be realized from increased income from hunting leases or recreational potential associated with vegetation manipulation. Costs used in the analysis include not only direct costs of the brush management treatments, but reduced benefits, such as the loss of income from leases or other activities during periods of non-use required by treatments.

Benefits and costs are used in a partial budget analysis to develop annual net cash flows that are then discounted at a selected rate over the planning horizon to produce the net present value of a planned investment strategy for brush management and an internal rate of return on investment. This capability is contained within the Grazing Land Applications (GLA) planning system and gives decision-makers the potential to rate alternative investment strategies based on economic performance.

There is a note of caution in determining economic feasibility of brush management practices. Brush management plans should be long term and not simply focused on "controlling" the current stand of brush (Ueckert and Hamilton 2000). The best opportunity to show positive returns on investments is by using planning horizons of 15-20 years and including both the initial treatment and maintenance treatments required to hold benefits near maximum for the entire period (Fig.5). History has shown that applications of initial treatments not followed by maintenance seldom produce acceptable economic returns before the end of treatment life. Planning periods that are too short to allow capture of the extended benefits associated with increased production from brush control practices will not be economically feasible. Another point to remember is that for the economic analysis described above, benefits and costs are expressed in monetary terms, while some benefits and costs are nonmonetary in nature (Conner 1985).

IMPLEMENT, MONITOR AND "RECYCLE" REAL-TIME INFORMATION IN TO THE PLANNING PROCESS

Once an alternative brush management program is selected and implemented, it is important to monitor the results and feed this "real time" information back into the planning process. This part of the process is frequently overlooked, yet it has the potential for greatly improving efficiency of future projects. Monitoring should include the efficacy of the treatment when it was actually applied to compare with that estimated during planning. Actual costs measured after application can be used to update planned costs and improve efficiency of future economic forecasts. The need for and timing of maintenance treatments can also be monitored and used to improve future programs. If brush management was planned correctly as an integrated package, the results of the treatment scenario on all components of the ecosystem should be observed and used to improve future projects (Hamilton 1985.)

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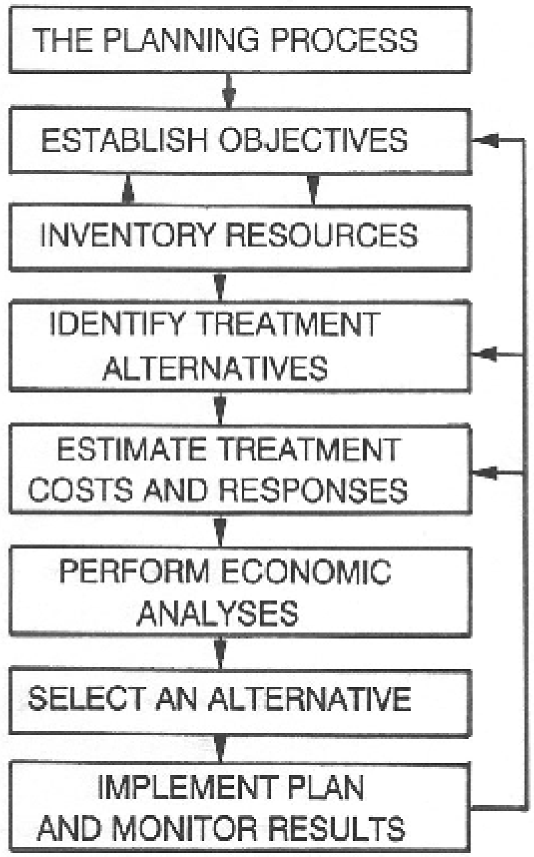

Figure 1 The management planning proccess

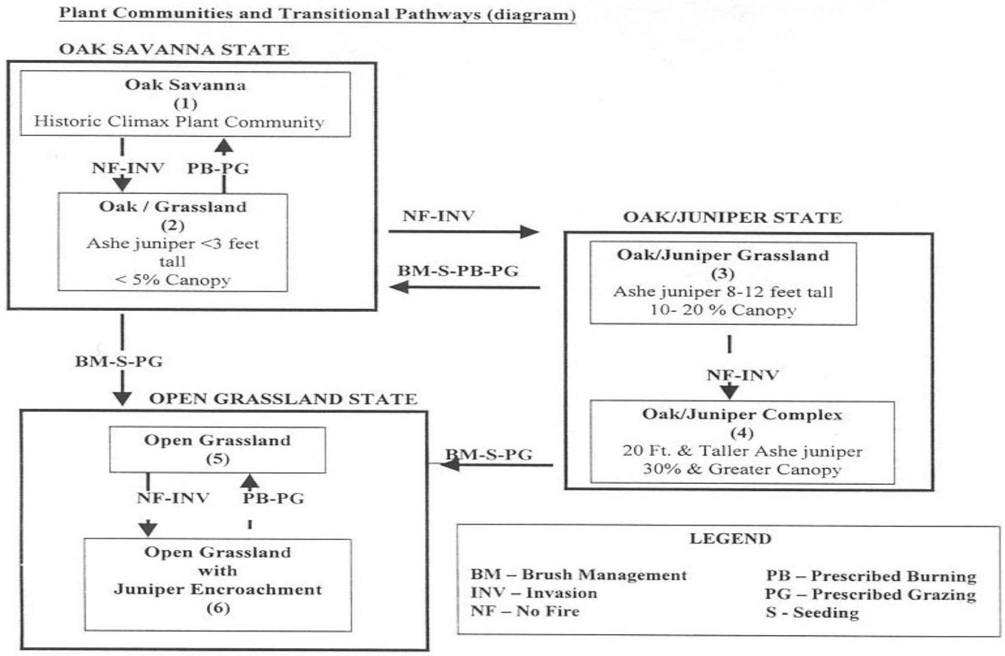

Figure 2. Plant communities and transitional pathways diagram for a Deep Redland ecological site. Source: USDA NRCS (2000)

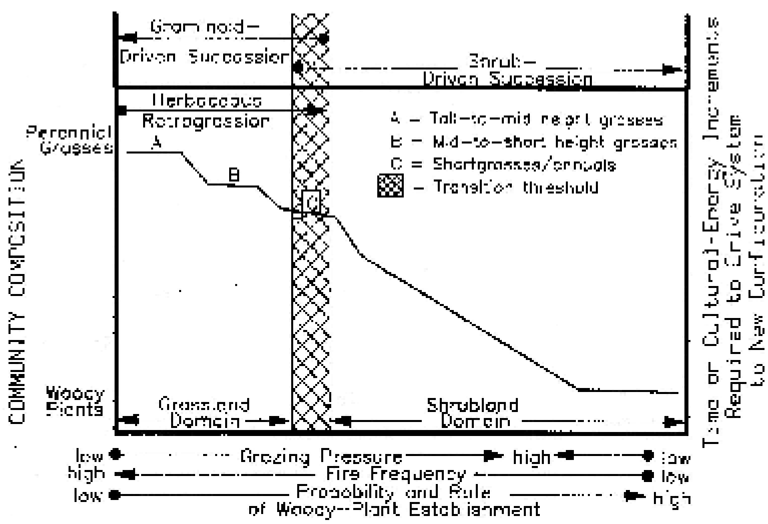

Figure.3. Conceptual diagram of threshold changes in community structure as a function of grazing pressure and fire frequency in thorn shrublands. Source: Archer (1989)

