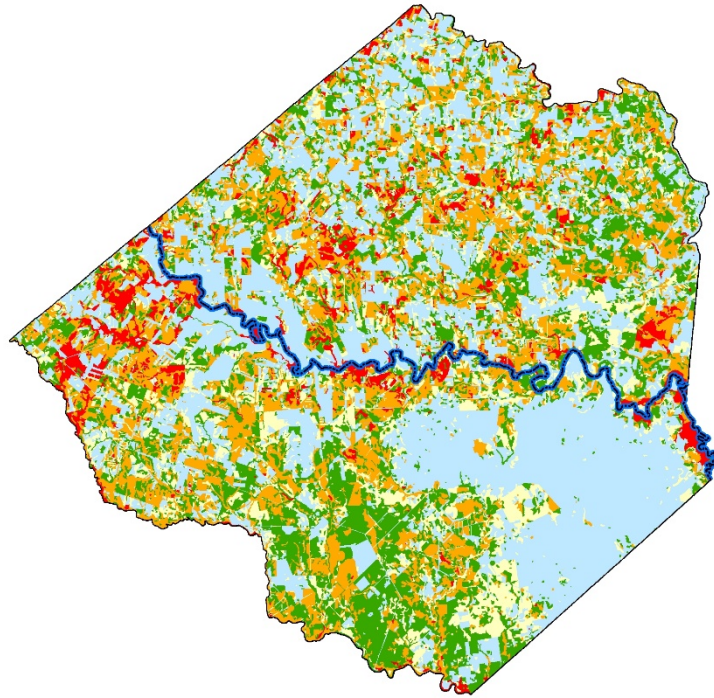


**DEVELOPMENT OF AN EDYS ECOLOGICAL MODEL FOR
GOLIAD COUNTY, TEXAS**

FINAL REPORT



PREPARED FOR:

SAN ANTONIO RIVER AUTHORITY

AND

TEXAS STATE SOIL AND WATER CONSERVATION BOARD

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TABLE OF CONTENTS

EXECUTIVE SUMMARY -----	2
1.0 INTRODUCTION -----	8
2.0 SPATIAL FOOTPRINT -----	9
3.0 TOPOGRAPHY -----	10
4.0 PRECIPITATION -----	12
4.1 Temporal Variability -----	12
4.2 Spatial Variability -----	16
5.0 SOILS -----	24
5.1 Soils Map -----	25
5.2 Profile Descriptions -----	26
6.0 VEGETATION -----	30
6.1 Plant Species -----	30
6.2 Vegetation Formations -----	33
6.3 Plant Communities -----	36
6.4 Spatial Heterogeneity of Vegetation -----	40
6.5 Plant Parameter Variables -----	42
7.0 ANIMALS -----	46
8.0 CALIBRATION -----	51
8.1 Vegetation -----	51
8.1.1 General Procedure -----	52
8.1.2 Examples -----	53
8.2 Ecohydrology -----	61
8.2.1 Evapotranspiration -----	61
8.2.2 Surface Runoff -----	66
8.2.3 Sediment Loadings -----	69
8.2.4 Flow Rates -----	71
9.0 SCENARIOS -----	81
9.1 Vegetation -----	82
9.1.1 Baseline -----	82
9.1.2 Dry Cycle -----	86
9.1.3 Wet Cycle -----	89
9.1.4 Brush Management -----	91
9.2 Ecohydrology -----	98
9.2.1 Water Balance: Average Rainfall -----	98
9.2.2 Runoff -----	100
9.2.3 Evapotranspiration -----	103
9.2.4 Groundwater Use by Vegetation -----	105
9.2.5 Change in Water Balance -----	105
9.2.6 Water Balance by Watershed -----	108
9.2.7 Maximum Effect of Brush Control on Water Balance -----	112
10.0 LITERATURE CITED -----	120
APPENDIX A: PRECIPITATION -----	142
APPENDIX B: SOILS -----	143
APPENDIX C: VEGETATION -----	145
APPENDIX D: ANIMALS -----	181
APPENDIX E: PLANT PARAMETERS -----	185

EXECUTIVE SUMMARY

San Antonio River Authority (SARA) is interested in developing an integrated set of ecological simulation models for the San Antonio River system. To accomplish this, EDYS ecological models are being developed for each county along the San Antonio River. The first two models of this project were developed for Karnes County and Wilson County. This report presents the description of the third model in the series, Goliad County, along with the calibration process and ecological and hydrological results from ten land management simulation scenarios.

Texas State Soil and Water Conservation Board (TSSWCB) is also interested in the development of county-wide simulation models. In particular, TSSWCB is interested in these models being used to evaluate potential enhanced water yields from control of woody species. Goliad County is one of the counties selected by TSSWCB to have a model available to evaluate enhanced water yield and has co-operated with SARA in the development of the Goliad County EDYS model.

Description of the Models

Goliad County covers about 859 mi² (549,984 acres) located along the boundary between South Texas and the Texas Coastal Prairies. The San Antonio River flows through the center of Goliad County, flowing in an approximately NNW to SSE direction.

The basic spatial unit of the EDYS model is the cell. The cell size for the San Antonio River models is 40 m x 40 m (0.40 acre). This results in the Goliad County model containing about 1.4 million cells. Each cell contains data on topography, soil, depth to groundwater, vegetation, and land use.

Surface topography in the model is defined by an average elevation for each cell, with slope and aspect determined by differences in elevation among adjacent cells. The elevation data used in the Goliad County model are USGS 10-m DEM. Each cell also has an average depth to groundwater value, from which a depth to groundwater grid is defined for the county.

The spatial domain is divided into four precipitation zones, with separate precipitation files used for the cells in each zone. The model simulates rainfall on a daily basis. For each of the four zones, a 122-year (1893-2014) daily precipitation record was created based on statistical relationships among recorded precipitation data from 30 stations in a 12-county region surrounding Goliad County.

A detailed soil profile description was assigned to each of the 1.4 million cells in the model. These profiles were developed from NRCS soil survey descriptions of Goliad County soils and from additional data available in the literature. A total of 24 soil types are included in the Goliad County model and each cell is assigned to one of the 24 types based on the location of the cell on the spatial landscape. Each of the 24 soil types is divided into 35 layers, with the thickness and physical and chemical characteristics of each layer varying among the types. Some of the soil variables remain constant throughout a simulation (e.g., soil texture) while values of other

variables (e.g., soil moisture) change by layer on a daily basis depending on environmental factors such as amount of rainfall received and amount of water and nutrients extracted by plants.

The number of plant species included in a specific EDYS application is flexible. A total of 84 species are included in the Goliad County model. Dynamics of each species are modeled by use of 346 parameter variables, with each variable having different values for each species. Changes in vegetation are modeled in EDYS on a plant species (or plant part) basis by simulating differential responses, defined by the different parameter values, to changes in environmental factors (e.g., rainfall, grazing, season).

The spatial footprint of the model was initially divided into plant communities and land management units (e.g., cultivated, urban, road) by assigning each cell type to one of 34 plot types (vegetation and land-use types). The locations of the vegetation types were based on NRCS soil survey maps and the locations of land-use types were based on 2012 NAIP aerial photographs. Each vegetation type was further divided based on amount of woody plant cover present, with these values visually estimated from the 2012 NAIP aerial photographs. Initial (i.e., start of a simulation) biomass values were entered for each plant species in each plot type, based on species composition for each type. Biomass (above- and belowground) values change for each plant species and each plant part (e.g., fine roots, trunks, leaves) per species at each time step (daily) during an EDYS simulation.

The animal component in EDYS models consists of the effects of herbivory by different types of animals, both domestic and wildlife, on the vegetation. Herbivory is modeled as a plant-part and plant-species specific process, where selection of plant parts and plant species varies by animal species. Densities of each animal species are entered and the model calculates the quantity of plant material the animals would consume daily and then determines how much of each species is removed based on selectivity, accessibility, and competitiveness among the animals. Four animal species (or groups) are included in the Goliad County model: cattle, deer, rabbits, and insects. An average white-tailed deer density of 1 deer per 15 acres was used in the model. Cattle stocking rates were calculated for each vegetation type and averaged 14.7 acres/AU for native rangeland. Horses and feral hogs can be added but were not included in the model because of lack of information on densities and distributions of these two species.

Calibration

Calibration in EDYS consists of making adjustments of parameter values, if needed, to achieve target values for the output variables under consideration. Target values are taken from independent validation data, either experimental validation studies or existing field data, if these data are available. In the absence of independent validation data, values from the literature and values based on professional judgement are used.

Only very limited independent validation data are currently available for Goliad County. Therefore, data from published studies in South Texas and the Central Texas Coast and professional judgement were used to calibrate the vegetation and hydrologic dynamics of the model. Ten-year simulations for six plot types (plant communities) were used in the vegetation calibration process. Results of simulated vegetation change in response to fluctuations in

rainfall, grazing, and time (succession) were compared to published results from 23 studies and to our professional experience in the region. The simulation results compared favorably to the patterns and levels expected from these studies and regional experience. Under the moderate rainfall regime and with livestock grazing, there was a 10% increase in overall biomass on the clay loam type at the end of the 10-year simulation. Huisache increased by 12% and there was an increase in major shrubs (whitebrush, granjeno, prickly pear). Midgrasses increased 20% and shortgrasses decreased by 50%. Plains bristlegrass and silver bluestem were the midgrasses that increased the most. Under moderate grazing by cattle, midgrasses decreased by 43% compared to the ungrazed scenario and shortgrasses increased by 155%. Forage production in the simulations (tenth year) was 237, 262, and 552 g/m² on the clay loam, sandy loam, and cordgrass types compared to 164, 252, and 543 g/m² on similar sites reported in literature studies in South Texas.

Twenty-five year calibration simulations were used for the hydrologic variables. The longer period used to include greater fluctuations in rainfall. Simulated amounts of evapotranspiration (ET) and surface runoff were compared to literature values for the region and for similar types of vegetation. The simulated ET values corresponded well with reported values in the literature. On the clay loam type (38% average woody plant cover), ET averaged 2.3 mm/day, compared to 2.6 mm/day on a mesquite-granjeno site in South Texas. The simulated ET was equal to 96% of annual rainfall compared to 94-97% on sites with similar vegetation reported in the literature.

Simulated runoff values also compared favorably with published values. For example, annual runoff on the clay loam type used in the calibration averaged 0.85 inch compared to 0.6 inch on a USGS gauged clay rangeland site in San Patricio County. The average annual runoff for the seven vegetation types used in the calibration was 1.85 inches, or 5.5% of annual rainfall. Average annual runoff from three USGS gauged sites in San Patricio County was 1.86 inches, or 3.1% of annual rainfall.

Averaged over the entire county over the 25-year calibration simulation at the moderate rainfall regime, annual sediment load was 47 g/m² (0.208 tons per acre). This value corresponds well with published values for rangeland systems in the western Edwards Plateau (33 g/m²), northern Edwards Plateau (34 g/m²), and the Rolling Plains of North Texas (83 g/m²).

There are two gauge stations in Goliad County that were used to compare measured flow rates with estimated flow from the EDYS simulations. The gauge station at Goliad measures flow of the San Antonio River at near Goliad. That flow includes flow entering from Karnes County plus runoff and subsurface flow in 33 watersheds in, or partially in, Goliad County. The difference in average monthly flow rate between the Goliad gauge and the next upstream gauge (at Runge) was 7,419 acre-feet for the period June 2011-March 2016. About half that amount likely entered the river between Runge and the Goliad-Karnes County line. Surface runoff plus maximum lateral subsurface seepage in the EDYS simulations for the Goliad portion of the watershed accounted for 1,064 acre-feet, or 28% of the expected increase in flow.

The second gauge used in the calibration is located on the Perdido Creek and its associated watershed is entirely within Goliad County. Comparison of gauged data to EDYS simulation of surface runoff over a seven-year simulation period indicated that the EDYS simulation accounted

for 85% of the total flow recorded at the gauge. However, the EDYS runoff and peak flows at the gauge often did not coincide on a monthly basis. Part of the reason for this difference in monthly patterns was likely because of the timing of water movement. EDYS runoff tended to enter the creek soon after a rainfall event and there was often a lag-time before the flow was recorded at the gauge.

Results

Ten 25-year scenarios were simulated as examples of how the models can be used. Three scenarios were included to illustrate the response to fluctuations in rainfall patterns. Only rainfall was varied in these three scenarios. One was baseline, which used the rainfall data from the 25 continuous years (1928-1952) which had a mean nearest the long-term mean. The second scenario used the rainfall data from the driest 25 continuous years (1915-1939) and the third scenario used the rainfall data from the wettest 25 continuous years (1957-1981). Five scenarios illustrated responses to brush management. In Scenario 4, 100% of the woody biomass (except for live oak) was removed from areas with 30% or more woody cover and had less than 12% slope. Brush removal was simulated in the first year only and this scenario used the baseline (moderate) rainfall regime (1928-1952). Scenario 5 was similar to Scenario 4 except that 50% of the live oak was also removed. Scenario 6 was similar to Scenario 5 except the dry rainfall regime (1915-1939) was used. Scenario 7 was similar to Scenario 5 except the wet rainfall regime (1957-1981) was used. Scenario 10 (maximum woody plant removal) was similar to Scenario 5 except the woody species were removed from all non-urban areas. The remaining two scenarios illustrated the impact of increased area in cultivation. In Scenario 8, 6.5% of the total land area of the county was placed under cultivation by removing the native vegetation and replacing it with cultivation of grain sorghum under the moderate rainfall regime. Scenario 9 was similar to Scenario 8 except the amount of cultivated land was increased to 21% of the total area of the county. The report presents the results of each of these ten scenarios on vegetation and hydrology.

Vegetation Changes

Vegetation change in the simulation scenarios varied by plot type and management scenario. Two of the major plot types were clay loam and loamy sand. Under the baseline scenario (average rainfall, moderate grazing by cattle, no brush control), there was a slight increase in woody species on the clay loam type overall but major changes in species composition. Huisache, whitebrush, granjeno, and prickly pear increased (13%, 47%, 6%, and 4%; respectively) while blackbrush, baccharis, and wolfberry decreased. On the loamy sand type, there was a 10% decrease in woody plant cover. Midgrasses increased on both types but much more so on the loamy sand type. Silver bluestem was the major midgrass that increased on the clay loam site and sideoats grama, silver bluestem, and little bluestem increased on the loamy sand site. Shortgrasses also increased substantially on both sites, with most of increase coming from purple threeawn and buffalograss.

Under the dry regime (11% lower rainfall), woody species decreased by about 1% compared to baseline and herbaceous species decreased by 11%. Grass production was strongly affected by the dry regime, with lower production especially for the midgrasses. Under the wet regime (15%

higher rainfall), woody species increased 3% overall compared to baseline and herbaceous production increased 21%.

Brush control substantially reduced woody plant cover. Under most of the brush control scenarios, woody plant biomass was only 10% of initial values at the end of 25 years. This assumed an initial removal of 100% of most woody species in the first year. A 95% rate would be more likely under field conditions. At 95% initial removal, the regrowth would likely be around 15-25% after 25 years, rather than the 10% at 100% initial removal.

Brush control substantially increased herbaceous production on some sites but not on others. On the clay loam site, grass production increased by 62% over baseline at the end of 25 years and 33% on the loamy bottomland site, but did not increase on the loamy sand site. These differences in responses were primarily the result of differences in soils and soil moisture responses. On clay loams, there was a substantial increase in silver bluestem, plains bristlegrass, and buffalograss following brush control. On the loamy bottomlands, Johnsongrass was the primary species that benefited, and on the loamy sand sites brownseed paspalum and little bluestem benefited the most from brush control.

Ecohydrology

Averaged over the entire county and under the moderate rainfall regime, an average of 1.3% of annual rainfall entered the creeks and river as surface runoff under the baseline scenario and ET accounted for an average of 116% of annual rainfall. This high ET rate was the result of high groundwater use by vegetation. There was also high annual variability in runoff and ET because of variability in annual rainfall. In the 25-year moderate rainfall regime, annual rainfall varied between 17.0 and 44.9 inches and annual surface runoff varied between less than 1000 acre-feet to more than 50,000 acre-feet and annual ET varied between 1.3 million acre-feet (93% of annual rainfall) and 2.2 million acre-feet (146% of annual rainfall). Annual groundwater use by vegetation varied between 130,000 and 424,000 acre-feet, with an annual average of 172,000 acre-feet (3.8 inches per year).

Under the dry regime, surface runoff decreased by an average of 64% compared to baseline and it increased by an average of 72% over baseline under the wet regime. The brush control scenarios had little effect on surface runoff under any of the rainfall regimes primarily because herbaceous vegetation was slow to recover following brush control. Increasing the amount of cultivated land decreased the amount of surface runoff, but not substantially (decrease of 820 acre-feet per year when 21% of the area was in cultivation).

Evapotranspiration (ET) averaged 38.0 inches per year (116% of annual rainfall) under baseline conditions, or an annual average of about 1,726,000 acre-feet. Brush control reduced this to an annual average of 1,620,000 acre-feet (35.7 inches per year), or an annual reduction of about 106,000 acre-feet. Under the 25-year dry regime, annual reduction in ET from brush control was even greater (132,000 acre-feet). An increase in cultivated acres also decreased ET. When 6.5% of the area was cultivated, annual ET was reduced by 50,600 acre-feet and when 21% of the area was cultivated annual ET was reduced by 155,000 acre-feet.

Under most of the scenarios, there was a negative annual water balance. This was the result of high groundwater use and depletion of stored soil moisture. A negative annual water balance cannot be maintained indefinitely. Either more groundwater will be used or water use by the vegetation will decrease, the later of which will lead to a reduction in vegetation structure and production. Much of this negative balance is likely the result of an increase in woody species over the past 25-50 years. The two exceptions to the negative balances were 1) brush control under the wet regime and 2) the 21% of area under cultivation scenario. Under the wet rainfall regime with brush control, there was an average annual surplus of almost 41,000 acre-feet, or slightly under 1 inch per year. Under the moderate rainfall regime, an annual surplus could probably be achieved if woody species were reduced substantially in 40-50% of the county. When area under cultivation was increased to 21%, there was an average annual surplus of 32,800 acre-feet under the moderate rainfall regime. This is about twice the amount of area under cultivation as was under cultivation around 1950.

A maximum brush control scenario was run to estimate the upper limit to what could theoretically be achieved in water yield enhancement from brush control. This scenario removed all woody species (except pecan and 50% of live oak) from all non-urban areas. As such, it is not a practical scenario, but was used to estimate maximum potential yield. Maximum potential enhanced water yield from this scenario averaged 287,000 acre-feet per year, 47% of which was from reduced groundwater use by deep-rooted species and 53% was from reduced ET use of annual rainfall.

Summary

The Goliad County EDYS model provides a tool that is useful for quantifying vegetation and hydrologic responses to various environmental and management changes, especially for quantifying relative differences. Vegetation dynamics, changes in both production and species composition, are simulated in an ecologically reasonable manner, with results comparable with those from published research studies. Flow, surface runoff, and sediment load dynamics fit both patterns and amounts indicated by gauged data and published literature values. Evapotranspiration values are comparable with published values and responses to changes in rainfall and vegetation management are ecologically reasonable and consistent with published values.

1.0 INTRODUCTION

The San Antonio River begins in Bexar County and flows southeastward through five counties before merging with the Guadalupe River and then flowing into San Antonio Bay on the central Texas Coast. Goliad is the middle county through which the San Antonio River flows (Fig. 1.1).

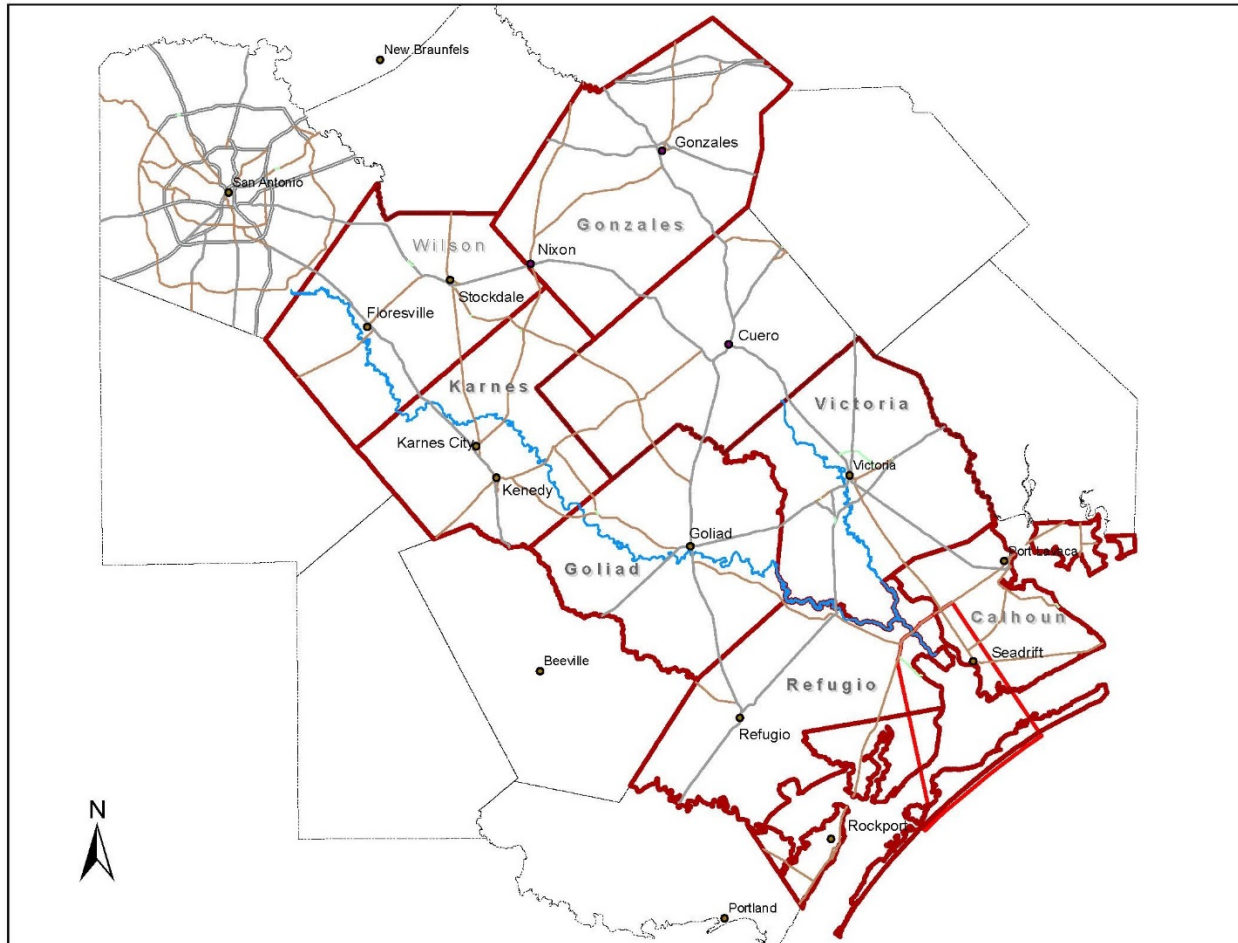


Figure 1.1 Map of the region of the San Antonio River watershed.

The San Antonio River Authority (SARA) has the dual responsibility of managing water quality and water quantity in the San Antonio River and its tributaries. The quality and quantity of river water are affected by both in-stream factors and characteristics of the respective watershed. SARA recognizes the importance of understanding the effects of in-stream responses and watershed ecohydrology to making good management decisions relative to the San Antonio River system.

Natural and anthropogenic changes across the landscape can have major impacts on the water quality and quantity of the river. Management tools that integrate spatial and temporal ecological dynamics at multi-species and multi-scale levels provide valuable support to the environmental decision-making process. Ecological simulation modeling is a tool that allows

complex hydrologic, ecological, and management responses to be integrated in a practical and scientifically valid manner, the results of which can substantially improve land-use planning and decision making.

SARA is interested in developing an integrated set of ecological models for the entire San Antonio River system for the purpose of supporting their decision-making process related to the management of the San Antonio River. In June 2011, SARA began the application of the EDYS model to San Antonio Bay as the first step in developing this set of integrated ecological models. EDYS is a mechanistic, spatially-explicit, dynamic ecosystem simulation model that has been widely applied to land management decision making (Ash and Walker 1999; Childress and McLendon 1999; Childress et al. 1999a, 2002; USAFA 2000; McLendon et al. 2000, 2012e, 2015; MWH 2003; Chiles and McLendon 2004; Price et al. 2004; McLendon and Coldren 2005, 2011; Naumburg et al. 2005; Amerikanuak, Inc. 2006; Johnson and Coldren 2006; Johnson and Gerald 2006; Mata-Gonzalez et al. 2007, 2008; Coldren et al. 2011a, 2011b; HDR 2015; Broad et al. 2016). In June 2013, SARA began the expansion of this model development to include up-river segments of the linked river-bay system. Karnes and Wilson Counties were selected as the first two counties to be included in the integrated model complex. These two models were completed in December 2014 (McLendon et al. 2015). In September 2013, SARA expanded work on the linked-model complex to include Goliad, Refugio, and Victoria Counties.

Texas State Soil and Water Conservation Board (TSSWCB) is also interested in the development of county-wide simulation models. In particular, TSSWCB is interested in the development and application of simulation models to be used to evaluate potential enhanced water yields from control of woody species. TSSWCB previously supplied funding for the development of EDYS models for Gonzales County (McLendon et al. 2012e; McLendon 2013) and most of Edwards, Kimble, Real, and Sutton Counties. In August 2013, TSSWCB provided funds to supplement those provided by SARA to develop EDYS models for Goliad and Victoria Counties.

This document reports on the results of the development of an EDYS model for Goliad County. It provides an overview of the model and presents results of a set of simulation scenarios.

2.0 SPATIAL FOOTPRINT

Goliad County covers 859.35 mi² (549,984 acres), located along the boundary between South Texas (South Texas Plains, Hatch et al. 1990) and the Texas Coastal Prairies (Diamond and Smeins 1984). The San Antonio River flows through the center of Goliad County, flowing in an approximately NNW to SSE direction.

In EDYS, the spatial footprint is divided into cells. A cell is the smallest unit that EDYS simulates in a particular application and it can be of any size, determined by the requirements of the application. EDYS averages values for each variable across an individual cell, therefore the cell size selected is a balance between 1) the largest size for which average values are acceptable and 2) reasonable simulation run times and memory requirements. The smaller the cell size, the more spatially precise the simulation is. However, smaller cell sizes result in more cells and a larger number of cells results in a slower run time per time step and more memory requirement.

The primary cell size selected for the Goliad model is 40 m x 40 m (0.40 acre), resulting in approximately 1.38 million cells for Goliad County. The following components (discussed in following sections) are included for each cell: topography (elevation, slope, aspect), soil, depth to groundwater, vegetation, and land use.

A practical upper limit for efficient EDYS operation (relative to run time and memory requirement) on appropriate PCs is about 1.5 million cells. Combining multiple counties into a single model and retaining the 40 m x 40 m cell size is impractical because the spatial domain increases to well over 1.5 million cells. The alternative approach is to keep each county model separate and then link the models, where output from one model can be used as input into another model. This has two primary advantages. First, it allows large spatial domains to be included with small cell sizes. Secondly, it allows for separate individual models that can be run either as linked models or separately as individual models. An advantage in having separate models available is that simulations can be run for the separate domains much faster than if there was only one large model. Having separate, but linked, models for each county also allows for the linked model to be easily expanded so that additional counties (e.g., Gonzales, Karnes, and Wilson) can be added.

EDYS has the ability to simulate selected areas at a finer resolution than the primary cell size used in the overall model. This capability is particularly useful for simulating ecological dynamics in critical areas where the smaller scale becomes important (e.g., some aquatic systems, critical habitat areas, urban development patterns). These critical areas have not yet been defined for the needs of SARA and TSSWCB in Goliad County. One of the purposes of developing the current models may be to investigate some of these areas. Once these areas are identified, finer-scale models can be developed for them and then added to the larger-scale model. The fine-scale models (1 m x 1 m cell size) developed for the validation plots in Atascosa, Karnes, and Goliad Counties are examples of this approach.

3.0 TOPGRAPHY

Surface topography is an important component in EDYS simulations. It controls the flow pattern and velocity of runoff water, inundation depth of flood water, water depth in ponds and lakes, and tidal depths and patterns in coastal wetlands, and it influences movement patterns for some wildlife species, foot and vehicle traffic, some management options (e.g., limitations to mechanical brush control), and fire events.

Elevation, slope, and aspect are the three topographic variables used in EDYS. All three are derived by EDYS from input elevation data. Surface topography is developed in EDYS based on differences in elevations among adjacent cells. Average elevation (USGS DEMs, or LIDAR data if available) is entered for each cell. From these elevations, EDYS determines slope (angle from horizontal) and aspect (direction). Differences in elevation among adjacent cells allow water to move from higher elevations to lower elevations and the greater the difference in elevation between two cells, the higher the velocity the water moves downslope and hence the greater the erosive potential and sediment carrying capacity. Direction of the difference in elevation (i.e., aspect) determines the direction of surface flow.

Initial elevations are entered from DEM or LIDAR data. For the Goliad County model, USGS DEM data are 10-m resolution were used to develop the initial elevation grid (Fig. 3.1). LIDAR data, supplied by SARA, were available for some locations. We tried to use these data where available spatially and fill in the gaps using 10-m DEM data but the fit using these two data sets was not smooth. Therefore, we used the 10-m DEM data throughout the county.

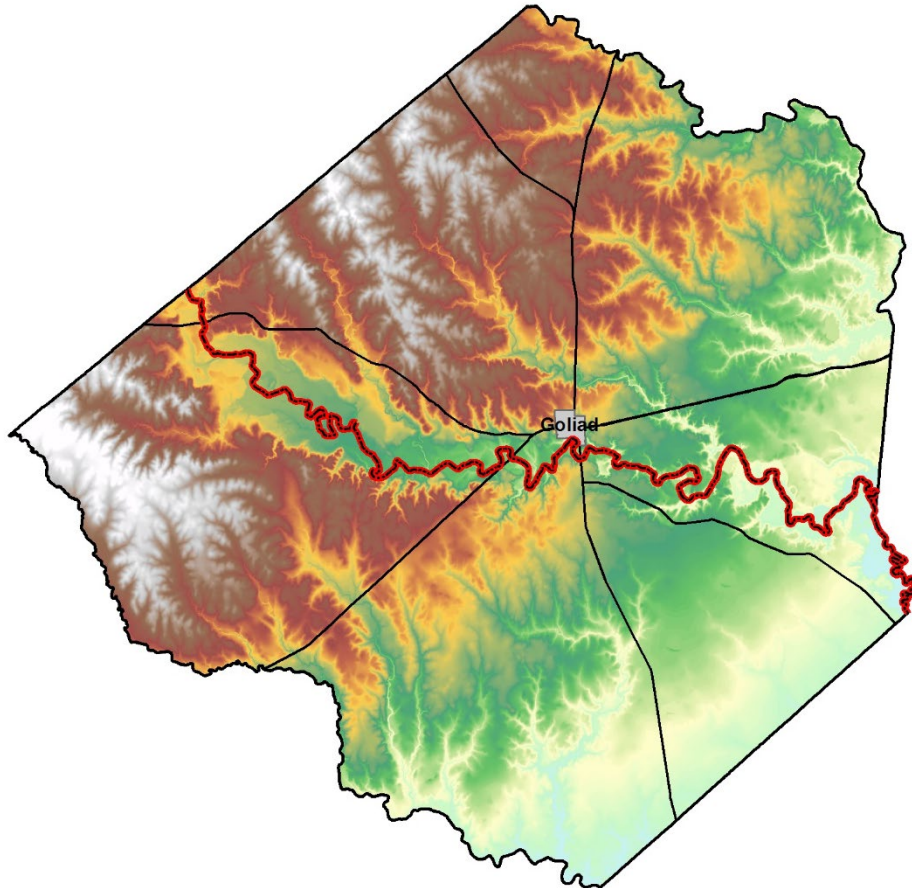


Figure 3.1 Topographic map of Goliad County based on USGS 10-m DEM data.

In EDYS, precipitation is applied to each cell. If that cell has the same elevation as all four adjacent cells (i.e., flat topography), there is no runoff and the water has maximum opportunity for infiltration in the soil profile, the only loss in this case is from evaporation. This condition in EDYS is termed “ponding”. If any of the adjacent cells have lower elevations than the central cell, some water flows from the central cell to the adjacent cells that have lower elevations. The amount of water that flows to the lower cells depends on the infiltration rate of the soil in the central cell, the slope between the central cell and each lower-elevation adjacent cell, and the intensity of the rainfall event. If an adjacent cell has a higher elevation than the central cell, water flows from the higher-elevation cell to the central cell, this amount of water is added to the quantity in the central cell that is available for runoff, and the total amount in excess of infiltration is moved to the adjacent lower-elevation cells. This process continues as a

downslope process until all runoff water is moved to the lowest elevation cells or removed from the spatial footprint (surface flow export).

During a simulation run, elevations can change because of erosion or deposition. This process is discussed in more detail in the soils section (Section 5.0).

4.0 PRECIPITATION

Precipitation is an important driving variable for many ecological processes. Both temporal and spatial variations are ecologically important.

4.1 Temporal Variability

Precipitation varies at different time steps, e.g., minute to hourly during a rainfall event, daily, seasonally, annually, and long-term. EDYS inputs precipitation on a daily basis. Use of shorter-term periods (e.g., hourly) is possible in EDYS and can be used in simulations when necessary. The value of precipitation data in simulation modeling, as in most ecological studies, increases substantially as the length of the period of record increases. Long-term (more than 100 years) precipitation data are not available for most recording stations and the data from most stations are not complete for the reported period of record (i.e., there are missing data). Constructed precipitation data sets (Section 4.3) are used in EDYS models to 1) account for missing data in the recorded data and 2) extend the length of the data set.

Precipitation patterns typically vary on short-, medium-, and long-term scales. Short-term fluctuations include 1) annual variations around a mean, with some years being either drier or wetter than average, and 2) series of below- or above-average precipitation years, the series often lasting 2-5 years but sometimes lasting a decade or more. For example, the long-term (1913-2015) mean annual rainfall recorded at Goliad (excluding years with incomplete data) is 34.84 inches. The driest year on record was 9.73 inches in 1917 (28% of long-term mean) and the wettest year on record was 59.48 inches in 1981 (171% of long-term mean)(Appendix Table A.1). The driest short-term (four continuous years) period on record was 1915-18, during which annual precipitation averaged 20.88 inches (60% of long-term mean) and the wettest short-term (four continuous years) period on record was 1973-76, during which annual precipitation averaged 46.00 inches (132% of long-term mean).

Short-term periodicity at Goliad involves wet-dry cycles of 3-20 years (average of 8 years)(Fig. 4.1). Above-average cycle periods (wet) have an average length of 8.5 years (range = 4-20 years), with average annual means of approximately 35-44 inches (average annual = 39.21 inches). Below-average cycle periods (dry) periods have an average length of 5.6 years (range = 3-10 years), with average annual means of approximately 20-30 inches (average annual = 26.89 inches). There have been six of these dry-wet cycles since 1915 (a seventh cycle began in 2011) and the average difference in annual rainfall between the dry and wet periods is 9.48 inches (Fig. 4.1).

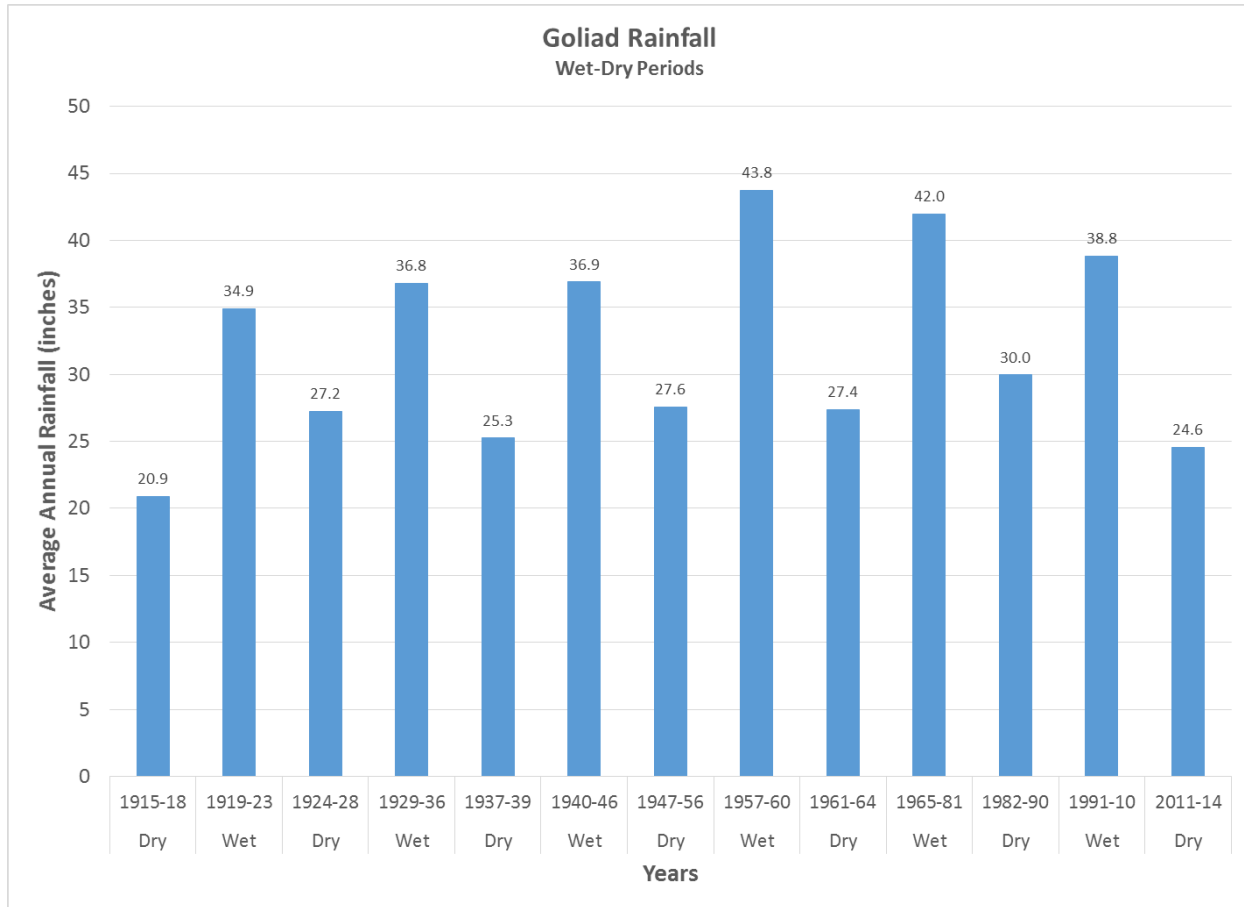


Figure 4.1 Mean annual precipitation (inches) during six consecutive wet-dry periods at Goliad, Texas (1915-2014).

Medium-term changes tend to be on the order of 40-60 years and, in the southwestern United States, are correlated with the Pacific Decadal Oscillation and the Atlantic Multidecadal Oscillation (Cayan et al. 1999; Hidalgo 2004). These multidecadal cycles result in major shifts in rainfall patterns in the Southwest, including South Texas, which have major impacts on ecological and hydrological systems. For example, average annual rainfall at Goliad during 1915-1956 (42 years) was 30.91 inches (Fig. 4.2). Average annual rainfall during the following 54 years (1957-2010) was 36.00 inches, an increase of 5.1 inches per year (16.4%) for 54 years. Over the last five years (2011-2015), annual rainfall has averaged 29.60 inches. This increase in rainfall following the drought of the 1950s is reflected at locations throughout the region (Table 4.1).

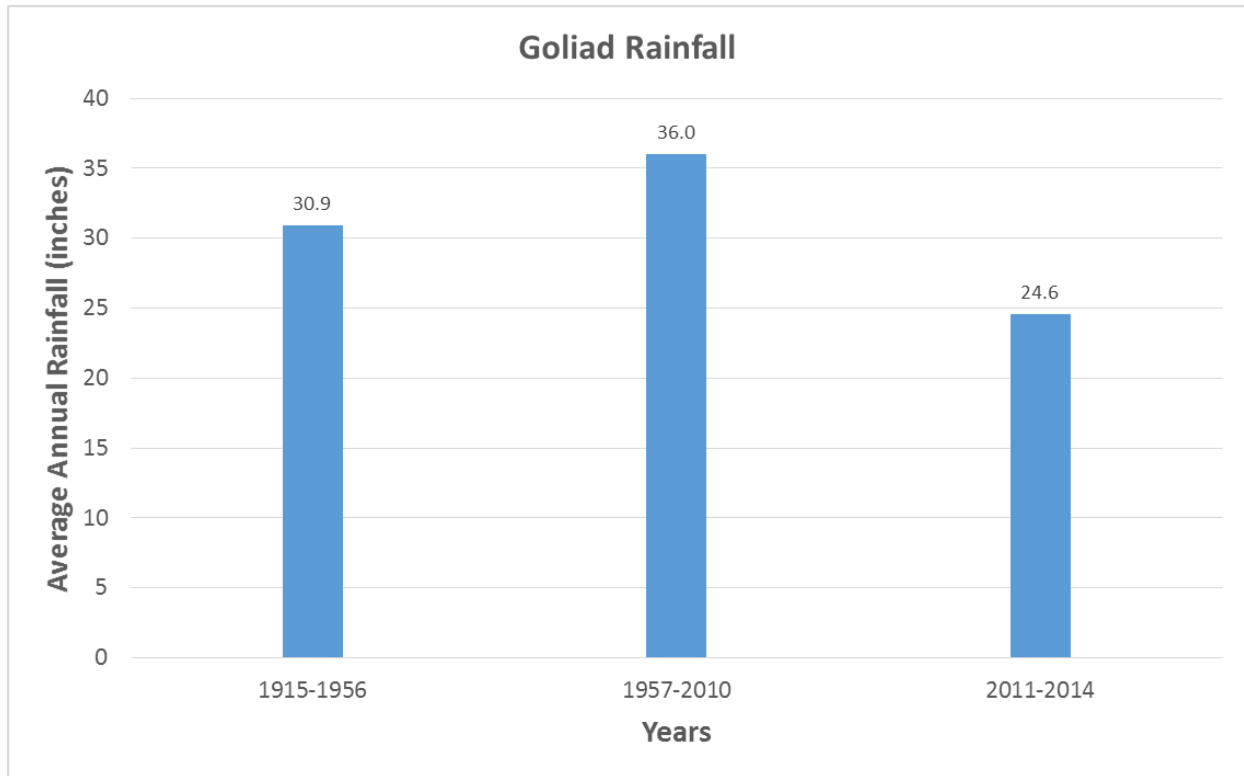


Figure 4.2 Average annual rainfall (inches) at Goliad, Texas, during two multidecadal periods (1915-1956 and 1957-2010) and the most recent four years (2011-2014).

Table 4.1 Average annual precipitation (PPT; inches) at eight sites in South Texas before the end of the drought of the 1950s and following the drought of the 1950s.

Location	Mean PPT	Period	Years ¹	PPT	Period	Years ¹	PPT	After/Before
Beeville	31.18	1903-1956	51	31.88	1957-2004	46	33.49	1.05
Cuero	34.48	1902-1956	54	33.98	1957-2004	39	35.93	1.06
George West	27.05	1916-1956	38	26.64	1957-2004	44	28.40	1.07
Goliad	34.82	1915-1956	42	30.91	1957-2010	54	36.00	1.16
Runge	30.25	1896-1956	48	29.09	1957-2005	48	32.29	1.11
San Antonio	29.12	1892-1956	65	26.10	1957-2004	48	32.57	1.29
Victoria	36.86	1898-1956	56	34.20	1957-2005	49	40.04	1.17
Mean								1.13

¹ Years refers to number of years during the period for which there are no missing data.

These medium-length precipitation fluctuations are not confined to arid or semi-arid regions. Humid regions experience similar cycles. Tree-ring data from North Carolina indicate that region has undergone alternating wet-dry cycles of about 30 years each and that 1956-1984 was one of the five wettest periods of the past 1600 years (Stahle et al. 1988). Oxygen ratios from stalagmites in Belize indicate that major droughts have occurred in the Yucatan at 100-200 year intervals over the past 1800 years and have lasted 50-80 years each occurrence (Kennett et al. 2012).

In addition to these annual and decadal fluctuations, precipitation changes over longer periods, e.g., centuries and millennia. Climatic patterns may be relatively stable for periods on the order of centuries and then, relatively rapidly (e.g., decades), change sufficiently to cause major vegetation shifts. Much of the western United States underwent a 2000-year period of increasing aridity beginning about 2600 years ago, during which many woodlands in the region decreased in extent and shrublands increased (Tausch et al. 2004). Then, about 650 years ago, the Little Ice Age began and conditions became much cooler, resulting in an increase in extent of woodlands and wetlands. During that period, vegetation patterns were very different from current patterns (Tausch et al. 2004). Little Ice Age conditions lasted until about 150 years ago when climate shifted again, with aridity again increasing. Much of northwestern Iowa was covered in deciduous forest from 9100-5400 BP, then changed to prairie grassland in 5400-3500 BP, and shifted to oak savanna after 3500 BP (Chumbley et al. 1990). These shifts in vegetation correspond to periods of rapid warming (3° C) followed by cooling (4° C) (Dorale et al. 1992). Nielson (1986) suggested that the black grama (*Bouteloua eriopoda*) desert grasslands encountered in the northern Chihuahuan Desert 100-150 years ago were a vegetation type established under, and adapted to, 300 years of Little Ice Age conditions and are only marginally supported, and perhaps not likely to be re-established, under present climatic conditions.

For 54 years, mean annual rainfall at Goliad was 5.1 inches per year more than in the previous 42 years. That amount of increased rainfall over that long (5 inches per year for 54 years) is likely to have resulted in major shifts in vegetation composition and hydrologic yields. Mid- and tallgrass prairie commonly occurs on areas receiving 20-40 inches of rain annually (Weaver and Clements 1938:517; Weaver 1954:7; Shelford 1963:334; Stoddart et al. 1975:28; Smeins and Diamond 1983; Smeins 1994a; Bailey 1995:46). As average annual precipitation increases above about 30 inches per year, tallgrasses begin to replace midgrasses as the dominant vegetation type. Above about 40 inches of annual precipitation, woodlands and forests begin to replace grasslands (Weaver and Clements 1938:510; Engle 1994; Bailey 1995). Stoddart and Smith (1955:48) suggested 38 inches as the upper precipitation limit of the tallgrass prairie. The upper limit on the Coastal Prairies of Texas is about 36 inches (Drawe 1994). In drier environments, sandy soils tend to support woodlands at lower precipitation levels than can be supported on adjacent clay or loam soils.

Average annual rainfall at Goliad was 36.00 inches from 1957-2010. This is the approximate level where the vegetation would shift from grassland to woodland and 54 years is ample time for trees to respond to this increased moisture. Therefore it is likely that woody vegetation became much more abundant in Goliad County following the drought of the 1950s than was present prior to the drought. That increase in deep-rooted woody species (e.g., mesquite, live oak, huisache) would also have probably increased the amount of groundwater use by the

vegetation and decreased the amount of potential groundwater recharge. This response to change in woody vegetation is discussed in more detail in Section 9.2.

4.2 Spatial Variability

Precipitation also varies spatially, often at relatively short distances. For example, there are two stations at Goliad and they are approximately 1 mile apart. For the period of record where data are available for the same years at both locations (37 years) the average annual rainfall at the northern station is 35.83 inches compared to 32.19 inches at the southern station. The difference in average annual rainfall between the two stations is 3.64 inches, or 11% of the annual mean of the southern station. In contrast, the average annual rainfall at Runge for those years in common (35) with the southern Goliad Station is 30.55 inches compared to 32.61 inches for the same years at the southern Goliad station. The difference between these two means is 2.06 inches, or 6% of the mean at the southern Goliad station, although Runge is 26 miles west of the southern Goliad station.

Spatial variations across a landscape can also change over time. Karnes County is the county directly northwest of Goliad County. Karnes City is located near the center of Karnes County and Runge is located 12 miles east of Karnes City. From 1920 through 1958, annual average rainfall was higher in Karnes City than in Runge (31.59 and 28.92 inches, respectively for the 35 common years between the two stations). From 1959 through 2005, annual average rainfall was lower in Karnes City than in Runge (29.31 and 31.67 inches, respectively for the 35 common years). Over those 86 years, the pattern of annual rainfall had reversed.

These spatial differences may be very important in accounting for ecological dynamics across a landscape. In EDYS, precipitation is entered cell by cell across the spatial footprint. Use of precipitation data from a single station may not provide realistic estimates of these patterns. To account for at least some of this spatial variation, the EDYS spatial footprint is divided into precipitation zones, each zone associated with a precipitation station. As a first approximation, all cells within a zone receive precipitation values associated with their respective station. Although this results in sudden changes in values as zone boundaries are crossed (i.e., a step function response), a more realistic pattern is achieved than if data from only one station were used. If precipitation differences between zones seem sufficiently large, a linear difference approach can be used that provides cell-by-cell differences in precipitation based on average differences among adjacent stations. In the Goliad County model, the first approximation approach is currently used.

In determining precipitation zones in EDYS, data were summarized from all available stations in a region, the region consisting of the counties included in the model (Goliad in this case) and surrounding counties (Aransas, Bee, Calhoun, DeWitt, Jackson, Karnes, Lavaca, Matagorda, Refugio, San Patricio, and Victoria in this case). Stations with data for more than 20 years are considered as primary stations (Table 4.2) and stations with data for 20 years or less are considered secondary stations.

Table 4.2 Primary precipitation stations, with corresponding data summaries, used in the Goliad County EDYS model.

County	Station	Mean Annual Precipitation (inches)	Period of Record	Number of Years With Complete 12-mo Data
Goliad	Goliad	34.84	1912-2015	95
Goliad	Goliad (1 SE)	32.40	1949-2005	35
Aransas	Aransas NWR	38.60	1941-2013	66
Aransas	Rockport	34.87	1901-2013	73
Bee	Beeville	31.18	1894-2013	105
Bee	Chase NAS	30.99	1945-1992	37
Calhoun	Point Comfort	43.35	1957-2013	50
Calhoun	Port Lavaca	38.33	1901-2013	49
Calhoun	Port O'Connor	39.25	1948-2013	39
DeWitt	Cuero	34.48	1901-2013	100
DeWitt	Yorktown	34.14	1940-2013	60
Jackson	Edna	40.22	1909-2013	91
Karnes	Cestohowa	27.94	1944-1982	21
Karnes	Karnes City	30.18	1919-2006	72
Karnes	Kenedy	30.50	1948-1977	24
Karnes	Runge	30.25	1895-2013	102
Lavaca	Hallettsville	36.92	1893-2013	115
Lavaca	Speaks	44.49	1967-2013	38
Lavaca	Yoakum	38.25	1917-2013	75
Matagorda	Bay City	45.17	1909-2013	61
Matagorda	Matagorda	42.61	1910-2013	95
Matagorda	Palacios	43.13	1943-2013	66
Refugio	Austwell	33.46	1897-2013	53
Refugio	Refugio	38.21	1948-2013	57
Refugio	Woodsboro	31.48	1916-64, 2007-12	44
San Patricio	Aransas Pass	32.41	1897, 1943-71	24
San Patricio	Mathis	31.00	1917-2013	48
San Patricio	Sinton	32.54	1921-2013	69
San Patricio	Welder WR	36.68	1964-2013	43
Victoria	Victoria	36.86	1893-2013	112

Primary stations are used to define precipitation zones. Distances between Goliad and each primary station were calculated (Table 4.3). The nearest station to Goliad in each direction was noted and lines are drawn connecting each of these nearest stations to Goliad. Mid-points along each line were determined. If a mid-point was near the county line or fell outside Goliad County, the area included in that sector was not separated into a new zone. Instead, it was included in the zone that includes the Goliad station. If the mid-point was located in Goliad County at a sufficient distance from the county line to be considered significant, a new zone was designated for the area from the mid-point to the county line. For example, Victoria is the closest primary station northeast of Goliad. It is approximately 26 miles from Goliad to Victoria and it is about 14 miles from Goliad to the county line in the direction of Victoria. Mid-point along this line would be about one mile in Goliad County. That distance was considered to be too small to separate out a separate precipitation zone in the northeast part of Goliad County. In contrast, the intersection of lines connecting the mid-point between Runge and Beeville (representing the western part of Goliad County) and Goliad fell about 15 miles within Goliad County. Therefore, a separate zone was designated for this southwestern part of Goliad County.

Table 4.3 Distances between Goliad and surrounding primary precipitation stations and mean annual precipitation (PPT; inches) for each station (period of record for each station). Mean annual precipitation at Goliad (1913-2015 = 34.84 inches).

Relative Direction	Station	County	Distance (mi)	Mean Annual PPT
North of Goliad				
	Cuero	Yoakum	31	34.48
	Yoakum	Lavaca	45	38.25
Northeast of Goliad				
	Victoria	Victoria	26	36.86
	Edna	Jackson	48	40.22
	Hallettsville	Lavaca	57	36.92
	Speaks	Lavaca	57	44.49
	Bay City	Matagorda	87	45.17
East of Goliad				
	Port Lavaca	Calhoun	46	38.33
	Point Comfort	Calhoun	50	43.35
	Port O'Connor	Calhoun	63	39.25
	Palacios	Matagorda	71	43.13
	Matagorda	Matagorda	87	42.61
Southeast of Goliad				
	Austwell	Refugio	40	33.46
	Aransas NWR	Aransas	48	38.60
	Rockport	Aransas	51	34.87
	Aransas Pass	San Patricio	57	32.41
South of Goliad				
	Refugio	Refugio	27	38.21
	Woodsboro	Refugio	33	31.48
	Welder WR	San Patricio	39	36.68
	Sinton	San Patricio	45	32.54
Southwest of Goliad				
	Beeville	Bee	30	31.18
	Chase NAS	Bee	33	30.99
	Mathis	San Patricio	47	31.00
West of Goliad				
	Whitsett	Live Oak	57	26.34
Northwest of Goliad				
	Yorktown	DeWitt	23	34.14
	Runge	Karnes	23	30.25
	Kenedy	Karnes	31	30.50
	Karnes City	Karnes	37	30.18
	Cestohowa	Karnes	42	27.94
	San Antonio	Bexar	84	29.12

Based on this procedure, Goliad County was divided into four precipitation zones (Fig. 4.3). If a primary precipitation station is located in a precipitation zone, data for that station is used for the precipitation input data (daily) for that entire zone. If no primary station is located in the zone, the precipitation data for that zone is calculated as the average of the nearest surrounding primary stations. Precipitation data for Goliad was used for most of the spatial extent of the Goliad County model but three zones along the northwest, southwest, and south edges of the county used averaged data (Table 4.4).

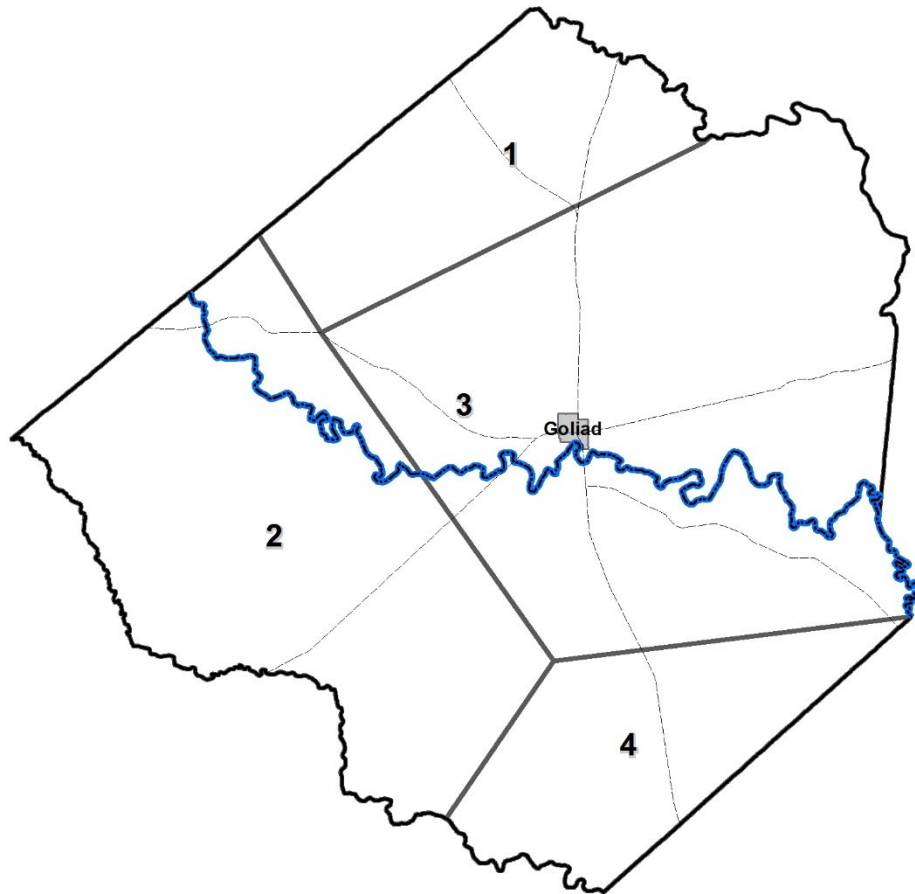


Figure 4.3 Location of the four precipitation zones used in the Goliad County EDYS model.

Table 4.4 Source of precipitation data for the four precipitation zones of the Goliad EDYS model.

Precipitation Zone	Station Data Used
Zone 1 (Northwest)	(Goliad + Yorktown + Runge)/3
Zone 2 (Southwest)	(Goliad + Beeville + Runge)/3
Zone 3 (Central and East)	(Goliad)
Zone 4 (South)	(Goliad 1SE + Beeville + Refugio)/3

The value of precipitation data in simulation modeling, as in most ecological studies, increases substantially as the length of the period of record increases. Long-term (more than 100 years) precipitation data are available for only three of the six stations used to supply data for the four precipitation zones (Table 4.4) and the periods of record vary substantially among the stations. In addition, none of the six stations or the 24 other primary precipitation stations have complete data sets for their respective period of record (i.e., there are some years with missing data for at least one month of the respective year). Consequently, constructed precipitation data sets were developed for each of the six stations.

Constructed precipitation data sets are long-term data sets that include recorded data for those dates where these data are available for a particular station plus estimated values for dates where recorded data are not available or where the recorded values are strongly suspect. The purposes for using constructed data sets in EDYS models are to 1) extend the length of the data set, 2) account for missing data, 3) adjust for apparent errors in the recorded data, and 4) provide data for all dates over a common period of record so that sites can be more appropriately compared. The estimated values in the constructed precipitation data sets are not presented as precise estimates of the actual amounts received. Instead, they represent reasonable estimates based on the temporal and spatial patterns of the area.

The first step in developing the constructed data sets was to determine the relationships between precipitation patterns at each two-station combination involving the six selected primary stations plus the 24 additional primary stations in the surrounding counties. For each two-station comparison, a conversion ratio was calculated (Table 4.5). This is the ratio of the average annual precipitation at the station being estimated to the average annual precipitation for the same year at the station being used to estimate, with the averages calculated only using years with complete (12-month) data for years in common between the two stations.

Table 4.5 Conversion ratios for the calculation of values for missing annual precipitation (PPT) data for the six primary stations (columns) used to estimate precipitation in the four precipitation zones in the Goliad County EDYS model. Ratios were calculated from means of annual precipitation using only values from common years with complete data for both stations of a comparison.

Station Data Used To Calculate From	Station Calculated For					
	Goliad	Goliad 1SE	Beeville	Refugio	Runge	Yorktown
Goliad	1.000	0.899	0.895	1.046	0.863	0.926
Goliad 1SE	1.112	1.000	0.956	1.181	0.946	1.036
Aransas NWR	0.938	0.860	0.811	0.961	0.790	0.854
Aransas Pass	1.029	0.886	0.857	1.071	0.906	0.963
Austwell	0.939	0.880	0.880	1.000	0.837	0.911
Bay City	0.755	0.680	0.661	0.786	0.641	0.703
Beeville	1.118	1.046	1.000	1.210	0.958	1.059
Cestohowa	1.291	1.199	1.070	1.340	1.063	1.160
Chase NAS	1.193	1.137	1.037	1.283	0.999	1.099
Cuero	0.994	0.932	0.901	1.079	0.871	0.970
Edna	0.857	0.757	0.789	0.888	0.762	0.814
Hallettsville	0.909	0.823	0.827	0.971	0.791	0.867
Karnes City	1.143	1.093	1.036	1.298	0.995	1.136
Kenedy	1.111	0.965	0.954	1.214	0.970	1.043
Matagorda	0.811	0.749	0.720	0.874	0.701	0.756
Mathis	1.194	1.005	1.051	1.281	1.007	1.143
Palacios	0.835	0.769	0.723	0.878	0.706	0.773
Point Comfort	0.862	0.767	0.745	0.906	0.714	0.793
Port Lavaca	0.875	0.786	0.783	0.910	0.747	0.800
Port O' Connor	0.903	0.853	0.778	0.963	0.782	0.836
Refugio	0.956	0.847	0.826	1.000	0.804	0.887
Rockport	1.025	0.908	0.901	1.068	0.878	0.954
Runge	1.158	1.057	1.044	1.244	1.000	1.103
Sinton	1.088	0.960	0.965	1.144	0.923	1.013
Speaks	0.861	0.785	0.744	0.890	0.707	0.782
Victoria	0.942	0.881	0.846	1.000	0.825	0.876
Welder WR	1.033	0.973	0.900	1.051	0.860	0.950
Woodsboro	1.023	0.915	0.923	1.085	0.894	0.930
Yoakum	0.942	0.890	0.918	0.998	0.797	0.890
Yorktown	1.080	0.965	1.031	1.127	0.907	1.000

To calculate an estimated value for one of the six primary sites the recorded value from another station for that date is multiplied by the conversion factor. For example, if data from Beeville were being used to estimate a value for Goliad, the Beeville value for that date would be multiplied by 1.118 (Table 4.5). Conversely, if data from Goliad were being used to estimate a value for Beeville, the Goliad value for that date would be multiplied by 0.895.

Which station to use to estimate a missing value for another station is determined by a substitution list (Table 4.6), which is based on distance from the primary station (Table 4.3) and average difference between monthly values for common years. For a specific date with a missing value for one of the six stations used to determine precipitation zone values (Goliad, Goliad 1SE, Beeville, Refugio, Runge, Yorktown) the first station in the substitution list is checked to determine if that station had a value for that date. If so, that value is multiplied by the appropriate conversion ratio (Table 4.5) and the product is entered as the estimated value for the missing value. If the first station in the list does not have a recorded value for that date, the next station in the list is checked. If the second station in the list does not have a value for that date, the third station is checked. This process continues until a station is found that does have a value. These estimated values are used only for dates with missing data. When a recorded value is available for the particular station, the recorded value is used.

Table 4.6 Selection order for stations to select for precipitation data to be used to estimate missing values for the primary stations.

Primary Station	Selection Order (Substitution List)
Goliad	Goliad 1SE, Victoria, Runge, Yorktown, Refugio, Cuero, Beeville, Kenedy, Chase NAS, Woodsboro, Karnes City, Austwell, Cestohowa, Sinton, Yoakum, Mathis, Port Lavaca, Aransas NWR, Edna, Point Comfort, Rockport, Hallettsville, Speaks, Aransas Pass, Whitsett, Port O'Connor, Palacios, San Antonio, Matagorda, Bay City
Goliad 1SE	Same as for Goliad, except Goliad substituted for Goliad 1SE
Beeville	Chase NAS, Goliad, Goliad 1SE, Kenedy, George West, Karnes City, Runge, Three Rivers, Sinton, Mathis, Welder WR, Woodsboro, Falls City, Cestohowa, Yorktown, Refugio, Rockport, Aransas Pass, Victoria, Cuero, Floresville, Whitsett, Austwell, Aransas NWR, Yoakum, San Antonio, Port Lavaca, Port O'Connor, Point Comfort, Edna, Hallettsville, Speaks, Palacios
Refugio	Woodsboro, Welder WR, Sinton, Rockport, Goliad, Austwell, Chase NAS, Beeville, Aransas NWR, Aransas Pass, Victoria, Mathis, Port Lavaca, Runge, Yorktown, Kenedy, Point Comfort, Cuero, Port O'Connor, Karnes City, Edna, Palacios, Cestohowa, Yoakum, Speaks, Matagorda, Hallettsville, Bay City, San Antonio
Runge	Kenedy, Karnes City, Yorktown, Cestohowa, Goliad, Goliad 1SE, Falls City, Nixon, Cuero, Stockdale, Beeville, Floresville, Whitsett, Three Rivers, Yoakum, George West, Gonzales, Jourdanton, Seguin, Poteet, San Antonio
Yorktown	Runge, Yoakum, Nixon, Cuero, Goliad, Goliad 1SE, Stockdale, Kenedy, Karnes City, Cestohowa, Falls City, Gonzales, Hallettsville, Speaks, Victoria, San Antonio, Edna, Beeville, Chase NAS, Seguin, Woodsboro, Austwell, Aransas NWR, Rockport, Port Lavaca, Point Comfort, Port O'Connor, Bay City, Palacios, Matagorda

Some stations in the Selection Order are not listed in Table 4.5. Those values were calculated for the Karnes-Wilson models (McLendon et al. 2015).

Victoria is the station with the longest period of record for rainfall data in the region. The Victoria data date back to 1893 (Table 4.2) and that year was selected as the starting date for the constructed precipitation data sets used in the Goliad County model. A constructed data set was developed for each of the six primary stations (annual totals presented in Appendix Table A.2) and from these six data sets daily constructed rainfall amounts were calculated for each of the four precipitation zones used in the Goliad County model. The annual totals for the four zones are presented in Table 4.7. Although constructed annual precipitation values are presented in Table 4.7, the precipitation input data used in EDYS are daily values.

Table 4.7 Long-term (122 years) constructed annual precipitation data (inches) for the four precipitation zones used in the Goliad County EDYS model.

Year	Zone 1 Northwest	Zone 2 Southwest	Zone 3 Central	Zone 4 South	Year	Zone 1 Northwest	Zone 2 Southwest	Zone 3 Central	Zone 4 South
1893	16.87	16.70	16.75	16.52	1954	15.32	15.09	16.11	16.97
1894	24.01	25.79	26.49	28.20	1955	22.84	21.58	25.22	20.21
1895	30.14	29.47	24.78	28.47	1956	17.30	18.74	19.47	21.55
1896	28.77	28.18	24.43	27.73	1957	46.19	44.88	51.45	44.70
1897	13.76	14.36	11.45	13.43	1958	40.21	37.17	42.97	40.42
1898	23.85	23.56	24.26	24.34	1959	32.46	31.42	32.31	36.14
1899	28.92	28.55	34.72	34.26	1960	45.49	45.00	48.17	50.24
1900	44.34	43.64	57.34	49.50	1961	25.36	24.49	28.96	24.44
1901	23.31	22.26	21.67	20.00	1962	29.37	29.91	31.64	28.16
1902	37.74	33.86	30.14	31.12	1963	20.43	20.20	23.56	20.28
1903	50.08	49.90	55.60	52.91	1964	25.82	25.06	25.14	24.99
1904	31.25	29.66	31.96	33.89	1965	40.67	39.43	43.93	35.87
1905	37.77	38.75	42.67	42.98	1966	30.83	30.80	37.57	31.21
1906	25.39	27.24	25.42	28.37	1967	46.34	43.45	44.00	43.42
1907	29.92	27.23	41.43	31.65	1968	37.11	35.00	42.03	40.71
1908	34.86	35.08	37.84	37.89	1969	37.11	35.25	35.40	33.18
1909	24.05	27.35	32.32	34.01	1970	29.27	28.96	30.15	32.85
1910	29.23	28.54	28.47	28.97	1971	36.66	38.54	39.56	44.86
1911	30.97	28.55	34.31	28.20	1972	40.31	39.54	52.80	43.87
1912	26.37	27.08	29.13	30.38	1973	53.05	49.75	51.07	53.10
1913	32.92	32.55	34.16	38.27	1974	33.41	32.24	38.20	34.72
1914	42.49	43.01	42.12	45.53	1975	31.14	31.55	39.33	35.58
1915	21.64	18.27	21.44	20.40	1976	50.25	47.99	55.28	47.89
1916	19.22	20.58	19.97	21.31	1977	35.75	34.15	38.51	33.05
1917	12.77	11.80	9.72	10.02	1978	31.24	32.50	29.45	35.66
1918	32.32	30.86	32.28	28.89	1979	40.81	38.44	40.70	38.76
1919	47.83	46.80	47.17	50.62	1980	30.84	33.63	35.52	36.59
1920	26.05	24.05	24.27	22.86	1981	49.97	48.84	59.38	56.49
1921	31.46	29.61	31.17	34.50	1982	26.90	23.49	26.61	24.22
1922	29.36	31.13	26.30	30.78	1983	32.62	32.97	36.50	43.27
1923	47.97	45.91	45.72	42.92	1984	26.30	25.94	28.36	29.63
1924	22.03	21.63	22.66	22.78	1985	38.19	35.44	38.02	35.01
1925	20.80	25.52	29.95	29.96	1986	33.11	33.52	35.69	38.26
1926	33.98	32.64	34.05	33.40	1987	32.00	32.32	29.04	32.82
1927	23.10	21.76	22.42	22.37	1988	19.14	19.13	19.75	16.45
1928	25.91	29.76	29.56	34.15	1989	23.17	20.74	22.61	21.36
1929	39.30	39.27	44.53	39.77	1990	27.92	29.69	33.76	37.61
1930	20.52	23.25	25.88	28.56	1991	44.36	41.00	47.35	41.07
1931	38.94	38.09	40.00	40.34	1992	37.91	40.64	40.88	46.16
1932	30.62	34.93	35.11	37.68	1993	31.35	33.12	37.89	39.57
1933	28.35	28.89	31.62	33.04	1994	40.02	39.55	43.20	41.68
1934	39.54	36.82	41.86	37.18	1995	26.30	25.69	33.54	28.71
1935	45.00	39.42	39.81	38.21	1996	22.84	25.78	23.89	23.28
1936	34.15	33.85	36.49	39.13	1997	47.54	44.62	53.75	48.89
1937	22.75	23.25	26.74	27.17	1998	45.47	43.00	51.44	40.54
1938	20.40	21.48	27.25	28.30	1999	21.15	20.70	22.92	24.15
1939	20.70	19.23	21.63	18.73	2000	38.61	34.76	37.05	32.82
1940	42.48	39.38	38.23	33.53	2001	41.45	41.58	45.84	41.19
1941	41.91	42.31	37.99	46.64	2002	41.40	39.91	42.33	36.62

Table 4.7 (Cont.)

Year	Zone 1 Northwest	Zone 2 Southwest	Zone 3 Central	Zone 4 South	Year	Zone 1 Northwest	Zone 2 Southwest	Zone 3 Central	Zone 4 South
1942	35.41	36.09	41.02	43.06	2003	34.66	33.91	34.43	37.13
1943	30.09	31.69	33.44	33.12	2004	45.11	46.84	47.87	44.46
1944	31.79	30.83	32.02	32.14	2005	31.40	31.29	28.87	31.47
1945	25.00	25.76	29.38	29.33	2006	28.80	29.12	32.71	30.64
1946	45.34	42.81	45.89	45.49	2007	46.85	48.61	51.77	52.80
1947	27.46	29.88	30.87	30.51	2008	20.38	19.36	22.51	21.65
1948	24.83	23.90	26.70	24.22	2009	37.06	33.46	35.92	32.56
1949	38.33	36.39	35.39	36.73	2010	37.04	40.10	41.33	44.93
1950	16.49	15.79	18.65	14.96	2011	18.86	16.83	17.24	17.64
1951	30.18	29.94	37.44	29.69	2012	24.14	24.61	28.99	28.45
1952	35.97	34.17	37.15	34.76	2013	24.71	25.70	27.76	29.78
1953	24.96	23.48	28.43	24.79	2014	26.41	22.10	25.63	23.85

Annual rainfall (constructed values) varied spatially across the county (Table 4.7). Averaged over the 122 years, there was an average maximum annual difference among the four zones of 5.10 inches (Table 4.8). This average spatial variability (5.10 inches) is equal to about 55% of the temporal variability between dry and wet periods (9.48 inches; Fig. 4.1). Although there were differences in mean annual rainfall among the four zones when averaged over the 122 years, there was no consistent pattern as to which zone was wetter or drier than the others in any particular year.

Table 4.8 Maximum difference among constructed annual rainfall (inches) for the four precipitation zones (Table 4.7) in the Goliad County EDYS model.

Year	Difference	Year	Difference	Year	Difference	Year	Difference	Year	Difference	Year	Difference
1893	0.35	1914	3.41	1935	6.79	1955	5.01	1975	8.19	1995	7.85
1894	4.19	1915	3.37	1936	5.28	1956	4.25	1976	7.39	1996	2.94
1895	5.36	1916	2.09	1937	4.42	1957	6.75	1977	5.46	1997	9.13
1896	4.34	1917	3.05	1938	7.90	1958	5.80	1978	6.21	1998	10.90
1897	2.91	1918	3.43	1939	2.90	1959	4.72	1979	2.37	1999	3.45
1898	0.78	1919	3.82	1940	8.95	1960	5.24	1980	5.75	2000	5.79
1899	6.17	1920	3.19	1941	8.65	1961	4.52	1981	10.54	2001	4.65
1900	13.70	1921	4.89	1942	7.65	1962	3.48	1982	3.41	2002	5.71
1901	3.31	1922	4.83	1943	3.35	1963	3.36	1983	10.65	2003	3.22
1902	7.60	1923	5.05	1944	1.31	1964	0.83	1984	3.69	2004	3.41
1903	5.70	1924	1.15	1945	4.38	1965	8.06	1985	3.18	2005	2.60
1904	4.23	1925	9.16	1946	3.08	1966	6.77	1986	5.15	2006	3.91
1905	5.21	1926	1.41	1947	3.41	1967	2.92	1987	3.78	2007	5.95
1906	2.98	1927	1.34	1948	2.80	1968	7.03	1988	3.30	2008	3.15
1907	14.20	1928	8.24	1949	2.94	1969	3.95	1989	2.43	2009	4.50
1908	3.03	1929	5.26	1950	3.69	1970	3.89	1990	9.69	2010	7.89
1909	9.96	1930	8.04	1951	7.75	1971	8.20	1991	6.35	2011	2.03
1910	0.76	1931	2.25	1952	2.98	1972	13.26	1992	8.25	2012	4.85
1911	6.11	1932	7.06	1953	4.95	1973	3.30	1993	8.22	2013	5.07
1912	4.01	1933	4.69	1954	1.88	1974	5.96	1994	3.65	2014	4.31
1913	5.72	1934	5.04								
MEAN	5.27	MEAN	4.32	MEAN	4.75	MEAN	5.37	MEAN	5.88	MEAN	5.07

Overall, Zone 3 (central) was the wettest, with an annual average of 34.02 inches, and Zone 2 (southwest) was the driest (mean = 31.46 inches). Zone 1 (northwest) had a similar mean to that of Zone 2 (31.97 inches) and Zone 4 was intermediate (mean = 33.31 inches). Based on recorded precipitation data (in contrast to constructed data), which do not include all of the same years or the same period of record, the highest annual precipitation occurs toward the southeast (Gulf of Mexico direction) and decreases in both the southeast to northwest and northeast to southwest directions (Fig. 4.4). The constructed precipitation data are consistent with this regional pattern.

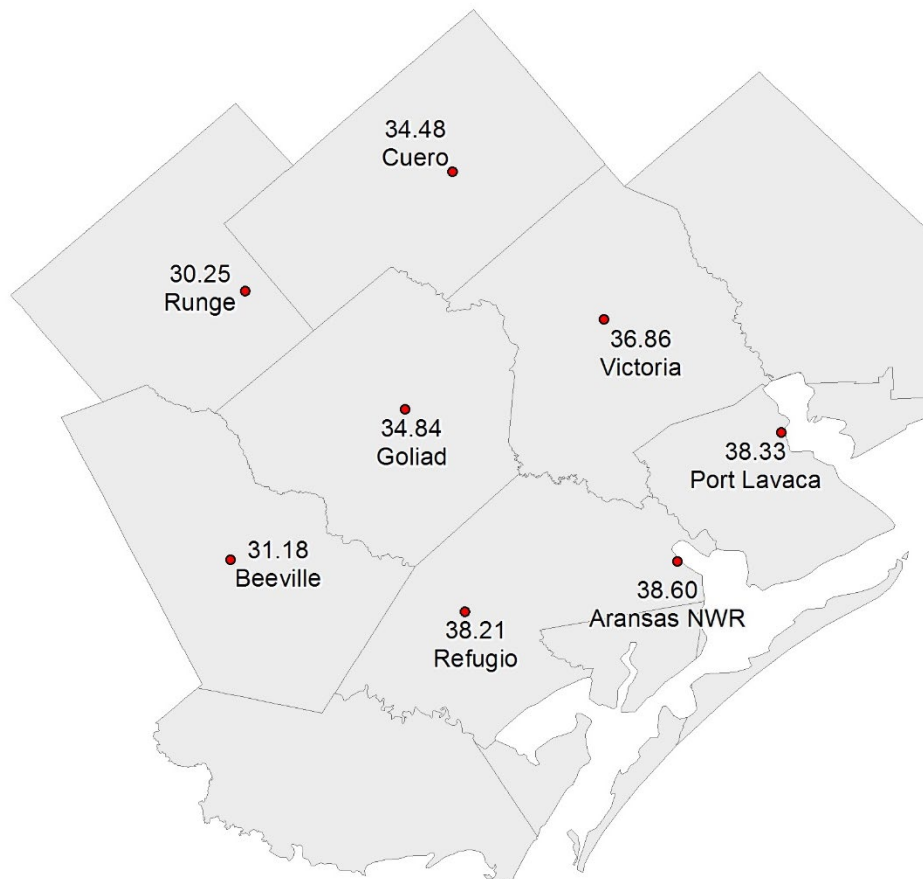


Figure 4.4 Average annual precipitation (inches) pattern across the Goliad County region. Values are annual means based on recorded data for periods of record at each station. Periods of record and years with complete (12-month) data vary among stations.

5.0 SOILS

Two soil components are included in an EDYS model. First, a soils map is constructed that indicates the spatial location of each soil unit (soil series or soil type) included in the spatial footprint of the model. Second, profile descriptions are developed for each of the soil units.

5.1 Soils Map

A total of 78 soil units are defined and mapped by the Natural Resource Conservation Service (NRCS) as occurring in Goliad County (Wiedenfeld 2010). Many of these are sub-divisions of soil series based on differences in slope, frequency of flooding, or thickness of an upper soil horizon. For example, the soil unit BsA is Buchel clay, 0-1% slope, occasionally flooded, whereas BuA is Buchel clay, 0-1% slope, frequently flooded; CrA is Clareville sandy clay loam, 0-1% slopes, rarely flooded and CrB is Clareville sandy clay loam, 1-3% slopes, rarely flooded. As such, these differences likely have little significance in affecting ecological responses. This is attested to by the fact that most of the sub-divisions have the same ecological site assigned to them (Wiedenfeld 2010).

In order to keep the number of cell types in the Goliad County EDYS model within practical limits, similar soil units were combined. The primary criteria used was whether or not the differences between the soil units were likely to result in measurable and ecologically significant differences in vegetation, hydrology, or management responses. Based on this criteria, the 78 soil units were reduced to 24 soil types (Table 5.1). This set of 24 soil types provided a unique soil to be assigned to each NRCS ecological site.

Table 5.1 Soil types included in the Goliad County EDYS model, along with their corresponding ecological site types.

Musym	Soil Type	Surface Texture	Surface Horizon Depth (inches)	Ecological Site
AnB	Ander	fine sandy loam	12	Tight Sandy Loam
BsA	Buchel	clay	7	Clayey Bottomland
CnA	Cieno	loam	7	Lowland Coastal
CyB	Coy	clay loam	6	Rolling Blackland
EdA	Edroy	clay	7	Lakebed Coastal
GrA	Greta	fine sandy loam	5	Salty Prairie
KyB	Kuy	fine sand	12	Deep Sand
LaA	Laewest	clay	12	Blackland Coastal
MoA	Monteola	clay	6	Blackland RG Plains
NuC	Nusil	fine sand	5	Sandy
OmD	Olmedo	very gravelly loam	6	Shallow Ridge
PrB	Parrita	sandy clay loam	6	Shallow Sandy Loam
PtC	Pernitas	sandy clay loam	11	Gray Sandy Loam
PuC	Pettus	loam	11	Gravelly Ridge
RaB	Raisin	loamy fine sand	5	Loamy Sand
RoA	Realitos	clay	6	Lakebed RG Plains
ScB	Sarco	coarse sand	5	Claypan Savannah
StC	Schattel	sandy clay loam	13	Sloping Clay Loam
SwA	Sinton	sandy clay loam	17	Loamy Bottomland
TeA	Telferner	fine sandy loam	9	Loamy Prairie
WcC	Weesatche	fine sandy loam	5	Sandy Loam
WeB	Weesatche	sandy clay loam	5	Clay Loam
WyA	Wyick	fine sandy loam	6	Claypan Prairie
ZaA	Zalco	sand	10	Sandy Bottomland

The NRCS mapped soil units were displayed on an aerial photograph (Fig. 5.1) and each 40 m x 40 m EDYS cell was then assigned one of the 78 original soil units based on the location of the

cell in relation to the spatial locations of the soil units. This 78-unit classification was then converted to the 24-type (Table 5.1) classification by combining units as appropriate.

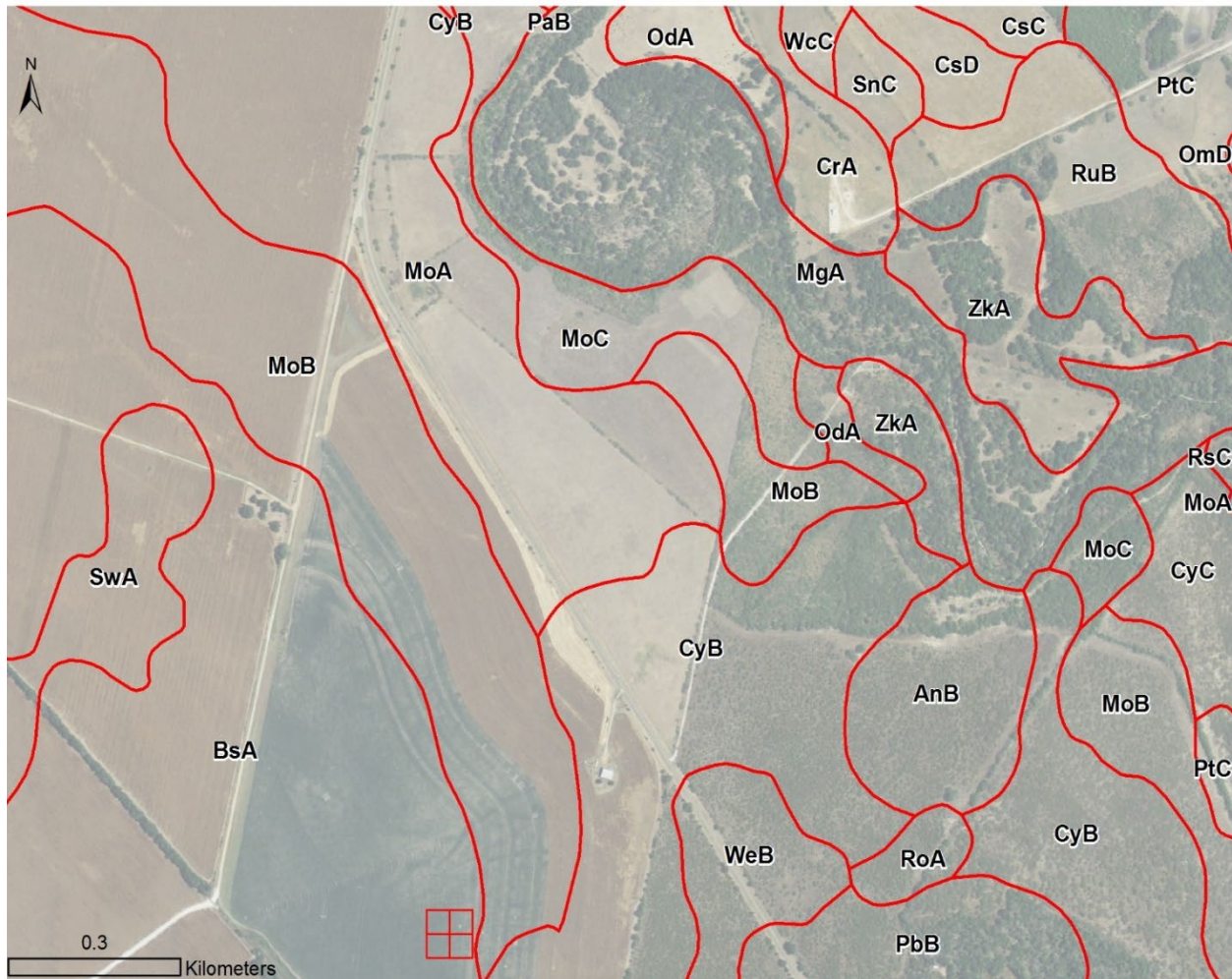


Figure 5.1 Example of the spatial distribution of NRCS soil units on a portion of the Goliad County landscape. The four red squares in the lower portion represent 40 m x 40 m cells in EDYS.

5.2 Profile Descriptions

A soil profile is a vertical section of a particular soil. Soils are composed of layers, called horizons, each horizon differing in some major physical or chemical variable from the layer above and the layer below it. Horizons are designated by capital letters (e.g., A, B, C) in a top-down order. Horizons are often subdivided and these subdivisions are designated by lower-case letters (e.g., Ap, Bk, Bt), the letters referring to specific types of soil conditions, and/or numbers (e.g., A1, A2, Bt1, Bt2), with the number designating vertical order within the horizon (capital letter). General profile descriptions of each soil occurring in a particular county are provided in the NRCS Soil Survey for that county. The Weesatche sandy clay loam, the soil covering the most area in Goliad County, is presented as an example (Table 5.2).

Table 5.2 NRCS profile description of the Weesatche sandy clay loam (Wiedenfeld 2010).