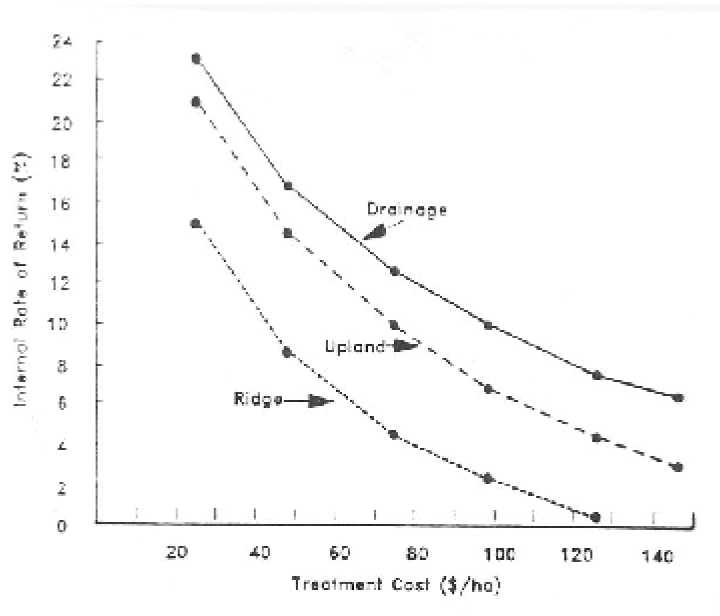

Figure 4. Relationship between treatment cost and projected internal rates of return after herbicide applications to ecological sites of varying production potential. Source: Scifres et al. (1988)

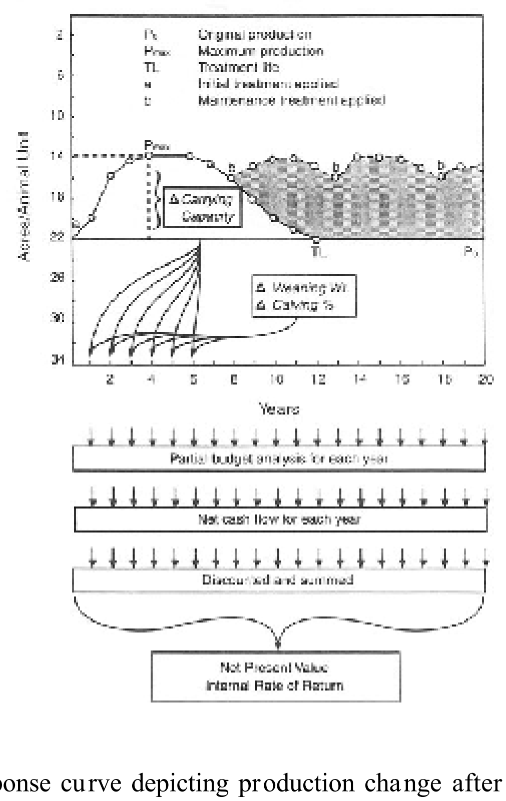

Figure 5 Generalized response curve depicting production change after an initial treatment for brush control and a series of maintenance treatments. Source: Scifres and Hamilton (1993)

CONSERVATION PRACTICES: A LIVESTOCK OPERATOR'S PERSPECTIVE

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COST

The first decision to be made about conservation practices concerns cost. Many effective conservation practices, such as rotational grazing and pasture deferment, do not involve direct costs. The mechanical and chemical control of brush and other undesirable plants do. It is important to conduct an analysis of the costs compared to the benefits. If the expected return is favorable to the cost expended, then a consideration might be given to even borrowing funds in the event cash reserves are insufficient.

CALCULATION OF COST

Conservation contractors commonly quote jobs as the cost per acre for the particular practice. However, the ranch operator must also consider the efficiency of the practice. For example, my experience in aerial application of chemicals to control mesquite indicates that the efficiency rate varies from 20 - 80%. Many factors determine this efficiency but include the quality and density of the leaf canopy, the amount of soil moisture and the soil temperature. If the quoted price is $35 per ac. but the efficiency ratio is 75%, then the actual cost per acre is $47 per ac. The same calculation must be applied to all practices.

RETURN COSTS

The operator must also estimate the increase in forage that the contemplated practice will produce. Some range scientists have observed that a 20% increase in available forage is to be expected for control of mesquite. It is also true that all practices are actually control and not eradication. Therefore, the length of the beneficial effect of the practice needs to be determined. The efficiency gained in forage production declines each year after the practice is performed so that the cited 20% increase may be true for the first few years, the increase will diminish during the later years, eventually returning to a zero increase at the end of the effective period.

Assume that my range requires 20 ac. per year to support a cow-calf unit and that the practice costs $50 per ac. This is a cost of $1,000 to be recovered per animal unit. If the practice results in an increase in forage production for twenty-five years, then the annual expense of the practice is $40 per animal unit. Assume further that there is a 20% increase in forage production, then the ac. required for each animal unit is reduced to 17 ac. This means, in practice, that the annual cost per animal unit in increased by an additional $34.

EFFECT ON WILDLIFE

To obtain the greatest return of the cots expended, the Operator must select the best areas of the ranch for conservation practices. To maximize the increase in forage production, the better sites must be chosen. This means that the shallow soil sites will be left with the brush undisturbed and that the practices will be conducted in areas with better prospects for increased production. Such a practice harmonizes with wildlife production as it provides secluded areas necessary for wildlife habitat.

All ranchers realize the economic value that hunting and other recreational uses of ranchland bring to the operation. Based upon recorded trends, this will be even more valuable in the future. Wildlife also benefits from additional forage production.

ADDITIONAL WATER SOURCES

The control and removal of brush will also increase the flow of springs and creeks as well as reduce the silt flowing into ponds and lakes. This is an additional benefit from conservation practices but difficult to calculate in determining cost recovery.

OTHER BENEFITS

Good conservation practices aid management of the ranch in handling livestock. Less time and labor is required to gather livestock from a pasture when there is control of the brush.

CONCLUSIONS

When deciding which conservation practices to conduct, the operator should carefully calculate how the costs would be recovered. Cost recovery will be realized through increased productivity and through other, less measurable gains. All improvements should be carefully analyzed.

BRUSH REMOVAL TO INCREASE WATER AND POSSIBLE EFFECTS ON WILDLIFE POPULATIONS

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Abstract: Removing brush to increase water supplies could effect wildlife populations. Brush has invaded much of the native prairies of Texas and many brush-dwelling wildlife species have increased because of this expanded habitat. The important concept to remember when removing brush is not how much brush is removed, but how much is left and how it is distributed over the landscape. Brush removal will affect wildlife species differently. An underlying concept is to retain vegetation diversity that will retain wildlife diversity. Wildlife concerns should be investigated and addressed in the ongoing studies to determine the feasibility of brush removal to increase human water supplies.

Removing brush to increase water supplies is a complex issue for Texas. Several issues concerning this topic have been identified (McCarl et al. 1987). Despite the complexity of the issue and the lack of scientific data, brush management may hold potential to increase water yields in Texas. However, if this process is not done properly, Texas could end up with less quality water and decreased wildlife populations. Mesquite (*Prosopis spp.*) is the most dominant brush species in Texas. During drought, mesquite can survive because its long taproot allows it to reach water sources far below the soil surface. If damaged through fire or mechanical means, the tree is not killed and the crown re-sprouts. Mesquite is spread throughout the countryside by domestic livestock and wild animals as they eat mesquite fruit pods and the seeds. It has been estimated that brush infests over 100 million ac. in Texas (Jensen 1988). Although mesquite is the dominant brush species in most areas, juniper (*Juniperus spp.*), live oak (*Quercus virginiana*), huisache (*Acacia farnesiana*), MaCartney rose (*Rosa bracteata*), Chinese tallow (*Sapium sebiferum*), sagebrush (*Artemesia spp.*), shinnery oak *(Q. havardii*), and persimmon (*Diospyros virginiana*) cover considerable portions of Texas.

For brush management to be successful in increasing water supplies, it must:

1. be economical
2. increase human water needs
3. increase grazing potential
4. not be harmful to wildlife populations

In this paper, I will touch on 3 of the 4 points from an ecological prospective. I will let the economic researchers determine the economics of the potential methods and results.

NEED FOR A NEW PARADIGM

Originally, native grasses, not brush, covered much of Texas. Mesquite began to spread because cattle spread its seeds and fires, that killed young mesquite trees, were controlled and/or occurred less frequently due to insufficient fuel load. The insufficient fuel load was caused primarily by over utilization of the grass by cattle. This brings us to my first point of this paper. For such a program to be successful, land management as done in the past will have to change. Removing brush and returning the range to healthy native grasses is only the first step in the process. With continued over utilization of the grass and lack of prescribed fires, the landscape will quickly return to brush. Thereby perpetuating a non-economical brush control cycle. Once brush is controlled, native grass species should be well established before the land is continuously grazed. Herein lies another problem. Due to past problems, much of the range (especially in the Hill Country) has lost considerable topsoil. Soil cannot be replaced overnight. Just how well the remaining soil can support luxurious native grassland is questionable. During the reestablishment stage, these native grasslands will need frequent fires in order to exclude re-invading brush. This poses a second problem, following the Las Alamos fire this past summer, prescribed burns will not be as welcomed by the public.