Horizon	Depth (cm)	Texture	Color	Structure	Alkalinity
A	000-013	sandy clay loam	dark brown	weak subangular blocky	slight
Bt1	013-031	sandy clay loam	dark gray	moderate prismatic	slight
Bt2	031-070	sandy clay	brown	moderate prismatic	slight
Btk	070-094	clay loam	light brown	moderate prismatic	moderate
Bk1	094-154	silt loam	light brown	weak prismatic	moderate
Bk2	154-203	clay loam	brown	moderate subangular blocky	moderate

EDYS soil profiles are based on the NRCS profiles, but differ in two primary ways. First, EDYS profiles contain more layers and extend to greater depths than their respective NRCS profiles. The usual time step in EDYS simulations is daily. Daily changes in belowground processes that affect plant growth (e.g., available soil moisture, root growth, availability of soil nutrients) occur at fine spatial scales (soil depths) than those designated for NRCS soil horizons. For example, many precipitation events supply only small amounts of water. The median summer rainfall event in many drier regions is less than 5 mm (Schwinning and Sala 2004). In many soils, a 5-mm rainfall event will supply water to only the top 5 cm (2 inches) of the soil and at that depth most of the rainfall-supplied water will be extracted by evaporation before it can be used by plants in transpiration. In contrast, a 10-mm rainfall event on the same soil might supply some moisture to a depth of 10 cm or more and, at that depth, some of the water would be extracted by evaporation and some by transpiration. Only that water used in transpiration would be available to support plant growth. Therefore, small differences in soil depth can substantially affect plant growth responses. For this reason, thinner soil layers are used in EDYS.

The number of soil layers is flexible in EDYS, but commonly 35 layers are used per soil. This is the case for the Goliad County model. Although there are 35 soil layers in each of these EDYS soil profiles, the thickness (depth) and characteristics of each layer vary among soils. EDYS soil layers are subdivisions of NRCS horizons and subhorizons, with each NRCS horizon or subhorizon divided into one or more EDYS layers. However, no EDYS layer combines parts of more than one NRCS horizon or subhorizon. For example, no EDYS layer would include the 010-015 cm depth of the Weesatche sandy clay loam (Table 5.2) because that would combine different horizons (lower part of A and upper part of Bt1). There could however be EDYS horizons of 010-013 cm and 013-015 cm because the first would be from the A horizon and the second from the Bt1 horizon.

NRCS profile descriptions do not include the subsoil material. Most NRCS profiles extend to only 203 cm (80 inches). EDYS profiles extend much deeper, the lower depth based on the maximum potential rooting depth of the deepest-rooted plant species included in the particular EDYS application (Appendix Table E.9). These deeper depths are included in EDYS because plant roots extend into these zones and those zones contain moisture and nutrients that can be accessed by the plants. The thickness and other characteristics of the lower EDYS soil layers are estimated from parent material information provided in the NRCS soil surveys and from other literature sources. These lower EDYS layers are thicker than the upper soil layers because daily changes in moisture inputs and root dynamics are not as dynamic as those in the upper layers and because less information is available about the characteristics of the lower layers.

The second primary way in which EDYS profiles differ from NRCS profiles is that some soil variables are included in the EDYS profiles that are not included in the NRCS profiles and some NRCS soil variables are not included in the EDYS profiles. Variables included in the NRCS profiles are largely descriptive variables, i.e., those useful in classifying soils. Variables included in EDYS profiles are functional variables, i.e., variables that affect ecological processes. For example, soil color is a major classification variable in NRCS profile descriptions (Table 5.2) but soil color has little direct impact on ecological or hydrological responses and is therefore not included in EDYS profiles. Conversely, total available moisture content is a very important variable influencing plant growth but is not useful in classifying a soil because it changes rapidly and frequently. Hence, it is included in EDYS profile descriptions but not in NRCS profile descriptions. Data used to provide values for the EDYS soil variables are taken from NRCS soil surveys, other literature sources, and estimates based on existing information.

Eleven soil variables are included, by soil layer, for each EDYS soil profile (Table 5.3). EDYS simulates belowground dynamics based on these 11 variables and the changes in their values that occur during a simulation. Five variables (soil texture, bulk density, maximum moisture content at saturation, field moisture capacity level, permanent wilting moisture level) remain constant during a simulation. Five variables (moisture content, nutrient content, organic matter content, salinity levels, and contents of any contaminants) change during a simulation as resources enter or exit the various soil layers. Thickness of each layer remains constant unless erosion or deposition occurs. If deposition occurs, the thickness of the top layer increases by the corresponding amount. If erosion occurs, the thickness of the top layer decreases by the corresponding amount. If erosion is sufficient to remove all the top layer, then the process shifts to the second layer and this process continues as long as erosion continues.

Table 5.3 Soil variables used in EDYS simulations.

Variable	Unit	Comment
Layer thickness	cm	Initial values entered as inputs.
Soil texture (sand, silt, clay)	%	Not directly used as an input variable. Used to calculate soil water holding capacities and infiltration and percolation rates.
Bulk density	g/cm ³	Not directly used as an input variable. Used to calculate pore space.
Maximum moisture content at saturation	g/layer	Calculated from (pore space – organic matter content).
Field capacity level	g/layer	Calculated from soil texture, unless specific laboratory data are available.
Permanent wilting level	g/layer	Calculated from soil texture unless specific laboratory data are available.
Available moisture content	g/layer	Calculated: (amount of water in layer – amount held at permanent wilting)
Nutrient levels (e.g., N, P)	g/layer	Initial values entered as inputs.
Organic matter content	g/layer	Initial values entered as inputs.
Salinity levels	ppm	Initial values entered as inputs.
Contaminant levels	ppm	Initial values entered as inputs.

Water is the major factor controlling belowground dynamics. Terrestrial plants uptake the water they need for maintenance and growth from the soil (including groundwater in the subsoil). The location (depth) of water stored in the soil (i.e., soil moisture) in relation to root architecture of

the various plant species is an important factor controlling the competition among the species. Nutrients and contaminants become available for plant uptake as they enter into soil solution and their concentrations vary as amounts are moved among layers by water movement. Organic matter is also moved among layers by water movement and the decomposition and mineralization rates of organic matter are controlled, in part, by the moisture content of the soil.

In EDYS, water can arrive at the surface of a spatial cell in two ways, by a precipitation event and by surface movement from a surrounding cell (i.e., run-on). Some of this water can enter the soil profile (infiltration) and some exits the cell as runoff. Litter on the soil surface has the first opportunity for absorption of water in EDYS. If litter is present and is at less than its maximum moisture content, it can absorb sufficient water to bring it up to maximum moisture content. The remaining water is available for infiltration into the soil profile and runoff from the cell.

In EDYS, the amount of water that can potentially enter into the soil profile during a rainfall event is modeled as a step function. The amount of rain in each rainfall event is divided into five parts (10%, 20%, 40%, 20%, and 10% of the total amount). The amount of water in Step 1 (10% of the rainfall event) is compared to the available storage capacity (saturation capacity minus current moisture content) of the first layer. If the amount of water is less than or equal to the available storage capacity, all that quantity of water (10% of the event) is moved into the first layer. If the amount is in excess of available storage capacity, the excess amount is moved to adjacent cells as runoff. This process is repeated through each of the next four steps, with the number of layers used to calculate available storage capacity increasing by one layer at each step (e.g., Step 3 = 40% of rainfall event compared to available storage capacity of top three layers).

Once water moves into a soil layer it is moved downward using a “tipping bucket” algorithm. Any water in excess of field capacity of the first layer moves into the second layer. Any water in excess of field capacity of the second layer is moved into the third layer. This process continues in a top-down manner until the amount of water is stored in the various soil layers, or if some remains once the wetting front reaches saturated soil (groundwater), the surplus amount is added to groundwater. If the groundwater is unconstrained (i.e., groundwater lateral flow can occur), this amount of added water is removed as “export”. If the groundwater is constrained, then the water content of the layer immediately above the saturated layer increases above field capacity. This increase can continue until the saturation level is reached for that entire layer, at which time the process continues in an upward manner into the next un-saturated layer.

As water moves downward by percolation, soluble materials (nutrients, contaminants, organic matter) are moved with the water. As water moves into the next layer at each time step, the concentrations of the soluble materials in that layer are recalculated based on the amount of those materials in the layer prior to entry of the new water and the new concentration resulting from all the surplus water (not just field capacity) that at least temporarily moves into that layer. Then if some water continues to move downward out of that layer, that water transports with it the amount of nutrients, contaminants, and organic matter corresponding to its relative concentration.

Soil water (including groundwater) is extracted from each layer at each time step by plant uptake (transpiration). The amount removed from each layer is determined by the amount of roots of

each plant species in that layer, the depth of the layer (root uptake is modeled as a top-down process), and the amount of water transpired by each species. Soil water can also be extracted by evaporation. However, evaporation occurs directly only from the surface soil layer. Stored soil moisture can be moved from a maximum of the next three soil layers upward to the surface soil layer and then lost by evaporation, but this is a time-step controlled process and plant roots get first priority use of the water as it moves upward from the second, third, and fourth layers.

In addition to movement by water, organic matter can be added to a soil layer by death of plant material (roots) in that particular layer and by some movement of surface litter into the upper soil layer. The deposition of this material is based on root death rates specific to each plant species and decomposition rates that are influenced by moisture content and nitrogen availability.

6.0 VEGETATION

6.1 Plant Species

The number of plant species included in a specific EDYS application is flexible. How many and which species to be included depends on the requirements of the application and the level of complexity desired. The inclusion of more species increases the potential for the model to simulate the complexity common to most landscapes, but it also increases run times and memory requirements.

The EDYS data base includes ecological data on over 250 species, not all of which occur in South Texas and not all of which have data for all plant parameter variables used in EDYS. In each EDYS application, a subset of all species occurring in the spatial domain is used. Several factors are considered in the selection of this subset.

- The subset should include the major species of the area, based on both ecological and management importance. Ecological importance includes dominant and sub-dominant species for each of the included plant communities, as well as species important successional and threatened and endangered species if they are present.
- There must be sufficient ecological data available for the included species such that the required parameter variable values can be determined or reasonably estimated. Data for all parameter variables may not be available for a major species. In such cases, reasonable estimates can often be made based on available data for closely-related or ecologically similar species.
- For species where a substantial amount of their parameter values are estimated, care must be taken that the estimates are not based largely on data from species used to estimate values for other included species. Otherwise, little new information is actually included in the model by adding another species.
- The inclusion of the species should be expected to sufficiently increase the ability of the model to simulate ecological responses to justify any associated increase in run time, memory requirements, or time required to interpret results.
- The inclusion of the species should not unduly increase unaccounted error (i.e., "noise") into the model output.

Based on these factors, 84 plant species are included in the model (Table 6.1).

Table 6.1 Plant species included in the Goliad County EDYS model.

Lifeform	Scientific Name	Common Name
Tree	<i>Acacia farnesiana</i>	huisache
Tree	<i>Carya illinoensis</i>	pecan
Tree	<i>Celtis laevigata</i>	sugar hackberry
Tree	<i>Prosopis glandulosa</i>	mesquite
Tree	<i>Quercus stellata</i>	post oak
Tree	<i>Quercus virginiana</i>	live oak
Shrub	<i>Acacia berlandieri</i>	guajillo
Shrub	<i>Acacia rigidula</i>	blackbrush
Shrub	<i>Aloysia lycioides</i>	whitebrush
Shrub	<i>Baccharis texana</i>	prairie baccharis
Shrub	<i>Borrchia frutescens</i>	sea oxeye
Shrub	<i>Celtis pallida</i>	granjeno
Shrub	<i>Lycium carolinianum</i>	wolfberry
Shrub	<i>Mahonia trifoliolata</i>	agarito
Shrub	<i>Rosa bracteata</i>	McCartney rose
Shrub	<i>Sesbania drummondii</i>	rattlepod
Vine	<i>Vitis mustangensis</i>	mustang grape
Cacti	<i>Opuntia lindheimeri</i>	prickly pear
Perennial grass	<i>Andropogon gerardii</i>	big bluestem
Perennial grass	<i>Andropogon glomeratus</i>	bushy bluestem
Perennial grass	<i>Aristida purpurea</i>	purple threeawn
Perennial grass	<i>Bothriochloa ischaemum</i>	King Ranch bluestem
Perennial grass	<i>Bothriochloa saccharoides</i>	silver bluestem
Perennial grass	<i>Bouteloua curtipendula</i>	sideoats grama
Perennial grass	<i>Bouteloua hirsuta</i>	hairy grama
Perennial grass	<i>Bouteloua trifida</i>	red grama
Perennial grass	<i>Buchloe dactyloides</i>	buffalograss
Perennial grass	<i>Cenchrus incertus</i>	sandbur
Perennial grass	<i>Chloris cucullata</i>	hooded windmillgrass
Perennial grass	<i>Chloris pluriflora</i>	trichloris
Perennial grass	<i>Cynodon dactylon</i>	bermudagrass
Perennial grass	<i>Digitaria californica</i>	Arizona cottontop
Perennial grass	<i>Distichlis spicata</i>	saltgrass
Perennial grass	<i>Elymus virginicus</i>	Virginia wildrye
Perennial grass	<i>Eriochloa sericea</i>	Texas cupgrass
Perennial grass	<i>Leptochloa dubia</i>	green sprangletop
Perennial grass	<i>Panicum coloratum</i>	kleingrass
Perennial grass	<i>Panicum maximum</i>	guineagrass
Perennial grass	<i>Panicum obtusum</i>	vine-mesquite
Perennial grass	<i>Panicum virgatum</i>	switchgrass
Perennial grass	<i>Paspalum lividum</i>	longtom

Table 6.1 (Cont.)

Lifeform	Scientific Name	Common Name
Perennial grass	<i>Paspalum plicatulum</i>	brownseed paspalum
Perennial grass	<i>Paspalum setaceum</i>	thin paspalum
Perennial grass	<i>Phragmites australis</i>	common reed
Perennial grass	<i>Schizachyrium scoparium</i>	little bluestem
Perennial grass	<i>Setaria geniculata</i>	knotroot bristlegrass
Perennial grass	<i>Setaria leucopila</i>	plains bristlegrass
Perennial grass	<i>Setaria texana</i>	Texas bristlegrass
Perennial grass	<i>Sorghastrum nutans</i>	indiangrass
Perennial grass	<i>Sorghum halepense</i>	Johnsongrass
Perennial grass	<i>Spartina spartinae</i>	gulf cordgrass
Perennial grass	<i>Sporobolus asper</i>	tall dropseed
Perennial grass	<i>Sporobolus cryptandrus</i>	sand dropseed
Perennial grass	<i>Sporobolus indicus</i>	smutgrass
Perennial grass	<i>Stipa leucotricha</i>	Texas wintergrass
Annual grass	<i>Sorghum bicolor</i>	milo
Annual grass	<i>Triticum aestivum</i>	wheat
Annual grass	<i>Zea mays</i>	corn
Grass-like	<i>Carex microdonta</i>	littletooth sedge
Grass-like	<i>Cyperus odoratus</i>	flatsedge
Grass-like	<i>Typha latifolia</i>	cattail
Perennial forb	<i>Ambrosia psilostachya</i>	ragweed
Perennial forb	<i>Aphanostephus ramosissimus</i>	lazydaisy
Perennial forb	<i>Aster spinosus</i>	spiny aster
Perennial forb	<i>Baptisia leucophaea</i>	wild indigo
Perennial forb	<i>Clematis drummondii</i>	old-mans beard
Perennial forb	<i>Desmanthus velutinus</i>	bundleflower
Perennial forb	<i>Phyla nodiflora</i>	frogfruit
Perennial forb	<i>Ratibida columnifera</i>	prairie coneflower
Perennial forb	<i>Rhynchosia americana</i>	snoutbean
Perennial forb	<i>Ruellia nodiflora</i>	ruellia
Perennial forb	<i>Rumex crispus</i>	curly dock
Perennial forb	<i>Sagittaria falacata</i>	bulltongue
Perennial forb	<i>Salicornia virginica</i>	glasswort
Perennial forb	<i>Simsia calva</i>	bush sunflower
Perennial forb	<i>Smilax bona-nox</i>	greenbriar
Perennial forb	<i>Verbena halei</i>	Texas verbena
Perennial forb	<i>Zexmenia hispida</i>	orange zexmenia
Annual forb	<i>Ambrosia trifida</i>	giant ragweed
Annual forb	<i>Amphichyris dracunculoides</i>	annual broomweed
Annual forb	<i>Chamaecrista fasciculata</i>	partridge pea
Annual forb	<i>Croton texensis</i>	Texas doveweed
Annual forb	<i>Helianthus annuus</i>	sunflower
Annual forb	<i>Thymophylla tenuiloba</i>	dogweed

6.2 Vegetation Formations

A vegetation formation is a subdivision of a biome (McLendon 1991), with the subdivision based on either a general environmental factor (e.g., sandy prairie, riparian woodland) or the dominant genus or species (e.g., oak woodland). Twelve major vegetation formations occur in Goliad County (Table 6.2), with several to numerous plant communities in each formation.

Table 6.2 Major vegetation formations in Goliad County, Texas.

Woodlands	Shrublands	Grasslands	Aquatic	Agricultural
Huisache woodlands	Mesquite shrublands	Clay/clay loam prairies	Lakes/ponds	Cultivated
Mesquite woodlands	Xeric shrublands	Sand prairies	River/creeks	Pasture
Oak woodlands				
Riparian woodlands				

6.2.1 Woodlands

Riparian woodlands occur along the banks of the San Antonio River and banks of the larger creeks. These woodlands commonly have a continuous or nearly continuous canopy cover of trees. The trees tend to be medium-sized to large and of mixed composition. The width of the community generally increases as the size and flow of the associated drainage increases. This bottomland community can extend outward 100-200 m, or more, from each bank of the San Antonio River in some areas, or be as narrow as 10-20 m along some areas of the mid-sized creeks.

Huisache (*Acacia farnesiana*) is a small- to medium-sized tree that can form dense stands on frequently flooded sites, recently disturbed areas, and grassland sites (both native and pasture). It is an aggressive, mid-seral colonizer. Huisache is particularly well-adapted to relatively wet sites, where the surface is frequently flooded and the water table is near the surface. However, it also forms extensive, but less dense, stands on drier sites. On drier, especially clay loam, sites huisache has a competitive advantage over mesquite (*Prosopis glandulosa*) earlier in succession but mesquite tends to have the competitive advantage over time.

In Goliad County, mesquite woodlands are particularly well-developed on clay loam sites with relatively deep soils that are not frequently flooded. Mesquite woodlands often occur as strips along the drier edges of the riparian woodlands and along the edges of oak woodlands. In these areas, the mesquite can become large (1-m diameter trunks) and form nearly continuous canopies. Many former grassland sites now support mesquite woodland because of long-term overgrazing by livestock.

Oak woodlands occur on sites where the soils are moderate to deep sands. Some oak, especially live oak (*Quercus virginiana*), are common components of the riparian woodlands. But as the soils become sandier, oaks tend to become the dominant species on wooded sites. Post oak (*Q. stellata*) woodlands tend to form somewhat continuous stands across the landscape, whereas

live oak woodlands tend to form mottes, some of which can be extensive. However, both species can occur in relatively extensive stands or in large clusters.

6.2.2 Shrublands

There are two primary shrubland formations in Goliad County, mesquite shrublands and xeric shrublands. Mesquite shrublands occur mostly on clay and loam sites that are either drier than those supporting mesquite woodlands or have been more recently or more frequently disturbed. The drier nature of these sites often occurs because there is either a deeper water table or a caliche layer nearer the surface, as compared to soils supporting mesquite woodlands. The mesquite on these shrubland sites tend to be smaller than those in the woodlands, although they can obtain tree size (e.g., 3-8 m tall). Shrubs are abundant in this formation, often forming dense stands under the canopies of scattered mesquite. Granjeno (*Celtis pallida*), prickly pear (*Opuntia lindheimeri*), whitebrush (*Aloysia lycioides*), and brasil (*Condalia hookeri*) are common in the shrub component, but mixtures of 10-20 species are common (McLendon 1991).

The xeric shrublands occur mostly on shallow, limestone (caliche) sites. These sites are scattered throughout the county but are most common in the central and western parts. The soils are thin (5-40 cm) over a generally fractured limestone substrate, the upper portion of which varies between somewhat soft to dense, indurated caliche. The vegetation on these sites tends to be short (2-4 m tall), dense shrublands. Blackbrush (*Acacia rigidula*) is the most common dominant and often occurs as very dense, almost monoculture, stands with little understory (Dodd and Holtz 1972; McLendon 1991). Numerous other xeric shrubs occur in this formation, along with small, scattered mesquite.

6.2.3 Grasslands

Native grasslands were probably extensive in Goliad County in the past, but cultivation, conversion to improved pastures, and increases in woody species have reduced their extent. There is relatively little area in native clay or clay loam grasslands remaining. In the past, these were concentrated in the western part of the county. Those that do currently exist have mostly been restored, either from previously cultivated land or from brush control. These clay/clay loam grasslands were midgrass prairie, dominated mostly by silver bluestem (*Bothriochloa saccharoides*) and little bluestem (*Schizachyrium scoparium*), with substantial amounts of other midgrass species such as sideoats grama (*Bouteloua curtipendula*), trichloris (*Chloris pluriflora*), plains bristlegrass (*Setaria leucopila*), Arizona cottontop (*Digitaria californica*), and Texas cupgrass (*Eriochloa sericea*). More mesic sites such as low-lying areas and ecotones to the riparian woodlands also contained large amounts of tallgrasses such as big bluestem (*Andropogon gerardii*), indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), and eastern gamagrass (*Tripsacum dactyloides*). The non-natives Johnsongrass (*Sorghum halepense*) and guineagrass (*Panicum maximum*) are now abundant on many of these sites.

Sand prairies in Goliad County have also been reduced in area over time but there are still substantial amounts remaining, primarily in the southeast part of the county (Goliad and McFaddin Prairies) and mixed in strips and mottes of the oak woodlands in the eastern and northern part of the county. The sand prairies are also midgrass prairies, typically dominated by

little bluestem (in the north), seascoast bluestem (*Schizachyrium scoparium* var. *littoralis*; in the south), and tall dropseed (*Sporobolus asper*). Other important midgrasses are arrowfeather threeawn (*Aristida purpurescens*), Pan-American balsamscale (*Elyonurus tripsacoides*), tanglehead (*Heteropogon contortus*), brownseed paspalum (*Paspalum plicatulum*), and thin paspalum (*P. setaceum*). Forbs are common in these prairies and, when moisture is sufficient, extensive stand of bluebonnets (*Lupinus texensis*), Indian paintbrush (*Castilleja indivisa*), coreopsis (*Coreopsis tinctoria*), and Indian blanket (*Gaillardia pulchella*) can be spectacular.

6.2.4 Aquatic Systems

The only major lake in Goliad County is the Coletto Creek Reservoir along the eastern edge of the county. There are abundant ponds and small lakes, mostly man-made, throughout the county. The vegetation associated with these, including stock tanks, varies by size, depth, and perennial water-holding capability of the pond or lake, but is typical of this type of wetland vegetation in the region. There is commonly an open water surface with little emergent or surface vegetation. As water depth decreases, floating species may occur if the pond has permanent water. Next is a zone of emergent vegetation, typically cattails (*Typha* spp.) and bulrushes (*Scirpus* spp.), then a zone of wetland species including cutgrass (*Leersia hexandra*), sedges (*Carex* spp.), spikerushes (*Eleocharis* spp.), flatsedges (*Cyperus* spp.), longtom (*Paspalum lividum*), and rattlepod (*Sesbania drummondii*). These zones can be narrow (25-50 cm) or wider (e.g., 10 m) depending on the size, structure, and permanency of the pond. Heavy use by livestock often reduces the size and diversity of these zones.

The San Antonio River flows through the center of the county and numerous small to medium-sized creeks flow into the river. Vascular plant development in the river and larger creeks is limited because of high turbidity. In most sections of the river, it is relatively slow moving. Therefore, vegetation along the edges of the river, and similarly along the edges of the larger creeks, is similar to that along the edges of the ponds when the river and creek banks have a gradual slope. Where the river and creek banks drop abruptly into the river, the aquatic vegetation is limited to a thin strip of wetland species. In many of these abrupt areas, the canopies of the riparian trees overhang much of the river. Upslope from the river and creek banks, the vegetation transitions to riparian or mesquite woodland, a wetland, or a shrubland depending on conditions adjacent to the bank.

Many of the mid-sized and smaller creeks are ephemeral streams. Along these creeks, the banks generally support mesquite or huisache woodlands, the widths of which may vary from 10-100 m. The streambeds are often bare of vegetation if water flows fairly frequently, but most of these streambeds are covered with forbs and grasses during dry periods. Giant ragweed (*Ambrosia trifida*), also known as bloodweed, is the most common of these species and often forms dense stands 2-3 m tall.

6.2.5 Agricultural

Approximately 8,500 acres (1.5%) in Goliad County are under cultivation, with an additional 19,000 acres in improved pasture (Wiendenfeld 2010). The major crops are corn, cotton, grain sorghum, wheat, and soybeans. Major improved pasture species are kleingrass (*Panicum*

coloratum), bermudagrass (*Cynodon dactylon*), King Ranch bluestem (*Bothriochloa ischaemum*), and Johnsongrass. Larger portions of the county were in cultivation in the past, but were either abandoned to cultivation and reverted to native, often woody, vegetation or were converted to improved pasture. Improved pastures in Goliad County are subject to invasion by woody species, especially huisache and mesquite. Woody plant invasion is slower in pastures that are routinely hayed, but woody species still tend to invade over time, especially huisache which has the ability to spread low-growing branches horizontally beneath the cutting height for hay production. Because of invasion by woody plants, improved pastures must be routinely maintained or they will revert to savannas (open stand of small trees with grass understory) in 10-20 years and woodlands in 20-40 years.

6.3 Plant Communities

In EDYS, each cell is assigned an initial vegetation composition based on some combination of the plant species included in the application (Table 6.1). Because species composition field data are not available for each cell in the spatial footprint, initial vegetation assignments are made on the basis of plant communities. A first-approximation of species composition of each plant community, as well as their spatial distribution, is made using NRCS soil survey maps (Wiedenfeld 2010). Each soil series is assigned an initial plant community based on NRCS ecological site descriptions (Table 5.1), other available literature (Appendix C), and professional experience. NRCS ecological site descriptions are largely based on late-successional conditions, which seldom occur on site. Instead, the sites are generally in a lower successional stage and often have some level of woody plant cover. Estimates of lower successional conditions and amounts of woody plant cover (estimated from aerial photographs) are used to adjust the literature data to arrive at initial estimates of species composition and biomass levels for each plant community.

An initial plant community may closely coincide spatially with its associated soil type. However, in some cases the plant communities associated with two or more soil types may be very similar and therefore was pooled. Conversely, visual observations from the aerial photographs may indicate that two or more areas in the same soil type have very different woody plant coverage, in which case they were separated into two or more plant communities.

Once all plant communities have been defined and mapped, all cells within a particular plant community are given the same initial species composition data. Although each cell in a vegetation polygon (initial plant community) has the same initial species composition, it does not necessarily remain the same during a simulation. Differences in topographic features, precipitation zones, depths to groundwater, natural disturbances (e.g., fire), and management impacts (e.g., livestock grazing intensity, brush control) often result in some cells in the same initial vegetation type changing sufficiently that they form a separate vegetation type.

In addition to literature data and aerial photographs, some ground truthing of the initial spatial distribution of the vegetation is generally conducted. The level of this field mapping depends on the needs of the project and is defined in the scope of work. Once the initial spatial footprint, including vegetation patterns, has been developed and initial simulations conducted, it may be deemed desirable to conduct additional field surveys to increase the detail of the spatial mapping. This can be done and updates incorporated into EDYS with a reasonable amount of effort.

Twenty-four initial native plant communities were identified for the Goliad County model (Table 6.3). These 24 communities were derived from the NRCS range sites and modified on the basis of information from the literature and from amounts of woody plant coverage (Appendix Table C.2). Woody plant coverage was estimated from NAIP aerial photographs and averaged 36.6% for Goliad County overall (Appendix Table C.28). Literature data used to modify the NRCS range site descriptions of the vegetation (Appendix C) were taken from Archer (1990), Archer et al. (1988), Bovey et al. (1970, 1972), Box (1961), Box and White (1969), Buckley and Dodd (1969), Diamond and Smeins (1984), Dodd and Holtz (1972), Drawe (1994), Drawe and Box (1969), Drawe et al. (1978), Garza et al. (1994), Johnston (1963), McLendon (1991, 1994, 2015), McLendon and Dahl (1983), McLendon and DeYoung (1976), McLendon et al. (2012a, 2012b, 2012c, 2012d, 2013a, 2013b), Powell and Box (1967), Scifres et al. (1980), Smeins (1994a, 1994b), and Smeins and Diamond (1983).

Table 6.3 Initial native plant communities used in the Goliad County EDYS model, with their associated NRCS range sites and primary associated soil type.

Plant Community	Range Site	Primary Soil Type
Clay Soils		
Mesquite-hackberry-ragweed	Clayey Bottomland	Buchel clay
Huisache-mesquite-purple threeawn	Blackland RG Plains	Laewest clay
Huisache-mesquite-buffalograss	Blackland Coastal	Monteola clay
Clay Loam Soils		
Mesquite-silver bluestem-buffalograss	Rolling Blackland	Coy clay loam
Live oak-little bluestem-trichoris	Loamy Bottomland	Sinton sandy clay loam
Mesquite-huisache-buffalograss	Sloping Clay Loam	Schattel sandy clay loam
Mesquite-huisache-silver bluestem	Clay Loam	Weesatche sandy clay loam
Mesquite-silver bluestem-little bluestem	Shallow Sandy Loam	Parrita sandy clay loam
Loam Soils		
Huisache-seacoast bluestem-longtom	Lowland Coastal	Cieno loam
Sandy Loam Soils		
Mesquite-huisache-hooded windmillgrass	Gray Sandy Loam	Pernitas sandy clay loam
Huisache-mesquite-little bluestem	Loamy Prairie	Telferner fine sandy loam
Huisache-little bluestem-knotroot bristlegrass	Claypan Prairie	Wyick fine sandy loam
Huisache-gulf cordgrass-sea oxeye	Salty Prairie	Greta fine sandy loam
Mesquite-live oak-silver bluestem	Sandy Loam	Weesatche fine sandy loam
Mesquite-silver bluestem-trichloris	Tight Sandy Loam	Ander fine sandy loam
Sandy Soils		
Live oak-little bluestem-Virginia wildrye	Sandy Bottomland	Zalco sand
Post oak-mesquite-little bluestem	Claypan Savannah	Sarco coarse sand
Live oak-mesquite-little bluestem	Loamy Sand	Raisin loamy fine sand
Mesquite-live oak-little bluestem	Sandy	Nusil fine sand
Live oak-little bluestem-ragweed	Deep Sand	Kuy fine sand
Shallow Soils		
Blackbrush-purple threeawn-buffalograss	Gravelly Ridge	Pettus loam
Blackbrush-ragweed-Texas wintergrass	Shallow Ridge	Olmedo very gravelly loam
Wetland Sites		
Huisache-longtom-knotroot bristlegrass	Lakebed RG Plains	Realitos clay
Huisache-longtom-flatsedge	Lakebed Coastal	Edroy clay

Ten land-use types were also included in the model (Table 6.4). These include urban areas, industrial sites, mineral developments, disturbed areas, cultivation, improved pastures, and areas subjected to brush control. They are treated in EDYS in a manner similar to vegetation types.

Table 6.4 Land-use types included in the Goliad County EDYS model.

Land-Use Type	Vegetation	Comment
Urban houses	mesquite-live oak-bermudagrass	50% of area vegetated (lawns)
Buildings/industrial	mesquite-huisache-baccharis	% woody plant cover from aerial photographs
Disturbed area	mesquite-huisache-bacchairs	% woody plant cover from aerial photographs
Oil/drill pad	mesquite-huisache	% woody plant cover from aerial photographs
Caliche pit	huisache-blackbrush-baccharis	% woody plant cover from aerial photographs
Road	none	
Tilled (cultivated)	milo (grain sorghum)	
Orchard	pecan	
Improved pasture	bermudagrass-huisache-mesquite	% woody plant cover from aerial photographs
Brush control	mesquite-silver bluestem-buffalograss	% woody plant cover from aerial photographs; grasses = 10% of rolling blackland type

The urban houses type was considered to be 50% of the spatial area covered with buildings and pavement and 50% in yard. The grass component of the yards was considered to be bermudagrass and the woody plants were considered to be 75% mesquite and 25% live oak, with the amount of canopy cover estimated from aerial photographs.

Woody plant cover in cells that were classified as buildings/industrial, disturbed areas, caliche pits, or oil/drill pads was considered to consist of combinations of mesquite, huisache, blackbrush, and baccharis (*Baccharis texana*). This vegetation was considered to be either on areas not cleared when the sites were disturbed or the plants were the result of re-invasion. Amount of canopy cover was estimated from aerial photographs.

Crops grown on individual cultivated fields vary throughout the county. No effort was made to distinguish different crops from the aerial photographs. Instead, all cultivated areas were assumed to be planted each year to milo (grain sorghum). All orchards were assumed to be pecan orchards.

There are several improved pasture species that are common in Goliad County. Most common are coastal bermudagrass, kleingrass, King Ranch bluestem, Kleberg bluestem (*Dichanthium annulatum*), Johnsongrass, and various types of forage sorghums (*Sorghum* spp.). Wheat is sometimes planted as a winter forage crop. Regardless of the species planted, other species tend to invade these improved pastures over time. Common invading woody species include huisache, mesquite, hackberry, and baccharis. Common invading herbaceous species include Johnsongrass, King Ranch bluestem, ragweed (*Ambrosia psilostachya*), and sunflower (*Helianthus annuus*).

The initial forage species planted in the improved pastures, the potential productivity of the pasture, and the most common invading species all vary by soil type, the pre-planting vegetation,

and the surrounding vegetation (Appendix Table C.22). Determining what the current composition is for each of the improved pasture polygons would require a substantial effort. As a first approximation, only one improved pasture type (sandy loam, Appendix Table C.22) was used for the initial biomass estimates for all improved pasture polygons. Even though they were all initially set with the same biomass values, changes in these improved pastures can occur during model simulation runs because of differences in precipitation zones and management.

Brush control is a management option in the model. However, it was apparent from the aerial photographs that some areas had been subjected to mechanical brush control without being converted to improved pastures. This was most often the case where brush had been removed in strips, with other strips or blocks left brush. This is a common practice in South Texas, used especially to improve wildlife habitat. The brush strips are left to provide wildlife shelter and the cleared strips are used to provide food, in particular forbs, for wildlife, along with clearing viewing areas for hunting.

In small-scale EDYS applications, these brush strips and adjacent cleared strips can be treated as separate plot types and the composition of both brush and cleared strips can be varied across the landscape. On large-scale applications, such as Goliad County, this effort becomes too complex. Therefore, average values were used for the vegetation in these brush control polygons. The initial vegetation data was based on that for the Rolling Blackland Range Site (Appendix Table C.2). The same woody plant composition was used for the brush control plots as for the Rolling Blackland Site, along with the same amounts and composition of forbs. However, grass biomass was reduced by 90% with composition remaining the same. The amount of woody plant cover in these polygons was estimated from the aerial photographs.

These brush control polygons were previously-treated areas. These are different from areas receiving brush control treatments in the simulation scenarios (Section 9). In the areas receiving the brush control treatment in the scenarios, the existing vegetation is treated in the first year of the simulation.

6.4 Spatial Heterogeneity of Vegetation

Simulation run times and memory requirements increase as the complexity of the model application increases. Model application complexity is determined by a number of factors. Of these, spatial heterogeneity has the greatest effect. Spatial heterogeneity includes several components. One component is number of cells, which is determined by cell size (40 m x 40 m in the Goliad County model) and the size of the overall spatial footprint of the model. A practical upper limit is about 1.5 million cells (Section 2.0).

Although EDYS can keep track of changes in condition in all 1.5 million cells at each time step, that is too many cells on which to simulate all ecological and hydrologic dynamics. Instead, EDYS simulates these dynamics for plot types and then applies the resulting value, at each time step, to all cells containing that particular plot type. For example, an area of mesquite-granjeno shrubland might contain 100 cells, each with the same vegetation and the same soil. Instead of making 100 sets of calculations for that area (polygon) at each time step, EDYS makes one set of calculations and then applies the results of those calculations to all 100 cells.

A plot type is a unique combination of soil, vegetation type (including land-use types), amount of woody plant cover, and precipitation zone. The Goliad County model contains 24 soil-vegetation types (Table 5.1) plus 10 land-use types (Table 6.4). There are seven potential woody plant coverage categories (0-1%, 1-10%, 10-25%, 25-50%, 50-75%, 75-90%, 90-100%), but all coverage categories do not occur in all vegetation types. Accounting for woody plant coverage, there are 154 vegetation-coverage types (Appendix C.27). There are four precipitation zones. This results in a potential for 616 initial plot types (154 x 4), although not all soil-vegetation-landuse types occur in all precipitation zones.

Plot types often become subdivided during EDYS simulations. This happens when some disturbance or treatment factor (e.g., fire, sediment deposition, brush control, cross fencing, placement of water facilities) affects one part of the plot type but not another part. The affected part, including all cells in it, then becomes a different plot type (e.g., root-plowed mesquite-granjeno community). Depending on the length of the simulation run and the number of management options applied, this plot proliferation can increase the number of plot types during the simulation run by a factor of 4-5. The use of different precipitation zones (Fig. 4.3) also increases the number of plot types. Two areas with the same initial plot type but that occur in different precipitation zones will function as different plot types because they receive different amounts of precipitation.

Because of plot type proliferation, the number of potential plot types in the Goliad County model may increase from about 600 at the beginning of the simulation run to 3,000 or more at the end of the run. The upper limit to number of plot types in an EDYS application that has about a million cells (e.g., the Goliad County model) is approximately 1700.

There are two approaches that can be taken to account for plot proliferation. One approach is to not allow it. This approach fixes the number of plot types at the original number. The advantage in using this approach is that greater initial ecological spatial heterogeneity can be included. The disadvantage is that no spatial changes can occur during a simulation. The vegetation can change within a polygon but the polygon cannot be subdivided as a result of disturbance or management.

The alternative approach is to reduce the number of initial plot types and then allow proliferation to occur during the simulation. The advantage of this approach is that the landscape becomes spatially dynamic as well as temporally dynamic. The disadvantage is that less ecological spatial heterogeneity can be included at the beginning of the simulation.

Which approach is selected depends on the relative importance of spatial dynamics versus increased spatial ecological complexity. For the Goliad County model, the second approach was selected. Spatial changes across the landscape, resulting from both natural and anthropogenic factors, were considered of high importance. In addition, much of the increased spatial complexity in ecological factors was considered to be of lesser importance. For example, differences in over two-thirds of the NRCS soil units (54 out of 78) were relatively minor variations based on slope and frequency of flooding (Section 5.1). Likewise, much of the fine-

scale changes in plant species composition among vegetation types cannot be determined without substantial on-site vegetation mapping.

The 616 potential plot types used in the Goliad County model allows for an average of almost three subdivisions per plot type during a simulation run. This seems to be a reasonable balance between initial ecological spatial heterogeneity and spatial dynamics during the simulation.

6.5 Plant Parameter Variables

EDYS is a mechanistic model. It simulates ecological dynamics by modeling how the various ecological components function. For plants, this is accomplished by using mathematical algorithms to model how plants grow and respond to various environmental stressors, such as drought, fire, and herbivory.

There are a large number of algorithms associated with plant dynamics in the EDYS model (Childress et al. 1999b; Coldren et al. 2011a). Each algorithm is applied to each plant species at each time step during a simulation to simulate the change in that plant or plant part from one time step to the next. Each algorithm contains one or more plant response variables (parameters). Differential responses among plant species are achieved in EDYS by assigning species-specific values to each of these plant parameters. For example, one of the algorithms is plant growth, more specifically, increase in plant biomass. This algorithm contains a number of parameters, one of which is “water to production”. This parameter (water to production) is the amount of water (in kilograms) required to produce one gram of new plant biomass and it is species specific (i.e., the water-use efficiency varies by species). Two of the major perennial grasses in the Goliad County model are little bluestem and buffalograss (*Buchloe dactyloides*). The water-to-production value for little bluestem is 0.90 and the value for buffalograss is 0.74. Buffalograss is the more xeric of the two grasses and indeed has a higher water-use efficiency.

There are 346 plant parameter variables in EDYS and each one of these has a specific value for each species in an application (84 species in the case of the Goliad County model). These variables are arranged into 37 matrices (Coldren et al. 2011a). Selected examples are presented in Appendix E, along with corresponding values for each of the species included in the Goliad County model.

General characteristics of each species are presented in Appendix Table E.1. Appendix Tables E.2-E.4 are the tissue allocation matrices. At each time step, EDYS calculates the amount of new biomass produced by each species. This amount is based on 1) amount of current photosynthetically active biomass, 2) potential growth rate, and 3) amount of required resources available to the species (function of amount of each resource available in the system and the competitive ability of the specific species to secure this resource). The amount of new biomass produced by each species is then allocated to the various plant parts based on the values in the allocation matrices.

Appendix Table E.2 provides the information that EDYS uses to allocate the beginning biomass values (Appendix Table C.2) to the various plant parts to begin a simulation. During a simulation, new biomass production is allocated during each time step to the various plant parts

based on the values in Appendix Table E.3. For example, if 10 g of new biomass is produced by huisache, 0.8 g would be coarse roots, 2.0 g would be fine roots, 0.9 g would be added to the trunk, 2.2 g would be added to stems, and 4.1 g would be added to leaves. These ratios are used throughout the growing season, except in months when the species flowers or undergoes green-out. Green-out occurs following winter dormancy, drought dormancy, or following severe defoliation. For months when green-out occurs, the values from Appendix Table E.4 are used instead of the values from Appendix Table E.3.

Root architecture varies substantially among plant species and these variations are important in determining competitive responses among species for belowground resources (e.g., water and nutrients). Two components of root architecture of primary importance are distribution of roots by soil depth and maximum potential rooting depth. Appendix Table E.9 provides the values for these two parameters for each of the species included in the model. These values are used in EDYS to determine the initial spatial distribution of root biomass.

The amount of roots for a particular species at the beginning of a simulation is determined by multiplying the coarse and fine root allocation values (Appendix Table E.2) by the initial biomass value for that species in a given plot type (Appendix Table C.2). The values in Appendix Table E.9 are then used to allocate this root biomass (coarse and fine) by soil depth. This is calculated as the product of:

(total root biomass)(% in a portion of the rooting depth)(maximum potential rooting depth).

For example, 4% of the roots of huisache are assumed to be located in the first 1% of the rooting depth of huisache, which is 12.62 m (Appendix Table E.9). Therefore, 4% of the initial root biomass of huisache is located in the upper 126 mm of the soil. If the maximum depth of a soil in a particular plot type is less than the maximum potential rooting depth, the maximum soil depth is used instead.

The values in Appendix Table E.9 are used to calculate the initial distribution of roots in an EDYS simulation. At each time step during a simulation, new root biomass is added (e.g., Appendix Table E.3). This new root biomass is allocated to the current root biomass in those soil depths where active root uptake of water and nutrients is taking place. This results in potential changes in root distribution during a simulation caused by resource distribution.

Appendix Table E.11 provides values used to determine when specified physiological processes occur. These processes are 1) green-out (breaking of winter dormancy), 2) beginning of winter dormancy, 3) those months in which flowering and seed production can occur, and 4) those months in which seed germination can occur.

Appendix Table E.13 provides values used to determine water requirements of each species for maintenance and production of new biomass. Maintenance water requirements (old and new growth) refers to the amount of water used each month to support existing biomass. Water to production is the amount of water required to produce 1 g of new biomass (i.e., water-use efficiency). Green-out requirement is the amount of water required to support the production of new biomass during green-out.

At each time step during the growing season for a particular species (Appendix Table E.11), EDYS calculates the amount of water that species would require if it produced at its maximum potential rate (Appendix Table E.14) plus the amount required for maintenance of existing tissue. EDYS then calculates how much soil moisture is available to that species at that time step, as determined by the distribution of moisture in the soil at that time and the competition for that water among all species with roots in each particular soil layer. If the amount of water available is equal to or greater than the amount required, the plant produces that much new biomass and that quantity of water is removed from the respective soil layers. If the amount of water available is less than the amount required, maintenance requirements are met first and any remaining water is used to produce new biomass, the amount of which is proportional to what can be produced on the remaining amount of water (water to production).

EDYS also determines nutrient requirements in a manner similar to water requirements. If nutrients are more limiting to plant growth than water requirements at that time step, the amount of new growth produced is determined by the amount of nutrients available rather than the amount of water available, and the amount of water used is reduced proportionately.

Appendix Table E.14 provides values used to determine maximum potential growth rate, size of the plants, and the maximum rate of tissue loss from drought. Maximum potential growth rate is the maximum rate that new biomass can be produced, under optimum conditions for that species. Maximum potential growth rate is genetically determined for each species. Actual growth rate is most often less than this value because of resource limitations and tissue loss (e.g., herbivory, trampling). The values in Appendix Table E.14 are multiplied by the amount of photosynthetically-active tissue (Appendix Table E.16) present in that species at that time step. The product is the maximum amount of new tissue that species can produce in that particular month. The actual amount produced is generally less than this maximum amount, based on resource limitations (water, nutrients, light, temperature).

Maximum aboveground biomass is the maximum amount of standing crop biomass (g/m^2) that is possible for that species. This variable limits the accumulation of biomass to realistic levels for the species. Maximum old biomass drought loss is the maximum amount (proportion of existing biomass) that can be lost in one month from drought.

Appendix Table E.15 provides a seasonal growth function for each species. A value of 1.00 indicates that the species can potentially grow at its maximum rate (Appendix Table E.14) during that month. Values less than 1.00 result in proportional decreases in the maximum potential growth rate during those months. The values in the table are estimates based on responses to both temperature and photoperiod.

Maximum potential growth rates (Appendix Table E.14) are based on photosynthetically-active tissue. For most species, the tissue with the highest potential photosynthetic rate are the leaves. Cacti are an exception. Cacti leaves are their thorns. Cacti stems are the photosynthetically-active tissue in cacti. Roots and trunks of most species are structural tissues and do not contribute directly to photosynthesis, although there are exceptions (e.g., trunks of retama and paloverde trees). Stems of many species contribute somewhat to photosynthesis, but generally at

a lower rate than leaves. Appendix Table E.16 provides values for the photosynthetic potential of each plant part for each species. The values are proportions of maximum rates for that species (leaves for most species).

Green-out in plants, whether as spring green-up or recovery from defoliation, requires an energy source. Carbohydrates stored in various tissues are used to produce the new biomass. Some storage is in areas near the meristematic regions (e.g., bud zones) whereas other storage is in more distant tissues (e.g., coarse roots, bases of trunks) and must be translocated to the points of new growth. In both cases, there is a loss of biomass (weight) in some tissue because of the loss of stored carbohydrates. Appendix Table E.17 provides values used to determine how much current biomass (stored carbohydrates) can be used to produce new tissue during green-out. A value of 1.00 indicates that the amount of tissue in that plant part can be doubled during a green-out month. A value of 0.10 indicates that 10% of the biomass in that plant part can be transformed into new biomass during one month of green-out. During a green-out month, that amount of biomass is removed from the supplying plant part and transferred to new biomass and allocated according to the ratios in Appendix Table E.4.

Appendix Table E.18 contains values for four physiological control variables. These variables are used in EDYS to assure that plant structure does not become unbalanced and that the conversion from seeds to new plant biomass occurs properly. Each species has a characteristic root:shoot ratio (Appendix Table E.9). This is the relative amount of roots and shoots for that species. However, these ratios change during the growth season as new aboveground biomass is added and over years as perennial tissues accumulate belowground. Growing season maximum root:shoot ratio is a control to keep too much root biomass accumulating over time. If this value is exceeded during a growing season, no new biomass is allocated to roots until the value drops below this maximum value. Growing season green-out shoot:root ratio has a similar function. Maximum 1-month seed germination limits the amount of the seed bank that can germinate in any one month. Maximum first-month seedling growth provides the value to convert germinated seed biomass to new plant biomass. The amount of germinated seed biomass is multiplied by this value and the product becomes new plant tissue for that species.

At the end of the growing season (Appendix Table E.11), plants enter winter dormancy (or summer dormancy for cool-season species) and lose some of their tissue. An obvious example is deciduous trees shedding their leaves in the fall. But other tissue losses also occur. Some stems die. There can be some loss of trunk biomass. Root death occurs. Appendix Table E.19 provides the values used to calculate these losses.

A major factor in competition among plant species in many areas is shading, i.e., competition for light. Tall plants have a shading effect on shorter plants. Appendix Table E.20 provides for this competitive response. The values listed are a reduction in maximum potential growth rate of the **shaded** species resulting from 100% canopy cover of the **shading** species. The values are estimates based on 1) relative heights of the species, 2) canopy foliage characteristics, and 3) shade-tolerance of the understory species. The values in Appendix Table E.20 do not represent the competitive effect of overstory species on understory species, only the direct effect of shading. Overstory species also affect the growth of understory species in other ways, e.g.,

competition for light and nutrients. Those competitive effects are simulated in EDYS using other parameters. The shading parameter only reflects competition for light.

In EDYS, values are averaged within a cell (Section 2.0), which are 40 m x 40 m in the Goliad County model. Within each cell, estimates are made of the amount of woody plant cover (e.g., 10-25%) based on aerial photographs (Section 6.4). A 25% cover of woody plants could result from various combinations of clusters (mottes) of trees and shrubs. In effect, the cell would consist of at least two vegetation types, one associated with the woody species clusters and distributed over 25% of the surface of the cell and the other associated with herbaceous vegetation in the interspaces and distributed over the remaining 75% of the cell. However, the EDYS routine is to average the two types across the cell because the cell is the smallest subdivision in an EDYS application. In effect, this reduces the size of the woody plants (25% of actual size in this example) and assumes that biomass is average (uniform) across the cell. If the shading factor is ignored, this averaging does not substantially alter the vegetation and hydrologic dynamics of the cell. But with shading, the effect is to reduce herbaceous understory vegetation across the entire cell instead of just under the woody plant clusters which cover 25% of the cell.

We are working on an update that will account for this spatial heterogeneity within a cell. However, that update is not complete and cannot be included in the initial version of the Goliad County model. In the interim, the shading factor is utilized in this version for the effect of woody species on other woody species (i.e., under the woody plant canopy) but not for the shading effect of woody species on herbaceous species. The shading factor is included to simulate the shading effect of herbaceous species on other herbaceous species (e.g., midgrasses shading shortgrasses). This dual-component approach allows dynamics of herbaceous species to be simulated in the portion not covered by woody species, while maintaining the major aspect of shading within the area covered by woody plants. This dual pattern is a major characteristic of the shrub and woodland mosaics of South Texas, which have little herbaceous vegetation under the woody canopies but relatively abundant grasses and forbs in the interspaces (Drawe et al. 1978; McLendon 1991). In addition, reduction in herbaceous species under woody plant canopies may not occur until cover of woody species increases above 30-50% (Scifres et al. 1982; Fuhlendorf et al. 1997).

7.0 ANIMALS

The animal component of EDYS consists of herbivory by different types of animals, both domestic and wildlife. Population dynamics and habitat requirements are not currently included in most applications, but can be included if required. Four types of herbivores are included in the Goliad County model (cattle, deer, rabbits, insects) and others can be added as needed.

Herbivory in EDYS is simulated using three matrices for each animal species included in the model. Examples are provided in Appendix E for cattle. The first matrix is the preference matrix (Appendix Table E.21). Each plant part (live and standing dead) are listed for each plant species in the model. For each part-species combination, a preference ranking is assigned for

each animal species. A ranking of 1 indicates that the plant part of that plant species is among the highest preferred foods for that particular animal. A low ranking (30 in the case of cattle) indicates the material is largely avoided by that animal.

The second matrix is the competition matrix (Appendix Table E.22). The values in this matrix indicate the order that animal (cattle in the case of Appendix Table E.22) has access to that plant part (whether they actually prefer it or not). In general, insects are considered to have first access (value = 1). The third matrix is the utilization matrix (Appendix Table E.23). These values indicate how much (percent) of that plant material the animal species could utilize if it desired that plant part. For example, cattle cannot consume 100% of the basal portions of most grasses because of their mouth structure. On the other hand, horses and deer can harvest this material to ground level.

Actual consumption of plant material in EDYS is a three-step process. First the amount of daily consumption is calculated by multiplying the amount of the animal species (either biomass or number, depending on the species) by a daily consumption value. The second step is to determine what the animal species consumes that day. That is accomplished by use of the preference, competition, and utilization matrices. If 100% of the daily consumption is available to that species (competition and utilization matrices) in the most highly preferred plant parts and plant species (preference matrix), the animal consumes that amount of the most preferred plant part. If that much is not available, the animal consumes what is available of that plant part and then selects from the next most-preferred plant parts and plant species. This process continues until the daily consumption amount is achieved. The third step is to subtract the quantity consumed from the standing crop biomass of that plant species and plant part.

7.1 Insects

Insect herbivory is modeled in the Goliad County model as consumption by grasshoppers. An average density of 3 grasshoppers/m² is used, with an average consumption rate of 0.1 g/m²/day.

7.2 Rabbits

Rabbits are considered to be eastern cottontails in the Goliad County model. An average density of about 0.3/ha (1 cottontail per 8 acres) was used. Rabbits are assumed to consume an amount of plant material equivalent to 5.4% of their body weight each day (Kanable 1977), or about 73 g per cottontail per day. This equals about 0.0022 g forage/m²/day.

7.3 Deer

Daily food intake (dry-weight basis) by white-tailed deer in South Texas is equal to about 3.23% of their live body weight for high-quality feed (Wheaton 1981). Daily intake in the western portion of the Edwards Plateau has been estimated to be 2.2% of live body weight (Bryant et al. 1979). Mature white-tailed does average about 43 kg (95 lbs) on the Welder Wildlife Refuge (central Texas Coast) and mature bucks average about 63 kg (139 lbs)(Knowlton et al. 1979), and mature does in the western part of the Edwards Plateau weight about 45 kg (Bryant et al.

1979). Deer in the central portion of South Texas tend to be larger than deer along the central Texas Coast and deer in the Edwards Plateau.

An average stocking rate of 0.164 deer/ha (1 deer/15 acres) was used in the Goliad County model. Using an average deer weight of 53 kg and a daily feed intake of 2.7% of body weight, this corresponds to an average daily feed intake of 1.43 kg/deer, or about 0.235 g/m² (2.1 lbs/ac).

In South Texas, deer consume a combination of shrubs, forbs, and grasses, with the specific combinations dependent on vegetation conditions of the site. In a mixed shrubland in Kleberg County, diets of free-ranging white-tailed deer (bite count method) consisted of 45% shrubs, 34% forbs, and 21% grasses (Graham 1982). In that study, a total of 141 plant species were consumed by deer over an 18-month period, with 22 plant species comprising a total of 80% of the diet. On the Welder Wildlife Refuge in San Patricio County, deer consumed 70-90% forbs, 10-20% grasses, and 3-10% shrubs (Chamrad et al. 1979; Kie et al. 1980). Based on preference ratings, deer on the Welder Wildlife Refuge selected mostly for forbs (69%), then for grasses (18%) and browse (13%)(Drawe and Box 1968). In Jim Hogg County, deer were found to consume 37% forbs, 33% browse, 18% cacti, and 2% grasses, with 10% of their rumen contents consisting on unidentifiable material (Everitt and Drawe 1974). White-tailed deer on the Sonora Experiment Station in the southwestern part of the Edwards Plateau were found to consume 61% shrubs, 31% forbs, and 8% grasses (Bryant et al. 1979).

7.4 Cattle

Cattle are primarily grazers (consumers of herbaceous species) instead of browsers (consumers of leaves and twigs of woody species)(Stoddart et al. 1975:257). In many systems, grasses make up 85-99% of the diets of cattle (Sanders 1975; Durham and Kothmann 1977; Frasure et al. 1979), although the proportion of grasses may be lower (75%) in South Texas (Drawe and Box 1968; Everitt et al. 1981). They consume some forbs, especially during seasons when grasses are dormant and the forbs are growing. Cattle also consume some shrubs, especially as a source of additional protein (Dalrymple et al. 1965; Herbel and Nelson 1966) or during the winter (Everitt et al. 1981). Cattle diets in South Texas often contain higher proportions of shrubs (6-10%: Drawe and Box 1968; Frasure et al. 1979; Smith and McLendon 1981; McLendon et al. 1982) than cattle diets in many other areas because of the abundance and diversity of shrubs in South Texas.

The amount of forage intake by cattle depends on a number of factors, including type of forage, size of the animal, and reproductive state. Of particular importance are protein content, moisture content, and digestibility of the forage species. A general rule for herbivores is that their daily intake, expressed on a dry-weight basis, equals about 3% of their body weight. Using this rule, a 1000-lb cow would consume about 30 lbs of forage per day. Published results from six grazing studies indicate a range in daily forage intake of 20 lbs/AUD in a desert grassland in New Mexico to 59 lbs/AUD on fertilized sand prairie on the Texas Coast, with an average of 34.9 lbs/AUD (Table 7.1). An average of 34 lbs/AUD was used as the estimated forage requirement in the Goliad County model.

Table 7.1 Forage consumption rate (forage disappearance) by cattle in selected studies reported in the literature.

Vegetation	Location	Amount/AUD		Reference
		lbs	grams	
Bluestem prairie, upland	Kansas	45.33	20,580	Anderson et al. 1970
Bluestem prairie, limestone breaks	Kansas	24.59	11,164	Anderson et al. 1970
Bluestem prairie, upland	Kansas	56.09	25,465	Owensby & Anderson 1967
Bluestem prairie, limestone breaks	Kansas	30.28	13,747	Owensby & Anderson 1967
Bluestem prairie, medium stocking	Louisiana	34	15,436	Duvall & Linnartz 1967
Bluestem prairie, heavy stocking	Louisiana	26	11,804	Duvall & Linnartz 1967
Bluestem coastal sand prairie	Texas	27.29	12,390	Drawe & Box 1969
Pasture, coastal Bermuda	Texas	32.25	14,642	McCawley 1978
Pasture, kleingrass	Texas	36.11	16,394	McCawley 1978
Pasture, Bell rhodesgrass	Texas	28.09	12,753	McCawley 1978
Mean		34.00	15,438	

AUD = animal unit day = amount of forage (dry weight) consumed by a 1000-lb cow in one day.

Long-term moderate stocking rates under good management are often based on removal of 40-60% of annual forage production (Paulsen and Ares 1962; Duvall and Linnartz 1967; Owensby and Anderson 1967; Drawe and Box 1969; Anderson et al. 1970). Average annual forage production for each ecological type, under late-seral condition, for Goliad County is presented in the NRCS Soil Survey (Wiedenfeld 2010). Average current forage production, accounting for the fact that most rangelands in South Texas are not in late-seral condition, was estimated at 70% of the values presented in the Soil Surveys (Appendix Table C.2). Proper management stocking rates were assumed to be based on 50% harvest of average available forage (Appendix Table C.22). These amounts were further reduced on the basis of amount of woody plant cover present (Appendix Table C.27).

The estimated amount of annual available forage was used to arrive at an estimated stocking rate for each EDYS plot type (Appendix Tables D.1 and D.2). Daily forage consumption rate (34 lbs/AUD, Table 6.1) was multiplied by 365 to arrive at an annual animal unit (AU) forage requirement. This value (12,410 lbs/AU) was divided by the estimated amount of annual available forage for each plot type (50% of forage production, Table 7.2). The medium stocking rates were used as the default values in the model. Averaged over all types, the mean stocking rates was 9.7 acres/AU for areas devoid of trees and shrubs (Table 7.2). This increased to 14.7 acres/AU when adjusted for woody plant cover.

Table 7.2 Cattle stocking rates, initial forage estimates, and mean woody plant cover used in the Goliad County EDYS model. Values are averages over various woody plant cover values per type.

Range or Land Use Type	Annual Forage Production				Stocking Rates		Woody Cover
	No Woody Cover (g/m ²)	(lbs/ac)	Mean Woody Cover (g/m ²)	(lbs/ac)	No Woody Cover (ac/AU)	Mean Woody Cover (ac/AU)	Mean (%)
Blackland, RG Plains	261	2331	136	1212	10.63	20.33	60.1
Blackland, Coastal	522	4661	426	3803	5.33	6.53	23.0
Clayey Bottomland	286	2554	140	1251	9.73	19.84	66.3
Clay Loam	286	2554	190	1696	9.73	14.63	42.0
Claypan Prairie	379	3384	345	3079	7.33	8.06	11.3
Claypan Savanna	306	2733	191	1708	9.10	14.53	46.9
Deep Sand	243	2170	163	1452	11.41	17.09	41.4
Gravelly Ridge	178	1590	116	1035	15.64	23.98	43.6
Gray Sandy Loam	260	2322	143	1279	10.71	19.41	56.1
Lakebed RG Plains	276	2465	187	1674	10.09	14.83	40.2
Lakebed Coastal	350	3126	285	2545	7.95	9.75	23.3
Loamy Bottomland	431	3849	237	2113	6.94	11.75	56.4
Loamy Prairie	410	3661	323	2881	6.79	8.62	26.6
Loamy Sand	295	2634	219	1957	9.41	12.68	32.1
Lowland Coastal	447	3992	345	3078	6.21	8.06	28.6
Rolling Blackland	260	2322	144	1289	10.71	19.26	55.7
Salty Prairie	520	4644	478	4272	5.35	5.81	10.1
Sandy	297	2652	208	1859	9.34	13.35	37.4
Sandy Bottomland	369	3295	203	1816	7.52	13.67	56.1
Sandy Loam	342	3054	290	2593	8.14	9.58	18.9
Shallow Ridge	134	1197	96	858	20.78	28.93	35.4
Shallow Sandy Loam	210	1875	100	889	13.26	27.92	65.8
Sloping Clay Loam	186	1661	140	1247	14.97	19.90	31.1
Tight Sandy Loam	285	2545	204	1822	9.73	13.62	35.5
Improved Pasture	566	5054	560	4998	4.92	4.97	1.4
Mean	324	2893	235	2096	9.67	14.68	

The range or land-use types are divided in the model on the basis of amount of woody plant coverage, and stocking rates are adjusted proportionately. No woody cover = forage production and stocking rates without woody plants coverage (Appendix Table C.2). Mean woody plant cover = values averaged (weighted by number of cells) over all woody coverage classes for that type (Appendix Table C.27), i.e., reduced forage production because of woody plants.

The moderate stocking rates used in the model (Table 7.2) compare well with rates reported in published research studies in the coastal region. Light stocking rate (32% forage utilization) on a sandy loam site on the Welder Wildlife Refuge in San Patricio County was 15 acres/AU (Drawe and Box 1969), which compares with a moderate stocking rate of 8.1 acres/AU on sandy loam and 11.4 acres/AU on deep sand sites in the model (Table 7.2). A moderate stocking rate (46% utilization) on silt loam bluestem sites in central Louisiana was 8.1 acres/AU (Duvall and Linnartz 1967). The stocking rate used in the model on clay loam sites was 9.7 acres/AU. A moderate to heavy stocking rate (61% utilization) on a seacoast bluestem clay prairie in Calhoun County, Texas, was 4.5 acres/AU (Durham and Kothmann 1977). The moderate stocking rate on coastal blackland sites in the model was 5.3 ac/AU. The average stocking rate in these three published studies was 9.2 acres/AU, with a corresponding average utilization of 46%. The corresponding values in the model are 8.3 acres/AU with an average utilization of 50%.

7.5 Horses

The model has the capability of including horses in the grazing options. However, at the present they are not included because of lack of information on stocking rates and locations. Although there are a substantial number of horses in Goliad County, most of these do not consume most of their feed from range vegetation. Instead, substantial portions are provided as hay and concentrates. In addition, their numbers are not distributed evenly across the landscape. Most horses in Goliad County are maintained for pleasure and are confined to areas near urban areas or farmsteads. These uneven distribution and supplemental feed factors make it likely that uniform modeling assumptions will lead to more inaccurate estimates in the simulations than if horses are excluded at this point in the modeling effort. When included in the model, horses are considered to have the grazing equivalent of 1.25 AU (Stoddart et al. 1975), i.e., one horse consumes an equivalent amount of forage as 1.25 1000-lb cows.

7.6 Feral Hogs

Feral hogs are a major species of concern throughout Texas. They are physically destructive to many habitats, especially wetlands, they compete with native wildlife and domestic livestock for food and habitat space, and their numbers are increasing. Modeling the impacts of feral hogs at large landscape scales, such as the Goliad County model, is difficult and perhaps counter-productive for the same reasons that modeling the impacts by horses is difficult on a landscape basis. The density and distribution patterns of feral hogs are not documented on a county-wide scale. Therefore, any scenarios including these estimates would be subject to substantial speculation. A more productive approach would be to model a specific scenario without feral hogs included and then compare those results to results from the same scenario except with specific spatial and density assumptions made relative to feral hog populations. This was the approach taken, for example, in EDYS modeling of feral hog impacts in the Upper Llano River Watershed Protection Plan (Broad et al. 2016). No such scenarios were included in the ten scenarios simulated for the Goliad County report.

8.0 CALIBRATION

Calibration in EDYS consists of adjustments of parameter values, if needed, to achieve target values for the output variables under consideration. Target values are from independent validation data, either from experimental validation studies or from existing field data, if these data are available. In the absence of independent validation data, values based on literature data and professional judgement are used.

8.1 Vegetation

Independent validation data are being collected in Goliad County, as well as Karnes and Wilson Counties, but these data were not available in time to be used in the development of the Goliad County model. Field validation studies were established in August 2014 and those data will be

used to validate the model. Because field validation data were not available, reasonable ecological estimates were used as target values for calibration comparisons.

8.1.1 General Procedure

The approach used in the calibration process is to begin with one vegetation type, obtain reasonable results for that type, and then add a second type, the second type having a substantially different combination of species. Once acceptable calibration results are obtained for both types in combination, then a third type is added. This iterative process is continued until a sufficient number of types are included that, in combination, include all the major species included in the model. In addition to adding types, variations in woody plant cover and differences in rainfall regimes are included in the calibration process.

EDYS contains a large number of variables (parameters; Section 6.5), the values of any combination of which can be adjusted during the calibration process. The following general procedure is used to determine which parameters are adjusted and to what extent.

Prior experience has shown vegetation responses in EDYS to be more sensitive to changes in some parameters than others. We start the calibration process with those parameters we expect the model to be more sensitive to changes in. Examples include water-use efficiency, root architecture, potential growth rate, allocation of current production, and end of growing season dieback. For most of these variables, we have a range in values in our data base that have been compiled from various literature references and from our own field and greenhouse studies. For example, we have root architecture data for little bluestem (*Schizachyrium scoparium*) from 13 profiles taken from nine published studies (Sperry 1935; Weaver and Zink 1946; Weaver 1947, 1950, 1954, 1958; Weaver and Darland 1949; Coupland and Bradshaw 1953; Jurena and Archer 2003). We begin the calibration process using the mean of these 13 profiles. If necessary, we can change the values of initial root biomass in each layer (Appendix Table E.9) to provide a better fit with expected little bluestem biomass values changes in the model simulations. However, whatever changes are made in the root architecture parameters for little bluestem must not exceed the range of values in our data base (i.e., the parameter values remain consistent with reported values in the literature). A second example is water-use efficiency. Silver bluestem is another major perennial grass species in the Goliad County model. McGinnies and Arnold (1939) reported an average water-use efficiency in production of new biomass for silver bluestem of 685 g water/g aboveground biomass. However, they reported a range over a two-year period of 337-1221, depending on season and amount of water available. Our calibration converged on a value of 760 (Appendix Table E.13), which is very near the mean (765) of the values reported by McGinnies and Arnold (1939) for the period May-September in their study and well within the overall range of values they reported.

By comparing changes in biomass of various species within a vegetation type and changes in biomass of the same species among vegetation types between calibration runs, as parameter values are modified, it can be determined which variables are controlling the changes (sensitivity analysis). Values in these parameter sets can be changed and the results compared in the next simulation. Once the values of the major plant species have stabilized near their target values, the vegetation calibration process is considered to be complete. It should be emphasized that the

completed calibration process results in single values for each of the parameters, i.e., the same value is used for that particular species for the respective parameter for all vegetation types in the model. The benefit of this approach is that simulated responses are consistent across vegetation types throughout the spatial landscape.

8.1.2 Examples

Six vegetation types were used to calibrate the model. Ten-year simulations were conducted for each calibration run. For each calibration run, initial composition and associated standing crop biomass values were defined for all vegetation types in the model (Section 6.3) and the entire model was run of a 10-year simulation. This allowed for surface hydrology interactions among all the vegetation types over time. Standing crop biomass values for each species were downloaded for each of the calibration types at the end of October (approximate end of growing season for most species in the model) of each year of the simulation.

Calibration was first conducted without grazing by livestock for two reasons. First, studies of vegetation change over time (especially successional studies) generally utilize grazing exclosures. This is done in order to determine natural patterns of secondary succession. Likewise, the calibration process must first determine if changes in species composition in the simulations are proceeding in a realistic ecological manner (e.g., trees and midgrasses increase during periods of higher rainfall and xeric shrubs and shortgrasses increase during periods of lower rainfall, forbs decrease as midgrasses increase and increase as midgrasses decrease). The second reason for excluding livestock grazing during calibration is that the actual level of livestock grazing is unknown for most, and perhaps all, the various spatial units (e.g., pastures, ranches) in a county-wide model. Therefore, if grazing was included the calibration the results would most likely reflect the effects of the grazing levels entered into the model rather than successional effects and responses to rainfall variations. Once the models were calibrated without livestock grazing, livestock grazing was included and the calibration simulations re-run to affirm that the response of grazing was reasonable.

Four calibration scenarios were conducted for each of the six vegetation types. The first scenario utilized a moderate precipitation regime (1940-49 daily rainfall data, annual mean = 35.14 inches) without livestock grazing. The second scenario used a 10-year dry precipitation regime (1947-56 daily rainfall data, annual mean = 27.59 inches) without livestock grazing. The third scenario used a 10-year wet precipitation regime (1972-81 daily rainfall data, annual mean = 44.08 inches). The fourth scenario utilized the moderate precipitation regime (1940-49) but included cattle grazing at moderate stocking rates (Table 7.2).

8.1.2.1 Clay Loam

Calibration began with Plot Type 137 (NRCS type = clay loam; Appendix Table C.2), with 25-50% (38% mean) woody plant cover, using the moderate precipitation regime. The clay loam type is the most common vegetation type in northeastern South Texas (Drawe et al. 1978; McLendon 1991) and is the most abundant type in the Goliad County model footprint, containing 24% of the area within the spatial footprint (Appendix Table C.28). It also contains 38 of the 84 (45%) plant species included in the model. Much of this type was probably once

midgrass prairie with scattered shrub mottes, but now it commonly supports moderate to dense shrublands unless recently cleared by brush control.

This type is a clay loam grassland with scattered mottes (clusters) of woody species covering 25-50% of the surface. The mottes are characterized by a mixture of mesquite trees with understory shrubs and scattered to moderately dense stands of huisache. Total initial aboveground biomass was initially set at 2,487 g/m², of which 49% was tree biomass (mesquite and huisache) and 39% was shrub biomass (mostly granjeno, blackbrush, whitebrush, and prickly pear). The remaining 12% (308 g/m²; 2744 lbs/ac) was from grasses and forbs, which primarily occurred the interspaces between the woody mottes. The herbaceous biomass consisted mostly of shortgrasses (hooded windmillgrass [*Chloris cucullata*], buffalograss, purple threeawn [*Aristida purpurea*]), with lesser amounts of midgrasses (plains bristlegrass, silver bluestem) and forbs (mostly ragweed).

Under the moderate rainfall regime (1940-49; mean annual rainfall = 35.14 inches) and without livestock grazing, there was a moderate increase (10.2%) in total aboveground biomass (Table 8.1). This increase suggests that the system has not reached overall equilibrium with precipitation. This was not an unexpected result because the initial herbaceous biomass was set at about 70% of the amount hypothesized by the NRCS for excellent range condition (Appendix Table C.2). The absence of livestock grazing combined with some increase in woody species easily accounts for the 10% increase in the calibration simulation value.

Table 8.1 Calibration results for 10-year simulations for the clay loam, 25-50% woody cover, vegetation type (Plot Type 137), Goliad County EDYS model. Values are total aboveground biomass (g/m²) in October (end of growing season) under three precipitation (PPT) regimes.

Lifeform/Species	Initial	Year 10, No Grazing			Year 10, Grazed
		Mod PPT	Dry PPT	Wet PPT	Moderate PPT
Trees	1221	1298	1240	1311	1278
Shrubs	958	1178	1045	1167	1040
Midgrasses	90	109	62	192	62
Shortgrasses	150	124	77	214	316
Forbs	68	32	16	45	17
Total	2487	2741	2440	2929	2713
Huisache	351	428	417	475	399
Mesquite	870	870	823	836	879
Blackbrush	191	179	164	177	120
Whitebrush	190	276	228	257	302
Baccharis	101	160	126	165	50
Granjeno	276	310	271	296	331
Wolfberry	21	20	18	18	14
Agarito	4	3	4	3	5
Prickly pear	175	230	234	251	218
Silver bluestem	24	34	19	53	50
Sideoats grama	4	3	2	6	3
Trichloris	6	2	2	4	6
Arizona cottontop	2	1	1	1	*
Little bluestem	6	3	2	6	2
Plains bristlegrass	34	56	32	101	0
Indiangrass	1	*	*	*	*
Johnsongrass	9	8	3	18	0
Tall dropseed	4	2	1	3	1
Purple threeawn	23	30	9	61	131
Hairy grama	3	1	1	1	1
Buffalograss	39	50	26	56	111
Hooded windmillgrass	68	23	28	42	73
Vine-mesquite	1	*	*	1	*
Brownseed paspalum	10	15	9	28	0
Knotroot bristlegrass	3	*	*	*	*
Texas wintergrass	3	5	4	25	*
Ragweed	13	6	2	8	9
Wild indigo	4	6	4	7	0
Old-man's beard	5	15	9	23	2
Bundleflower	2	*	*	*	*
Frogfruit	3	1	*	1	1
Prairie coneflower	3	*	*	*	0
Snoutbean	4	*	*	1	0
Ruellia	4	*	*	1	0
Bush sunflower	9	3	1	3	4
Orange zexmenia	7	1	*	1	1
Annual broomweed	7	0	0	0	0
Sunflower	7	0	0	0	0

An asterisk (*) indicates a trace amount (< 0.5 g/m²).

Aboveground biomass of trees increased by 6.3%, with all of this increase coming from huisache. Huisache increased by 12% over the ten years. In comparison, huisache increased by 46% on mesquite-mixed grass communities of the Welder Wildlife Refuge over a period of 16 years (Box et al. 1979). Shrub aboveground biomass also increased (23%) during the 10-year simulation, with whitebrush and baccharis increasing the most (45% and 58%, respectively).

Both of these species are aggressive invading species under moist conditions. Prickly pear and granjeno also increased (31% and 12%, respectively), but there was a decrease in blackbrush. A decrease of blackbrush over a 15-year period following the end of the drought of the 1950s was also reported for the chaparral-mixed grass community on the Welder Wildlife Refuge (Drawe et al. 1978).

There was an increase in midgrasses with a corresponding decrease in shortgrasses over the 10-year simulation. This is the expected pattern under conditions of moderate rainfall and no livestock grazing. Midgrasses increase during secondary succession on the coastal prairies and shortgrasses during periods of lower rainfall or under heavy grazing (Drawe et al. 1978). In the central Great Plains, replacement of shortgrasses by midgrasses following drought takes about 8-12 years (Weaver 1954). Plains bristlegrass and silver bluestem were the primary midgrasses that increased (65% and 42%, respectively). Both of these species are mid-seral grasses that are among the first midgrasses to respond to a reduction in grazing pressure (Box 1961; Powell and Box 1967; Drawe et al. 1978). Of the three major shortgrass species on this type at the beginning of the simulation, two increased (purple threeawn and buffalograss) and one decreased (hooded windmillgrass). Hooded windmillgrass is the earliest seral species of the three and would therefore be expected to decrease first once the midgrasses increased.

There was an overall decrease in forbs over the 10 years, which would also be expected as secondary succession proceeded from earlier to later stages (Drawe et al. 1978). Forb abundance is less in late seral conditions in bluestem prairie and greater in earlier (weedy) stages. Ragweed is an early-seral species and it decreased by 46%. Conversely, old-man's beard (*Clematis drummondii*) increased in abundance, which is consistent with results reported for the Welder Wildlife Refuge (Drawe et al. 1978).

Changing the rainfall regime affected the vegetation dynamics (Table 8.1), which was the expected result. Under the dry regime (1947-56, mean = 27.59 inches), there was an increase in huisache but at a slower rate than under the moderate rainfall regime and there was a decrease (5.4%) in mesquite. Mesquite decreases in cover during drought periods in South Texas (Archer et al. 1988). Compared to their respective values under the moderate rainfall regime, all shrub species had lower values after 10 years except for prickly pear. Prickly pear is well-adapted to drought conditions and was also benefited by the decrease in competition from other woody species. Compared to their respective values under the moderate rainfall regime, all herbaceous species except hooded windmillgrass had equal or lower values under the dry regime. Hooded windmillgrass is a relatively xeric seral-seral species that was benefited by the lower level of competition from the other herbaceous species. The two midgrasses that maintained their biomass levels under the dry regime were trichloris and Arizona cottontop, both of which are relatively xeric midgrasses.

Under the wet regime (1972-81, mean = 44.08 inches), huisache increased more than it did under the moderate regime and mesquite decreased slightly (Table 8.1). A decrease in mesquite cover following the return of relatively high rainfall levels following the drought of the 1950s was reported on clay and clay loam soils on the Welder Wildlife Refuge (Drawe et al. 1978). There was little overall difference in shrub biomass between moderate and wet rainfall regimes, and this was also true for most individual shrub species. This lack of shrub increase under the wet

regime was likely the result of increased competition from the herbaceous component and from huisache. Almost all herbaceous species increased in biomass under the wet regime compared to the moderate regime. There were substantial increases in most midgrasses, which is typical of successional dynamics in bluestem grasslands (Weaver 1954; Jensen and Schumacher 1969). In particular, there were substantial increases (percentage-wise) in silver bluestem, sideoats grama, plains bristlegrass, and little bluestem. These are species that increased in abundance on the Welder Wildlife Refuge during the relatively wet period of the 1960s and early 1970s (Drawe et al. 1978). The shortgrass species that had the greatest increase percentage-wise under the wet regime was Texas wintergrass (*Stipa leucotricha*). This is the only shortgrass species specifically mentioned as increasing significantly on clay loam sites of the Welder Wildlife Refuge following the drought of the 1950s (Drawe et al. 1978).

Livestock grazing also had an impact on vegetation change in the calibration simulation (Table 8.1). The major difference between grazed and ungrazed was a decrease in midgrasses and an increase in shortgrasses under the grazing regime. Compared to ungrazed conditions at the end of 10 years, midgrass biomass was 43% lower and shortgrass biomass was 155% higher. This is what would be expected to occur. Most of the midgrasses are more preferred forage species by cattle than most of the shortgrasses. Therefore, the midgrasses receive a higher proportion of the grazing pressure. Two midgrass species, plains bristlegrass and Johnsongrass, decreased the most. Both of these species are highly palatable to cattle. Silver bluestem and trichloris both increased under grazing. Both of these species are less preferred by cattle than most of the other midgrasses, hence they would be expected to increase as the more preferred midgrasses decreased. Most shortgrasses increased under the grazing scenario which should be expected because of less competition from the midgrasses. The two exceptions were brownseed paspalum and Texas wintergrass. Brownseed paspalum is a more highly preferred forage species by cattle than most shortgrasses and Texas wintergrass is heavily utilized by cattle during winter months when it is one of the few forage species providing green forage.

Huisache biomass decreased slightly under the grazing scenario, compared to the ungrazed scenario, whereas mesquite increased. Huisache is a palatable browse species whereas mesquite leaves are relatively unpalatable. The decrease in huisache was the result of greater browsing pressure, from cattle in early spring and during drier periods but especially from increased browsing from deer. As cattle removed more of the herbaceous material by their grazing, deer shifted more to browse. This also explains most of the differential responses of the shrub species to the grazing scenario. Blackbrush, wolfberry (*Lycium carolinianum*), and prickly pear decreased compared to the ungrazed scenario and all three of these species are important browse species to deer. Whitebrush increased substantially under cattle grazing and it is a relatively unpalatable browse species. Baccharis decreased under grazing and it is not a particularly preferred browse species but it is similar in ecological and successional status to whitebrush. Therefore the decrease in baccharis under the grazing scenario was likely the result of increased competition from whitebrush. Granjeno is an important browse species and it increased in biomass under the grazing scenario. This was most likely the result of lower competition from other woody species.

Total aboveground biomass of herbaceous species was 395 g/m² in the tenth year with livestock grazing (Table 8.1). Total aboveground biomass in EDYS simulations includes the basal crown

(trunk) biomass that is rarely sampled in clipping studies. Trunk biomass accounts for about 40% of total aboveground biomass of herbaceous species in EDYS simulations. Adjusting total aboveground herbaceous biomass to account only for clippable biomass results in a value of 237 g/m² of clippable biomass. This compares with 164 g/m² on a moderately grazed pasture on the Welder Wildlife Refuge 10 years after drought and heavy grazing (Box and White 1969) and 141 g/m² on a heavily-grazed pasture in Goliad County (Dodd and Holtz 1972).

8.1.2.2 Other Types

Five other vegetation plot types were used in the calibration process (Table 8.2). Combined with the area included in the clay loam type, the six types include 61% of the area included in the spatial footprint of the model and 63 of the 84 (75%) plant species. Although all four calibration scenarios were run for each of the five additional types, only results of the moderate-rainfall no grazing scenarios are presented (Table 8.2) and discussed.

Woody species (trees and shrubs) decreased over the ten years on all these sites except the loamy bottomland. Live oak decreased the most, followed by mesquite and with huisache least. Live oak is experiencing a decline on many sites in South Texas and the results of the calibration scenarios suggest that at least part of the reason may be that live oak requires above average rainfall to maintain or increase in abundance. This supports the suggestion that much of the larger live oak type in South Texas may be a relict of past climatic conditions (Drawe et al. 1978). There has also been a slight decrease in mesquite canopy on many sites on the Welder Wildlife Refuge (Drawe et al. 1978) and Archer et al. (1988) suggested that mesquite will likely decrease along drainages in central South Texas under average or above average rainfall as larger species with more dense canopies increase in abundance. On the loamy bottomland site in the calibration simulations, pecan (*Carya illinoensis*) and huisache increased while mesquite, hackberry (*Celtis laevigata*), and live oak decreased.

Shrub biomass varied by species and by vegetation type (Table 8.2). Blackbrush and whitebrush remained relatively stable and prickly pear decreased, especially on the sand and sandy loam types. This is consistent with what has been reported on the Welder Wildlife Refuge (Drawe et al. 1978). Granjeno and baccharis decreased in the loamy bottomland type, perhaps in response to the increase in huisache. Granjeno also decreased on the blackland type but increased on the sand and sandy loam types. The blackland type occurs on Monteola clay soils (Table 6.3) and these soils are more droughty than sands and loams except during wetter periods. Biomass of all lifeforms decreased on this type over the 10-year simulation. This may suggest that the initial biomass values were set too high to begin the simulations (i.e., the site cannot support as high a grassland productivity as suggested by the NRCS under moderate rainfall).

Table 8.2 Initial (00) and tenth-year (10) values (aboveground biomass, g/m²) for lifeforms and major plant species in six of the vegetation types used in the vegetation calibration process (ungrazed, moderate rainfall scenario). Percentages refer to amount of woody plant cover.

Lifeform/Species	Plot 046		Plot 118		Plot 004		Plot 090		Plot 031	
	Blackland, Coastal 1-10%		Bottomland, Loamy 50-75%		Tight Sandy Loam 25-50%		Loamy Sand 25-50%		Salty Prairie 1-10%	
	00	10	00	10	00	10	00	10	00	10
Trees	246	231	6684	7178	3469	3286	5344	5084	315	301
Shrubs	73	58	853	709	650	717	384	427	96	101
Midgrasses	203	93	154	142	128	212	123	302	587	815
Shortgrasses	412	327	69	37	96	164	134	82	68	86
Grass-likes	0	0	33	57	0	0	0	0	0	0
Forbs	184	79	70	69	61	26	73	53	19	19
Total	1118	788	7863	8192	4404	4405	6058	5948	1085	1322
Huisache	126	121	582	1268	0	0	0	0	277	263
Pecan	0	0	801	824	0	0	0	0	0	0
Hackberry	7	6	1232	1179	0	0	0	0	0	0
Mesquite	99	91	481	432	1305	1302	1015	921	38	38
Live oak	14	13	3588	3475	2164	1984	4329	4163	0	0
Blackbrush	13	8	0	0	287	287	0	0	0	0
Whitebrush	15	10	158	162	0	0	0	0	0	0
Baccharis	0	0	168	79	0	0	0	0	0	0
Sea oxeye	0	0	0	0	0	0	0	0	96	101
Granjeno	22	18	153	117	276	368	184	256	0	0
Agarito	*	*	0	0	0	0	0	0	0	0
Mustang grape	0	0	374	351	0	0	113	112	0	0
Prickly pear	23	22	0	0	87	62	87	59	0	0
Big bluestem	4	2	6	2	0	0	0	0	0	0
Bushy bluestem	0	0	3	6	0	0	0	0	0	0
Silver bluestem	27	23	7	2	49	124	13	21	0	0
Sideoats grama	5	2	16	13	14	34	26	143	0	0
Trichloris	6	1	28	4	52	47	0	0	0	0
Arizona cottontop	0	0	0	0	2	*	2	1	0	0
Virginia wildrye	0	0	9	1	0	0	0	0	0	0
Texas cupgrass	0	0	2	*	0	0	0	0	0	0
Switchgrass	12	3	16	6	0	0	7	7	1	*
Common reed	0	0	0	0	0	0	0	0	5	7
Little bluestem	36	12	35	21	0	0	69	119	5	1
Plains bristle	52	33	14	15	11	7	6	11	0	0
Indiangrass	8	1	0	0	0	0	0	0	2	*
Johnsongrass	31	10	18	72	0	0	0	0	0	0
Gulf cordgrass	0	0	0	0	0	0	0	0	574	807
Tall dropseed	22	6	0	0	0	0	0	0	0	0
Purple threeawn	62	46	0	0	27	151	17	23	0	0
Hairy grama	14	3	0	0	10	2	8	2	0	0
Red grama	0	0	0	0	5	*	0	0	0	0
Buffalograss	179	201	18	1	0	0	0	0	0	0
Sandbur	0	0	0	0	16	5	13	6	0	0
Hooded windmill	55	12	0	0	38	6	19	3	0	0
Bermudagrass	0	0	4	1	0	0	0	0	7	2
Saltgrass	0	0	0	0	0	0	0	0	18	11
Vine-mesquite	5	1	6	2	0	0	0	0	0	0
Longtom	0	0	0	0	0	0	0	0	16	3
Brownseed paspalum	37	27	16	30	0	0	52	45	0	0
Thin paspalum	0	0	0	0	0	0	25	3	0	0
Knotroot bristle	22	2	11	1	0	0	0	0	27	70
Texas wintergrass	38	35	14	2	0	0	0	0	0	0
Littletooth sedge	0	0	14	1	0	0	0	0	0	0
Flatsedge	0	0	19	56	0	0	0	0	0	0

Table 8.2 (Cont.)