If permanent cover is not established quickly, runoff from rains will reduce water quality and will not recharge aquifers. For permanent grass cover to be most effective at increasing water quality and quantity, grazing must be reduced and dead organic matter must accumulate in order to slow runoff and increase percolation into already depleted topsoil. Native bunchgrasses such as little bluestem (*Schizachyrium scoparium*) are probably best at reducing runoff. During this period of native grass reestablishment, the landowner may lose income due to decreased cattle stocking rates.

EFFECTS OF BRUSH CONTROL ON WILDLIFE

Landowners and game managers are concerned that reduction of brush on the landscape will reduce economically important wildlife populations. In the past, brush control has been used successfully to increase many of these wildlife species. The effects of brush clearing on wildlife populations are difficult to estimate. First, brush removal will affect wildlife populations in different ways; some species will not be affected while others will increase and still others will decrease. From a purist's point of view, returning brush land back to native grassland (its pristine condition) should be considered "good". However, if such a change affects rare and/or endangered species, then political and/or social issues come into play. Also, if brush control reduces landowner income from hunter leasing, then economic considerations come into play.

One usually has the impression that brush clearing will affect cover for white-tailed deer (*Odocoileus virginianus*), wild turkey (*Meleagris gallopavo*) northern bobwhite (*Colinus virginianus*), scaled quail (*Callipepla squamata*), and nesting sites for numerous birds including mourning doves (*Zenaida macroura*). Doves readily nest on the ground (Eng 1986) in the absence of trees or shrubs, although tree nesting is most common. If brush is not available, tall native grass will provide the necessary screening cover for white-tailed deer (in populations which are not hunted heavily), wild turkey, and quail. However, obligate species such as the golden-cheeked warbler (*Dendroica chrysoparia*) are tied to Ashe juniper (*Juniperus ashei*) and could be affected if additional juniper is not located nearby (Pulich 1976). Depending on how the brush is removed within the landscape, wildlife species will be affected in different ways. The important concept to remember is not how much brush is removed, but how much is retained, its distribution, and its position with respect to other vegetation types. Remember, the important concept is how much cover remains on the land. This cover must have the structure necessary to provide screening and food for different wildlife species. Diversity in vegetation types will produce a greater diversity in wildlife species. This cover may consist of brush, forbs, grass, trees, or a combination of these types. Wildlife concerns should be addressed in ongoing feasibility studies to not only determine if water supplies will be increased, but to determine the effects of brush clearing on wildlife populations. Research is needed to determine the effects of such large-scale brush clearing on wildlife populations.

In summary, clearing brush without consideration of how much brush is to be left and where the brush will be left may prove a problem for many wildlife species. In addition, the proper management of the land following clearing has to be considered or the proposed solution to our water supply problem will only be temporary.

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DESIGNING BRUSH MANAGEMENT PROGRAMS TO INDUCE INVESTMENT BY WATER USERS

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Abstract: Water users seeking to acquire new water supplies may be enticed to invest in brush management programs. Competitive cost and long-term reliability will be key issues for any potential investors. New law may be required before a brush management program can offer these assurances.

Brush management has been studied for many years for its potential to increase water yields. Generally, this research has been funded by governmental entities such as the U.S.D.A Natural Resources Conservation Service, the Texas Agricultural Experiment Station and others. To the extent that brush management programs may create new surface or ground water supplies that are quantifiable and recoverable, those supplies could be made available to a water user in return for investment by that water user in the brush management program.

A brush management program can be funded by a governmental entity, usually a regional, state or federal agency, from taxes or other general sources of revenue. In this model, the beneficiaries of the new water supplies created do not directly pay all the costs of the program. The new water supply created in surface or ground water hydrologic systems by implementing brush management will become available to the water users tapping those sources according to the laws and rules that govern water use from those sources. There is no problem with this type of program. This is a legitimate government function with the expectation that the benefits of the program will work for the good of a larger community.

However, some programs may not provide sufficient benefits to the larger community to justify this type of government program. Those desiring to develop a brush management program that is otherwise unsupportable financially because the other benefits do not justify the costs may cause the program to become financially viable with the inclusion of an element that contributes money in return for the new water supply created. The brush management program developer desiring to take advantage of this investment from water users must design his program to be competitive on price with other water supply options available to the water user and the program must deliver a reliable long-term supply. This paper will offer some suggestions for elements to be included in a program design of this nature.

Recent information suggests that groundwater and surface water are currently valued between $20 to $200 per ac.-ft. annually for a lease or water sale contract, and $200 to $1,500 per ac.-ft. for a one-time purchase of the water right (HDR 2000). Typically, annual delivery costs for distant supplies can be five to ten times greater per ac.-ft. than the cost of water at the source (HDR 2000). The brush management program developer must understand the potential water user's market for other supplies and delivery costs associated with these supplies and factor those considerations into his pricing strategy.

A water user considering investment in a brush management water supply source will be concerned about reliability of supply, particularly if infrastructure such as pipelines and pump stations will be required. These facilities are typically financed over twenty to thirty year terms. The water user will want a guarantee on the supply for that period of time. Somewhat problematic are reports by researchers that early year increases in water yields may decrease over time following removal of ashe juniper (*Juniperus ashei*) (Dugas and Hicks 1998). The brush management program developer can expect to be questioned about the long-term reliability of his supply in any discussions with water users seriously considering investment in water supplies created by brush management. The annual costs to maintain the level of brush management achieved and new water supplies created by the initial investment must be included in the program costs.

If the new supply for brush management is manifested as a groundwater supply, the regulatory environment may place some restrictions on the recoverability of that supply. The Edwards Aquifer Authority's enabling statute specifically provides for recovery of new water supplies in the aquifer created by recharge enhancement projects separate and apart from the other regulations of Edwards Aquifer pumping (Sect. 1.44, S.B. 1477, 73rd Texas Legislature). However, if the brush management program creates recharge to an aquifer other than the Edwards Aquifer, the enhanced recharge will be subject to the rule of capture or the rules of any groundwater conservation districts in the program area. The ability of the brush management program developer to guarantee the use of that enhanced recharge to the funding water user may be severely limited in areas where there is no groundwater district. Groundwater districts may need to review and/or modify their rules to equitably allow the new supply to be recovered.

If the new water supply becomes surface water, the full effect of state surface water administration will likely come into play and water rights permits from the Texas Natural Resource Conservation Commission will be required. In addition to those permits, protection will likely be necessary to prevent losses to other users. For example, new downstream impoundments, such as stock tanks, that are exempt from requiring a permit under State law would induce deep percolation or evaporation of the new supplies. Wright (1996) reported removal of ashe juniper on the Seco Creek Demonstration Project resulted in 46,000 gallons of enhanced spring flow per treated ac. or 0.14 ac.-ft. per ac. It is easy to see that a small lake or stock tank subsequently built downstream of that spring could evaporate several ac.-ft. per year and offset the gains in surface flows from many treated ac. Existing state law may limit effective management of a brush management program that includes a surface water supply element. Parenthetically, some of the protections mentioned here in both the groundwater and surface water scenarios may be necessary even for a program implemented by a governmental entity that serves a larger community of beneficiaries.

The developer of a brush management program would also need to provide adequate assurances to a customer/water user that the brush management practices implemented would produce additional water supplies. The mixed results of brush management projects over the years raise the question of whether the practice increases water yields, or just change the values of the variables in the water balance equation (Gerston 1998). Changing the variables of the water balance equation brings into focus the different outcomes from brush management desired by rangeland managers and water managers. Increasing water yield off-site may decrease the amount of water available for production of forage for livestock. If this is indeed the case, the brush management program developer will need to include the appropriate compensation to the landowner in his program costs.