Lifeform/Species	Blackland, Coastal 1-10%		Bottomland, Loamy, 50-75%		Tight Sandy Loam 25-59%		Loamy Sand 25-50%		Salty Prairie 1-10%	
Ragweed	37	5	14	3	16	14	28	40	0	0
Spiny aster	0	0	6	1	0	0	0	0	7	1
Wild indigo	63	33	0	0	0	0	0	0	0	0
Old-man's beard	31	40	10	30	0	0	0	0	0	0
Bundleflower	4	*	1	*	1	*	2	*	0	0
Frogfruit	0	0	2	*	0	0	0	0	6	14
Prairie coneflower	0	0	0	0	2	*	3	*	0	0
Snoutbean	0	0	4	1	6	0	6	0	0	0
Ruellia	11	1	4	1	0	0	0	0	0	0
Bush sunflower	0	0	0	0	20	12	16	13	0	0
Greenbriar	0	0	15	34	0	0	0	0	0	0
Giant ragweed	0	0	7	0	0	0	0	0	0	0
Partridge pea	0	0	*	0	2	0	1	0	0	0
Texas doveweed	0	0	0	0	4	0	17	0	0	0
Sunflower	38	0	7	0	10	0	0	0	0	0
Glasswort	0	0	0	0	0	0	0	0	0	0

An asterick (*) indicates a trace amount (< 0.5 g/m²).

Biomass of midgrasses increased on the tight sandy loam, loamy sand, and salty prairie types (Table 8.2), as would be expected under conditions of moderate rainfall and no grazing.

Biomass of shortgrasses also increased on the tight sandy loam and salty prairie types, but decreased on the loamy sand type. The decrease on the loamy sand type was likely the result of increased competition from the substantial increase in midgrasses (146%) and the increase in granjeno. Most of the increase in midgrasses came from silver bluestem (tight sandy loam), sideoats grama and little bluestem (loamy sand), and gulf cordgrass (*Spartina spartinae*; salty prairie). These are major mid- or late-seral dominants on these grasslands (Drawe et al. 1978; Scifres et al. 1980; Diamond and Smeins 1984; McLendon 1991; Garza et al. 1994) and therefore should increase in abundance under moderate-rainfall conditions with no livestock grazing. Purple threeawn was the only shortgrass species to increase on the tight sandy loam and loamy sand sites. It is a vigorous mid-seral species that would be expected to decrease over time as the midgrasses continue to increase. However, threeawns are also important components of late-seral sandy prairies in South Texas and the Texas Coast (Diamond and Smeins 1984; McLendon 1991). Knotroot bristlegrass (*Setaria geniculata*) was the shortgrass that increased in the salty prairie type and this species is a common secondary species in gulf cordgrass communities (Scifres et al. 1980). Johnsongrass was the major grass species to increase on the loamy bottomland site and this species can form dense stands on these mesic sites in the absence of livestock grazing.

Aboveground forage production (adjusted to reflect clippable biomass) was 241 g/m² on the tight sandy loam type, 262 g/m² on the loamy sand type, and 552 g/m² on the salty prairie type. These compare favorably with values reported in the literature for South Texas and the Texas Coast (Table 8.3).

Table 8.3 Aboveground biomass (g/m², clippable) on sandy grassland and gulf cordgrass communities in South Texas and the Texas Coast.

Type	Location	Biomass	Reference
Seacoast bluestem community	Aransas National Wildlife Refuge	380	McLendon 2014
Seacoast bluestem community	Dimmit County	187	McLendon 1977
Fine sandy loam	Welder Wildlife Refuge	238	Drawe and Box 1969
Sandy loam	Victoria County	203	Bovey et al. 1972
Gulf cordgrass community	Welder Wildlife Refuge	543	Garza et al. 1994

8.2 Ecohydrology

Three ecohydrological components were assessed in the model calibration: 1) evapotranspiration, 2) surface runoff and sedimentation, and 3) groundwater use by vegetation. These components were also combined to develop several basic water balances. Direct field data were not available for use in these calibrations. Instead, literature values and professional judgment were used.

8.2.1 Evapotranspiration

In EDYS, evapotranspiration (ET) is separated into its two components: evaporation (E) and transpiration (T). Evaporation is the conversion of liquid water to water vapor, with the subsequent movement of the water vapor into the atmosphere. Transpiration is the process of water loss from plants by evaporation through their stomates. In EDYS, transpiration is accounted for as a function of water use by individual plant species. Evaporation is subdivided into interception and evaporation, where interception is the amount of water intercepted by the vegetation canopy and then evaporated and evaporation is the amount of water evaporated from the soil (including bare ground, litter, and rocks and other bare surfaces) and open water surfaces.

The amount of ET varies widely among plant communities, regions, seasons, and years. Three primary variables determining the amount of ET are 1) temperature, 2) available moisture, and 3) vegetation. Warmer regions, or warmer seasons, have higher ET rates than cooler regions or seasons, other factors held constant. Under the same temperature regime, an increase in available moisture results in an increase in ET. Conversely, as conditions become drier, less water is available for evaporation and transpiration and therefore ET decreases. However, drier regions are often warmer than mesic regions and this increase in temperature also has an effect on ET rates. Potential evaporation rates are often estimated for a locale from measurement of evaporation from a free-water surface. Evaporation rates from exposed surfaces (e.g., leaf surfaces, rocks, surface of the litter) may approximate this rate. Evaporation from a soil surface is generally less than the maximum potential rate because the water is being translocated to the surface from which evaporation actually occurs and this translocation process slows the rate of evaporation. If the soil surface is shaded, for example by vegetation cover, the lower temperature also reduces the evaporation rate.

Plants move water from various soil depths, into their roots, through the plant, and into stomatal cavities where the evaporation actually occurs. This movement of water is in response to a water

potential gradient between the various soil layers and the atmosphere at the leaf surface. The largest gradient occurs when the atmosphere is very dry and the soil is very wet. Very little transpiration occurs when the atmosphere is moist (high relative humidity) or when the soil is very dry. In the first case, the water potential gradient is too weak to result in much water movement. In the second case, there is too little water to move.

Therefore the transpiration **rate** is largely dependent on the water potential gradient and the amount of water available to the roots. However, the **amount** of transpiration is largely dependent on the amount, and type, of vegetation present and the amount of water available to the plants. As the amount of transpiring surface (primarily leaf surface area) increases, the amount of water transpired increases, provided there is sufficient moisture available in the rooting zone of the particular vegetation. For example, ET in mesquite-shrublands at a site in South Texas was about 37% higher than on bare soil in wet years, but only about 30% higher on adjacent shortgrass sites than on bare soil (Table 8.4). In dry years, ET from bare soil decreased by almost 68% compared to wet years and ET decreased by about 64% on vegetated sites.

Table 8.4 Evapotranspiration (ET; mm) and rainfall (PPT; mm) in dry and wet years on the La Copita Experiment Station in South Texas (data from Wertz and Blackburn 1995).

Vegetation	----- Dry Year -----			----- Wet Year -----		
	PPT	ET	ET/PPT	PPT	ET	ET/PPT
Mesquite-granjeno shrubland	310	330	1.06	887	881	0.99
Red grama-threawn grassland	310	298	0.96	887	833	0.94
Bare soil	310	208	0.67	887	643	0.72

The ET from the bare soil was all from evaporation (E) and evaporation from a soil surface is limited to the upper soil layers. Therefore, any moisture that percolates past these surface layers is largely protected from loss by evaporation. Red grama (*Bouteloua trifida*) and threawn are relatively shallow-rooted grass species, but they can extract soil moisture from deeper soil depths than can be extracted by evaporation alone. Consequently, the ET values on the grassland were higher than ET values on the bare soil (Table 8.4). Mesquite and granjeno are woody species that have deeper root systems than red grama and threawn. Therefore, there is additional soil moisture available to them than is available to the shortgrasses. Consequently, the ET values on the shrubland was higher than on the grassland.

Under conditions of limited available moisture, the effect of plant species on ET rates is primarily a function of different rooting depths among species. In dry years, the mesquite-granjeno community ET exceeded the amount of rainfall received that year (Table 8.4), indicating the use of deeper soil moisture that had been stored during previous wetter years. Conversely, the ET of the shallower-rooted grasses was less than the annual rainfall. In the wet year, the amount of rainfall received exceeded the annual ET capacity of both the shrubland and the grasses, resulting in a net storage of soil moisture in the deeper soil layers.

Differences in root architecture can also have a substantial effect on ET when deeper soil layers contain higher soil moisture. On an arid site in eastern California, a saltgrass (*Distichlis spicata*)

community containing some rabbitbrush (*Chrysothamnus nauseosus*) had an annual ET of 47.2 cm (18.6 inches) and a nearby rabbitbrush-sacaton community had an annual ET of 60.5 cm (23.8 inches)(Duell 1990). Both communities had similar depth to groundwater (3.3 and 3.2 m, respectively). The reason for the higher ET in the rabbitbrush-sacaton community was because of the abundance of the deeper-rooted rabbitbrush shrubs and alkali sacaton (*Sporobolus airoides*), which is a deep-rooted perennial grass. In a similar study in southern Arizona, a big sacaton (*Sporobolus wrightii*) community had an ET of less than half that of an adjacent deeper-rooted mesquite community at similar depths to groundwater (Table 8.5).

Table 8.5 Evaporation (ET) and depth to groundwater for two communities on the San Pedro River floodplain in southern Arizona (data from Scott et al. 2000, 2006).

	Big sacaton grassland		Mesquite woodland	
Depth to groundwater (m)	2.5	3.0	2.0	10.0
Evapotranspiration (cm)	40.6	27.2	84.8	63.8
Evapotranspiration (inches)	16.0	10.7	33.4	25.1

In arid regions, evaporation often comprises the greater portion of ET because vegetative cover is low. In more mesic regions, transpiration comprises the greater portion of ET because of higher vegetative cover, less bare ground, and cooler soil surfaces because of shading. In the Owens Valley of eastern California, a part of the Mojave Desert with a high water table, ET for three species of grasses with an average canopy cover of 37% had an average E:T ratio of 55:45, with a range of 40-69% evaporation (Evans et al. 2013; Mata-Gonzalez et al. 2014). A desert site in North Africa had an average E:T ratio of 57:43, with a range of 38-78% evaporation (Floret et al. 1982).

8.2.1.1 Clay Loam

The clay loam (Plot Type 137) is a mixed grass community with moderate amounts (average of 38% cover) of woody species, mostly mesquite and huisache (Table 8.1). Annual rainfall used in a 25-year calibration simulation varied between 15.79 and 42.81 inches, with an annual average of 31.49 inches. Simulated annual ET averaged 33.50 inches, or 106% of annual precipitation. This equates to an ET rate of 3.5 mm/day for a 245-day growing season (March-October) or an annual (365-day) ET rate of 2.3 mm/day. These are reasonable rates based on literature values. An average daily rate for a mesquite-granjeno community on a sandy loam site in South Texas was 2.6 mm (Weltz and Blackburn 1995) and 2.5 mm for a mesquite riparian community in southern Arizona (Scott et al. 2000, 2006). The simulated ET equivalent of 106% of annual precipitation is higher than the 97% value reported for mesquite-grasslands in the Rolling Plains of Texas (Carlson et al. 1990), 95% for oak-grasslands in the Edwards Plateau (Thurow et al. 1988), and 94% on bluestem prairie in Kansas (Bremer et al. 2001). However, the EDYS simulations indicated that an annual average of 3.36 inches of groundwater were transpired on the clay loam type. Reducing the simulated total average annual ET (33.50 inches) by this amount results in a rainfall-supported average ET of 30.14 inches, or 96% of annual rainfall.

The ratio of annual ET to annual rainfall fluctuates among years, in part because the supply of soil water is not entirely dependent on the amount of rainfall received in the particular year. Some soil water may be carried over from a previous year and late-season rainfall may not be fully utilized by plants in the year the rainfall was received (Table 8.6). ET exceeded annual rainfall in one-third of the years in the Rolling Plains study (Table 8.6). By comparison, ET exceeded annual rainfall in 60% of the years of the calibration simulations (Table 8.7). The higher rate in the calibration simulations was because of groundwater usage by the vegetation on the clay loam sites in Goliad County.

Table 8.6 Annual rainfall and evapotranspiration (ET) at sites in the Rolling Plains (Carlson et al. 1990) and in South Texas (Weltz and Blackburn 1995) in wet and dry years.

	Rolling Plains						South Texas			
	Grassland			Mesquite-Grassland			Grassland		Mesquite-Granjeno	
Rainfall (mm)	769	677	629	769	677	629	310	887	310	887
ET (mm)	644	804	555	658	756	511	298	833	330	881
Balance (mm)	+125	-127	+ 74	- 79	+118	+ 12	+ 12	+ 54	- 20	+ 6
ET/Rainfall	0.86	1.19	0.88	0.86	1.12	0.81	0.96	0.94	1.06	0.99

Table 8.7 Annual rainfall (inches) and evapotranspiration (ET) variables (inches) for the 25-year baseline calibration simulation for the clay loam type, Goliad County EDYS model.

PPT Year	Rainfall	Interception	Evaporation	Total Evaporation	Transpiration	ET	Balance (Rainfall – ET)	ET/Rainfall
1928	29.76	1.36	6.25	7.61	17.64	25.25	4.51	0.848
1929	39.27	1.68	1.75	3.43	35.51	38.94	0.33	0.992
1930	23.25	1.78	1.57	3.35	27.21	30.56	- 7.31	1.314
1931	38.09	1.86	2.29	4.15	34.09	38.24	- 0.15	1.004
1932	34.93	2.10	2.28	4.38	34.69	39.07	- 4.14	1.119
1933	28.89	2.39	1.86	4.25	29.62	33.87	- 4.98	1.172
1934	36.82	1.74	2.32	4.06	29.25	33.31	3.51	0.905
1935	39.42	3.04	2.54	5.58	40.58	46.16	- 6.74	1.171
1936	33.85	3.73	2.97	6.70	34.20	40.90	- 7.05	1.209
1937	23.25	1.56	1.00	2.56	18.58	21.14	2.11	0.914
1938	21.48	1.64	1.84	3.48	24.89	28.37	- 6.89	1.321
1939	19.23	1.61	1.12	2.73	21.88	24.61	- 5.38	1.280
1940	39.38	2.52	1.16	3.68	30.89	34.57	4.81	0.878
1941	42.31	4.89	3.46	8.35	41.56	49.91	- 7.60	1.180
1942	36.09	3.31	4.24	7.55	30.08	37.63	- 1.54	1.043
1943	31.69	2.37	4.09	6.46	23.66	30.12	1.57	0.950
1944	30.83	2.93	3.22	6.15	29.79	35.94	- 5.11	1.166
1945	25.76	2.79	2.41	5.20	23.36	28.56	- 2.80	1.109
1946	42.81	4.55	3.17	7.72	34.85	42.57	0.24	0.994
1947	29.88	3.74	2.60	6.34	26.10	32.44	- 2.56	1.086
1948	23.90	3.08	2.33	5.41	24.21	29.62	- 5.72	1.239
1949	36.39	3.61	2.40	6.01	28.34	34.35	2.04	0.944
1950	15.79	1.87	2.18	4.05	17.95	22.00	- 6.21	1.393
1951	29.94	2.56	1.81	4.37	24.52	28.89	1.05	0.965
1952	34.17	2.19	3.13	5.32	25.03	30.35	3.82	0.888
MEAN	31.49	2.60	2.56	5.16	28.34	33.50	- 2.01	1.064 ¹

¹ Calculated on the basis of (Mean ET)/(Mean Rainfall) instead of 25-year mean of ET/Rainfall.

The clay loam vegetation intercepted an annual average of 2.60 inches of rainfall in the calibration simulations (Table 8.7), or an average of 8% of annual rainfall. This is comparable with values reported in the literature for various vegetation types: 4% for shadscale shrubland in Utah (West and Gifford 1976), 8% for California grasslands (Corbett and Crouse 1968), 8% for huisache woodlands in Nuevo Leon (Carlyle-Moses 2004), and 11% for curly mesquite (*Hilaria belangeri*) and 18% for sideoats grama in the Edwards Plateau (Thurrow et al. 1987). Transpiration accounted for 85% of total ET in the simulations, compared to 15% for evaporation (Table 8.7).

8.2.1.2 Other Vegetation Types

Average annual ET varied between 27.9 and 48.4 inches per year on the seven types evaluated in the calibration (Table 8.8). The highest average annual ET was on the loamy bottomland type where there was an abundance of mature trees and groundwater was near the surface. Average annual groundwater use by vegetation on this type was 16.80 inches, or 35% of total annual ET. Substantial use of shallow groundwater by trees has been reported in the literature. Ashe juniper (*Juniperus ashei*) has been reported to utilize up to 25% of its transpirational water from groundwater in some areas of the Edwards Plateau (Jackson et al. 2000), mature sugar maple (*Acer saccharum*) trees utilized groundwater almost exclusively when groundwater was at 3 m (Dawson 1996), and ET in mesquite riparian woodlands in southern Arizona was 33% higher when depth to groundwater was 2 m rather than 10 m (Scott et al. 2000, 2006). During drier periods of the year, velvet mesquite (*Prosopis velutina*) in southern Arizona primarily used groundwater (70% of transpiration)(Snyder and Williams 2003). In shallow groundwater semiarid woodlands in Australia, trees utilized primarily groundwater 50-70% (depending on species) of the year in lower rainfall sites and 25-40% for the same species in higher rainfall areas (Cramer et al. 1999). In the dry season in the Northern Territory of Australia, riparian woodlands utilize 50% or more of the water they transpire from groundwater (Lamontagne et al. 2005) and during the drier portions of summers in wet forests of coastal British Columbia, Douglas fir (*Pseudotsuga menziesii*) trees extracted 15% of their transpired water from their deepest rooting depth (Nnyamah and Black 1977).

Table 8.8 Average annual rainfall (inches) and evapotranspiration (ET) variables (inches) for the 25-year calibration simulations for seven vegetation plot types, Goliad County EDYS model.

Type	Rainfall	Interception	Evaporation	Total Evaporation	Transpiration	ET	ET/Rainfall
Clay loam	31.49	2.60	2.56	5.16	28.34	33.50	1.064
Blackland	33.79	2.02	3.18	5.20	22.69	27.89	0.825
Tight sandy loam	33.79	1.98	3.10	5.08	29.30	34.38	1.017
Loamy sand	33.79	2.17	2.74	4.88	29.41	34.29	1.015
Loamy bottomland	33.79	2.49	2.41	4.90	43.51	48.41	1.433
Salty prairie	33.79	1.88	3.09	4.97	24.37	29.34	0.868
Shallow ridge	31.49	5.38	1.00	6.38	28.88	35.26	1.120
Mean	33.13	2.65	2.58	5.23	29.50	34.73	1.049

The clay loam, tight sandy loam, and loamy sand types were grasslands with substantial amounts of woody species (25-50% canopy cover). Annual ET on these sites averaged 33.5-34.4 inches (Table 8.8). These values are typical ET values for mesquite shrublands in South Texas. Weltz and Blackburn (1995) reported an average annual ET of 33.7 inches in mesquite shrubland in South Texas. The salty prairie type had a simulated average annual ET of 29.3 inches, which compares to 24.5-32.3 inches reported for salt meadows in eastern California with depth to water of 1.8-2.4 m (Duell 1990). The simulated annual ET rate of 29.3 inches equates to an average daily ET rate of 2.0 mm, which compares favorably with daily ET rates of 2.2 mm for saltgrass in Nevada (Grosz 1972) and 2.4 mm for sacaton grasslands in Arizona and New Mexico (Weeks et al. 1987; Scott et al. 2006).

Excluding the bottomland type, the remaining six types utilized an average of 98.5% of annual rainfall in ET (Table 8.8). This is a similar value to those reported in the literature for similar vegetation types: 94% for bluestem grassland (Bremer et al. 2001), 95% for oak-grassland (Thurow et al. 1988), and 97% for mesquite grasslands in the Rolling Plains (Carlson et al. 1990) and 98% for mesquite shrublands in South Texas (Weltz and Blackburn 1995).

The average canopy interception rate for the seven types was 8% of average annual rainfall (Table 8.8). This compares favorably with reported rates of 8% for huisache woodlands in northeast Mexico (Carlyle-Moses 2004) and chaparral communities in southern California (Hamilton and Rowe 1949), 13% for *Acacia* woodlands in Australia (Pressland 1973), 8% for bluestem prairie in the Great Plains (Corbett and Crouse 1968), and 11-18% for grasslands in the Edwards Plateau (Thurow et al. 1987).

8.2.2 Surface Runoff

Surface runoff (overland flow) occurs when the rate at which the supply of water exceeds the infiltration rate of the soil. This most commonly occurs during intense rainfall events or when soils become saturated because of an extended rainfall period. As runoff water flows downslope, it can increase in quantity as runoff water from adjacent locations are added to the flow or the quantity can decrease if the runoff water flows across a drier soil or a fractured surface. In addition to the supply rate of incoming water, the amount of runoff is affected by slope (as slope increases, amount of runoff increases), soil texture (related to infiltration rate), and surface roughness. Surface roughness refers to the microtopography of the soil surface, including the presence of objects at the soil surface (e.g., rocks, litter, and plant stems, crowns, and trunks). Other factors held constant, runoff decreases as surface roughness increases.

There are both spatial and temporal aspects to the dynamics of runoff. Runoff changes spatially across a landscape in response to differences in topography and soils. Ockerman (2002) reported runoff from a loamy sand range site and a nearby clay range site on the Welder Wildlife Refuge. Both sites received approximately the same amount and intensity of rainfall at the same dates. Surface runoff averaged 2.7 inches/year on the loamy sand site but only 0.6 inch/year on the clay site. Wright et al. (1976) reported runoff from adjacent sites on the northern edge of the Edwards Plateau, one site with 3% slope and one with 13% slope. Runoff averaged 0.5 inch/year on the 3% slope and 2.7 inches on the 13% slope.

Temporal changes in runoff occur for a variety of reasons. Intensity of the rainfall event is a primary factor influencing the amount of runoff from a site. Most rainfall events do not result in measurable runoff. Along the central Texas Coast, rainfall events measuring less than two inches generally do not result in runoff (Ockerman and Petri 2001; Ockerman 2002) and in the Edwards Plateau the threshold level is about 0.7 inch (Thurow et al. 1988). In San Patricio County, there were only nine runoff events recorded over a two-year period and five of these were minor (0.07 inch or less; Ockerman 2002). Even at the lower threshold level in the Edwards Plateau (0.7 inch), there was an average of only nine runoff events per year over a six-year period (Thurow et al. 1988).

Amount of runoff is also affected by antecedent soil moisture conditions. A specific rainfall event is likely to result in much different runoff amounts when the event occurs following a dry period than when the soil is near field capacity. A 4.7-inch rainfall event in October 2000 resulted in less than 0.02 inch of runoff at a site in San Patricio County, compared to 0.34 inch of runoff from a 4.2-inch rain in November of the following year (Ockerman 2002). The October 2000 event was preceded by a very dry period and the November 2001 event occurred 10 weeks after a 7.5-inch rainfall event. A 4.6-inch rainfall event in early October 1998 resulted in 1.0 inch of runoff from an agricultural watershed in Kleberg and Nueces Counties in South Texas and a 5.5-inch rainfall event later that month produced 2.7 inches of runoff from the same, but now rain-soaked, watershed (Ockerman and Petri 2001).

A third important factor affecting landscape-level runoff dynamics is vegetation, and vegetation is itself dynamic. Carlson et al. (1990) compared runoff from nearby locations in the Rolling Plains of Texas where the vegetation had been manipulated. Annual runoff, averaged over three years, was 1.2 inches on sites with mesquite overstory plus a grass understory, 0.4 inch where the mesquite had been removed but the grasses remained, and 3.8 inches where both mesquite and grasses were removed. Grazing management can also have a substantial impact on runoff. Runoff on the Sonora Experiment Station located on the western edge of the Edwards Plateau averaged 2.9% of annual precipitation on a continuously-grazed pasture and 3.5% on a nearby site grazed under a four-pasture rotation system (Thurow et al. 1988). Both sites were moderately-stocked. Brush control methods can also affect amount of runoff. Wright et al. (1976) measured runoff on plots in the northern Edwards Plateau that had been previously bulldozed to reduce juniper density. Plots that were burned to remove the juniper slash and regrowth had 10% less runoff than on plots where the slash and regrowth had not been removed.

8.2.2.1 Clay Loam

Simulated annual runoff varied between 0.0 and 3.4 inches for the clay loam plot type (Table 8.9). Annual runoff averaged 0.85 inch in the simulations, compared to 0.6 inch on a gauged clay rangeland watershed on the Welder Wildlife Refuge over a two-year period (Ockerman 2002). The clay loam plot type in Goliad County had more rolling topography than the clay site on the Welder Wildlife Refuge, therefore runoff might be expected to be higher in Goliad County. The ratio of annual runoff to annual rainfall in the simulations varied from 0.000 to 0.088 and averaged 0.025 (2.5% of annual rainfall)(Table 8.9). This compares favorably with values reported in the literature of 1.1% for clay rangeland in San Patricio County, 2.9% for

continuously grazed oak-mixed grass sites in the western Edwards Plateau, and 4.2% for mesquite-grassland in the Rollings Plains (Table 8.10).

Table 8.9 Annual rainfall (inches), surface runoff (inches), and ratio of runoff to rainfall on clay loam and loamy sand types for the 25-year calibration simulation, Goliad County EDYS model.

Rainfall Year	Clay Loam Type			Loamy Sand Type		
	Rainfall	Runoff	Runoff/Rainfall	Rainfall	Runoff	Runoff/Rainfall
1928	29.76	0.53	0.018	29.56	1.37	0.046
1929	39.27	1.29	0.033	44.53	4.01	0.090
1930	23.25	0.00	0.000	25.88	0.00	0.000
1931	38.09	3.36	0.088	40.00	3.48	0.087
1932	34.93	1.70	0.048	35.11	2.44	0.069
1933	28.89	0.08	0.003	31.62	1.46	0.046
1934	36.82	1.32	0.036	41.86	3.89	0.093
1935	39.42	0.58	0.015	39.81	0.88	0.022
1936	33.85	0.02	0.001	36.49	1.51	0.041
1937	23.25	0.35	0.016	26.74	0.58	0.022
1938	21.48	0.66	0.031	27.25	2.84	0.104
1939	19.23	0.25	0.013	21.63	1.00	0.046
1940	39.38	1.44	0.036	38.23	1.31	0.034
1941	42.31	0.37	0.009	37.99	0.45	0.012
1942	36.09	2.92	0.081	41.02	5.41	0.132
1943	31.69	0.20	0.006	33.44	0.56	0.017
1944	30.83	0.21	0.007	32.02	0.87	0.027
1945	25.76	0.00	0.000	29.38	0.22	0.007
1946	42.81	0.47	0.011	45.89	2.18	0.048
1947	29.88	0.00	0.000	30.87	1.69	0.055
1948	23.90	0.00	0.000	26.70	0.00	0.000
1949	36.49	0.57	0.016	35.39	0.07	0.002
1950	15.79	0.00	0.000	18.65	0.45	0.024
1951	29.94	2.06	0.069	37.44	5.68	0.152
1952	34.17	2.88	0.084	37.15	1.82	0.049
Mean	31.49	0.85	0.025	33.79	1.77	0.049

Table 8.10 Examples of average annual runoff values (inches) in Texas reported in the literature, with corresponding runoff:precipitation ratios (RO/PPT).

Vegetation Type	Location	Runoff	RO/PPT	Reference
Mesquite-grassland	Rolling Plains	1.22	0.042(0.021-0.081)	Carlson et al. 1990
Grassland (mesquite removed)	Rolling Plains	0.43	0.015(0.004-0.036)	Carlson et al. 1990
Bare soil	Rolling Plains	3.82	0.141(0.087-0.195)	Carlson et al. 1990
Grassland, nearly level	N Edwards Plateau	0.24	0.008	Wright et al. 1976
Grassland, 13% slope	N Edwards Plateau	1.10	0.039	Wright et al. 1976
Oak-mixed grass (HILF)	W Edwards Plateau	----	0.050	Thurow et al. 1988
Oak-mixed grass (4-pasture)	W Edwards Plateau	----	0.035	Thurow et al. 1988
Oak-mixed grass (continuous)	W Edwards Plateau	----	0.029	Thurow et al. 1988
Rangeland + cultivated	San Patricio Co.	2.40	0.039(0.001-0.148)	Ockerman 2002
Loamy sand rangeland	San Patricio Co.	2.56	0.041(0.000-0.174)	Ockerman 2002
Clay rangeland	San Patricio Co.	0.63	0.011(0.000-0.042)	Ockerman 2002
Cultivated (PPT = 12.9 in)	Kleberg-Nueces Cos.	0.04	0.004(0.000-0.042)	Ockerman & Petri 2001
Cultivated (PPT = 26.7 in)	Kleberg-Nueces Cos.	4.06	0.152(0.012-0.488)	Ockerman & Petri 2001
Cultivated (PPT = 38.1 in)	Kleberg-Nueces Cos.	6.38	0.167(0.003-0.502)	Ockerman & Petri 2001

RO/PPT values outside parentheses are annual mean, values inside parentheses are ranges for individual PPT events.

HILF = high-intensity low-frequency grazing system; 4-pasture = 4-pasture rotation grazing system.

8.2.2.2 Loamy Sand

Simulated annual runoff varied between 0.0 and 5.7 inches for the loamy sand plot type (Table 8.9). Annual runoff averaged 1.77 inches over the 25-year simulations, compared to 2.56 inches on a gauged loamy sand rangeland watershed on the Welder Wildlife Refuge over a two-year period (Ockerman 2002). The ratio of annual runoff to annual rainfall in the simulations varied from 0.000 to 0.152 and averaged 0.049 (4.9% of annual rainfall). These values compare favorably with values reported from a gauged watershed on a loamy sand site in San Patricio County (0.000-0.174 of annual rainfall, with a mean of 0.041; Table 10). The simulations therefore produced results that are reasonable, based on comparisons to gauged data from a similar loamy sand type.

8.2.2.3 Other Vegetation Types

Annual runoff in the calibration simulations, averaged over seven vegetation types and over 25 years, was 1.85 inches or 5.5% of annual rainfall (Table 8.11). Annual runoff from gauged field studies on uncultivated sites typically range between 0.2 and 3.8 inches (Table 8.10), with an average of 1.43 inches. The average for three range sites in San Patricio County was 1.86 inches (Table 8.10). Annual runoff averaged 3.1% of annual rainfall on uncultivated sites in the measurement studies (Table 8.10) and varied between 0.8 and 5.0%.

Table 8.11 Average annual rainfall (inches), surface runoff (inches), and ratio of runoff to rainfall for seven vegetation types for the 25-year calibration simulation, Goliad County EDYS model.

	Blackland Coastal	Clay Loam	Loamy Bottomland	Loamy Sand	Salty Prairie	Shallow Ridge	Tight Sandy Loam	Mean
Runoff	5.56	0.85	1.78	1.77	1.74	0.32	0.94	1.85
Rainfall	33.79	31.49	33.79	33.79	33.79	31.49	33.79	33.13
Runoff/Rainfall	0.164	0.027	0.053	0.052	0.051	0.010	0.028	0.055

The runoff/rainfall values for clay loam and loamy sand differ slightly from the mean values in Table 8.10. The values in Table 8.11 were calculated as the ratio of the two means whereas the values in Table 8.10 were calculated as the mean of 25 annual ratios.

In summary, the runoff values in the simulations corresponded well with measured values from similar sites in Texas, especially sites in South Texas. These results indicate that the EDYS runoff values, both amount and proportional to rainfall, are reasonable.

8.2.3 Sediment Loadings

The amount of sediments transported in runoff water is of major importance in watershed management. Sediment loadings tend to increase as the amount and intensity of rainfall events increase and as surface roughness, especially vegetation cover, decreases. For example, typical sediment loadings at the Sonora Experiment Station are 25-50 g/m²/yr (Thurrow et al. 1988), but following a high-intensity event (0.8 inch in 30 minutes) increased to 387 g/m²/yr (McCalla et al. 1984), a ten-fold increase. Similarly, annual sediment loadings on a mesquite-grassland in the

Rolling Plains of Texas averaged 140 g/m² compared to 2,337 g/m² on nearby bare soil (Carlson et al. 1990).

Type, as well as amount, of vegetation cover also affects the amount of sedimentation. Grass cover tends to decrease both soil erosion (dislodging of soil particles) and sediment transport (movement of water-borne particles), compared to cover by woody species. Mesquite-grasslands in the Rolling Plains had annual sediment loadings of 140 g/m² compared to 25 g/m² on adjacent grassland sites where the mesquite had been removed. Sediment loadings on sites at the Sonora Experiment Station supporting midgrasses (e.g., sideoats grama and bluestems) were less than 40% the loadings on adjacent sites supporting shortgrasses (e.g., curly mesquite and hairy grama)(McCalla et al. 1984).

Typical sediment loadings from rangelands in Texas vary between about 2 and 140 g/m²/yr, or an equivalent of 0.03-2.13 g/m²/cm of annual precipitation (Table 8.12). A sediment loading of 2 g/m²/yr is equivalent to about 5 g/m²/inch of rainfall or about 50 lbs/ac/inch of rainfall.

Table 8.12 Examples of measured sediment loadings on sites in the Edwards Plateau and the Rolling Plains of Texas.

Vegetation	Location	Amount (g/m ² /yr)	Sediments/Rainfall (g/m ² /cm PPT)	Reference
Oak-mixed grass (rotation)	W Edwards Plateau	41	0.74	Thurrow et al. 1988
Oak-mixed grass (continuous)	W Edwards Plateau	25	0.45	Thurrow et al. 1988
Grassland (level, unburned)	N Edwards Plateau	2	0.03	Wright et al. 1976
Grassland (level, burned)	N Edwards Plateau	2	0.03	Wright et al. 1976
Grassland (13% slope unburned)	N Edwards Plateau	17	0.23	Wright et al. 1976
Grassland (18% slope, burned)	N Edwards Plateau	51	0.61	Wright et al. 1976
Mesquite-grassland	Rolling Plains	140	2.13	Carlson et al. 1990
Grassland (mesquite removed)	Rolling Plains	25	0.38	Carlson et al. 1990
Bare soil	Rolling Plains	2337	35.52	Carlson et al. 1990

Annual sediment loadings, averaged over the entire county and over the 25-year simulation period under the moderate rainfall regime, were 46.73 g/m² (0.208 tons per acre). This is a weighted average (total sediments divided by total acres), adjusting for differences in sizes of the various watersheds. An annual sediment loss of 47 g/m² is similar to values reported for mixed woodland-grassland systems in the Edwards Plateau and about one-third of the value for mesquite-grasslands in the Rolling Plains of North Texas (Table 8.12).

Sediment loss was highest in the north and west parts of Goliad County and least in the central and southern portions (Table 8.13). Across the entire county, average annual sediment loss ranged from 0-216 g/m², with most watersheds having losses of 10-100 g/m². These values are consistent with reported values in other areas of Texas (Table 8.12). Although site specific values for sediment loss are not available for Goliad County, the EDYS values appear to be reasonable based on comparisons to values reported for other regions.

Table 8.13 Average annual sediment loadings (tons per acre and g/m²) by watershed (WSHD) under the moderate rainfall regime, per Goliad County EDYS model simulations (25-year means).

Northeast Sector			West Sector			Central Sector			South Sector		
WSHD	T/acre	g/m ²	WSHD	T/acre	g/m ²	WSHD	T/acre	g/m ²	WSHD	T/acre	g/m ²
1101	0.382	85.70	594	0.000	0.04	672	0.611	136.94	1124	0.020	4.56
1102	0.811	181.89	602	0.033	7.45	674	0.029	6.45	1125	0.160	35.91
1103	0.352	78.85	604	0.006	1.39	676	0.066	14.70	1126	0.181	40.59
1105	0.158	35.43	606	0.196	43.97	686	0.093	20.88	1127	0.152	34.14
1106	0.202	45.20	608	0.008	1.80	688	0.123	27.51	1128	0.333	74.69
1108	0.130	29.07	610	0.218	48.77	690	0.259	58.05	1129	0.007	1.60
1136	0.812	182.10	612	0.111	24.80	692	0.080	17.87	1130	0.045	10.16
1137	0.191	42.71	614	0.221	49.53	694	0.165	37.08	1131	0.067	14.94
			616	0.291	65.23	696	0.090	20.25	1132	0.009	1.95
			618	0.006	1.27	698	0.001	0.25	1133	0.020	4.52
			620	0.216	48.41	700	0.147	32.90	1134	0.017	3.84
			622	0.044	9.79	702	0.098	22.03	1135	0.020	4.55
			624	0.354	79.42	704	0.097	21.81			
			626	0.033	7.50	706	0.083	18.69			
			628	0.185	41.36	708	0.034	7.71			
			630	0.001	0.20	710	0.077	17.20			
			632	0.011	2.51	712	0.016	3.55			
			634	0.205	45.96	714	0.016	3.60			
			636	0.114	25.57	716	0.005	1.03			
			638	0.110	24.60	718	0.012	2.60			
			640	0.593	133.03	720	0.066	14.63			
			648	0.051	11.48	722	0.108	24.10			
			650	0.384	85.97	724	0.028	6.32			
			652	0.272	61.03	726	0.018	3.95			
			654	0.103	23.03	728	0.009	1.98			
			656	0.035	7.79	730	0.019	4.15			
			658	0.966	216.48	732	0.001	0.26			
			660	0.126	28.16	734	0.000	0.00			
			662	0.192	43.08						
			664	0.037	8.31						
			666	0.023	5.03						
			668	0.632	141.67						
			670	0.384	86.08						
MEAN	0.380	85.12	MEAN	0.187	41.87	MEAN	0.084	18.80	MEAN	0.086	19.29

Means in Table 8.13 are simple arithmetic means and do not account for differences in areas within each watershed.

8.2.4 Flow Rates

Flow data are available for two gauge stations in Goliad County (8177300, 8188500; Fig. 8.1). There are two additional gauge stations (8176900, 8177400) but the watersheds associated with these two stations are only partially in the spatial footprint of the Goliad County model. Therefore, they cannot be used for calibration purposes.



Figure 8.1 Locations of the four gauge stations and their associated watersheds in Goliad County.

There are 81 numbered watersheds in Goliad County (Fig. 8.2). Of these, 33 flow into the San Antonio River above the Goliad gauge station. This group of watersheds is designated as the West Sector for reporting purposes. Twenty-eight watersheds flow into the San Antonio River below the Goliad gauge station. This group is designated as the Central Sector. Eight watersheds (Northeast Sector) are in the northeast part of Goliad County and do not flow directly into the San Antonio River within Goliad County. The remaining 12 watersheds (South Sector) drain to the south and southeast.

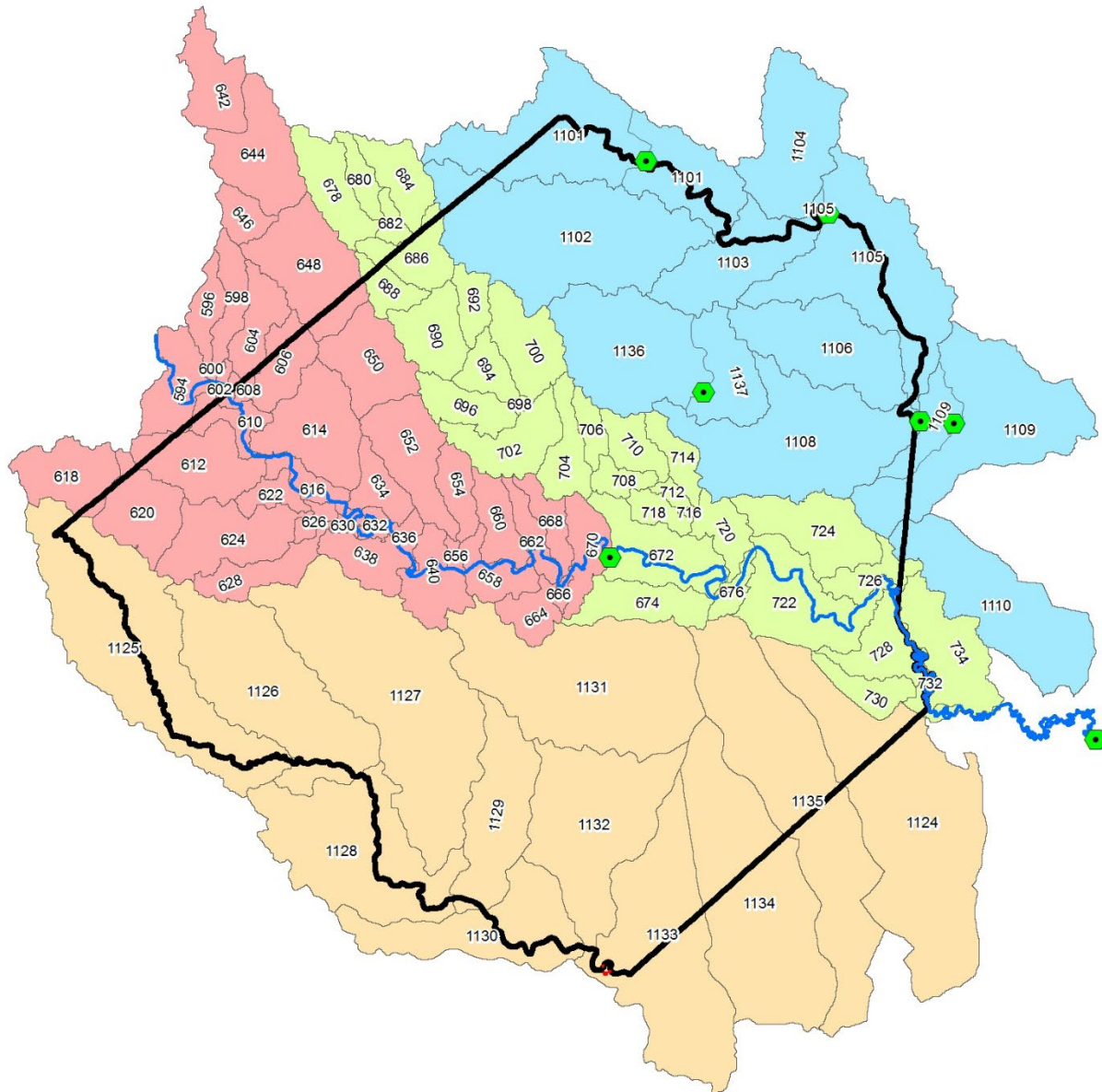


Figure 8.2 Locations of the 81 numbered watersheds in Goliad County divided into four sectors (West = red; Central = green; Northeast = blue; South = tan).

Gauge Station 8188500 is located on the San Antonio River. Water measured at the station includes both the San Antonio River flow entering Goliad County from Karnes County and the addition of runoff and subsurface flow from 33 subwatersheds located between the gauge station and the Karnes County line. Twenty-three of the subwatersheds are located entirely in Goliad County, and therefore modeled by the Goliad County model, and ten are only partially located in Goliad County (Fig. 8.2). The portions of those ten subwatersheds that are located in Goliad County are included in the Goliad County model. Gauge Station 8177300 receives flow from

one subwatershed (1136) and it is located entirely in Goliad County. Only data from stations 8177300 and 8188500 were used in the calibration process.

8.2.4.1 Gauge 8188500, San Antonio River at Goliad

There are two components to the flow at this gauge: 1) San Antonio River flow entering from Karnes County and 2) water entering the San Antonio River from the associated watershed in Goliad County. There is no gauge on the San Antonio River at the Goliad-Karnes county line. The nearest upstream gauge is the station near Runge. It is about 10 miles along the river between this station and the Goliad County line and about 25 miles along the river between the Goliad County line and the gauge station at Goliad.

Monthly flow data from June 2011 through March 2016 were used to compare flows between the Runge and Goliad stations. Over this period, the average monthly flow at Goliad exceeded the average monthly flow at Runge by 7,419 acre-feet (Table 8.14). About 51% of the watershed monitored by the Goliad gauge (i.e., the combined Karnes-Goliad portion between the Runge and Goliad gauge stations) is located in Goliad County, the remaining 49% being in Karnes County. Assuming a linear relationship between watershed area and increased flow between Runge and Goliad, 49% of this increased flow may have originated in Karnes County, leaving 3,784 acre-feet that originated in the Goliad County part of the watershed.

Table 8.14 Total and average monthly flow (acre-feet) at the Runge and the Goliad gauge stations, June 2011 through March 2016.

Period	Rainfall (inches)		Total Flow			Average Monthly Flow		
	Goliad	Runge	Goliad	Runge	Difference	Goliad	Runge	Difference
Jun-Dec 2011	10.28	8.39	97,987	74,152	23,835	13,998	10,593	3,405
Jan-Dec 2012	29.00	15.49	407,560	338,332	69,228	33,963	28,194	5,769
Jan-Dec 2013	27.77	12.96	308,695	234,787	73,908	25,725	19,566	6,159
Jan-Dec 2014	25.63	17.72	267,053	208,997	58,056	22,254	17,416	4,838
Jan-Dec 2015	28.17	28.17	781,535	574,458	207,077	65,128	47,872	17,256
Jan-Mar 2016	5.11	5.11	97,155	98,987	- 1,832	32,385	32,996	- 611
Overall	125.96	87.84	1,959,985	1,529,713	430,272	33,793	26,374	7,419

EDYS simulation of surface runoff averaged 362 acre-feet per month for the Goliad County portion of this watershed for the period Jun 2011-Mar 2016, or about 9.6% of the increase in river flow. The EDYS simulations also accounted for a monthly average of an additional 702 acre-feet entering the watershed soils during the runoff process, a portion of which would move laterally into the river as seepage. Combining surface runoff with maximum seepage results in a total of 1,064 acre-feet per month flowing into the river, or about 28% of the estimated increase in flow within Goliad County. This leaves 72% of the increase in river flow (2,720 acre-feet per month) unaccounted for (Fig. 8.3).

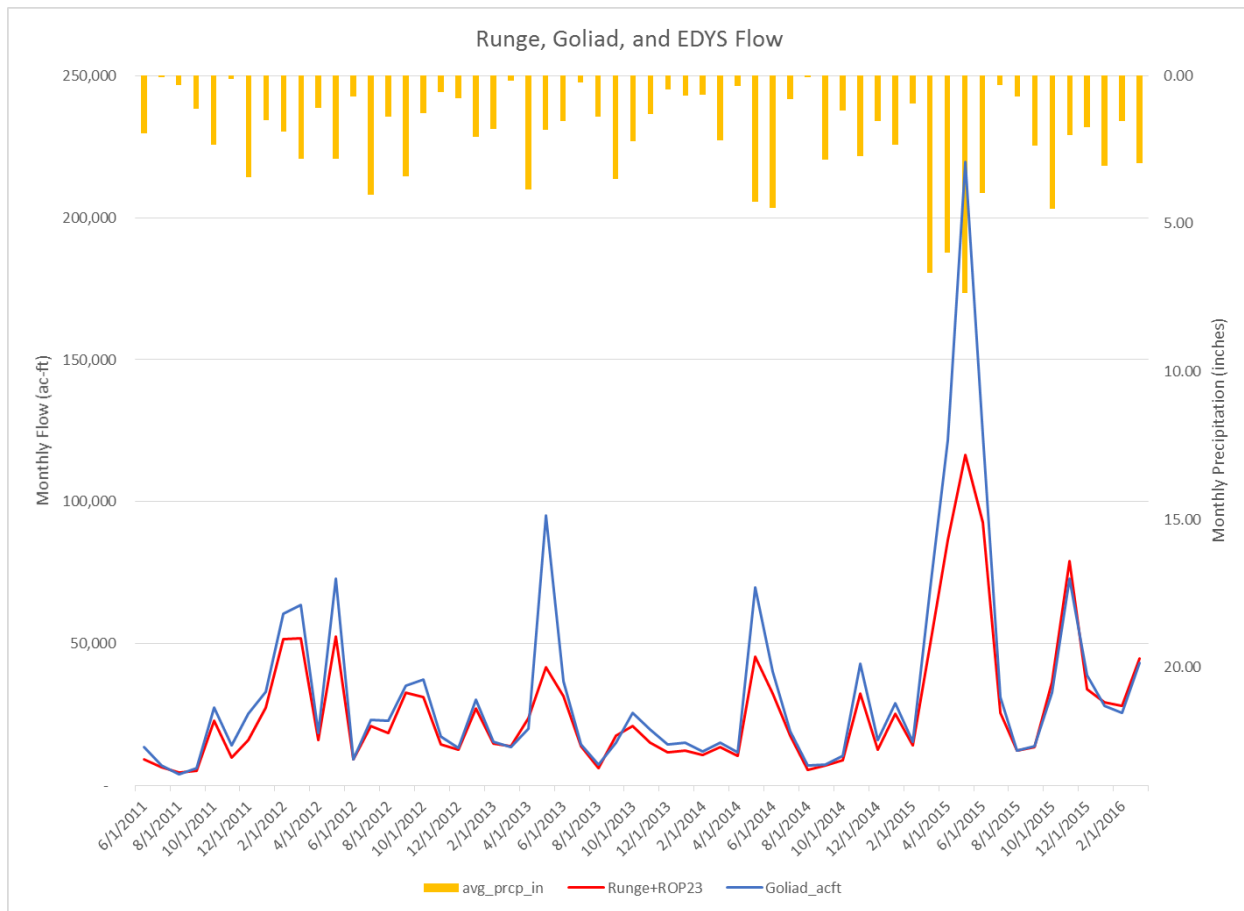


Figure 8.3 Comparison of gauged (blue) and simulated (red) monthly flows (acre-feet) at the Goliad station on the San Antonio River, June 2011-March 2016.

8.2.4.2 Gauge 8177300, Perdido Creek

The Perdido watershed (Watershed 1136) is a gauged watershed completely within Goliad County (Fig. 8.1). Therefore it provides a good example to use to estimate how well the EDYS simulations are matching gauged flows. Creek flow is measured at the USGS gauge. Flow is partially estimated from EDYS output by using runoff. However, runoff is not the only contribution to flow. Flow also includes lateral seepage and any spring flows plus some water that EDYS calculates as recharge (export = water infiltrating below the root zone or to groundwater, whichever is shallower). Without accounting for this lateral movement (seepage, spring flow, groundwater lateral flow), EDYS estimates of flow will likely be less than recorded flow. This is the case for the Perdido watershed. When summed over the seven-year period of record, EDYS runoff accounted for 85% of the recorded flow (Table 8.15). The remaining 15% is a first-approximation of subsurface lateral flow into the creek.

Table 8.15 Annual flow at USGS Gauge 8177300 and simulated surface runoff for the same watershed using the Goliad County EDYS model, 2008-2014.

Period	Goliad Rainfall (inches)	USGS Flow (ac-ft/yr)	EDYS Runoff (ac-ft/yr)	EDYS/USGS
Jan-Dec 2008	22.51	2.56	62.09	
Jan-Dec 2009	35.90	942.31	882.32	
Jan-Dec 2010	41.32	2,000.06	678.59	
Jan-Dec 2011	17.24	263.95	101.66	
Jan-Dec 2012	29.00	73.38	111.47	
Jan-Dec 2013	27.77	22.08	836.85	
Jan-Dec 2014	25.63	34.21	175.75	
Total 2008-14	199.37	3,338.55	2,848.73	0.853

Summed over the seven years, the EDYS surface runoff values gave a reasonable estimate (85%) of USGS gauged flow. However when viewed on a monthly or annual basis, there was a poor match between EDYS runoff and gauged flow (Fig. 8.4). In general, EDYS indicated surface runoff to the creek more often than flow was recorded at the gauge, although gauged flow was greater than EDYS runoff overall. EDYS recorded runoff in 55 of the 84 months of 2008-14 while there were only 23 months with gauged flow (Table 8.16).

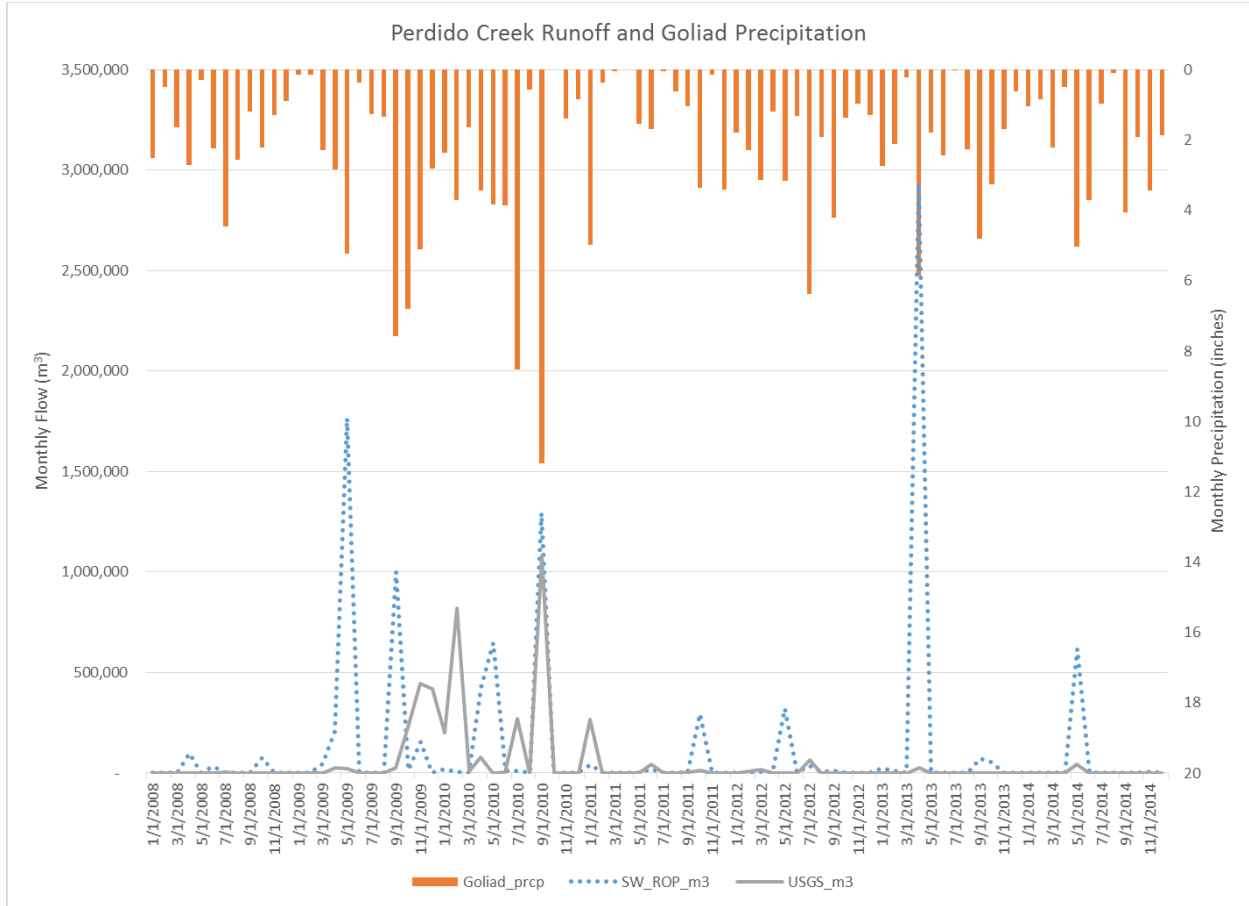


Figure 8.4 Comparison of gauged (blue) and simulated (red) monthly flows (acre-feet) at the Perdido Creek gauge station, Goliad County, 2008-14, and monthly rainfall (inches; vertical bars).

Table 8.16 Monthly gauged flow for the Perdido Watershed and EDYS surface runoff. Rainfall is in inches and flow and runoff are in acre-feet.

Month	Rainfall	Gauged Flow	EDYS Runoff	Month	Rainfall	Gauged Flow	EDYS Runoff
Jan 2008	2.52	0.00	1.03	Jul 2011	0.03	0.00	0.00
Feb 2008	0.50	0.00	0.00	Aug 2011	0.62	0.00	0.00
Mar 2008	1.65	0.00	0.00	Sep 2011	1.04	2.20	0.07
Apr 2008	2.70	0.00	29.90	Oct 2011	3.35	9.87	83.54
May 2008	0.30	0.00	0.00	Nov 2011	0.15	0.00	0.00
Jun 2008	2.24	0.00	8.98	Dec 2011	3.41	0.00	0.27
Jul 2008	4.47	2.57	0.70	Jan 2012	1.80	0.00	0.79
Aug 2008	2.57	0.00	0.36	Feb 2012	2.29	7.28	0.66
Sep 2008	1.18	0.00	0.00	Mar 2012	3.13	14.53	1.89
Oct 2008	2.21	0.00	21.20	Apr 2012	1.18	0.00	0.06
Nov 2008	1.29	0.00	0.01	May 2012	3.17	0.00	92.26
Dec 2008	0.88	0.00	0.00	Jun 2012	1.31	0.00	0.00
Jan 2009	0.14	0.00	0.00	Jul 2012	6.38	51.65	10.38
Feb 2009	0.14	0.00	0.00	Aug 2012	1.91	0.00	2.03
Mar 2009	2.28	0.00	12.64	Sep 2012	4.22	0.00	2.92
Apr 2009	2.83	20.35	59.95	Oct 2012	1.36	0.00	0.00
May 2009	5.23	18.02	485.11	Nov 2012	0.97	0.00	0.07
Jun 2009	0.37	0.00	0.00	Dec 2012	1.28	0.00	0.53
Jul 2009	1.26	0.00	0.03	Jan 2013	2.74	0.00	7.07
Aug 2009	1.34	0.00	0.00	Feb 2013	2.11	0.00	2.84
Sep 2009	7.58	22.09	276.01	Mar 2013	0.22	0.00	0.00
Oct 2009	6.81	183.17	4.66	Apr 2013	5.85	22.10	790.27
Nov 2009	5.11	360.18	43.73	May 2013	1.79	0.00	0.29
Dec 2009	2.81	339.62	1.23	Jun 2013	2.44	0.00	0.01
Jan 2010	2.36	164.48	5.54	Jul 2013	0.01	0.00	0.00
Feb 2010	3.70	665.99	2.44	Aug 2013	2.25	0.00	1.15
Mar 2010	1.64	6.96	0.05	Sep 2013	4.80	0.00	20.32
Apr 2010	3.43	62.38	121.67	Oct 2013	3.25	0.00	15.84
May 2010	3.82	0.00	182.40	Nov 2013	1.69	0.00	0.06
Jun 2010	3.85	3.99	3.32	Dec 2013	0.62	0.00	0.00
Jul 2010	8.53	218.88	3.21	Jan 2014	1.04	0.00	0.00
Aug 2010	0.58	0.00	0.00	Feb 2014	0.83	0.00	0.00
Sep 2010	11.19	879.75	360.74	Mar 2014	2.21	0.00	0.22
Oct 2010	0.00	0.00	0.00	Apr 2014	0.49	0.00	0.00
Nov 2010	1.38	0.00	0.01	May 2014	5.03	34.25	172.05
Dec 2010	0.84	0.00	0.00	Jun 2014	3.72	0.00	0.46
Jan 2011	5.00	216.73	13.25	Jul 2014	0.96	0.00	0.00
Feb 2011	0.37	0.00	0.00	Aug 2014	0.08	0.00	0.00
Mar 2011	0.04	0.00	0.00	Sep 2014	4.05	0.00	1.05
Apr 2011	0.00	0.00	0.00	Oct 2014	1.92	0.00	0.00
May 2011	1.55	0.00	0.74	Nov 2014	3.43	0.00	1.86
Jun 2011	1.68	35.47	4.19	Dec 2014	1.87	0.00	0.32

Gauged flow and EDYS runoff were both minimal (less than 0.1 acre-foot) when rainfall was less than 1.5 inches (Table 8.15), with one exception for each (Sep 2011 for gauged; Dec 2012 for EDYS). This is consistent with results from experimental studies in the area. For example, rainfall events of less than two inches produced little or no runoff on gauged watersheds in San Patricio, Kleberg, and Nueces Counties (Ockerman and Petri 2001; Ockerman 2002).

As rainfall increased above 1.5 inches, both runoff and flow increased as would be expected. However, there were a number of inconsistencies in the relationship between rainfall and both flow and runoff. There were eight months when monthly flow was greater than 100 acre-feet (Table 8.17). Three of these months received less than 5 inches of rainfall, and rainfall in the previous month was greater than 2.3 inches in each case. However, there were 22 months with rainfall between 2.4 and 5.0 inches that had less than 100 acre-feet of flow, and 17 of these

months had less than 10 acre-feet of flow. Of the 22 months, 5 received more than 2.3 inches of rainfall in the previous month. The second highest flow month was Feb 2010, with 666 acre-feet of flow. That month received 3.70 inches of rainfall and the previous month received 2.36 inches. In contrast, 3.72 inches of rainfall was received in Jun 2014 and 5.03 inches were received in the previous month, but there was no flow (0.00 acre-feet) that month. Ten months received 5 inches or more of rainfall. In those ten months, flow exceeded 180 acre-feet in 5 months and was less than 52 acre-feet in each of the other 5 months.

Table 8.17 Comparison of monthly rainfall (inches; months > 1.5 inches) to monthly flow (acre-feet) at the USGS gauge station and monthly runoff (acre-feet) simulated by the EDYS Goliad County model for the Perdido watershed.

Month	Rainfall	Gauged Flow	EDYS Runoff	Previous Month Rainfall	Month + Previous Month Rainfall	Month Rainfall + 50% Previous Month Rainfall
May 2011	1.55	0.00	0.74	0.00	1.55	1.55
Mar 2010	1.64	6.96	0.05	3.70	5.34	3.49
Mar 2008	1.65	0.00	0.00	0.50	2.15	1.90
Jun 2011	1.68	35.47	4.19	1.55	3.23	2.46
Nov 2013	1.69	0.00	0.06	3.25	4.94	3.32
May 2013	1.79	0.00	0.29	5.85	7.64	4.72
Jan 2012	1.80	0.00	0.79	3.41	5.21	3.51
Dec 2014	1.87	0.00	0.32	3.43	5.30	3.59
Aug 2012	1.91	0.00	2.03	6.38	8.29	5.10
Oct 2014	1.92	0.00	0.00	4.05	5.97	3.95
Feb 2013	2.11	0.00	2.84	2.74	4.85	3.48
Oct 2008	2.21	0.00	21.20	1.18	3.39	2.80
Mar 2014	2.21	0.00	0.22	0.83	3.04	2.63
Jun 2008	2.24	0.00	8.98	0.30	2.54	2.39
Aug 2013	2.25	0.00	1.15	0.01	2.26	2.26
Mar 2009	2.28	0.00	12.64	0.14	2.42	2.35
Feb 2012	2.29	7.28	0.66	1.80	4.09	3.19
Jan 2010	2.36	164.48	5.54	2.81	5.17	3.77
Jun 2013	2.44	0.00	0.01	1.79	4.23	3.34
Jan 2008	2.52	0.00	1.03	0.63	3.15	2.84
Aug 2008	2.57	0.00	0.36	4.47	7.04	4.81
Apr 2008	2.70	0.00	29.90	1.65	4.35	3.53
Jan 2013	2.74	0.00	7.07	1.28	4.02	3.38
Dec 2009	2.81	339.62	1.23	5.11	7.92	5.37
Apr 2009	2.83	20.35	59.95	2.28	5.11	3.97
Mar 2012	3.13	14.53	1.89	2.29	5.42	4.28
May 2012	3.17	0.00	92.26	1.18	4.35	3.76
Oct 2013	3.25	0.00	15.84	4.80	8.05	5.65
Oct 2011	3.35	9.87	83.54	1.04	4.39	3.87
Dec 2011	3.41	0.00	0.27	0.15	3.56	3.49
Apr 2010	3.43	62.38	121.67	1.64	5.07	4.25
Nov 2014	3.43	0.00	1.86	1.92	5.35	4.39
Feb 2010	3.70	665.99	2.44	2.36	6.06	4.88
Jun 2014	3.72	0.00	0.46	5.03	8.75	6.24
May 2010	3.82	0.00	182.40	3.43	7.25	5.54
Jun 2010	3.85	3.99	3.32	3.82	7.67	5.76
Sep 2014	4.05	0.00	1.05	0.08	4.13	4.09
Sep 2012	4.22	0.00	2.92	1.91	6.13	5.18
Jul 2008	4.47	2.57	0.70	2.24	6.71	5.59
Sep 2013	4.80	0.00	20.32	2.25	7.05	5.93
Jan 2011	5.00	216.73	13.25	0.84	5.84	5.42
May 2014	5.03	34.25	172.05	0.49	5.52	5.28
Nov 2009	5.11	360.18	43.73	6.81	11.92	8.52
May 2009	5.23	18.02	485.11	2.83	8.06	6.65
Apr 2013	5.85	22.10	790.27	0.22	6.07	5.96
Jul 2012	6.38	51.65	10.38	1.31	7.69	7.04
Oct 2009	6.81	183.17	4.66	7.58	14.39	10.60
Sep 2009	7.58	22.09	276.01	1.34	8.92	8.25
Jul 2010	8.53	218.88	3.21	3.85	12.38	10.46
Sep 2010	11.19	879.75	360.74	0.58	11.77	11.48

EDYS runoff values were correlated more closely with monthly rainfall than were gauged flows, but there was also substantial variability in the runoff values (Table 8.17). EDYS runoff values exceeded 100 acre-feet in 7 months and rainfall exceeded 3.4 inches in each of these months. However, rainfall exceeded 3.4 inches in 14 other months and runoff was less than 5 acre-feet in 10 of these 14 months. Runoff exceeded 15 acre-feet in 6 months receiving less than 3.4 inches of rainfall and previous-month rainfall exceeded 1 inch in each of these months. However, previous-month rainfall exceeded 1 inch in 16 months receiving less than 3.4 inches of rainfall and runoff was less than 15 acre-feet in each of these months.

Amount of monthly rainfall is not the only factor affecting amount of monthly runoff. Intensity of the rainfall events is also a major factor. EDYS utilizes daily rainfall amounts as input. These daily amounts are divided into segments, each segment corresponding to a duration of the rainfall event, as a method of estimating rainfall intensity. Another factor affecting landscape-level runoff is antecedent moisture conditions (e.g., Ockerman and Petri 2001). The same amount of rainfall will result in different amounts of runoff depending on the moisture conditions of the soil at the time of the rainfall event. EDYS accounts for this adequately on the plot (cell) level. On the landscape-level, where surface runoff is moving across a watershed, EDYS appears to be under-estimating flow under high-rainfall conditions. This issue has been identified in other applications and discussed in the respective reports (McLendon et al. 2015; Booker and McLendon 2015, 2016). A modification of the EDYS code is currently being developed to improve this accuracy but these upgrades are not yet available. A mathematical approximation, which forms the basis on which the mechanistic algorithms of the updated code are developed, is available. This approximation is a step function that divides precipitation periods into three groups (dry, medium, wet) and applies a different equation to calculate accumulated runoff under each respective precipitation group. In effect, this results in lower landscape runoff in drier periods and higher runoff in wetter periods than the respective values using the current algorithms. Whereas the current approach results in total surface runoff being equal to 85% of the gauged flow along the Perdido Creek (Table 8.15), the application of the mathematical approximation equations results in total runoff being equal to gauged flow when totaled over the seven years (although values still differ on a monthly basis).

Flow is also affected by factors other than amount of rainfall received in a particular month or previous month. There is often a lag time between a rainfall event, or series of events, and flow being recorded at a gauge station. Flow is composed of both runoff and subsurface movement of water into the drainage. The Perdido watershed gauge recorded 340 acre-feet of flow in Dec 2009, a month receiving 2.81 inches of rain (Table 8.17). That gauge recorded 20 acre-feet of flow in Apr 2009 when 2.83 inches of rainfall occurred. The difference in flows could be attributed to differences in previous month rainfall. In Nov 2009 there was 5.11 inches of rain compared to 2.28 inches in Mar 2009. Part of the Dec 2009 flow was likely from subsurface lateral movement of water that originated as rainfall in the previous month.

The high flow from October 2009 through February 2010 was the result of five consecutive months of relatively high rainfall (Table 8.16). The monthly flows during that time were undoubtedly a function of both rainfall and subsurface lateral flow. Rainfall-to-flow relationships in other months, where there was not such a series of wet months, are more erratic. For example, there were four months, excluding Nov 2009, where rainfall was 5.0-6.0 inches

(Table 8.17). Monthly flow was 18-34 acre-feet in three of those months and 217 acre-feet in the other, and the high-flow month did not have high rainfall in the previous month.

In summary, EDYS simulations tended to give reasonable estimates of total flow into the Perdido Creek watershed (85% of gauged flow) but the timing of the events were often different between EDYS and the gauge data. The reason likely being that EDYS moved water more rapidly than what actually occurred because of lateral flow rates (lag-time) into the creek. EDYS did not account as well for change in flow rates between the Runge (Karnes County) and Goliad (Goliad County) gauge stations. Runoff and maximum subsurface flow in the EDYS simulations accounted for only about 28% of the expected increase in river flow.

9.0 SCENARIOS

A scenario in EDYS consists of a specific simulation run. Each scenario is defined by a selection of inputs that can include any combination of precipitation, stressor, management, and time factors. The specific combination defining a scenario can be applied across the entire spatial footprint or can be localized. Ten scenarios were defined as examples to be included in this report. A 25-year simulation period was used for each of the 10 scenarios.

1. Baseline. No changes in land management options; daily precipitation data from 1928-1952 were used as most indicative of long-term average conditions (1913-2015 annual mean for Goliad = 34.84 inches; 1928-1952 annual mean for Goliad = 33.77 inches).

2. Dry Cycle. No changes in land management options; daily precipitation data from 1915-1939; 1915-1939 were the driest 25 consecutive years on record for Goliad (annual mean = 30.96 inches = 0.889 of long-term mean).

3. Wet Cycle. No changes in land management options; daily precipitation data from 1957-1981 used; 1957-1981 were the wettest 25 consecutive years on record for Goliad (annual mean = 39.92 inches = 1.146 of long-term mean).

4. Brush Management, Average Rainfall Pattern. 100% of aboveground biomass of woody species and 50% of aboveground biomass of herbaceous species removed in Year 1 (root plowing) on all non-urban areas with more than 30% cover of woody species and less than 12% slope; average rainfall pattern (1928-1952); moderate grazing by livestock maintained.

5. Brush Management, Reduced Live Oak Removal. Same as Scenario 4 except only 50% of the aboveground biomass of live oak was removed.

6. Brush Management, Dry Rainfall Pattern. Same as Scenario 4 except dry rainfall pattern (1915-1939) was applied.

7. Brush Management, Wet Rainfall Pattern. Same as Scenario 4 except wet rainfall pattern (1957-1981) was applied.

8. Cultivated Land (6.5%). 6.5% of total land in the county placed under cultivation; native vegetation (randomly selected) changed to cultivation; average rainfall pattern (1928-1952).

9. Cultivated Land (21%). 21% of total land in the county placed under cultivation; native vegetation (randomly selected) changed to cultivation; average rainfall pattern (1928-1952).

10. Maximum Potential Water Enhancement from Brush Control. Same as Scenario 4 except brush control was applied to all non-urban areas.

9.1 Vegetation

9.1.1 Baseline

9.1.1.1 Clay Loam Type

Under baseline conditions (average rainfall over 25 years, moderate stocking rate of cattle), there was a slight decrease in woody plants (trees and shrubs) in the simulations for the clay loam type overall, but this decrease was not uniform among woody species (Table 9.1). Huisache and whitebrush increased substantially (13% and 47%, respectively) and there were more moderate increases in granjeno (6%) and prickly pear (4%). Huisache and whitebrush are both aggressive invading species, especially under early- and mid-seral conditions. Conversely, there were substantial decreases in blackbrush, baccharis, and wolfberry and a slight decrease (2%) in mesquite. The decreases in these four woody species were most likely the result of competitive from the more aggressive huisache and whitebrush.

In addition to changes in the woody plants (i.e., the overstory species in the shrub and woodland mosaic), there were also changes in both standing crop biomass and species composition of the herbaceous component (Table 9.1). At the beginning of the simulations, the herbaceous component of the clay loam type had an average standing crop biomass of 144 g/m² (1284 lbs/ac) at the end of the growing season. This consisted of about 50% shortgrasses (hooded windmillgrass, buffalograss, purple threeawn [*Aristida purpurea*]), 30% midgrasses (silver bluestem, plains bristlegrass), and 20% forbs (mostly ragweed). By the end of the 25-year simulation, herbaceous standing crop had increased to 452 g/m² (4032 lbs/ac). This is a realistic level for silver or little bluestem grasslands under moderate grazing by cattle (355-422 g/m² = 3167-3764 lbs/ac; Hazell 1967).

Species composition also changed by the end of the simulation period. Shortgrasses increased as the type dominants, with most of this being purple threeawn (Table 9.1). Buffalograss increased in biomass, but not as much proportionately as did purple threeawn. Silver bluestem became the major midgrass, and trichloris also increased. These two species are major midgrasses under mid-seral conditions in the bluestem grasslands of South Texas (Box 1961, Box and White 1969, McLendon 1991). Little bluestem and plains bristlegrass decreased during the 25-year simulation. These changes in composition are consistent with what would be expected under moderate grazing. The more palatable species (little bluestem, Arizona cottontop, plains bristlegrass) received more grazing pressure than the less palatable species (silver bluestem,

trichloris, purple threeawn) and therefore decreased in abundance. Within the shortgrasses, buffalograss is more palatable to cattle than purple threeawn, and therefore purple threeawn increased by a greater amount than buffalograss. All forb species decreased on this type because of browsing pressure by deer and increased competition from the grasses.

Table 9.1 Aboveground biomass (g/m²), by lifeform and major species, in seven plot types¹ at the end of growing season in the first (01) and last (25) years of a 25-year simulation under the baseline scenario, Goliad County EDYS model.

Lifeform or Species	Blackland Coastal		Clay Loam		Loamy Bottomland		Loamy Sand		Salty Prairie		Shallow Ridge		Tight Sandy Loam	
	01	25	01	25	01	25	01	25	01	25	01	25	01	25
Trees	246	213	1247	1278	6623	6028	5181	4695	320	323	444	558	3402	2952
Shrubs	72	37	976	898	851	739	394	324	96	138	1592	1561	648	397
Midgrasses	63	62	49	67	52	388	74	471	527	740	17	3	73	547
Shortgrasses	229	548	71	383	26	4	38	256	37	55	29	3	37	284
Grass-likes	0	0	0	0	17	230	0	0	0	0	0	0	0	0
Forbs	67	1	34	2	32	24	37	5	13	57	14	54	28	4
Total aboveground	677	861	2377	2628	7601	7413	5724	5751	993	1313	2096	2179	4188	4184
Huisache	125	116	364	411	620	536	---	---	281	269	---	---	---	---
Pecan	---	---	---	---	810	820	---	---	---	---	---	---	---	---
Sugar hackberry	6	4	---	---	1228	747	---	---	---	---	---	---	---	---
Mesquite	101	82	883	867	484	375	1034	826	39	54	444	558	1332	1078
Live oak	14	11	---	---	3481	3550	4147	3869	---	---	---	---	2070	1874
Guajillo	---	---	---	---	---	---	---	---	---	---	525	165	---	---
Blackbrush	11	5	186	76	---	---	---	---	---	---	974	1349	274	113
Whitebrush	15	6	198	291	155	343	---	---	---	---	---	---	---	---
Baccharis	---	---	99	27	158	45	---	---	---	---	---	---	---	---
Sea oxeye	---	---	---	---	---	---	---	---	96	138	---	---	---	---
Granjeno	22	13	283	300	157	81	192	220	---	---	---	---	287	254
Wolfberry	---	---	21	8	---	---	---	---	---	---	---	---	---	---
Agarito	t	t	5	4	---	---	---	---	---	---	---	---	---	---
Mustang grape	---	---	---	---	381	270	114	66	---	---	---	---	---	---
Prickly pear	24	13	184	192	---	---	88	38	---	---	93	47	87	30
Big bluestem	1	10	---	---	1	115	---	---	---	---	---	---	---	---
Bushy bluestem	---	---	---	---	7	t	---	---	---	---	---	---	---	---
Purple threeawn	27	260	9	255	---	---	6	254	---	---	3	1	11	276
Silver bluestem	19	42	17	57	3	1	10	40	---	---	---	---	40	323
Sideoats grama	2	1	2	2	7	162	14	313	---	---	4	1	6	2
Hairy grama	8	8	1	t	---	---	3	1	---	---	4	1	5	6
Red grama	---	---	---	---	---	---	---	---	---	---	3	t	2	0
Buffalograss	140	267	24	92	7	t	---	---	---	---	---	---	---	---
Sandbur	---	---	---	---	---	---	1	0	---	---	---	---	1	0
Hooded windmill	26	6	33	36	---	---	6	1	---	---	4	1	18	2
Trichloris	2	t	2	7	7	2	---	---	---	---	1	t	22	224
Bermudagrass	---	---	---	---	3	t	---	---	6	t	---	---	---	---
Arizona cottontop	---	---	1	t	---	---	1	t	---	---	1	t	1	t
Saltgrass	---	---	---	---	---	---	---	---	6	0	---	---	---	---
Virginia wildrye	---	---	---	---	2	t	---	---	---	---	---	---	---	---
Texas cupgrass	---	---	---	---	1	t	---	---	---	---	---	---	---	---
Green sprangletop	---	---	---	---	---	---	---	---	---	---	1	t	---	---
Vine-mesquite	3	0	1	t	3	4	---	---	---	---	---	---	---	---
Switchgrass	4	1	---	---	5	14	3	4	t	t	---	---	---	---
Longtom	---	---	---	---	---	---	---	---	4	0	---	---	---	---
Brownseed paspalum	4	0	1	0	3	0	10	0	---	---	---	---	---	---
Thin paspalum	---	---	---	---	---	---	12	t	---	---	---	---	---	---
Common reed	---	---	---	---	---	---	---	---	1	0	---	---	---	---
Little bluestem	18	4	3	1	14	94	43	114	2	t	7	2	---	---
Knotroot bristle	9	1	1	t	5	t	---	---	21	55	---	---	---	---
Plains bristlegrass	5	0	20	0	3	0	3	0	---	---	---	---	4	0
Texas bristlegrass	---	---	---	---	---	---	---	---	---	---	8	0	---	---
Indiangrass	3	1	t	t	---	---	---	---	1	t	---	---	---	---

Table 9.1 (Cont.)

Lifeform or Species	Blackland Coastal		Clay Loam		Loamy Bottomland		Loamy Sand		Salty Prairie		Shallow Ridge		Tight Sandy Loam	
	01	25	01	25	01	25	01	25	01	25	01	25	01	25
Johnsongrass	2	0	2	0	2	0	---	---	---	---	---	---	---	---
Gulf cordgrass	---	---	---	---	---	---	---	---	523	740	---	---	---	---
Tall dropseed	7	3	2	t	---	---	---	---	---	---	---	---	---	---
Sand dropseed	---	---	---	---	---	---	---	---	---	---	4	t	---	---
Texas wintergrass	12	6	1	t	5	t	---	---	---	---	6	t	---	---
Littletooth sedge	---	---	---	---	6	t	---	---	---	---	---	---	---	---
Flatsedge	---	---	---	---	11	230	---	---	---	---	---	---	---	---
Ragweed	26	t	11	1	9	2	28	2	---	---	13	54	16	2
Spiny aster	---	---	---	---	1	t	---	---	2	t	---	---	---	---
Wild indigo	5	0	1	0	---	---	---	---	---	---	---	---	---	---
Old-mans beard	30	1	6	t	10	5	---	---	---	---	---	---	---	---
Bundleflower	2	0	1	t	1	t	t	t	---	---	---	---	t	0
Frogfruit	---	---	5	t	2	t	---	---	8	55	---	---	---	---
Coneflower	---	---	1	0	---	---	t	t	---	---	---	---	t	0
Snoutbean	---	---	1	0	1	0	1	0	---	---	---	---	2	0
Ruellia	3	0	1	0	1	0	---	---	---	---	---	---	---	---
Glasswort	---	---	---	---	---	---	---	---	3	2	---	---	---	---
Bush sunflower	---	---	4	1	---	---	7	3	---	---	---	---	9	2
Greenbriar	---	---	---	---	6	17	---	---	---	---	---	---	---	---
Orange zexmenia	---	---	2	t	---	---	---	---	---	---	---	---	---	---
Giant ragweed	---	---	---	---	1	0	---	---	---	---	---	---	---	---
Annual broomweed	---	---	1	0	---	---	---	---	---	---	1	0	---	---
Partridge pea	---	---	---	---	t	0	t	0	---	---	---	---	1	0
Texas doveweed	---	---	---	---	---	---	1	0	---	---	---	---	---	---
Sunflower	1	0	t	0	t	0	---	---	---	---	---	---	t	0

Dashes (---) indicate that the species was not included in the simulation for that type.

A trace amount (< 0.5 g/m²) is indicated with a “t”.

9.1.1.2 Loamy Sand Type

There was a substantial decrease (10%) in woody plant biomass over the 25-year simulation on the loamy sand type, with a corresponding increase (550%) in grass biomass (Table 9.1). Both mesquite and live oak decreased but there was a 14% increase in granjeno. The decrease in tree biomass was likely in response to the amount of rainfall simulated in this scenario. The average annual rainfall in the baseline scenario was 33.77 inches (85.8 cm). This amount of annual rainfall is marginal for support of woodlands. Forty inches of annual rainfall is a general estimate of the level where woodlands dominate over grasslands (Weaver and Clements 1938:510; Engle 1994; Bailey 1995). Stoddart and Smith (1955:48) suggested 38 inches for the transition to tallgrass prairie and Drawe (1994) considered 36 inches to be the transition point on the Coastal Prairies of Texas. Trees are supported at lower moisture levels on sandy soils than on adjacent clay or loamy soils, therefore the transition point on sands in South Texas is probably close to the 36 inches suggested by Drawe (1994). This level is still above the annual mean under the baseline scenario, which would suggest that trees, especially live oak, might be expected to decrease over the 25 years. In contrast, granjeno is a shrub species that is well-adapted to annual rainfall regimes of 20-35 inches (McLendon 1991) and therefore might be expected to be favored by the 33-34 inches rainfall regime of the baseline scenario.

The substantial increase in grasses on the loamy sand type over the 25 years of the baseline scenario is likely to have been the result of two primary factors. First, is the rainfall regime. Mid- and tallgrass prairie commonly occurs on areas receiving 20-40 inches of rain annually (Weaver and Clements 1938:517; Weaver 1954:7; Shelford 1963:334; Stoddart et al. 1975:28; Smeins and Diamond 1983; Smeins 1994a; Bailey 1995:46). Consequently, the 33-34 inches average annual rainfall level is near the upper level for grasslands and therefore would favor relatively high production by grasses. Second, the livestock stocking rate was held to a moderate level for the initial conditions (112 g/m² of grasses = 1000 lbs/ac). As grass production increased, stocking rate did not increase and therefore the stocking rate became light over time. A low stocking rate combined with abundant moisture resulted in an increase in grasses.

The improved conditions for the grasses also resulted in a change in species composition (Table 9.1). Sideoats grama and purple threeawn were secondary species initially. They had become site dominants by the end of 25 years. Sideoats is a midgrass that can rapidly increase under favorable environmental conditions because of its relatively rapid growth rate, high seed production, and production of rhizomes. Sideoats had become the dominant herbaceous species on this site by Year 25, producing 43% of total aboveground herbaceous biomass. Purple threeawn is a rapidly-growing species characteristic of early mid-seral conditions. It rapidly increases once grazing pressure is reduced, and then begins to decrease once production of midgrasses increases substantially. Purple threeawn contributed 35% of total aboveground herbaceous biomass in Year 25. Little bluestem is a midgrass that is likely to become the dominant species on this site over time. However, it has a slower rate of increase than sideoats. By Year 25, little bluestem production had increased almost two-fold over initial conditions and contributed 16% of total aboveground herbaceous biomass.

Ragweed is a native perennial forb that increases under heavy grazing and other stress disturbances (e.g., drought). Standing crop biomass of ragweed on the loamy sand type was 28 g/m² initially, comprising 19% of total aboveground herbaceous biomass (Table 9.1). By Year 25, ragweed produced only 2 g/m² and this was less than 0.2% of total aboveground herbaceous biomass. The species was replaced successionally by the grasses, which is the expected response under the conditions of the baseline scenario.

9.1.1.3 Other Types

Results of the simulations for the other selected types also reflect expected ecological responses (Table 9.1). On the loamy bottomland type, tree biomass decreased overall but biomass of the late-seral trees (pecan, live oak) increased. All shrubs decreased except for whitebrush, which is well-adapted to the moderate rainfall conditions of the baseline scenario and is a shrub species that can form dense stands moderate conditions of moderate shading. Big bluestem is a tallgrass adapted to mesic conditions. It increased ten times more on the loamy bottomland type than on the blackland (coastal) type, which would be expected because of higher water availability on the bottomland type. The other herbaceous species that increased substantially on the loamy bottomland site were sideoats grama, little bluestem, and flatsedge (*Cyperus odoratus*). All three of these species would be expected to have substantial increases on this relatively wet site.

The salty prairie type occurs on wet sites that are saline. Gulf cordgrass and sea oxeye (*Borrchia frutescens*) increased substantially on this type and both species are salt-tolerant wetland species. Two other species, knotroot bristlegrass and frogfruit (*Phyla nodiflora*), also increased on this type and both of these are species that tolerate frequent flooding.

The shallow ridge type initially supported a blackbrush-guajillo-mesquite shrubland, with a sparse herbaceous component consisting of 46 g/m² of grasses and 14 g/m² of forbs (Table 9.1). At the end of the 25-year simulation, total woody plant biomass remained about the same as at the beginning of the simulation but blackbrush and mesquite increased and guajillo (*Acacia berlanderi*) decreased. Guajillo is a relatively palatable shrub for deer, and for cattle during winter and in dry periods. Livestock stocking rate was not decreased during the 25-year simulation and the amount of available grasses was low throughout the simulation. Therefore, grasses were heavily utilized by both cattle and deer, reducing grass production to 6 g/m² compared to 46 g/m² at the beginning of the simulation. Production of the palatable guajillo also decreased because of browsing by deer and cattle, while production of the less-palatable blackbrush and the unpalatable mesquite increased because of less competition from guajillo. In addition, production of the relatively unpalatable ragweed also increased, from 13 g/m² in Year 1 to 54 g/m² in Year 25. In summary, the shallow ridge type changed from a blackbrush-guajillo-mesquite community with a weak understory of perennial grasses to a blackbrush-mesquite-guajillo community with a ragweed understory.

9.1.2 Dry Cycle

The dry cycle scenario was simulated as the baseline scenario except with the rainfall input changed from that of 1928-1952 (average rainfall cycle, annual mean = 33.77 inches) to that of 1915-1939 (dry rainfall cycle, annual mean = 30.96 inches). Initial conditions, including livestock stocking rates, were the same for both the baseline and dry scenarios.

Overall mean aboveground biomass, averaged over the seven plot types, in Year 25 was 3,372 g/m², of which 2,838 g/m² (84%) were from woody species and 534 g/m² (16%) were from herbaceous species (Table 9.2). Under the baseline scenario, these values were 3,475 g/m² total, 2,877 g/m² woody, and 598 g/m² herbaceous (Table 9.1). Rainfall for the dry scenario was 8.3% less than under the baseline scenario. The reduction in rainfall resulted in total aboveground biomass decreasing by 3.0%. However, the effect of the reduced rainfall was not uniform over lifeforms. Herbaceous species biomass decreased by 10.7% whereas woody species decreased by only 1.4%.