SUMMARY

Brush management programs may be designed to include an element of new water supply in surface or groundwater to be made available in return for investment by a water user. Competitive costs and long-term reliability will be the major interest areas of those water users considering an investment in the brush management program. The new supplies created must be guaranteed to be delivered to the water user investing in the brush management program. Existing law may not provide this guarantee.

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Brush Management, Water, & Wildlife: A Checklist for Ecosystem Management

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Abstract: Brush clearing operations in Texas can have multiple goals, techniques, and management objectives that may, upon superficial review, appear in conflict. If, however, one works from the single goal of a healthier, more sustainable ecosystem, and evaluates elements of a brush-clearing program against that goal, a good, sound plan can be developed and implemented.

Several important questions must be answered before embarking on a program of brush management:

1. What is the current vegetative and soil state of the rangeland?
2. What was its historical vegetative composition?
3. What happened to change the land from its historical to its present condition?
4. How has the hydrology of the rangeland system changed over time?
5. What would be the projected natural climax state of the vegetation in the system, and at what stage in that continuum is the range currently?
6. What are the wildlife and livestock components of the ecosystem at present?
7. What were the wildlife components of the ecosystem before livestock?
8. What stages can be identified along this continuum?
9. Are there wildlife components of the ecosystem that are thriving?
10. What elements of the current system support this?
11. Are the wildlife components healthy and in balance, and are population numbers stable, increasing, or decreasing?
12. Are there exotic elements in the landscape (plant or animal) that are causing problems for native wildlife?
13. How has the ability of the rangeland to support livestock changed, degraded, or improved?
14. Are there elements of the current rangeland composition that favor livestock over wildlife?
15. If there are such trends, are they sustainable if they continue, or should they be redirected toward historical rangeland composition?
16. What are the indicator species for the rangeland, and how are they faring?
17. Are there endangered, threatened, or watchlist species-plant or animal-on the rangeland?
18. What are the specific ecosystem/habitat requirements for these species?
19. What is the state of health of these species and habitats across the subject rangeland; is there important or critical habitat on this land, or does this land provide buffer or corridor habitat for the species?
20. What methods of brush control are available for use at the site?
21. What would be the effectiveness of each option short and long term?
22. What kind of follow-up treatment would be required for long-term effectiveness?
23. What side effects-positive or negative-might be related to use of each option, e.g., chemical residues, increased runoff, erosion, creation of windbreaks, impacts on non-target plant species.
24. How will the projects be paid for and by whom?
25. Does the project scope include eradication only or revegetation and range improvement, as well?
26. If increased water yields-underground or surface-result, who, if anyone, gets credit and how?

In summary, evaluation of a brush management project from an environmental perspective must look at the total ecosystem structure from past, present, and future points of view. Any project must be planned before it is executed, and have clear measures of effectiveness established and employed throughout the project's life. Most important, range management is not a one-shot effort. It involves long-term planning, commitment, monitoring, sensitivity, and understanding.

DIVERSIFYING RANCH INCOME THROUGH NATURE TOURISM

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There is a growing interest among agricultural producers in diversifying farm and ranch income by providing wildlife-associated recreational opportunities. Many ranches in Texas already derive substantial income from hunting. Opportunities exist for attracting other segments of the recreation market, such as birders, wildlife watchers, hikers, mountain bikers, or nature photographers, to the so-called nature tourism business.

For example, ranchers with established hunting businesses might consider marketing non-consumptive activities such as birding or biking during the non-hunting season. This can fill empty lodging facilities and bring in off-season income. Opportunities also exist for landowners and entrepreneurs interested in developing tourism- related businesses such as Bed and Breakfasts (B&B) that specialize in birding and wildlife watching.

Hunting outfitters are an established part of wildlife-associated recreation in Texas. With the growing interest in diversification among landowners, opportunities abound for the "new breed of outfitter" specializing in interpreting the natural and cultural resources of Texas for wildlife watchers, birders, photographers and those interested in history and culture.

Although opportunities exist to profit from the growing demand for outdoor recreation, it is important to be realistic about your assets, management ability, personal style and preferences, and how new endeavors integrate into your existing business. Nature tourism is not a cure-all to "save the ranch." It can diversify income, but those in the business will tell you that it takes commitment and vision. It is not for everyone.

Providing recreational opportunities is a people-oriented business. It's not a business for you if you don't enjoy dealing with people and providing services to your customers. The ability to enjoy the company of others, to share your experiences and knowledge with those of different backgrounds and to be flexible enough to adjust to people with personalities and tastes different from your own are important attributes for success in a "people business" such as nature tourism.

In developing a nature-based tourism enterprise, the first step is to inventory the natural and cultural resources that form the basis of what you are selling. Ask yourself these questions:

1. *What does your ranch have that is unique or different from others?* (Think about plants, animals, geology, local history and ranching heritage.)
2. *What are your ranch's special habitats and how can you provide viewing opportunities?* (Think about watering areas, wildlife gardens close to lodging, feeders, blinds, elevated observation areas, trails and boardwalks.)
3. *What outside perspective can I get?* (Remember the common or ordinary to you may be of great interest to urban residents or visitors from other states and countries.)

Nature tourists are looking for the natural, historical and cultural heart of the place they are visiting, and their defining principle is authenticity. They are interested in what is real, and they want to be immersed in a rich natural, cultural or historical experience. Focus on providing an enjoyable experience that also teaches. Good interpretation of the resources adds immensely to the learning experience and overall enjoyment. A satisfying experience that meets visitor expectations will generate repeat customers and positive word-of-mouth recommendations.

Once you have an adequate assessment of your natural and cultural resources, think about what activities you could offer that best fit with your current operation and interests. Start slow and focus on what you can do best based on your resource assessment and financial resources. Consider the preferences and abilities of other family members and employees. Be honest with yourself about your temperament, time, management ability and preferences for certain type of activities and people. Examples of activities offered on Texas ranches include:

- Guided bird and wildflower walks
- Special viewing areas for hummingbirds
- Wildlife watching from blinds (turkey, deer, birds)
- "Owl prowls" at night
- Stargazing in dark, rural settings, sometimes with telescopes
- Special hikes to unique or scenic areas
- Fossil walks along creek beds
- Interpretive walks featuring geology, historic sites, ranching heritage
- Mountain bike trails
- Horseback riding trails
- Camping and backpacking
- Chuck-wagon meals with music or storytelling
- Observing or participating in working livestock
- Just relaxing and experiencing a rural setting with family or friends

For many agricultural landowners, marketing nature-tourism activities is the most difficult part of starting a new business. It often is easier for people of the land to understand the resources themselves than how to sell the experiences of those resources to others. Marketing is vitally important, however, as the time and energy invested in researching and developing a business endeavor is wasted if potential customers are not aware of its existence. Although a full discussion of marketing is beyond the scope of this article, here are some of the most important principles:

First, identify the market segment that you want to attract. Segmentation allows businesses to divide a homogenous market into smaller groups, see the diversity among customers and concentrate on pleasing a segment that might find their product or service attractive.

Without question, one of the most valuable things you can do in developing your business is to visit an existing business that has a product or market segment similar to the one you are considering. If you want to attract birders, visit an enterprise that offers birdwatching experiences or targets a particular segment of the birding market. Searching the Internet for birding-related websites provides contact information, as well as information on activities and pricing.

Networking with others involved in the tourism industry provides valuable information and contacts. In order to meet potential customers and make contact with others offering nature-based tourism opportunities, attend some birding and nature festivals. Develop a close relationship with your nearest Chamber of Commerce or CVB if you want to establish your business as a destination for travelers to your area.

Encourage partnerships between two or more businesses so that everyone benefits. Partnering allows small businesses to pool talent and resources to create a product that is more attractive than any one business can provide on its own. Tour packages are a good example. Cooperating with other landowners, lodging facilities and restaurants in your area attracts more visitors to your destination and encourages them to stay longer and spend more money.

Texans are blessed with an abundance of wildlife and natural beauty, and opportunities abound for sharing this natural heritage with fellow Texans and visitors from all over the world. For some landowners, diversifying agricultural income through nature-based tourism can be both enjoyable and profitable.

For more information, contact Linda Campbell, Nature Tourism Coordinator, Texas Parks and Wildlife, Austin, Texas (512-389-4396).

Helpful Internet Sites:

Texas Parks and Wildlife Department
http://www.tpwd.state.tx.us/nature/tourism/yo

urbusiness/index.htm

Texas A&M University, Texas Nature Tourism Initiative http://tnti.tamu.edu

1996 U.S. Fish and Wildlife Service National Survey of Fishing, Hunting, and Wildlife-associated Recreation http://fa.r9.fws.gov/surveys/surveys/html

1997 Results from the National Survey on Recreation and the Environment http://www.fs.fed.us/research/rvur/recreation/publications/Outdoor_Recreation/title/html

Emerging Markets for Outdoor Recreation in the U.S. http://www.outdoorlink.com/infosource.nsre/

Fermata, Inc. Austin, Texas (private nature-based tourism consulting business) http://www.fermatainc.com

Texas Department of Economic Development, Tourism Division http://research.travel.state.tx.us

PROTECTING ENDANGERED ECOSYSTEMS OF THE EDWARDS PLATEAU

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Abstract: The U.S. Fish and Wildlife Service encourages new approaches for conservation, large-scale planning to accommodate land use and wildlife habitat, and innovative public and private partnerships. The Edwards aquifer and overlying Hill Country, located along the eastern and southern edges of the Edwards Plateau, are a hotbed of increasingly complex and controversial conservation issues. This area supports many endangered, threatened, and other rare species of aquatic and terrestrial plants and animals. The Edwards aquifer provides the sole source of drinking water for over 1.5 million people, a popular source of recreation, and baseflow for rivers that sustain human settlements and ecological communities downstream to the Gulf of Mexico. The increasing human population is placing increasing demands on this finite water resource, and the Hill Country woodlands are being cleared for the rapidly expanding urban development.

Several representatives from Federal, State, local, agricultural, and private sectors have been encouraging the removal of Ashe juniper (*Juniperus ashei*), locally known as "cedar", and other brush species from the Hill Country as a means to enhance water quality and quantity in the Edwards aquifer. To assess the appropriateness of this management option, the Service has considered the status and habitat requirements of the threatened and endangered species that occur in the Edwards aquifer and Hill Country. In addition, the Service reviewed several accounts from early explorers of this area, which consistently report that the original Hill Country landscape had abundant springflows and "cedar-covered hills". Based on imminent threats from ongoing habitat loss and fragmentation, the Service believes that implementing brush removal in areas occupied by one or more of the listed terrestrial species would be detrimental to these species and the ecosystems on which they depend. Although Ashe juniper and other woody species have recently been targeted as culprits in the decline of water quality and quantity in the Edwards aquifer, the major causes for which solutions must be sought are groundwater pumping, land clearing, and urbanization. The Service is continuing to work with stakeholders to find other alternatives that meet the increasing demands for water, while ensuring the protection of endangered and threatened species.

About a quarter century ago, Congress took the far-sighted step of creating the Endangered Species Act, widely regarded as the world's strongest and most effective wildlife conservation law. It set an ambitious goal: to reverse the alarming trend of human-caused extinctions that threaten the ecosystems we all share.

Congress assigned primary responsibility for administering the Endangered Species Act to the Service. The Fish and Wildlife Service office in Austin, Texas covers endangered species issues across 75% of the state of Texas including 191 counties, from east of Austin to the Mexico, New Mexico, Oklahoma, Arkansas, and Louisiana borders. Much of the Austin office's resources have been concentrated on the Edwards Plateau, a hotbed of controversy from water rights to endangered species issues. The southern and eastern edge of the Edwards Plateau is known as the Balcones Canyonlands or "Hill Country" and is underlain by the Edwards aquifer and its contributing zone. This area of the Edwards Plateau contains many rare and endemic species, of which 20 terrestrial and 9 aquatic species are listed or proposed for listing as threatened or endangered. Because of the diversity of these species and the increasing human pressures on their ecosystems, the Service must carefully evaluate management options to meet the growing demands while ensuring the protection of threatened and endangered species.

DESCRIPTIONS OF ENDANGERED AND THREATENED SPECIES OF THE EDWARDS PLATEAU

In determining appropriate management strategies, the Service must consider the best available information for any species that may be positively or negatively affected, the ecosystems on which they depend, their existing and projected status, and potential impacts from the proposed action. The following is a list of endangered and threatened species that occur in the Edwards aquifer and the Hill Country, a brief description of the ecosystems on which they depend, and threats to their survival.

Edwards Aquifer Species

The Edwards aquifer, including its springs and springflows, provides habitat for 9 listed species, including 1 species that may already be extinct. The San Marcos Springs ecosystem in Hays County supports the endangered Texas wild-rice (*Zizania texana*), Comal Springs riffle beetle (*Heterelmis comalensis*), fountain darter (*Etheostoma fonticola*), and threatened San Marcos salamander (*Eurycea nana*); the endangered San Marcos gambusia (*Gambusia georgei*) is likely extinct. The endangered Texas blind salamander (*Typhlomolge rathbuni*) occupies the subterranean waters in the San Marcos area of the Edwards aquifer. The Comal Springs ecosystem and the aquifer in Comal Springs support Peck's cave amphipod (*Stygobromus pecki*), Comal Springs dryopid beetle (*Stygoparnus comalensis*), and Comal Springs riffle beetle; the fountain darter occurs in the springruns. Peck's cave amphipod has also been found at Hueco Springs (Comal County), and the Comal Springs dryopid beetle has been found at Fern Bank Springs (Hays County). The Barton Springs salamander (*Eurycea sosorum*) is known only from Barton Springs in Travis County. All 9 of these species and many other rare endemics depend on a constant and abundant supply of clean, flowing water in the Edwards aquifer.

Hill Country Species

Terrestrial species found in the Hill Country include 11 endangered species, 9 species proposed for listing as endangered, and many other rare species. Endangered species include 2 plants, 7 karst invertebrates, and 2 songbirds. Nine karst invertebrates are proposed for listing as endangered in Bexar County.

Texas snowbells (*Styrax texanus*) occurs in 4 counties along the southern edge of the Edwards Plateau: Edwards, Kinney, Real, and Val Verde. It is found on steep limestone bluffs and cliff faces along streams and dry creek beds, in the dry gravels of streambeds and on thin soils overlying limestone ledges. Associated species include Texas ash (*Fraxinus texensis*), sycamore (*Platanus occidentalis*), little walnut (*Juglans microcarpa*), Texas oak (*Quercus texensis*), Mexican-buckeye (*Ungnalia speciosa*), Texas mountain laurel (*Sophora secundiflora*), Texas persimmon (*Diospyros texana*), and Ashe juniper. Primary threats to this plant include browsing by deer, exotic game, and livestock, flooding and erosion, fungal or bacterial diseases, and declines of springs. These factors have resulted in a lack of seedlings for recruitment into the population. When protected from grazing animals, Texas snowbells can grow on level sites with deeper soils.

Tobusch fishhook cactus (*Ancistrocactus tobuschii*) occurs on limestone gravels of stream terraces, limestone ledges, ridges, and openings on the rocky hills of live oak (*Quercus fusiformis*) - juniper woodlands in 8 counties along the southern edge of the Edwards Plateau: Bandera, Edwards, Kerr, Kimble, Kinney, Real, Uvalde, and Val Verde. Currently about 50 sites are recorded for the species, following a recent rangewide survey. Most of the populations are extremely small (5-20 plants), with individuals widely scattered. Demographic data collected in the ongoing rangewide assessment study conducted by the Texas Parks and Wildlife Department show that only one of the known populations is even marginally viable. Threats to the species include inappropriate timing of range management practices (such as fire and clearing practices that disturb the soil), extensive predation by beetle grubs, loss of habitat to real estate development, and some collection by cactus enthusiasts.