The smaller effect of the dry cycle on woody species was the result of the greater rooting depth of woody species compared to herbaceous species, with the corresponding ability of woody species to deep moisture, especially groundwater. The relatively large increase in huisache (11%; Table 9.3) was the result of reduced competition by grasses for soil moisture. Within the shrub component, most species were largely unaffected ($\pm 5\%$ of baseline) by the dry cycle (Table 9.3). The exceptions were blackbrush and whitebrush. Blackbrush was unaffected by the dry cycle except on the shallow ridge type (Table 9.2), where blackbrush production was about half that under baseline conditions. The shallow ridge type is the most xeric of the types supporting blackbrush, therefore it is logical that production would be most affected on this type.

Whitebrush increased under the dry cycle on most types. This was likely the result of reduced competition from grasses.

Table 9.2 Aboveground biomass (g/m²), by lifeform and major species, in seven plot types at the end of the growing season in Year 25 of a 25-year simulation under dry and wet precipitation scenarios, Goliad County EDYS model. Average annual rainfall for the dry scenario = 30.96 inches and for the wet scenario = 39.92 inches.

Lifeform or Species	Blackland Coastal		Clay Loam		Loamy Bottomland		Loamy Sand		Salty Prairie		Shallow Ridge		Tight Sandy Loam	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Trees	213	209	1217	1203	6153	5528	4582	4656	340	326	735	477	2898	2910
Shrubs	34	36	874	771	1005	533	353	340	145	135	885	1993	431	390
Midgrasses	75	221	54	187	46	34	501	619	680	769	t	9	410	446
Shortgrasses	580	660	314	642	1	55	197	270	31	55	t	3	299	458
Grass-Likes	0	0	0	0	151	473	0	0	0	0	0	0	0	0
Forbs	3	2	2	2	31	79	3	3	4	62	355	10	5	4
Total aboveground	905	1128	2461	2805	7387	6702	5636	5888	1200	1347	1975	2492	4043	4208
Huisache	116	114	411	413	558	596	---	---	283	268	---	---	---	---
Pecan	---	---	---	---	823	723	---	---	---	---	---	---	---	---
Sugar hackberry	4	4	---	---	743	741	---	---	---	---	---	---	---	---
Mesquite	82	80	806	790	373	370	838	817	57	58	735	477	1100	1088
Live oak	11	11	---	---	3656	3098	3744	3839	---	---	---	---	1798	1822
Guajillo	---	---	---	---	---	---	---	---	---	---	161	173	---	---
Blackbrush	5	5	76	77	---	---	---	---	---	---	688	1755	113	114
Whitebrush	6	6	298	222	600	155	---	---	---	---	---	---	---	---
Baccharis	---	---	26	28	46	42	---	---	---	---	---	---	---	---
Sea oxeye	---	---	---	---	---	---	---	---	145	135	---	---	---	---
Granjeno	13	13	280	272	76	80	248	237	---	---	---	---	279	246
Wolfberry	---	---	8	7	---	---	---	---	---	---	---	---	---	---
Agarito	t	t	5	3	---	---	---	---	---	---	---	---	---	---
Mustang grape	---	---	---	---	283	256	66	66	---	---	---	---	---	---
Prickly pear	10	12	181	162	---	---	39	37	---	---	36	65	39	30
Big bluestem	16	29	---	---	7	3	---	---	---	---	---	---	---	---
Purple threeawn	284	292	214	285	---	---	195	269	---	---	t	1	290	282
Silver bluestem	53	165	46	167	1	1	37	65	---	---	---	---	239	260
Sideoats grama	t	2	1	2	16	10	346	376	---	---	0	6	5	2
Hairy grama	35	48	t	3	---	---	1	t	---	---	0	1	6	174
Buffalograss	256	309	68	278	t	t	---	---	---	---	---	---	---	---
Hooded windmill	5	6	32	76	---	---	1	1	---	---	0	1	3	2
Trichloris	t	9	6	17	2	2	---	---	---	---	t	t	166	184
Vine-mesquite	0	t	t	t	1	2	---	---	---	---	---	---	---	---
Switchgrass	1	2	---	---	5	4	4	4	t	t	---	---	---	---
Little bluestem	3	4	1	1	15	14	114	174	t	t	0	3	---	---
Knotroot bristle	t	t	t	t	t	t	---	---	31	55	---	---	---	---
Indiangrass	t	2	t	t	---	---	---	---	t	t	---	---	---	---
Gulf cordgrass	---	---	---	---	---	---	---	---	680	769	---	---	---	---
Tall dropseed	2	8	t	t	---	---	---	---	---	---	---	---	---	---
Texas wintergrass	t	5	t	t	t	53	---	---	---	---	0	t	---	---
Flatsedge	---	---	---	---	151	473	---	---	---	---	---	---	---	---
Ragweed	1	1	1	1	1	2	1	1	---	---	355	10	2	2
Old-mans beard	2	1	t	t	21	69	---	---	---	---	---	---	---	---
Frogfruit	---	---	t	t	t	t	---	---	3	59	---	---	---	---
Glasswort	---	---	---	---	---	---	---	---	1	3	---	---	---	---
Bush sunflower	---	---	1	1	---	---	2	2	---	---	---	---	3	2
Greenbriar	---	---	---	---	9	8	---	---	---	---	---	---	---	---

Grass production was strongly reduced under the dry cycle, and midgrasses more than shortgrasses (Table 9.3). The largest proportional decrease in grasses was for big bluestem. Big bluestem is a tallgrass, adapted to mesic conditions. It is therefore not surprising that it was strongly affected by the lower rainfall regime of the dry cycle. Little bluestem was the second-most strongly affected and it is the second-most mesic of the midgrass group. Silver bluestem is the most drought-resistant of the midgrasses (e.g., water-use efficiency of 620 g water/g dry biomass compared to 712 for sideoats grama; McGinnes and Arnold 1939) and it was the least affected except for gulf cordgrass. Gulf cordgrass occurs on low-elevation sites which receive surface runoff and have relatively high water tables. Therefore, it would be expected to be less affected than the more upland species.

Table 9.3 Aboveground biomass (g/m²) of major species in seven plot types at end of the 25-year simulation under three rainfall regimes, Goliad County EDYS model. Values averaged over the seven types (Tables 9.1 and 9.2).

Species	Mean Aboveground Biomass			Proportion of Medium-Regime Biomass		
	Dry	Medium	Wet	Dry	Medium	Wet
Trees						
Huisache	1368	1232	1391	1.110	1.000	1.129
Pecan	823	820	723	1.004	1.000	0.882
Sugar hackberry	747	751	745	0.995	1.000	0.992
Mesquite	3991	3840	3680	1.039	1.000	0.958
Live oak	9209	9304	8770	0.990	1.000	0.943
Shrubs						
Blackbrush	882	1543	1951	0.572	1.000	1.264
Whitebrush	904	640	383	1.413	1.000	0.598
Sea oxeye	145	138	135	1.051	1.000	0.978
Granjeno	896	868	848	1.032	1.000	0.977
Mustang grape	349	336	322	1.039	1.000	0.958
Prickly pear	305	320	306	0.953	1.000	0.956
Midgrasses						
Big bluestem	23	125	32	0.184	1.000	0.256
Silver bluestem	376	463	658	0.812	1.000	1.400
Sideoats grama	368	481	398	0.765	1.000	0.827
Trichloris	174	233	212	0.747	1.000	0.910
Little bluestem	133	215	196	0.619	1.000	0.912
Gulf cordgrass	680	740	769	0.919	1.000	1.039
Shortgrasses						
Purple threeawn	983	1046	1128	0.940	1.000	1.078
Hairy grama	42	16	226	2.625	1.000	14.125
Buffalograss	324	359	587	0.903	1.000	1.635
Knotroot bristlegrass	31	56	55	0.554	1.000	0.982
Forbs						
Ragweed	361	61	17	5.918	1.000	0.279
Old-mans beard	23	6	70	3.833	1.000	11.667

Knotroot bristlegrass, a shortgrass, is most commonly found on wet sites or sites with poor drainage. Of the four shortgrasses listed (Table 9.3), it was the species most affected by the dry cycle. Hairy grama is a drought-tolerant shortgrass that is abundant throughout the Southwest United States and northern Mexico. McGinnes and Arnold (1939) reported an average water-use efficiency of 483 (g water/g dry-weight aboveground production) for hairy grama, compared to 620 for silver bluestem and 712 for sideoats grama. In the simulations, hairy grama increased substantially under the dry cycle and this increase can be attributed to reduced competition from the other more drought-sensitive grasses. The dry cycle shifted the moisture conditions to those more similar to areas where hairy grama is most abundant. Similarly, the perennial forbs ragweed and old-mans beard increased substantially under the dry cycle. This was also most likely the result of reduced competition from grasses and the ability of ragweed to tolerate relatively dry conditions.

9.1.3 Wet Cycle

The wet cycle scenario was simulated as the baseline and dry scenarios except with the rainfall input changed to that of 1957-1981. Average annual rainfall during 1957-1981 was 39.92 inches, an increase of 5.25 inches (18.2%) per year.

Overall mean aboveground biomass in Year 25 under the wet cycle scenario was 3,510 g/m² (Table 9.2). This was only slightly higher than as under the baseline scenario (3,475 g/m²). Although overall production did not increase much, the composition of the various lifeforms and species changed substantially. Average woody aboveground biomass for woody species was 2,787 g/m² and 723 g/m² for herbaceous species. This was a 3.1% decrease in woody species biomass compared to baseline and a 20.9% increase in herbaceous biomass.

Relatively wet conditions occurred in South Texas beginning in 1957, following the drought of 1950-1956. Despite above-average rainfall mesquite, granjeno, and prickly pear decreased in cover on the Welder Wildlife Refuge in San Patricio County over a 15-year period following the drought while huisache increased (Drawe et al. 1978). These were the same responses as those in the simulations under the wet scenario. Mesquite decreased by 4%, granjeno decreased by 2%, prickly pear decreased by 4%, and huisache increased by 13% (Table 9.3).

Whereas drought-tolerance and water-use efficiency were the primary factors explaining vegetation responses under the dry cycle, growth rate and maximum potential productivity were the major factors under the wet cycle. Herbaceous species decrease more rapidly under dry conditions than do woody species and they increase more rapidly than woody species under wet conditions. The 40-inch average annual rainfall level of the wet cycle is the approximate level at which woodlands replace grasslands as the dominant vegetation type (Section 9.1.1.2). At this rainfall level (i.e., 40 inches per year), the successional pattern beginning with the initial (Year 1; Table 9.1) conditions used in the simulations would likely be an increase in grasses until the maximum production of these species is reached, then an increase in mid-successional woody species, followed by an increase in late-seral species. The transition to mid- and late-successional trees would likely take more than the 25 years of the simulation.

Within the herbaceous component, production by midgrasses was about equal to that under the baseline scenario (362 and 359 g/m², respectively) but production by shortgrasses increased substantially over baseline (314 and 219 g/m², respectively). As rainfall increases, competitive advantage should shift from shortgrasses to midgrasses in the absence of grazing by livestock. Conversely, as grazing intensity increases there is a competitive shift back to shortgrasses. A moderate stocking rate by cattle was simulated under both the baseline and wet scenarios. This level of grazing was sufficient to keep midgrass production at baseline levels while allowing shortgrasses to increase.

Overall grass production (midgrasses + shortgrasses) averaged 676 g/m² over the seven vegetation types under the wet scenario (Table 9.2). This amount includes basal crown biomass, which is generally not included in biomass values reported in literature studies of grassland production. Clippable biomass, which is what most literature studies report, for grasses in EDYS simulations varies by species, but it averages about 60% of aboveground biomass. Converting the total aboveground value of 676 g/m² to clippable would equal 406 g/m² of aboveground biomass of grasses under a precipitation regime that averaged 39.9 inches per year. This compares favorably with published values for bluestem grasslands (Table 9.4).

Table 9.4 Aboveground production (g/m² clippable biomass) and annual precipitation (PPT; inches) reported for various bluestem and coastal prairie communities.

Community	Location	PPT	Production	Reference
Big bluestem-little bluestem	Kansas	34.4	357	Briggs & Knapp 1995
Big bluestem-little bluestem	Kansas	31.9	325	Owensby & Anderson 1967
Big bluestem-little bluestem	Oklahoma	44.8	349	Brummer et al. 1988
Little bluestem-big bluestem	Oklahoma	32.7	422	Hazell 1967
Tall dropseed-silver bluestem	Oklahoma	32.7	355	Hazell 1967
Sandhill bluestem-splitbeard bluestem	Louisiana	57.9	340	Duvall & Linnartz 1967
Sandhill bluestem-splitbeard bluestem	Louisiana	57.9	377	Grelen & Epps 1967
Little bluestem-tall dropseed	Texas	31.5	208	McLendon et al. 2001
Buffalograss-silver bluestem	Texas	28.3	164	Box & White 1969
Knotroot bristlegrass-plains bristlegrass	Texas	28.3	249	Box & White 1969
Gulf cordgrass-bermudagrass	Texas	35.0	543	Garza et al. 1994
MEAN		36.9	335	

Of the major species of midgrasses, two increased (silver bluestem, gulf cordgrass) and four decreased under the wet regime when compared to baseline (Table 9.3). Three of the four midgrasses that decreased are decreaser species, i.e., they are among the first species to decrease as grazing intensity increases. The exception, trichloris, is an earlier mid-successional species that would be expected to decrease in response to an increase in other midgrasses (e.g., silver bluestem). Silver bluestem is less preferred by cattle than big bluestem, little bluestem, or sideoats and would therefore increase under moderate grazing before there was an increase in the other three grasses. Silver bluestem was the major midgrass species that increased over a 15-year period following reduction in grazing pressure on the Welder Wildlife Refuge (Drawe et al. 1978).

Gulf cordgrass also increased during the wet regime. This species forms almost monospecific stands in saline depressions in the coastal prairie region. Although average rainfall in the wet

scenario increased 18% over baseline, production of gulf cordgrass increased by only 4% (Table 9.3). The corresponding aboveground biomass value of 769 g/m² is probably approaching the upper limit of potential productivity of this species (Garza et al. 1994).

Of the four major species of shortgrasses, three increased (Table 9.3). Purple threeawn has a lower preference rating for cattle than many other grasses and it is not surprising that it increased under more favorable growing conditions. Buffalograss is one of the first species to begin to increase once more favorable conditions return (Box and White 1969).

Of the two major perennial forb species, one decreased and one increased. Ragweed is an upright perennial forb most abundant in lower successional semi-arid grasslands. It decreased under the wet regime, most likely because of competition from the grasses. Old-mans beard is a trailing vine that can form dense stands under mesic conditions (Drawe et al. 1978). This species increased under the wet scenario. The relative importance of these two forb species reversed between the baseline and wet scenarios. Under baseline, ragweed averaged 61 g/m² and old-mans beard averaged 6 g/m² (Table 9.3). Under the wet scenario, ragweed averaged 17 g/m² and old-mans beard averaged 70 g/m².

9.1.4 Brush Management

Five brush management scenarios were simulated. In each case, the basic brush treatment was the same: 100% of the aboveground woody biomass and 50% of the aboveground herbaceous biomass were removed from all non-urban areas that initially had 30% or more woody plant cover and less than 12% slope. Brush control was simulated to occur in March of Year 1. Pecan and live oak were excluded from the brush control operation, assuming that these trees would be left as desirable species. The 50% level was selected in order to allow large live oak trees to remain on the landscape. The removal of 50% of herbaceous vegetation was included because the brush management method being simulated was root-plowing, which disturbs the soil surface thereby removing a portion of established herbaceous plants.

The five brush management scenarios were: 1) the basic brush treatment applied under the average rainfall regime (daily rainfall amounts corresponding to 1928-1952), 2) the basic brush treatment applied under average rainfall regime, but removing 50% of oak biomass, 3) the basic brush treatment applied under the dry rainfall regime (daily rainfall amounts corresponding to 1915-1939) and removing 50% of oak biomass, 4) the basic brush treatment applied under the wet rainfall regime (daily rainfall amounts corresponding to 1957-1981) and removing 50% of oak biomass, and 5) the basic brush treatment applied under the moderate rainfall regime and removing 100% of woody species from all non-urban sites (i.e., not restricted to >30% woody cover and <12% slopes).

In four of the scenarios, brush management (root-plowing) was applied only to those areas with relatively dense (30% or more cover) stands of woody species. In actual practice, this would not likely be the case on a county-wide basis. In practice, different landowners throughout the county would make brush control decisions based on conditions specific to their particular land and management goals and therefore the density of brush treated would likely vary across the county. However, simulating treatment of the densest stands throughout the county should

provide an estimate of the maximum effect that brush control might have on ecohydrology, given the specific amount of area treated. The actual area treated in each of the four brush management scenarios was 18.4% of the area of Goliad County.

Each of the affected vegetation-soil-precipitation zone cell types responded differently to the brush management scenarios, as would be expected because of the ecological diversity. The ecological responses are integrations of the vegetation and land-use mosaics over each watershed. However, reporting vegetation responses for each vegetation type would be a substantial effort. There were 91 cell types that received brush control in these simulations. Instead of reporting each individually, results of vegetation responses on four major vegetation types are presented to illustrate the effects of the brush management on vegetation (Tables 9.6-9.8).

Brush control substantially reduced woody plant biomass even after 25 years on the clay loam site (Table 9.5). Under most scenarios, mesquite recovered to less than 10% of its initial biomass and huisache was largely eliminated from this site. Recovery of all woody species combined (trees and shrubs, Table 9.5) was 9.5%. This simulation assumed 100% removal of aboveground biomass of these two species from the initial root-plowing operation. In practice, a 95% rate would be more realistic. With a 95% initial removal, mesquite regrowth would likely be at least twice that of a 100% aboveground removal. Therefore, aboveground biomass of mesquite might be 10-20% of initial conditions after 25 years and total woody species perhaps 15-25%. Based on average height of shrub stands, Drawe et al. (1978) reported a 60% recovery of brush in the chaparral-mixed grass community on the Welder Wildlife Refuge in San Patricio County 30-35 years after root-plowing and that only half that increase, or about 30% recovery, occurred in 20-25 years. Based on the data from San Patricio County, the EDYS simulation values for brush recovery seem reasonable, but slightly on the low side. Instead of 10% recovery after 25 years from 100% removal (15-25% from 95% removal), recovery would probably be more on the order of 10-15%.

Table 9.5 Aboveground biomass (g/m^2) on the clay loam plot type (38% initial woody plant cover), by lifeform and by major species, at the end of 25 years following brush management in Year 1 under five brush control scenarios¹, Goliad County EDYS model.

Lifeform/Species	No BC Mod PPT	100% BC Mod PPT	50% Oak Mod PPT	50% Oak Dry PPT	50% Oak Wet PPT	All Sites Mod PPT
Trees	1278	54	54	16	2	52
Shrubs	898	152	151	143	133	173
Midgrasses	67	231	231	168	337	274
Shortgrasses	383	499	499	469	552	453
Forbs	2	24	25	26	20	24
Total Aboveground	2628	960	960	822	1044	976
Huisache	411	t	t	t	t	t
Mesquite	867	54	54	16	1	52
Blackbrush	76	t	t	t	t	t
Whitebrush	291	1	0	1	t	3
Baccharis	27	5	5	12	t	t
Granjeno	300	3	2	1	t	4
Prickly pear	192	143	144	130	133	166
Silver bluestem	57	174	173	120	250	169
Sideoats grama	2	14	14	6	16	21
Trichloris	7	8	8	11	32	6
Little bluestem	1	4	4	3	5	6
Plains bristlegrass	0	30	30	25	31	60
Johnsongrass	0	1	1	1	1	11
Purple threeawn	255	277	277	287	290	276
Buffalograss	92	203	204	162	239	163
Hooded windmillgrass	36	16	16	19	21	12
Wild indigo	0	16	16	16	14	17
Old-man's beard	t	4	4	6	1	2

¹ Brush control scenarios: No BC = no brush control (baseline, moderate rainfall); 100% BC = removal of 100% of woody species (except live oak) on sites >30% woody cover and <12% slopes; 50% Oak = removal of 100% of woody species (except 50% of live oak), on sites >30% woody cover and <12% slopes, under moderate (Mod), dry, and wet rainfall regimes; All Sites = removal of 100% of woody species (50% live oak) on all non-urban sites. Dashes (---) indicate that the species was not included in the simulation for that type. A trace amount (< 0.5 g/m^2) is indicated with a "t".

The brush control scenarios increased herbaceous production substantially. Total herbaceous aboveground biomass was 452 g/m^2 on the clay loam type under baseline conditions (no brush control, moderate rainfall regime) and 754 g/m^2 with brush control (Table 9.5), or an increase of 67% at the end of 25 years. Total aboveground herbaceous biomass in EDYS simulations includes the basal crown (trunk) biomass that is rarely sampled in clipping studies. Trunk biomass varies by species but in general accounts for about 40% of total aboveground biomass of herbaceous species in EDYS simulations (Appendix Table D.2). Adjusting the total aboveground herbaceous biomass values to clippable biomass results in values of 271 g/m^2 for the clay loam type under the baseline scenario and 452 g/m^2 with brush control, or an increase of 181 g/m^2 (1611 lbs/ac) in clippable biomass.

Production of midgrasses more than tripled following brush control (+ 164 g/m^2 = + 245%) and shortgrasses increased by 30% (+ 116 g/m^2)(Table 9.5). The major increase in midgrasses was from silver bluestem, with a smaller increase in plains bristlegrass. Buffalograss was the primary

shortgrass that increased. Silver bluestem and buffalograss were two of the major species that increased on the clay and clay loam sites on the Welder Wildlife Refuge over 8 years following reduction in livestock grazing (Box 1961; Box and White 1969) and silver bluestem increases as shrub density decreases on these clay loam sites (Drawe et al. 1978).

Similar patterns occurred in the brush control scenarios under dry and wet rainfall regimes as occurred under the moderate rainfall regime (Table 9.5). Total aboveground biomass was lower under the dry regime than under the moderate regime and was higher under the wet regime. Under the dry regime, there was a smaller increase in biomass for silver bluestem, sideoats grama, plains bristlegrass, and buffalograss than under the moderate regime but a larger increase in trichloris, purple threeawn, and hooded windmillgrass. The last three species are more xeric species than the first four and would therefore be expected to be favored more, in relation to the more mesic species, by drier conditions. Conversely, silver bluestem, sideoats grama, little bluestem, and buffalograss increased more under the wet regime. Trichloris also increased under the wet regime. It is a midgrass and although more xeric than silver bluestem, it also responded favorably to the increased moisture.

Woody species did not recover as quickly under the wet regime as they did under the moderate rainfall regime. The likely reason was competition for moisture from the herbaceous species. The 100% removal of aboveground parts of the woody species effectively reduced these species to the seedling stage during early recovery. The dense stand of more rapidly growing grasses that then developed largely out-competed the small shrub plants. The trees and shrubs would be expected to continue to slowly grow and over a longer period of time would eventually replace the grasses. However, under the conditions of these simulations it will take longer than 25 years.

On the loamy bottomland site, the brush control operations effectively reduced the target woody species (Table 9.6). Under the 100% brush control scenario, no live oak was removed. Under these conditions, Johnsongrass and greenbriar (*Smilax bona-nox*) dominated the understory community. Production of other herbaceous species, except for the perennial grass brownseed paspalum and the vine-like old-man's beard, was reduced compared to baseline conditions. When 50% of the live oak was removed, Johnsongrass and brownseed paspalum increased even more, greenbriar production remained about the same, but production of old-man's beard decreased. The dry regime favored most of the other grasses at the expense of Johnsongrass, but both greenbriar and old-man's beard increased.

Johnsongrass strongly dominated the herbaceous community under the wet regime, producing 70% of the aboveground biomass of all herbaceous species combined. Plains bristlegrass and old-man's beard also increased under the wet regime, but at a lesser rate than Johnsongrass. The plant community developing under the wet regime consisted of a discontinuous overstory of live oak trees with a dense stand of grasses, mostly Johnsongrass, as an understory. Aboveground biomass of grasses and grass-likes was 740 g/m², or about 440 g/m² (4000 lbs/ac) clippable. This level of annual herbaceous production is typical of bluestem grasslands in mesic regions of Kansas, Louisiana, and Oklahoma (340-420 g/m²: Grelen and Epps 1967; Hazell 1967; Brummer et al. 1988; Briggs and Knapp 1995) and almost as much as improved pastures on the Coastal Plains (500-1100 g/m²; McCawley 1978, Kapinga 1982).

Table 9.6 Aboveground biomass (g/m^2) on the loamy bottomland type (63% initial woody plant cover), by lifeform and by major species, at the end of 25 years following brush management in Year 1 under five brush control scenarios¹, Goliad County EDYS model.

Lifeform/Species	No BC Mod PPT	100% BC Mod PPT	50% Oak Mod PPT	50% Oak Dry PPT	50% Oak Wet PPT	All Sites Mod PPT
Trees	6028	3315	1670	1636	1576	2435
Shrubs	739	253	249	256	253	250
Midgrasses	388	486	519	450	708	515
Shortgrasses	4	34	42	19	31	33
Grass-Likes	230	11	1	5	1	1
Forbs	24	234	208	289	110	194
Total Aboveground	7413	4333	2689	2655	2679	3429
Huisache	536	t	t	t	t	t
Pecan	820	5	6	2	t	771
Sugar hackberry	747	1	1	1	t	1
Mesquite	375	3	4	1	t	3
Live oak	3550	3308	1659	1632	1575	1659
Whitebrush	343	t	t	t	t	t
Baccharis	45	t	t	t	t	t
Granjeno	81	t	t	t	t	t
Mustang grape	270	253	248	256	253	250
Big bluestem	115	18	14	31	7	13
Sideoats grama	162	50	41	38	6	33
Switchgrass	14	10	10	10	7	10
Little bluestem	94	56	49	60	49	44
Plains bristlegrass	0	22	22	14	42	21
Johnsongrass	0	324	378	291	592	390
Brownseed paspalum	0	27	32	11	2	28
Texas wintergrass	t	t	t	t	24	t
Flatsedge	230	11	1	5	1	1
Old-man's beard	5	28	6	35	40	13
Greenbriar	17	204	200	255	69	179

¹ Brush control scenarios: No BC = no brush control (baseline, moderate rainfall); 100% BC = removal of 100% of woody species (except live oak) on sites >30% woody cover and <12% slopes; 50% Oak = removal of 100% of woody species (except 50% of live oak), on sites >30% woody cover and <12% slopes, under moderate (Mod), dry, or wet rainfall regimes; All Sites = removal of 100% of woody species (50% live oak and 0% pecan) on all non-urban areas.

Dashes (---) indicate that the species was not included in the simulation for that type.

A trace amount (<0.5 g/m^2) is indicated with a "t".

Brush control had less of a positive effect on herbaceous production on both the tight sandy loam type (Table 9.7) and the loamy sand type (Table 9.8). When 50% of the oak was removed under the moderate rainfall regime there was only a 3% increase in herbaceous production on the tight sandy loam type and a 4% increase on the loamy sand type. This was likely because the woody species were primarily utilizing deeper soil moisture, rather than shallower moisture that was also in the rooting zone of the herbaceous species. Therefore, removal of the woody species had little effect on the amount of moisture available to the herbaceous species.

Table 9.7 Aboveground biomass (g/m²) on the tight sandy loam type (38% initial woody plant cover), by lifeform and by major species, at the end of 25 years following brush management in Year 1 under five brush control scenarios¹, Goliad County EDYS model.

Lifeform/Species	No BC Mod PPT	100% BC Mod PPT	50% Oak Mod PPT	50% Oak Dry PPT	50% Oak Wet PPT	All Sites Mod PPT
Trees	2952	1947	1118	942	941	1010
Shrubs	397	37	39	61	41	39
Midgrasses	547	578	580	493	493	580
Shortgrasses	284	277	276	296	408	278
Forbs	4	5	6	6	5	6
Total Aboveground	4184	2844	1919	1798	1888	1913
Mesquite	1078	18	25	18	t	9
Live oak	1874	1929	993	923	941	1001
Blackbrush	113	t	t	t	t	t
Granjeno	254	t	t	t	t	t
Prickly pear	30	36	38	61	41	38
Silver bluestem	323	304	314	248	271	309
Sideoats grama	2	66	62	95	55	79
Trichloris	224	207	202	147	166	190
Purple threeawn	276	273	272	292	281	273
Hairy grama	6	2	1	1	125	1

¹ Brush control scenarios: No BC = no brush control (baseline, moderate rainfall); 100% BC = removal of 100% of woody species (except live oak) on sites >30% woody cover and <12% slopes; 50% Oak = removal of 100% woody species (except 50% of live oak), on sites >30% woody cover and <12% slopes, under moderate (mod), dry, and wet rainfall regimes; All Sites = removal of 100% of woody species (50% live oak) on all non-urban areas. Dashes (---) indicate that the species was not included in the simulation for that type. A trace amount (< 0.5 g/m²) is indicated with a “t”.

Table 9.8 Aboveground biomass (g/m²) on the loamy sand type (38% initial woody plant cover), by lifeform and by major species, at the end of 25 years following brush management in Year 1 under five brush control scenarios¹, Goliad County EDYS model.

Lifeform/Species	No BC Mod PPT	100% BC Mod PPT	50% Oak Mod PPT	50% Oak Dry PPT	50% Oak Wet PPT	All Sites Mod PPT
Trees	4695	4056	2167	1998	1998	2098
Shrubs	324	119	117	121	117	117
Midgrasses	471	400	460	513	597	426
Shortgrasses	256	254	299	215	300	310
Forbs	5	4	5	4	1	4
Total Aboveground	5751	4873	2968	2851	3013	2955
Mesquite	826	3	5	1	t	4
Live oak	3869	4053	2082	1997	1998	2094
Granjeno	220	t	t	t	t	t
Mustang grape	66	83	81	84	81	81
Prickly pear	38	36	36	38	36	36
Silver bluestem	40	30	32	35	55	34
Sideoats grama	313	248	303	351	410	267
Switchgrass	4	3	4	4	8	4
Little bluestem	114	115	118	122	123	113
Plains bristlegrass	0	3	3	4	2	7
Purple threeawn	254	250	255	169	275	250
Brownseed paspalum	0	41	41	44	23	55

¹ Brush control scenarios: No BC = no brush control (baseline, moderate rainfall); 100% BC = removal of 100% of woody species (except live oak) on sites >30% woody cover and <12% slopes; 50% Oak = removal of 100% of woody species (except 50% live oak) on sites >30% woody cover and <12% slope, under moderate (Mod), dry, and wet rainfall regimes; All Sites = removal of 100% woody species (50% live oak) on all non-urban sites.

Dashes (---) indicate that the species was not included in the simulation for that type.

A trace amount (< 0.5 g/m²) is indicated with a “t”.

Under most of the brush control scenarios, herbaceous production was higher on the tight sandy loam type (Table 9.7) than on the loamy sand type (Table 9.8). This was the result of the higher sand content on the loamy sand type. Conversely, woody plant production was higher on the loamy sand type than on the tight sandy loam type. This was in response to higher soil moisture at deeper soil depths on the sand.

The vegetation relationships mentioned in this section up to this point are comparisons at the end of the 25 years. The model also simulates successional dynamics during the 25 years that occur in each of these types. For example, hooded windmillgrass, plains bristlegrass, and Johnsongrass are early- to mid-seral species on the clay loam type. Their abundance increases following brush control and then begins to decrease as other species become more abundant. Conversely, silver bluestem and buffalograss tend to increase later in succession. These were the responses simulated in the brush control scenarios (Fig. 9.1). Likewise, bushy bluestem (*Andropogon glomeratus*) is an early-seral species on the wetter sites. On the bottomland site following brush control, bushy bluestem production was 8 g/m² in the first year, increased to 63 g/m² by the fifth year, and then decreased to 2 g/m² by Year 25.

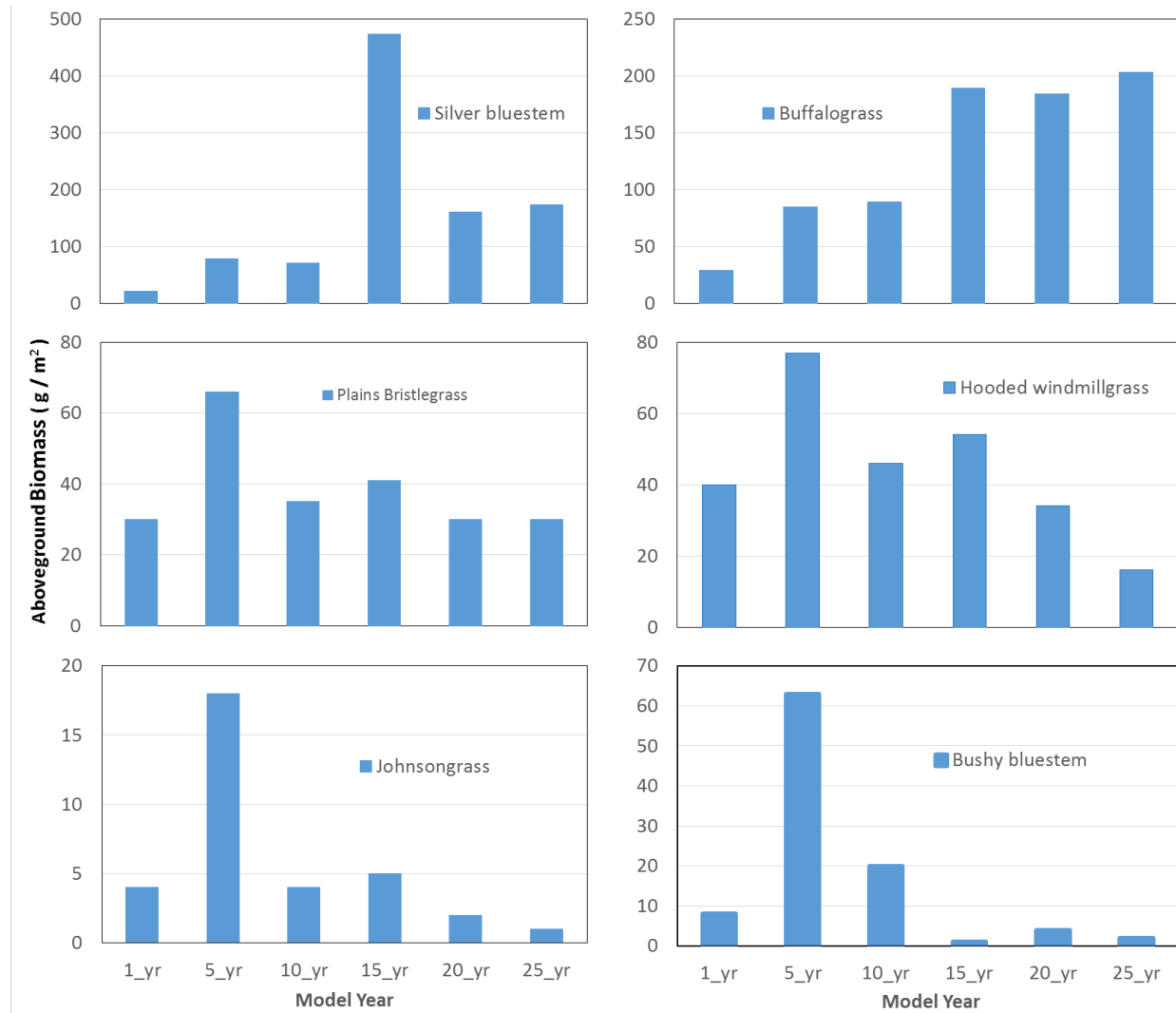


Figure 9.1 Changes in aboveground biomass (g/m²) of selected herbaceous species on the clay loam and loamy bottomland (bushy bluestem) type over a 25-year simulation following brush control under a moderate rainfall regime, Goliad County EDYS model.

9.2 Ecohydrology

9.2.1 Water Balance: Average Rainfall

Rainfall averaged 32.76 inches per year over the 25-year simulation under the average rainfall regime (Table 9.9). The difference in this amount from the 33.77 inches in the stated average rainfall scenario (Section 9.0) was the result of spatial variability across the County (Section 4.2). An average of 1.3% of annual rainfall left the landscape as surface runoff. This is about half as much as reported from gauged watersheds in San Patricio County (Ockerman 2002). The gauged watersheds in San Patricio County were much smaller than the area included in the Goliad County simulations and runoff would be expected to decrease across large landscapes because of increased surface roughness and longer transport distances. Evapotranspiration (ET)

was 16% more than rainfall when averaged over the 25 years (Table 9.9). This was possible because of a relatively high amount of groundwater use by the vegetation and by extraction of stored soil moisture. Groundwater use equaled almost 12% of annual rainfall and thus accounted for almost 75% of the amount that ET exceeded rainfall (12 out of 16 percentage points).

Table 9.9 Annual fluctuations in simulated hydrologic variables averaged over the entire Goliad County under the baseline (average rainfall regime) conditions.

Year	Rainfall (inches)	Rainfall (ac-ft)	Runoff (ac-ft)	Runoff/ Rainfall	ET (ac-ft)	ET/ Rainfall	GW Use (ac-ft)	GW Use/ ET	Net Soil Storage (ac-ft)
01	30.36	1,378,370	13,188	0.010	1,682,213	1.248	424,164	0.252	+ 107,133
02	41.64	1,889,942	37,880	0.020	2,007,592	1.062	197,197	0.098	+ 41,667
03	24.70	1,120,559	794	0.001	1,637,262	1.461	228,397	0.138	- 289,100
04	39.34	1,784,981	50,335	0.028	1,893,274	1.061	176,053	0.094	+ 17,425
05	33.79	1,578,504	27,986	0.018	1,887,143	1.196	193,431	0.103	- 143,194
06	30.54	1,385,587	10,384	0.007	1,783,913	1.287	196,237	0.110	- 212,473
07	39.46	1,790,059	37,024	0.021	1,672,730	0.934	179,817	0.107	+ 260,122
08	40.24	1,825,392	15,577	0.009	2,153,829	1.180	154,269	0.072	- 189,475
09	35.71	1,620,658	12,128	0.007	2,047,857	1.264	168,963	0.083	- 270,364
10	25.20	1,143,483	6,861	0.006	1,214,303	1.062	170,726	0.141	+ 93,045
11	24.70	1,120,640	25,690	0.023	1,523,016	1.359	159,143	0.104	- 268,923
12	20.42	926,631	8,687	0.009	1,321,310	1.426	161,881	0.123	- 241,485
13	38.61	1,751,956	18,797	0.011	1,660,962	0.948	143,372	0.086	+ 215,569
14	40.94	1,858,033	5,374	0.003	2,187,408	1.177	130,144	0.060	- 204,605
15	39.02	1,770,682	61,625	0.035	1,947,041	1.100	142,871	0.073	- 95,113
16	32.43	1,471,614	5,668	0.004	1,605,112	1.091	139,490	0.087	+ 324
17	31.66	1,436,587	7,400	0.005	1,775,597	1.236	144,795	0.082	- 201,615
18	27.70	1,256,563	2,128	0.002	1,537,608	1.224	140,001	0.091	- 143,172
19	44.86	2,035,293	22,274	0.011	2,114,782	1.039	143,689	0.068	+ 41,936
20	30.08	1,364,976	11,949	0.009	1,648,704	1.208	145,033	0.088	- 150,644
21	25.30	1,147,991	284	0.000	1,607,639	1.400	157,903	0.098	- 302,029
22	36.29	1,646,512	4,994	0.003	1,757,201	1.067	152,776	0.087	+ 37,093
23	17.04	773,153	3,110	0.004	1,279,204	1.655	158,559	0.124	- 350,602
24	33.23	1,507,469	54,365	0.036	1,567,823	1.040	148,307	0.095	+ 33,588
25	35.81	1,624,816	33,199	0.020	1,642,890	1.011	148,522	0.090	+ 97,249
Mean	32.76	1,487,218	19,094	0.013	1,726,256	1.161	172,230	0.100	- 85,902

Rainfall Year is the year from which the annual rainfall data were taken.

ET = evapotranspiration. GW Use = groundwater used by vegetation in transpiration (included as part of ET).

Net Soil Storage = Rainfall + GW Use – ET - Runoff.

The remaining amount of ET in excess of rainfall came from extraction of stored soil moisture. On average, there was an annual deficit of 85,900 acre-feet of soil moisture per year (Table 9.9). EDYS begins a simulation with a specified amount of soil moisture in each soil layer. This amount can be set at any level but is commonly set at 50% of field capacity for each layer. The amount of water corresponding to this level of soil moisture in each soil layer is available to plants for those layers within the rooting zone of each particular species. In this baseline scenario for the Goliad County model, there was soil moisture recharge in 11 years and an annual deficit in 14 years (Table 9.9). Both the direction and magnitude of this annual dynamic is dependent on a number of factors, including amount of rainfall, when the rainfall occurred, and vegetation composition and production.

In the baseline simulation, there was a net deficit over the 25 years and a deficit cannot be continued indefinitely. Over a sufficiently long period, soil moisture would eventually be

depleted and vegetation would adjust to a level and composition that could be supported by rainfall and groundwater only. The 85,900 acre-feet of annual deficit simulated in the baseline scenario for the entire County equals an average of 1.58 inches of soil water per year. At a 20% average field capacity, this equals to a dewatering rate of 7-8 inches per year. In 10-15 years, this rate would effectively dewater the rooting zone of most grasses and therefore make them dependent only on annual rainfall in most years. Deeper rooted woody species would continue to have access to deeper soil moisture for several decades longer and on groundwater as long as the water table did not decrease substantially.

Annual rainfall varied between 17.04 and 44.86 inches in the simulation and this variation resulted in substantial hydrologic variability (Table 9.9). Runoff was less than 1000 acre-feet county-wide in two years and was more than 50,000 acre-feet in three years. ET varied from less than 1.3 million acre-feet to almost 2.2 million acre-feet and from 93% of annual rainfall to 146% of annual rainfall. Groundwater use by vegetation varied between 130,000 acre-feet and 424,000 acre-feet.

9.2.2 Runoff

Runoff varied by year (Table 9.9) and under the different scenarios (Table 9.10). Annual variation resulted in large part because of 1) changes in amount of rainfall, 2) timing of the rainfall, and 3) changes in vegetation.

Table 9.10 Annual rainfall (inches) and annual runoff (acre-feet) averaged over the entire Goliad County under various 25-year EDYS simulations.

Scenario	Annual Runoff (ac-ft)	Runoff/Acre/Yr (inches)	Annual Rainfall (inches)	Runoff/Rainfall
Baseline	19,094	0.42	32.76	0.013
Dry Regime	15,900	0.35	29.80	0.012
Wet Regime	34,477	0.76	37.99	0.020
Brush Control				
100% Oak; Ave PPT	19,101	0.42	32.76	0.013
50% Oak; Ave PPT	19,121	0.42	32.76	0.013
50% Oak; Dry PPT	15,923	0.35	29.80	0.012
Brush Control, No Grazing				
50% Oak; Ave PPT	19,043	0.42	32.76	0.013
Maximum Brush Control				
All non-urban areas	19,149	0.42	32.76	0.013
Cultivation 6.5% of Area	18,897	0.41	32.76	0.013
Cultivation 21% of Area	18,281	0.40	32.76	0.013

Brush Control scenarios include 100% removal of all woody species except live oak. The amount of live oak removed is either 100% or 50%.

Cultivation scenarios replaced 6.5% or 21% of current vegetation in the County with cultivated land.