Karst invertebrates in Travis and Williamson counties include the Bee Creek Cave harvestman (*Texella reddelli*), Bone Cave harvestman (*Texella reyesi*), Tooth Cave spider (*Neoleptoneta myopica*), Tooth Cave pseudoscorpion (*Tartarocreagris texana*), Tooth Cave ground beetle (*Rhadine persephone*), Kretschmarr Cave mold beetle (*Texamaurops reddelli*), and Coffin Cave mold beetle (*Batrisodes texanus*). An additional 9 karst invertebrates are proposed for listing as endangered in Bexar County. All of these species spend their entire lives in caves, sinkholes, and other karst features. Major threats include loss of native surface plant and animal communities, real estate development, and fire ants. Because of the absence or low levels of sunlight in caves, karst ecosystems depend on surface plant and animal communities for nutrient input. These ecosystems receive nutrients from the surface in the form of leaf litter and other organic debris that wash or fall into the caves, tree and other vascular plant roots, and through the feces, eggs, or dead bodies of animals that forage on the surface and bring nutrients into the cave (USFWS 1994). A survey of 21 caves on the Edwards Plateau revealed that roots of 6 species reached caves, of which juniper was the most common tree (Jackson et al. 1999). Maintaining the native woodland community over the caves is needed to support this direct nutrient input. The surface plant community also buffers karst ecosystems from changes in the temperature and moisture regimes, pollutants entering from the surface, and other factors such as sedimentation from soil erosion.

Preserving native woodlands helps control certain exotic species, such as the red-imported fire ant (*Solenopsis invicta*), that compete with and/or prey upon the listed species and other fauna. Research in some areas indicates that fire ants are associated with open habitats disturbed as a result of human activity (such as old fields, lawns, roadsides, ponds, and other open, sunny habitats) but are absent or rare in late succession or climax communities such as mature forest (Tschinkel 1986). Thus, maintaining large, undisturbed areas of forest may help deter fire ant infestations that threaten these and other ecosystems (Porter et al. 1988, 1991).

Golden-cheeked warbler (*Dendroica chrysoparia*) breeds only in the mixed Ashe juniper-deciduous woodlands of the Hill County and has one of the smallest breeding ranges of any North American songbird. The warbler requires the shredding bark of mature Ashe junipers for nesting material and forages for insects in Ashe juniper and various deciduous tree species. The greatest threats are imminent and on-going destruction of its habitat due to land clearing and urban encroachment. Research on the warbler suggest that occupancy and productivity are considerably lower in "small" patches of habitat than in larger ones (Coldren 1998, Maas 1998). The heart of the warbler's range lies along the rapidly urbanizing corridor between San Antonio and Austin, and thus efforts to protect its remaining habitat are essential to prevent its extinction. Currently there are only 3 populations receiving some degree of protection: within the Balcones Canyonlands Preserve, Balcones Canyonlands National Wildlife Refuge, and Ft. Hood Military Reservation.

Black-capped vireo (*Vireo atricapillus*) nests from Oklahoma south through central Texas to the Edwards Plateau, then south and west to central Coahuila, Mexico. Although vireo habitat throughout Texas is quite variable with respect to plant species, soils, and rainfall, all habitat types have a similar overall appearance: patchy shrublands and open woodlands with a distinctive patchy structure. The shrub vegetation generally extends from the ground to about 6 feet above ground and covers about 30 - 60% of the total area. Open grassland separates the clumps of shrubs. In the Edwards Plateau region, the vireo typically occupies areas where oak-juniper woodlands have been disturbed. In certain portions of the Edwards Plateau, suitable habitat for the vireo represents an early successional stage in a process that eventually results in suitable habitat for the warbler. Thus, where habitat for these 2 songbirds overlap, large areas are needed to provide enough habitat to maintain viable populations of both species. The vireo continues to experience range contraction on the northern and eastern parts of its range due to nest parasitism by brown-headed cowbirds and habitat loss and degradation due to succession, real estate development, and land clearing.

ACCOUNTS OF HILL COUNTRY VEGETATION AND SPRINGFLOWS, PRE-EUROPEAN SETTLEMENT

In addition to available information on listed species, sound management practices should mimic natural ecosystems. In response to conflicting information about the native vegetation communities of the Edwards Plateau, the Service has reviewed written accounts of early explorers to help determine what this area originally looked like. These early accounts consistently describe a vast expanse of hills covered with "cedar" from San Antonio to north of Austin. At the same time, abundant clean, flowing water teaming with fish and other wildlife flowed from these cedar-covered hills. The following are some direct quotes from the literature.

Fray Francisco Celiz, Diary of the Alarcon Expedition into Texas, 1718-1719: *"We traveled about three leagues of very rugged land owing to the heavy woods and many rocks; and at the end of the three leagues two soldiers left for upstream to reconnoiter the land. They said that it could not be traveled because it is more wooded and contains more rocks, so that we returned to spend the night at [New Braunfels]. The woods consist of oaks and junipers...This day we traveled east and southeast, and many detours were made to avoid the thick woods"* (Celiz 1935).

Juan Antonio de la Pena, Pena's Diary of the Aguayo Expedition (1722): *"Although the [Comal] creek is not very deep, it carries water the entire year, and about it there are junipers, poplars, walnuts, mulberries, and many vines. The country is wooded as far as the Guadalupe...at this season the latter river is usually very low, but at the time of our arrival its waters, as clear as crystal, were about three feet in depth and covered the stones... Travel in this country was dangerous, for it borders on the Lomeria Grande [Hill Country] inhabited by the warlike Apaches"* (Pena 1935).

Bernardo de Miranda, Miranda's Inspection of Los Almagres (1756): *"Having left the pass of the Payayas [Cibolo Creek], and going past the Balcones, we arrived at the river they call Alarcon [Guadalupe River]. This [travel] was an effort because of the many hills and rocks, the many arroyos formed by the hills, and some thickets that contain valuable cedar and oak timber...After many hardships because of the many hills, arroyos, and brush, we arrived at a creek generally known as Arroyo Blanco [Blanco River], which joins the Rio de San Marcos almost at its source...In all this region there are no commodities nor anything except good cedar and oak timber...We encountered a creek with much water, good level ground on both banks, and much rock and wood, all useful...Crossing many swollen creeks and thickets of cedar and oak timber...On my return I inspected it [Blanco River] as far as the spring of water about which the knowledgeable ones had been telling me of its permanence. Having seen it and examined it, I found almost a buey de agua [apparently a measure of the discharge of a spring or stream equivalent to several thousand gallons per minute; descriptions fit the Blanco State Park area]...It has such convenience as easily withdrawn water, much rock, and cottonwood, oak and cedar timber, all in considerable amount*" (de Miranda 1970).

J.W. Benedict, Diary of a Campaign Against the Comanches (1838): *"Further to the west appeared the skirting timber thickening the further it receded and rising gradually so that mile after mile of the dark boding forest rose to our view...We crossed the Guadalupe, the water of this river has the purest look of any I ever saw. It flows over a bed of small pebbles. The current is rapid and difficult to cross"* (Benedict 1929).

Francis Moore, Jr., Map and Description of Texas, 1840: *"Above the undulating region a section of hilly country extends inland about one hundred miles towards the sources of the San Saba. This region, although much less fertile than the sections below it, abounds in the most picturesque and romantic scenery, and is watered by innumerable beautiful streams, flowing over pebbly beds, and forming numerous cascades that would afford excellent mill seats. Few of these hills attain an elevation exceeding five hundred feet; their summits are generally flat, and tufted with dense thickets of cedar...The hills have a very light thin soil, consisting chiefly of a layer of vegetable mould only a few inches deep, resting upon horizontal strata of limestone...The forests furnish vast quantities of valuable timber, consisting of live-oak, pine, cedar, mesquite which* *nearly resembles mahogany, bois d'arc, and other timber highly prized for cabinet furniture."* (Moore 1965).

____Josiah Gregg, Trip into Texas, June 1841, to June, 1842: *"But to the N.W. [of Austin] set in a chain of rough, though low, woody mountains. These commence hardly a mile to the N.W. of the city and continue to the S.W. a little to the N. of San Antonio. How far to the N.E. they extend I have not learned, but, I believe beyond the Brazos"* (Gregg 1941).

____Prince Solm's 10th report, dated 27 March, 1845 on Comal Creek: *"On the left bank of the Comal Creek there is well forested bottom land which extends to the cedar, oak, and elm covered cliffs which here already have considerable height. Beyond this there is a high ridge with summits here and there similar to our Black Forest. The ridge runs from N.W. to S.E. Through this bottom land the Comal Spring [River] flows. This stream of crystal clear water of considerable depth steadily widens, winds about like a forest torrent, and rushes on. On the 20th of this month, I ascended the ridge on horseback, forcing a path through the heavy cedar thickets and using the outcropping ledges as steps"* (Solms-Braunfels 1966).

Dr. Ferdinand Roemer, Roemer's Texas 1845-1847: *"Our path led us again past the springs of the Comal, but suddenly ascended the steep, wooded slope of the hill...The cedar trees, which covered the slopes exclusively, formed an impenetrable thicket through which a path had to be cut. The cedars here are not the stunted shrub-like plants found in the Northern States of the Union, but are stately trees with straight trunks, seldom more than twenty to twenty-five feet in height and one and one-half feet thick. They have a uniformly spreading crown. This cedar forest was a treasure to the colonists of New Braunfels, since the wood was preferred above all others on account of its durability when used in building houses and fences...Several other streams of West Texas, such as the San Antonio and the San Marcos, are quite similar to the Comal in that they too issue forth as full-fledged streams from mighty springs...About two miles distant from [Austin], a beautiful rounded hill, probably eight hundred feet high with sharp outlines and a heavy growth of cedar on its slope, presented an unusual sight. The Colorado issues from among these hills in a manner similar to that of the Guadalupe at New Braunfels. [Traveling from Austin to New Braunfels] toward the south and southeast the immeasurable, undulating prairie could be seen, whereas in the north and northeast the wooded chain of hills arose." To the west of the Hill Country, Roemer describes "an open, grassy plain, only broken here and there by brushwood and scattered live oak trees"* (Roemer 1935).

Viktor Bracht, Texas in 1848: *"The surrounding country is quite beautiful, however, dark, steep, cedar-covered mountains rise about five miles north of the city [Austin]...The hills which extend all the way from Austin to New Braunfels, are covered with timber...On the one side the Guadalupe rushes by with great speed, while on the other the matchless Comal, crystal clear, rolls by at a speed of about six miles an hour"* (Bracht 1931).

Alex Terrell, The City of Austin from 1839 to 1865: *"The night before [Jacob] Harrell had told [General] Lamar that he had gone up the Colorado for thirty miles in the dark of the moon, when he could go with safety (for Indians always made their forays in the light of the moon), and that he had not found a valley as 'big as a saddle blanket,' and that the mountains were covered with cedar"* (Terrell 1910).

W.B. Dewees, Letters from an Early Settler of Texas, 1852: *"Our route lay through a beautiful country, the creeks were bounded by tall cedars, the land was hilly, and well covered with timber...The Guadalupe and San Marcos rivers are as beautiful streams as I ever saw in my life, and as finely timbered"* (Dewees 1968).

____William Preston Johnston, Austin to Fort Chadbourne, March, 1855: *"We road [from Austin] to the Brushy Creek [near Cedar Park], 20 miles, and camped for the night. Our road was for about 14 miles of the way over a rich rolling prairie and for about six miles through a heavy cedar brake. Cedar is the main reliance for rail timber in this section, the live oak being too gnarled for such purposes"* (Johnston 1964).

____J. De Cordova, Texas: Her Resources and Her

Public Men (1858): *"There are mountains on both sides of Coryell Creek, which furnish large quantities of cedar...The country on [Barton] Creek presents an extensive range of cedar hills...From the Medina to the Hondo the soil is rich weed and mesquite prairie fairly timbered up to the mountains, which are covered with cedar, and send clear crystal waters gushing from them at several different points...To the right of the road [from San Marcos to the Guadalupe River, 16 miles long] is a chain of hills...which are covered with a dense growth of mountain cedar and live oak"* (De Cordova 1858).

____N.M.C. Patterson, The Texas Almanac for 1861: *"...in the mountainous part of [Uvalde] county and in the canyons, is cedar in abundance, and some post oak, which is fine for fencing...There are a great many springs in this country"* (Patterson 1860).

ACCOUNTS OF HILL COUNTRY VEGETATION AND SPRINGFLOWS, POST-EUROPEAN SETTLEMENT

Mexico opened land up for farming and grazing to foreign immigrants in the early 1800s and encouraged settlement by giving each settler 177 acres of land (Weniger 1984). Ashe juniper wood was used for charcoal, fence posts, housing, and furniture. The dependency on junipers led to extensive cedar-based industries and societies of "charcoal burners" and "cedar choppers." By the latter half of the nineteenth century, much of the timber from the Hill Country had been cleared for farming and livestock, and the introduction of sheep, goats, and other livestock eliminated much of the native grasses (Bray 1904, Weniger 1984, Cartwright 1966).

William L. Bray, The Timber of the Edwards Plateau of Texas (1904): *"The mountain cedar is one of the most pronounced and hardy xerophytic trees of all the arid Southwest. It is, in fact, one of the most valuable assets of the region, as well as the most characteristic feature of the hill timber. It is most conspicuous on the white, arid hills of crumbly limestone, because it is there the dominant and practically only species. But it also grows in mixture with other species, and attains its largest growth in the mixed forest of lower flats...where there is more water and richer, deeper soil. In such situations the best yield of poles and ties is found. Reasonably clear poles 20 to 30 feet in length and with a base diameter of from 1-1/2 to 2 feet were formerly common...In general, cedar timber occurs upon all of the hilly or rough parts of the limestone region of Texas from the Palo Pinto country to the Colorado, and thence westward over all of the drainage breaks and the escarpment nearly to the eastern forks of the Devils River. The most extensive bodies of cedar known to the writer are those of the Colorado River breaks from Austin to the San Saba country...Cedar likewise is extensively consumed as fuel and in charcoal burning; but its great value lies in its yield of railway ties, poles, posts, sills, and innumerable other articles which utilize its great durability...but cedar timber large enough to furnish ties and poles is becoming scarce, except in remote districts...A considerable amount of level uplands has also been cleared." Bray describes the western extent of the Edwards Plateau as open prairie.*

"One of the most important services of a forest cover is the mechanical effect which it exercises upon falling rain and upon the run-off. In this way it both checks erosion and promotes the entrance of water into the earth. In the first place, the crowns of the trees, especially when the foliage is on, break the force of the rain and cause it to run harmlessly down the trunk, or to drip slowly through the canopy. Further, the organic debris of the forest floor holds back the fallen water until it has time to soak into the soil. The spreading and interlacing network of roots serves the same purpose, and binds the soil fast against erosion. Thus the rain is kept from swift discharge into the streams, gullying is prevented, and the run-off does not gain sudden volume and velocity after a downpour. The removal of timber from broken or mountainous areas is pretty sure to be followed by more frequent and destructive floods. A forest also increases the water supply from a region by increasing the moisture-holding capacity of the soil. The undecomposed litter which forms the upper layer of the forest floor will itself take up much water, as well as delay its run-off...Thus the forest builds up a storage reservoir the loss of which often makes necessary the construction on a large scale of artificial lakes to conserve the water supply. This work the forest does...without expense.

"Forests also protect from drying winds and sunshine, and tend to maintain a higher water-level in the soil...The transpiration of water vapor which is constantly going on from the leaf surface of a forest also operates to reduce the temperature to some degree...Over against this, however, must be set the fact that the transpiration from heavy grass is still greater than that from a forest...the presence of timber would doubtless conduce to some mitigation of the intense heat, and would also tend to increase the moisture in the air through evaporation from the leaves...Not only does the forest store water in the soil, but it also prevents its loss by evaporation. The trees themselves shield the ground from the sun, and check the movement of drying winds. They also keep the soil cool, and in consequence lessen the giving off of moisture. This defense against evaporation is further reenforced by the undergrowth and the leaf litter, while the forest itself acts as a mulch to prevent drying out...It is true that a forest evaporates much water from the foliage, but it draws this largely from the lower soil levels; so that, even if the total loss of water from a forest area were equal to that on an exposed area, the earth would not be baked so dry, nor would shallow-rooted herbaceous vegetation be so effectually excluded...For all these reasons forests tend to conserve the water supply and maintain full springs and an even flow of streams" (Bray 1904).

____Gunnar Brune, Springs of Texas (1981): *"Clearing of forests was especially damaging to ground-water levels. The deep, open structure of the forest soils was altered as the organic matter was consumed and the soils became more impervious. Plowing of hillsides and the soils soon caused severe erosion and loss of the permeable mulch layer and top soil. Huge gullies began to scar the landscape. Floods and sediment damage began to increase in severity. The real damage to the ground-water reservoirs began in the nineteenth century with the influx of Anglo-American settlers. The cattle barons, so often idealized in the literature, caused catastrophic damage when they turned their vast herds onto the native prairie grasses. In the middle 1800s deep wells began to be drilled. It was found that flowing wells could be brought in nearly everywhere...Nothing could have had a more disastrous effect upon spring flows than the release of these tremendous artesian pressures through flowing wells. Most of these wells were allowed to flow continuously, wasting great quantities of water, until they stopped flowing...When the wells ceased flowing, pumping began...Beginning around 1930, enormous quantities of ground water began to be withdrawn for crop irrigation. Irrigation now takes about 75% of the ground water used in Texas"* (Brune 1981).

____Walter J. Cartwright, The Cedar Chopper (1966): *"Men in the cedar brakes of the Texas hill country and in the valleys of the Colorado and the Brazos rivers still cut cedar fence posts for a living...The development of barbed wire fencing [in 1879] created the first great demand for cedar fence posts in Texas...The use of fence posts on the plains and a need to clear cedar from the ranch lands...greatly expanded the market for cedar choppers. Especially 'about the time of World War I the need for more land for farming and ranching became acute, so much so that farmers and ranchers began a systematic eradication of the cedar...' As early as the 1920s, Kerr County ranchers and farmers hired gangs of cedar choppers, paid either $2.00 per acre or for the cedar posts that were cut...By 1937 the United States government in a program under the Agricultural Adjustment Act began to contribute to the cost of cedar eradication."* Cartwright makes specific reference to communities of cedar choppers in the hills around Austin, Kerr County, Palo Pinto County, and San Saba (Cartwright 1966).

ACCOUNTS OF HILL COUNTRY VEGETATION AND SPRINGFLOWS, RECENT

In contrast to early explorer accounts, several 20th century publications, beginning as early as 1917, assert that the Hill Country was originally composed of grasslands and savannahs that are being invaded by Ashe juniper (including Foster 1917, Tharp 1926, Fowler and Dunlap 1986, Garriga et al. 1997, Hicks and Dugas 1997, Kothmann et al. 1997, Reinecke et al. 1997, Taylor et al. 1997, Thurow and Hester 1997, Thurow and Thurow 1997, Thurow et al. 1997, Ueckert 1997, Dugas and Hicks 1998). Other studies and reports are more consistent with historical accounts (including Bray 1904, Cartwright 1966, Van Auken et al. 1979, 1980, Weniger 1984, Riskind and Diamond 1988, Diamond et al. 1995, Diamond 1997, Diamond et al. 1997, Nelle 1997). Van Auken et al. (1979, 1980) provide a quantitative description of upland woody plant communities of the Hill Country, and found that Ashe juniper, live oak, and persimmon accounted for 80% of all species present.

Satellite imagery data from 1996 and 1997 acquired by the Service show remnants of oak-juniper woodlands along the eastern and southern edge of the Edwards Plateau. The largest concentrations occur on Ft. Hood Military Reservation, along the rapidly urbanizing corridor between Austin and San Antonio, and west of San Antonio in Bandera, Kerr, Real and northern Medina and Uvalde counties. These areas provide the best habitat for the warbler. The northern and western portions of the Edwards Plateau gradually become dominated by grasslands.

IMPLICATIONS OF BRUSH REMOVAL ON THE EDWARDS PLATEAU

The Service is unaware of any research that has demonstrated long-term benefits to water quantity nor any benefits to water quality in the Edwards aquifer from brush removal. On the contrary, the native forests of the Hill Country appear to serve an important role in providing shade from drying winds and sun, streambank stability, filtration of upland runoff, and baseflow needed to sustain water supplies during drought cycles. As forests are cleared, streamflow shifts from predominantly baseflow to predominantly surface runoff. With increasing surface runoff, the severity of flooding increases. The increased quantity and velocity of runoff increases erosion and streambank destabilization, which in turn leads to increased sediment loadings, channel widening, and changes in the morphology and ecology of the affected creek. Increased erosion and sedimentation can in turn clog recharge features and flow paths in the aquifer. Furthermore, runoff that occurs too fast may exceed the maximum recharge rate and bypass the aquifer.

IMPLICATIONS OF BRUSH REMOVAL ON THE HILL COUNTRY

The available information indicates the eastern and southern extent of the Edwards Plateau, known as the Hill Country, was originally a mosaic of extensive oak-juniper forests interspersed with areas of dense shrubbery and tall grasses. From these hills flowed an abundance of springs, creeks, and rivers. Farther to the north and west, where the plateau levels off and rainfall declines, prairies and savannahs become more predominant.

Although much of the Hill Country's oak-juniper woodlands have been cleared and fragmented, patches remain from Ft. Hood south to San Antonio and west to Real County. Because of the imminent threats to the golden-cheeked warbler, black-capped vireo, karst invertebrates, Texas snowbells, and Tobusch fishhook cactus, efforts to protect their remaining habitat are critical to ensuring the continued survival and recovery of these species. In accordance with Section 7 of the Endangered Species Act, any federal assistance or programs that encourage the conversion of oak-juniper woodlands and/or shrublands in areas occupied by 1 or more of these species require consultation under the Endangered Species Act to cover impacts that may occur and ensure that impacts do not jeopardize the continued survival and recovery of any listed species.

The Service is particularly concerned about the use of Federal programs to promote the conversion of native Hill Country woodlands to grasslands and the concept that Ashe juniper is a "bad", invasive species that needs to eradicated. Under Section 7(a)(1) of the Endangered Species Act, Federal agencies must use their programs to conserve listed species and the ecosystems on which they depend. In the Hill Country, this includes the oak-juniper woodlands that provide the only breeding habitat for the golden-cheeked warbler and many other endangered and rare species.

For private landowners who are not receiving Federal assistance, the Texas Parks and Wildlife Department and the Service have developed habitat descriptions and management guidelines for the warbler, vireo, karst invertebrates, and Edwards aquifer species. These leaflets are intended to assist private landowners in determining whether or not their activities could impact one or more of these listed species. Where impacts are unavoidable, landowners should contact the Service for further assistance.

The Service is also working with Environmental Defense, Inc. on a Safe Harbor permit to cover habitat restoration activities for the black-capped vireo and golden-cheeked warbler under the Endangered Species Act. A Safe Harbor permit provides a means by which landowners can restore habitats for endangered species without incurring additional regulatory restrictions on the use of their property. This voluntary incentives program would assist private landowners in restoring habitat for the black-capped vireo and golden-cheeked in 25 Hill Country counties. Private landowners who are interested in this effort should contact the Service or Environmental Defense.

CONCLUSION

Based on the habitat requirements of the listed species, historic accounts prior to extensive land clearing activities, the pervasive threats of land clearing and real estate development to the remaining habitat, and the importance of forests in protecting water supplies and the terrestrial ecosystems on which so many listed and other rare species depend, conservation of the Hill Country's oak-juniper woodlands and shrublands is essential to the continued survival and recovery of the terrestrial species. Although Ashe juniper and other woody species have recently been targeted as culprits in the decline of water quality and quantity in the Edwards aquifer, the major causes for which solutions must be sought are groundwater pumping, land clearing, and urbanization. The Service will continue to work with Federal, State, local, and other stakeholders to explore viable solutions to conserving water in this finite resource and protecting threatened and endangered species.

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