Average annual rainfall amounts in Table 9.10 do not equal those listed for the scenarios because of spatial variation over the County. The amounts listed for the scenarios are for the Goliad station.

Runoff decreased in drier years and increased in wetter years (Table 9.11). On average, runoff in dry years (average rainfall = 24 inches) decreased by 64% compared to runoff in moderate-rainfall years when rainfall averaged 40% more (mean = 33 inches). Runoff in wet years averaged 72% more than runoff in moderate-rainfall years. Rainfall increased by an average of 23% in these wet years compared to moderate rainfall years. By comparison, a 43% increase in annual rainfall resulted in a 57% increase in runoff on cultivated clay sites in Kleberg and Nueces Counties (Ockerman and Petri 2001). On average in the Goliad model simulations, one inch of annual rainfall resulted in 228 acre-feet of runoff in dry years, 549 acre-feet in moderate-rainfall years, and 768 acre-feet in wet years.

Table 9.11 Annual runoff (acre-feet, county-wide), annual rainfall (inches), and previous-year rainfall (inches) in EDYS simulations for dry, moderate, and high rainfall years, Goliad County EDYS model.

	Dry Years (< 29 in)			Moderate (29-38 in)			Wet Years (> 38 in)		
	Annual Rainfall	Annual Runoff	Previous Rainfall	Annual Rainfall	Annual Runoff	Previous Rainfall	Annual Rainfall	Annual Runoff	Previous Rainfall
	17.04	3,110	36.29	30.08	11,949	44.86	38.61	18,797	20.42
	20.42	8,687	24.70	30.36	13,188	-----	39.02	61,625	40.94
	24.70	794	41.64	30.54	10,384	33.79	39.34	50,335	24.70
	24.70	25,690	25.20	31.66	7,400	32.43	39.46	37,024	30.54
	25.20	6,861	35.71	32.43	5,668	39.02	40.24	15,577	39.46
	25.30	284	30.08	33.23	54,365	17.04	40.94	5,374	38.61
	27.70	2,128	31.66	33.79	27,986	39.34	41.64	37,880	30.36
				35.71	12,128	40.24	44.86	22,274	27.70
				35.81	33,199	33.23			
				36.29	4,994	25.30			
Mean	23.58	6,793	32.18	32.99	18,126	33.92	40.50	31,111	31.59

Although there was a strong relationship between runoff and average annual rainfall, there was high variation among years (Table 9.11). The four lowest runoff years occurred in the dry rainfall group, as would be expected. However, one dry year that received 24.7 inches of rainfall had as much runoff as a moderate-rainfall year that received 33.8 inches and more runoff than four of the high-rainfall years. Three of the high-rainfall years that received about the same amount of rainfall (40.2, 40.9, and 41.6 inches) had annual runoff that varied between 5,374 and 37,880 acre-feet. This among-year variability in runoff was not likely to have been the result of antecedent rainfall because average previous-year rainfall was similar among the three categories (dry, moderate, wet) and there was no consistent relationship among amount of runoff, previous-year rainfall, and annual rainfall.

The factors that most likely affected runoff on an annual basis were timing of the rainfall and vegetation condition at the time of rainfall. For example, annual rainfall was similar in Years 16 (1943 = 32.4 inches) and 24 (1951 = 33.2 inches), but annual runoff in Year 16 was 5,668 acre-feet compared to 54,365 acre-feet in Year 24 (Table 9.9). Monthly rainfall in Year 16 (1943) was less than 5 inches, except for May when it was about 6 inches. In Year 24 by contrast, nearly 9 inches was received in May and over 13 inches was received in September. Vegetation cover in Year 24 (1951) was low because of the beginning of the drought of the 1950s. Therefore, Year 24 received high rainfall in two months and had relatively low herbaceous

cover, resulting in high runoff. Rainfall in Year 16 (1943) was more uniform and herbaceous cover was higher because the three previous years received above average rainfall. Consequently, runoff in Year 16 was low.

Under the dry scenario (29.80 inches average annual rainfall), annual runoff decreased by about 3,100 acre-feet compared to baseline (32.76 inches average annual rainfall; Table 9.10). This was a 17% decrease in runoff corresponding to a 9% decrease in average annual rainfall. This response ratio to decreased rainfall over a 25-year period (17% decrease in runoff/9% decrease in rainfall = 1.9) is similar to the ratio indicated in the dry vs. moderate periods of the baseline scenario (64%/29% = 2.2; Table 9.11). Therefore, surface runoff may be expected to decrease at a rate (% basis) equal to twice that of the decrease in rainfall.

Under the wet scenario (37.99 inches average annual rainfall), annual runoff increased by about 15,500 acre-feet compared to baseline (Table 9.10). This was an 81% increase in runoff corresponding to a 16% increase in rainfall sustained over 25 years. This equals a 5.1 response ratio (81% increase in runoff/16% increase in rainfall = 5.06). The corresponding numbers for the moderate and wet years within the baseline scenario (Table 9.11) are a 61% increase in runoff at a 23% increase in rainfall, or a response ratio of 2.7 (61%/23%). The higher response ratio under the wet scenario was because there were more extreme events in the wet scenario. The wet scenario had 10 years (40%) receiving more than 42 inches per year, whereas only one year in eight (13%) exceeded 42 inches in the wet-year grouping under baseline conditions (Table 9.11), and five of the 25 years (20%) under the wet scenario received more than 50 inches of rainfall. Under rangeland conditions on the central Texas Coast, rainfall events of more than 4 inches produced six times as much surface runoff as moderate events (1.9-2.6 inches; Ockerman 2002). The response ratio in that study was 2.5 over a period of two years. That was very similar to the 2.7 response ratio for the EDYS simulations over the eight wet years of the baseline scenario.

Brush control had very little impact on surface runoff, under either average or dry rainfall scenarios (Table 9.10). This result was because herbaceous vegetation did not increase substantially following brush control. Woody plants have a substantial impact on ET and groundwater use, but herbaceous cover has a greater impact on influencing surface runoff. To achieve an increase in herbaceous cover following brush control, it is necessary to decrease livestock grazing for a long enough period (1-3 years) to allow the grasses to recover from the root plowing and to respond to the decrease in woody species. Without this rest period, livestock will consume the new growth before the plants can develop increased perennial structures. In many areas, reseeding of grasses is also required to achieve an increase in grass production in a reasonable period (e.g., less than 10 years).

Another brush control scenario was run to determine the effect of livestock grazing on hydrology following brush control. This scenario (Brush Control, No Grazing: Table 9.10) was the same as the 50% oak, average rainfall brush control scenario except that all livestock grazing was eliminated from the treated areas. It would not be practical to eliminate all livestock grazing for 25 years, but this scenario was run to determine what the maximum effect would be. Runoff decreased by almost 90 acre-feet per year (Table 9.10).

The brush control treatments were applied to about 102,400 acres county-wide (18% of the area) and these treated areas formed a mosaic throughout the county. Part of any increase in runoff from treated acreage can be reduced as it moves onto an adjacent untreated area, thereby reducing the overall effect of brush control on runoff. This also likely contributed to the minor effect of brush control on surface runoff.

There is relatively little cultivated land in Goliad County (8,527 acres; Wiedenfeld 2010). The normal scenarios used in EDYS applications to evaluate potential impacts from cultivation are to increase or decrease cultivation by a specified percentage, usually 25 or 50%. However, with such a small acreage of cultivated land included in baseline, increasing or decreasing this amount by 50% was not likely to have a noticeable effect on county-wide hydrology. Instead, two cultivation scenarios were run for Goliad County to evaluate potential impacts of cultivation on hydrology. In both scenarios, native vegetation was replaced by cultivated land (grain sorghum as a crop). In one scenario, cultivated land was increased to equal 6.5% of the total area in the county and in the other scenario 21% of the area of the county was placed into cultivation.

More land in Goliad County was under cultivation in the past. In 1954, 43,334 acres were under cultivation, mostly in corn, cotton, and milo (Dallas Morning News 1958), or about 7.9% of the area of the County. Cultivated acreage decreased substantially during and following the drought of the 1950s. Between 1950 (first year of the drought) and 1954, cultivated acreage had decreased by almost 10%. Therefore, the 6.5% area under cultivation scenario approximates the amount of cultivated land in Goliad County in the mid-1950s. The maximum potential amount of cultivated land in Goliad County, based on the USDA prime farmland classification (Wiedenfeld 2010:107), is 392,735 acres or nearly 71% of the County. Therefore, the 21% area under cultivation scenario would include about 30% of the maximum potential.

An increase in cultivation decreased surface runoff on a county-wide basis, but only by a small amount (Table 9.10). When cultivation was increased to 6.5% of the county (about 36,000 acres under cultivation), average annual runoff decreased by about 200 acre-feet. When cultivation was increased to 21% of the county (about 114,400 acres), average runoff decreased by about 820 acre-feet, compared to baseline. Surface runoff is generally lower from cultivated land than from areas covered in native vegetation because cultivation increases the porosity of the surface soil, thereby increasing infiltration, and cultivation generally reduces average slope. Furrowing also decreases runoff by restricting off-site flow of water. Ockerman and Petri (2001) reported surface runoff to be substantially lower on cultivated subwatersheds in Kleberg and Nueces Counties of South Texas, compared to adjacent rangeland subwatersheds.

9.2.3 Evapotranspiration

Evapotranspiration (ET) averaged 38.0 inches over the 25-year simulation period under baseline conditions, or about 116% of annual rainfall, but varied substantially from year to year (Table 9.9). In dry years (annual rainfall less than 29 inches), ET averaged 31.9 inches, 38.4 inches in moderate-rainfall years, and 43.1 inches in wet years (more than 38 inches)(Table 9.12). Although ET increased as rainfall increased, the ratio of annual ET:annual rainfall decreased (1.37 in dry years, 1.17 in moderate, and 1.06 in wet years; Table 9.12). This decrease was the

result of rainfall becoming increasingly sufficient to supply the moisture requirements of the vegetation, i.e., less groundwater was required.

Table 9.12 Annual evapotranspiration (ET; acre-feet, county-wide), annual rainfall (inches), and previous-year rainfall (inches) in EDYS simulations for dry, moderate, and high rainfall years, Goliad County EDYS model.

	Dry Years (< 29 in)				Moderate (29-38 in)				Wet Years (> 38 in)			
	Annual Rainfall	Annual ET	ET/ Rainfall	Previous Rainfall	Annual Rainfall	Annual ET	ET/ Rainfall	Previous Rainfall	Annual Rainfall	Annual ET	ET/ Rainfall	Previous Rainfall
	17.04	28.20	1.66	36.29	30.08	36.36	1.21	44.86	38.61	36.60	0.95	20.42
	20.42	29.16	1.43	24.70	30.36	37.08	1.25	-----	39.02	42.95	1.10	40.94
	24.70	33.60	1.36	41.64	30.54	39.36	1.29	33.79	39.34	41.63	1.06	24.70
	24.70	36.12	1.46	25.20	31.66	39.12	1.24	32.43	39.46	36.84	0.93	30.54
	25.20	26.76	1.06	35.71	32.43	35.39	1.09	39.02	40.24	47.39	1.18	39.46
	25.03	35.40	1.40	30.08	33.23	34.56	1.04	17.04	40.94	48.23	1.18	38.61
	27.70	33.84	1.22	31.66	33.79	41.63	1.20	39.34	41.64	44.29	1.06	30.36
					35.71	45.12	1.26	40.24	44.86	46.56	1.04	27.70
					35.81	36.23	1.01	33.23				
					36.29	38.75	1.07	25.30				
Mean	23.58	31.87	1.37	32.18	32.99	38.36	1.17	33.92	40.50	43.06	1.06	31.59

When groundwater is too depth for any significant use by vegetation, vegetation is dependent on precipitation, both current-year and stored soil moisture unused from previous years. This effectively limits maximum ET to an average of about 1.00 of annual precipitation when averaged over several years. Annual ET can exceed annual precipitation in some years because of use of stored moisture. For example, ET in a mesquite-granjeno shrubland in South Texas was 1.06 of annual rainfall in a dry year (13.0 inches ET) compared to 0.99 in a wet year (ET = 34.6 inches)(Weltz and Blackburn 1995). In the Rolling Plains of Texas, the annual ET:rainfall ratio varied over a three-year study period between 0.81 and 1.12 on a mesquite-grassland site and between 0.86 and 1.19 on an adjacent grassland site (Carlson et al. 1990).

Conversely, when groundwater is within reach of the vegetation root systems ET generally exceeds annual precipitation. The amount that it exceeds annual precipitation is dependent on depth to groundwater and the maximum productivity (and therefore maximum water requirement) of the vegetation. Mesquite woodland in southeastern Arizona had 33.4 inches of annual ET when depth to groundwater (DTW) was 6.5 feet, compared to 25.1 inches when DTW was at 32.6 feet (Scott et al. 2000, 2006).

Under simulated current conditions (baseline, no brush control), average annual ET was 38.04 inches, which was equal to 1,726,256 acre-feet of water removed county-wide (Table 9.13). The brush control scenario reduced that to 35.71 inches, or an average of 1,620,937 acre-feet per year. This was a reduction in water lost to ET of 105,319 acre-feet per year. In the dry-regime scenario, brush control reduced water lost to ET by 132,484 acre-feet per year. The maximum brush control scenario (removing all woody plants in non-urban areas) reduced ET substantially. This scenario is discussed in detail in Section 9.2.7.

Table 9.13 Effect of brush control and cultivation on annual evapotranspiration (ET) and annual groundwater use by vegetation averaged over 25-year simulations of the Goliad County EDYS model.

Scenario	Annual Rainfall (inches)	Annual ET (inches)	Annual ET (ac-ft)	ET/Rainfall	Annual Groundwater Use (inches)	Annual Groundwater Use (ac-ft)
Baseline, Average PPT	32.76	38.04	1,726,256	1.16	3.79	172,230
Baseline, Dry PPT	29.80	35.40	1,640,361	1.19	3.67	166,383
Brush Control						
50% Oak; Ave PPT	32.76	35.71	1,620,937	1.09	2.68	121,510
50% Oak; Dry PPT	29.80	33.23	1,507,877	1.12	2.63	118,991
Maximum; Ave PPT	32.76	31.71	1,439,006	0.97	0.80	36,326
Cultivation 6.5% of Area	32.76	36.92	1,675,645	1.13	3.48	157,674
Cultivation 21% of Area	32.76	34.42	1,561,468	1.05	2.76	125,343

An increase in cultivation also reduced ET (Table 9.13). When cultivation was increased to include 6.5% of the area of the county, ET was 50,611 acre-feet less than under baseline conditions (average rainfall regime). When cultivation was increased to 21% of the area, ET was 154,893 acre-feet less than under baseline conditions.

9.2.4 Groundwater Use by Vegetation

The baseline scenario indicated that present vegetation in Goliad County was utilizing an average of 172,230 acre-feet of groundwater per year, or an equivalent of 3.79 inches per year. This groundwater use was primarily by deep-rooted woody species such as mesquite, live oak, hackberry, and pecan. Brush control reduced this useage by an average of 50,720 acre-feet per year under the baseline rainfall regime and by an average of 57,392 acre-feet per year under the dry regime (Table 9.13). This reduction was because of the removal of most of the deep-rooted woody species.

Cultivation also had an effect on groundwater use by vegetation (Table 9.13). Under baseline conditions (average rainfall regime), groundwater use was reduced by 14,556 acre-feet per year when 6.5% of the area was under cultivation and by 46,887 acre-feet when cultivation increased to 21% of the area.

9.2.5 Change in Water Balance

In the most basic form, a landscape water balance compares water inputs, exports, and storage across the landscape. For the terrestrial component (i.e., excluding river and stream flows) of the Goliad County model, inputs are from rainfall and groundwater use. Exports are ET, surface runoff, and groundwater recharge (if any). Storage refers to moisture stored in the soil profile. The basic water balance equation is therefore given by:

$$\text{rainfall} + \text{groundwater use} = \text{ET} + \text{runoff} + \text{groundwater recharge} + \text{soil storage},$$

where the soil storage factor is a change (+ or –) in annual amount.

All scenarios except brush control under the wet regime and 21% of County in cultivation resulted in an average net water deficit over the 25-year simulation period (Table 9.14). The deficit increased under the dry regime as compared to the moderate rainfall regime and decreased under the wet regime. In the baseline scenarios (no brush control and no increase in cultivation), the wet regime (18% increase in average annual rainfall compared to the moderate regime), which used the daily rainfall data from 1957-1981, resulted in conditions where water losses were almost offset by water inputs. However, there was an average net annual deficit even under this wet regime. This suggests that under the present vegetation conditions, especially the amount of woody species present, it is unlikely that any consistent recharge will occur in Goliad County as a whole.

Table 9.14 Effect of moisture regime, brush control, and cultivation on average annual water balance components (acre-feet) simulated for 25-year scenarios using the Goliad County EDYS model.

Scenario	Rainfall	Groundwater Use	Runoff	ET	Net Storage
Moisture Regime					
Baseline, Ave PPT	1,487,218	172,230	19,094	1,726,256	- 75,902
Baseline, Dry PPT	1,365,762	166,383	15,900	1,604,361	- 88,116
Baseline, Wet PPT	1,723,842	155,747	34,477	1,855,027	- 9,915
Brush Control					
100% Oak; Ave PPT	1,487,218	131,096	19,101	1,641,010	- 41,797
50% Oak; Ave PPT	1,487,218	121,510	19,121	1,620,939	- 31,332
50% Oak; Dry PPT	1,365,762	118,991	15,923	1,507,877	- 39,047
50% Oak; Wet PPT	1,723,842	111,476	34,498	1,759,930	+ 40,890
Cultivation					
6.5% of County Area	1,487,218	157,674	18,897	1,675,645	- 49,650
21% of County Area	1,487,218	125,343	18,281	1,561,468	+ 32,812

Baseline = no brush control or change in amount of cultivated land.

Brush Control: all woody species oak and pecan removed from all areas with >30% woody plant cover and

less than 12% slope. In 100% oak scenario, all oak also removed. In 50% oak scenarios, only 50% oak removed.

Cultivation scenarios are at the moderate (baseline) rainfall regime.

Negative net soil water storage cannot be maintained indefinitely. In the model scenarios, the initial soil moisture condition throughout the soil profile was set at 50% of field capacity in each layer. Once this stored water is depleted by plants, the vegetation will either 1) utilize more groundwater or 2) adjust to the lower amount of available moisture by reducing the amount of vegetation present and its productivity. The model scenarios were for 25-year simulations. The 75,900 acre-feet deficit under the baseline, average rainfall scenario (Table 9.14) equals an average annual deficit of about 1.5 inches of water per year, averaged over the entire County. This corresponds to dewatering about 15-20 inches of soil per year (at 8-10% available water holding capacity), or about 30-40 feet over the 25-year simulation. The actual depth of

dewatering varies from year to year as more moisture is added from the top during wet periods and greater amounts are transpired from lower levels during dry periods. In addition, dewatering patterns are very different on wooded sites than on adjacent sites supporting mostly grasses.

The brush control scenarios decreased by annual water deficits by 50-60%, reducing the annual deficit to about 31,000 acre-feet in moderate-rainfall years and 39,000 acre-feet in dry years (Table 9.14). This reduction was achieved by reductions in vegetation biomass and in groundwater use. Under the 50% oak, 100% other woody species scenario reduced ET by 105,000 acre-feet per year, of which 45,000 acre-feet were from less transpiration of groundwater. The remaining 60,000 acre-feet resulted from a lower amount of transpired soil moisture because of lower vegetation demands. Under the dry regime, brush control reduced ET by 96,000 acre-feet per year, of which 47,000 acre-feet were from reduced transpiration of groundwater and 49,000 acre-feet were from reduced use of soil moisture.

When the wet regime (rainfall corresponding to 1957-81) was used in conjunction with brush control, there was a positive net storage of almost 41,000 acre-feet per year (Table 9.14). This amount of increased soil moisture storage equals about 0.9 inches of soil moisture per year, or a re-wetting of about 10 inches of the soil profile per year (assuming 8-10% available water-holding capacity). If this moisture regime continued sufficiently long to bring the soil profile above the water table up to field capacity, then this amount of water (41,000 acre-feet) would be added to groundwater or lateral flow to creeks and the river each year. In addition, 34,500 acre-feet would be added directly to creeks and the river each year from surface runoff (Table 9.14).

Only about 18% of the area of the County was treated in each of the brush control scenarios. Although these areas supported the densest stands of woody species, brush control on additional acres would reduce the annual water deficit even more. If woody species were substantially reduced on 40-50% of the area of the County, it is likely that there would be a water surplus in most years. This surplus would first recharge the soil profile and once the profile reached field capacity, additional water would likely move into groundwater recharge.

Cultivation had a similar effect on water balance as did brush control, for much the same reason (i.e., removal of deep-rooted woody species). When 6.5% of the County was modeled as cultivated land, annual water deficit was reduced to 50,000 acre-feet, or a reduction of about 35% compared to baseline (Table 9.14). This was equal about 60% of the reduction accomplished by applying brush control to 18% of the County. The increased effectiveness of water storage under cultivation compared to brush control is the result of the cultivated land being fallow for a large part of the year. And much of the fallow period is when the area receives much of its annual rainfall.

When cultivation was increased to 21% of the area, there was an annual surplus of moisture when averaged over the 25 years (Table 9.14). The annual surplus (32,812 acre-feet) is equal to about 0.72 inch per year averaged over the entire County, or 3.5 inches per acre of cultivated land, under the moderate rainfall regime. Around 1950, about 9% of the area of Goliad County was under cultivation. Under a moderate rainfall regime, that level of cultivation might result in a county-wide deficit of about 30,000 acre-feet per year, compared to a deficit under current

conditions of 76,000 acre-feet. Under a wet regime, the deficit might shift to a 5,000-10,000 acre-feet surplus.

9.2.6 Water Balance by Watershed

The water balance information presented previously was, for the most part, averaged over the entire county. However, landscape hydrology varies widely across the county because of differences in topography, soil, vegetation, and depth to groundwater. There are 81 watersheds delineated in Goliad County (Table 9.15), some of which have part of their area outside Goliad County (Fig. 9.2). The watersheds vary in size from less than 100 acres to more than 38,000 acres (Table 9.15).

Table 9.15 Average annual water balance components by watershed simulated for 25-year baseline scenario, expressed as watershed totals and per-acre averages, using the Goliad County EDYS model.

Watershed	Area (acres)	Rainfall (acre-feet)	Watershed Totals (acre-feet)			Per-Acre (inches)		
			GW-Use	ET	Runoff	GW-Use	ET	Runoff
Northeast Sector								
1101	10,392	27,109	2,365	29,710	340	2.73	34.31	0.39
1102	28,956	75,549	4,690	79,890	632	1.94	33.11	0.26
1103	9,076	25,112	3,139	29,263	381	4.15	38.69	0.54
1105	11,398	31,730	3,517	36,043	535	3.70	37.95	0.56
1106	14,382	40,039	3,696	43,932	418	3.09	36.66	0.35
1108	24,500	68,207	8,584	78,853	1,488	4.20	38.62	0.73
1136	18,068	49,876	4,893	56,046	690	3.25	37.22	0.46
1137	7,321	20,380	1,790	22,161	299	2.93	36.32	0.49
SUM	124,093	338,002	32,674	375,898	4,783	3.16	36.35	0.46
West Sector								
594	62	162	20	195	1	3.87	37.74	0.18
602	295	765	153	1,019	27	6.22	41.45	1.10
604	277	719	136	956	9	5.89	41.42	0.39
606	3,567	9,263	755	10,268	80	2.54	34.54	0.27
608	224	582	88	728	7	4.71	39.00	0.33
610	2,452	6,361	887	7,725	140	4.34	37.81	0.69
612	7,502	19,465	2,649	23,624	190	4.50	37.79	0.30
614	9,962	25,873	1,646	27,625	239	1.98	33.28	0.29
616	2,930	7,603	1,652	10,475	139	6.77	42.90	0.53
618	358	930	65	1,023	9	2.18	34.29	0.30
620	6,606	17,138	2,127	20,441	135	3.86	37.13	0.24
622	2,089	5,420	849	6,853	57	4.83	39.36	0.32
624	9,236	23,964	3,258	29,328	200	4.23	38.10	0.26
626	1,188	3,081	235	3,398	63	2.37	34.32	0.64
628	4,600	11,935	1,534	14,480	99	4.00	31.25	0.26
630	366	950	173	1,257	11	5.67	42.21	0.36
632	982	2,547	718	3,828	72	8.77	46.78	0.89
634	3,298	8,662	604	9,186	208	2.20	33.42	0.76
636	1,262	3,292	478	3,982	98	4.55	37.87	0.93
638	4,362	11,316	1,252	13,202	109	3.44	36.32	0.30
640	5,490	14,359	1,657	16,918	175	3.62	36.98	0.38
648	1,766	4,607	422	5,135	63	2.87	34.89	0.43
650	7,860	20,502	2,383	24,164	169	3.64	36.89	0.26
652	8,127	22,474	2,734	26,371	256	4.04	38.94	0.38
654	3,235	9,005	884	10,192	100	3.28	37.81	0.37
656	548	1,522	572	2,542	32	12.45	55.67	0.70
658	3,792	10,552	2,551	14,771	267	8.07	46.74	0.84
660	3,922	10,919	1,118	12,394	128	3.42	37.92	0.39

Table 9.15 (Cont.)

Watershed	Area (acres)	Rainfall (acre-feet)	Watershed Totals (acre-feet)			Per-Acre (inches)		
			GW-Use	ET	Runoff	GW-Use	ET	Runoff
662	2,561	7,130	940	8,484	219	4.40	39.75	1.03
664	3,194	8,835	1,122	10,430	123	4.22	39.19	0.46
666	448	1,246	266	1,689	45	7.13	45.24	1.20
668	2,771	7,714	656	8,424	111	2.84	36.48	0.48
670	4,449	12,385	1,936	15,180	303	5.22	40.94	0.82
SUM	109,781	291,278	36,520	346,287	3,884	3.99	37.85	0.42

Central Sector

672	8,866	24,681	3,389	29,133	627	4.59	39.43	0.84
674	5,916	16,470	997	16,973	265	2.01	34.43	0.54
676	1,709	4,758	875	6,081	147	6.14	42.70	1.03
686	3,546	9,249	587	9,817	90	1.99	33.22	0.30
688	2,327	6,071	362	6,361	59	1.87	32.80	0.30
690	5,852	15,265	960	16,173	141	1.97	33.16	0.29
692	2,598	6,778	441	7,228	65	2.04	33.38	0.30
694	3,105	8,413	435	8,650	94	1.68	33.43	0.36
696	4,316	11,898	1,336	13,826	148	3.71	36.12	0.41
698	254	706	45	750	35	2.13	35.43	1.65
700	6,717	18,071	1,429	19,714	192	2.55	35.22	0.34
702	6,518	18,147	1,572	20,025	207	2.89	36.87	0.38
704	4,420	12,304	887	13,093	162	2.39	35.55	0.44
706	2,007	5,587	383	5,844	90	2.24	34.94	0.54
708	1,997	5,560	773	6,603	74	4.64	39.78	0.48
710	3,423	9,530	723	10,196	129	2.53	35.74	0.45
712	787	2,190	205	2,408	35	3.13	36.72	0.53
714	2,870	7,990	860	9,110	117	3.60	38.09	0.49
716	128	355	59	438	10	5.53	40.28	0.86
718	2,056	5,724	420	6,075	94	2.45	35.46	0.55
720	3,563	9,919	1,380	11,726	206	4.65	39.49	0.69
722	11,834	32,945	5,957	41,622	851	6.04	42.04	0.86
724	8,813	24,534	1,538	25,449	362	2.09	34.65	0.49
726	2,747	7,648	1,115	9,143	179	4.87	39.94	0.78
728	5,131	14,285	6,738	26,442	289	15.76	61.86	0.68
730	3,322	9,246	1,899	12,327	247	6.86	44.53	0.89
732	699	1,943	700	3,183	201	12.02	54.64	3.45
734	2	4	2	9	0	12.00	54.00	0.00
SUM	105,523	290,271	36,067	338,399	5,116	4.10	38.48	0.58

South Sector

1124	9,166	25,397	5,794	35,328	457	7.59	46.25	0.60
1125	15,479	40,161	4,976	48,298	503	3.85	37.45	0.39
1126	23,007	59,692	4,634	66,168	405	2.42	34.51	0.21
1127	38,674	100,340	7,308	109,605	602	2.27	34.01	0.19
1128	6,165	15,996	1,036	17,258	237	2.05	33.59	0.40
1129	12,817	33,458	2,325	35,691	176	2.18	33.42	0.17
1130	6,277	17,304	2,739	21,437	122	5.24	40.98	0.23
1131	32,660	89,311	8,299	98,361	973	3.05	36.14	0.36
1132	22,357	61,283	9,975	77,177	365	5.40	41.42	0.19
1133	12,795	35,273	2,429	38,025	320	2.28	35.68	0.30
1134	12,322	33,981	6,357	44,699	391	4.57	43.53	0.38
1135	20,021	55,474	11,095	73,624	760	6.65	44.13	0.45
SUM	211,740	567,670	66,967	665,671	5,311	3.32	37.73	0.30

County Totals

551,137	1,487,221	172,228	1,726,255	19,094	3.75	37.54	0.42
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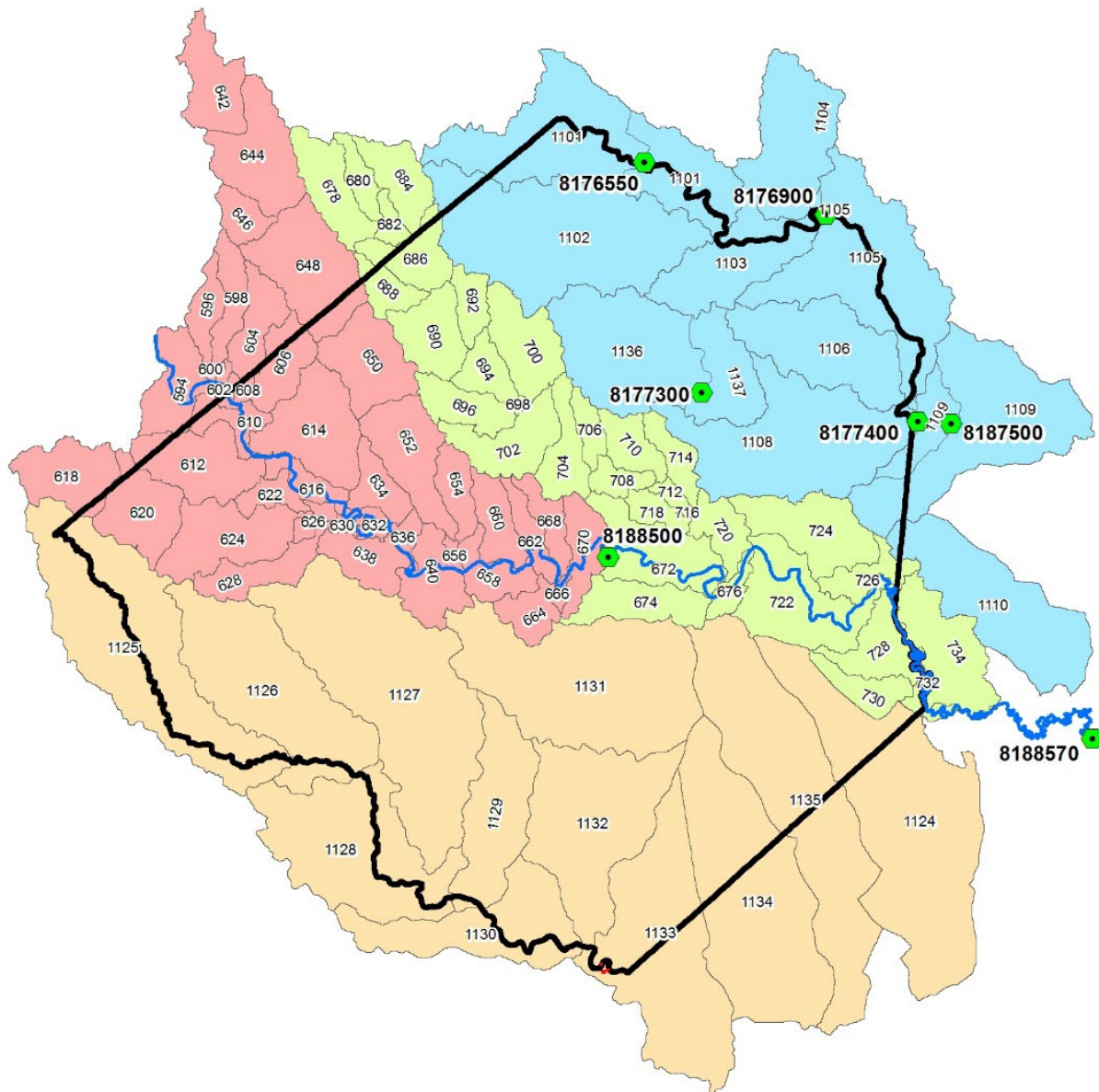


Figure 9.2 Locations of the 81 watersheds delineated in Goliad County, along with the locations of the gauge stations (circles with 7-digit numbers) for each sector of watersheds.

Per-acre annual ET averaged 37.54 inches county-wide (Table 9.15), but ranged between 31.25 inches per acre on Watershed 628 about mid-way between Charco and Berclair in the west-central part of the county and 55.67 inches per acre on Watershed 656 on the San Antonio River about 6 miles west of Goliad. The lower ET rates occurred in watersheds with shallower soils and therefore less dense vegetation. Higher ET rates occurred in watersheds along the river, where vegetation was dense and with high water tables, which resulted in high groundwater

usage. Runoff averaged 0.42 inch county-wide (Table 9.15), and averaged less than one inch per year in all but six watersheds.

The simulations indicated that groundwater was utilized by vegetation in all watersheds in the county, however the amounts varied substantially (Table 9.15). Most watersheds (61 = 75%) had average annual groundwater use by vegetation of 2-6 inches (Fig. 9.3). Average annual groundwater use was less than 2 inches in six watersheds (8%), 6-10 inches per year in ten (12%), and more than 10 inches per year in four watersheds (5%). Groundwater use by vegetation was highest in watersheds along the river, especially on the eastern edge of the county, and least in the northwest part of the county.

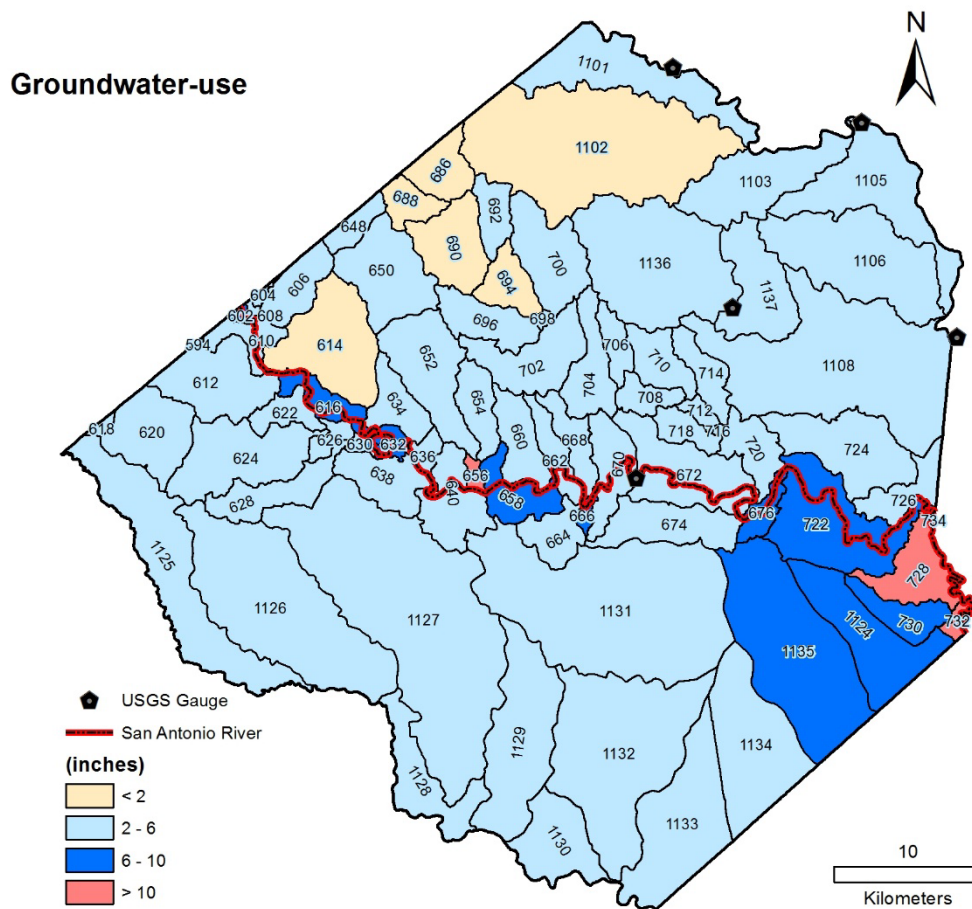


Figure 9.3 Average annual groundwater-use by vegetation (inches/acre) based on 25-year baseline simulations of the Goliad County EDYS model.

The ET values (Table 9.15) include groundwater used by vegetation (GW-Use) because the vegetation uses that water as part of plant transpiration. Net water yield from a specific watershed can be estimated by:

$$\text{Net yield} = \text{Rainfall} - \text{ET} + \text{Runoff} + \text{Recharge}.$$

However, the net yield value provided by this equation does not account for change in soil storage. Therefore, only a portion of this estimated net yield would likely leave the watershed in a particular year. Characteristics of the lower soil profile are not well known for most, if not all, the locations. Those edaphic characteristics have a substantial effect on how much water is stored in lower zones and how much is transferred as groundwater recharge or lateral flow into streams and the river, either in the particular watershed or subsurface lateral transfer to adjacent watersheds. Because of this lack of information on deep vadose zone characteristics, net yield cannot be assigned to a specific spatial location. Better understanding this linkage between soil moisture storage, groundwater usage, and transpiration by vegetation is a major need in ecohydrologic modeling (Maxwell and Condon 2016).

9.2.7 Maximum Effect of Brush Control on Water Balance

Vegetation is a major factor affecting the water balance and a vegetation component of primary importance influencing this is the amount of woody plants, particularly deep-rooted species. Vegetation dynamics strongly affect both ET and groundwater use. Vegetation dynamics are controlled by both natural and anthropogenic factors. Brush control and cultivation are two management factors that have substantial impacts on vegetation and therefore on water balance.

The maximum impact of change in woody vegetation, whether from natural (e.g., drought, succession) or anthropogenic causes, on water balance was simulated by applying the brush control option to all non-urban sites throughout the county. In this scenario, all woody species (except pecan and 50% of live oak) were removed in the first year of the simulation and allowed to regrow over the 25 years. This is not a practical scenario from the standpoint of actual landuse because it is unlikely that all areas would be treated, especially in the same year. However, it is a scenario that estimates the maximum potential effect of brush control on water balance and is useful to determine which areas have the highest potential for increased water yield from brush control. The moderate 25-year rainfall regime (baseline) was used and results would likely be somewhat different under other rainfall regimes.

Maximum potential increased yield was determined by comparing the water balance values from this maximum brush control scenario to those from the baseline scenario. Three water balance variables (GW-use, ET, runoff) were compared. Decreases in GW-use and ET were considered to be net increases in water yield although there would likely be a lag-time before decreased ET might result in increases in groundwater or subsurface flows into streams and the river.

Maximum potential enhanced water yield from brush control was simulated to be 287,188 acre-feet per year county-wide (Table 9.16). This was calculated from decreased ET (287,249 acre-feet) minus 61 acre-feet reduced runoff. Of the 287,188 acre-feet, 47% was from reduced groundwater-use by vegetation (135,906 acre-feet; Table 9.16). The remaining 53% was from

reduced transpiration of soil moisture and reduced evaporation from rainfall intercepted by the plant canopy. Under this maximum brush control scenario, average annual total ET (including groundwater use) was simulated to be 1,439,006 acre-feet (Table 9.16), or 97% of average annual rainfall (1,487,221 acre-feet; Table 9.15). Averaged over three years, ET/rainfall ratios at a South Texas site were 99% for a mesquite shrubland and 94% for a shortgrass community (Weltz and Blackburn 1995). Similar values have been reported for mesquite-grasslands in the Rolling Plains of Texas (97%; Carlson et al. 1990), oak-grasslands in the Edwards Plateau (95%; Thurow et al. 1988), and bluestem prairie in Kansas (94%; Bremer et al. 2001). The simulated maximum brush control scenario resulted in a relatively sparse grassland in the early part of the 25-year simulation, followed by a mixed shrub-grassland as the shrubs re-established on some sites. Therefore, the 97% ratio from the maximum brush control scenario seems reasonable.

Table 9.16 Differences in average annual water balance components (acre-feet) between 25-year simulations of baseline and maximum brush control, by watershed, under moderate rainfall regime using the Goliad County EDYS model.

Watershed	Area (acres)	Baseline Scenario			Maximum Brush Control			Difference		
		GW-Use	ET	Runoff	GW-Use	ET	Runoff	GW-Use	ET	Runoff
Northeast Sector										
1101	10,392	2,365	29,710	340	691	26,351	337	1,674	3,359	3
1102	28,956	4,690	79,890	632	1,118	72,608	628	3,572	7,282	4
1103	9,076	3,139	29,263	381	985	24,903	382	2,154	4,360	- 1
1105	11,398	3,517	36,043	535	1,387	31,543	536	2,130	4,500	- 1
1106	14,382	3,696	43,932	418	1,368	38,887	416	2,328	5,045	2
1108	24,500	8,584	78,853	1,488	3,196	66,941	1,498	5,388	11,912	- 10
1136	18,068	4,893	56,046	690	1,517	49,125	686	3,376	6,921	4
1137	7,321	1,790	22,161	299	625	19,729	296	1,165	2,432	3
SUM	124,093	32,674	375,898	4,783	10,887	330,087	4,779	21,787	45,811	4
West Sector										
594	62	20	195	1	3	160	1	17	35	0
602	295	153	1,019	27	36	782	27	117	237	0
604	277	136	956	9	23	724	9	113	232	0
606	3,567	755	10,268	80	138	8,993	79	617	1,275	1
608	224	88	728	7	5	554	7	83	174	0
610	2,452	887	7,725	140	201	6,319	142	686	1,406	- 2
612	7,502	2,649	23,624	190	487	19,187	192	2,162	4,437	- 2
614	9,962	1,646	27,625	239	304	24,868	238	1,342	2,757	1
616	2,930	1,652	10,475	139	565	8,260	141	1,087	2,215	- 2
618	358	65	1,023	9	8	905	9	57	118	0
620	6,606	2,127	20,441	135	178	16,471	136	1,949	3,970	- 1
622	2,089	849	6,853	57	168	5,435	58	681	1,418	- 1
624	9,236	3,258	29,328	200	314	23,255	200	2,944	6,073	0
626	1,188	235	3,398	63	78	3,061	63	157	337	0
628	4,600	1,534	14,480	99	65	11,429	99	1,469	3,051	0
630	366	173	1,257	11	57	1,015	11	116	242	0
632	982	718	3,828	72	206	2,789	75	512	1,039	- 3
634	3,298	604	9,186	208	189	8,351	208	415	835	0
636	1,262	478	3,982	98	97	3,213	99	381	769	- 1
638	4,362	1,252	13,202	109	149	10,921	110	1,103	2,281	- 1
640	5,490	1,657	16,918	175	321	14,181	176	1,336	2,737	- 1
648	1,766	422	5,135	63	53	4,378	63	369	757	0
650	7,860	2,383	24,164	169	160	19,509	170	2,223	4,655	- 1
652	8,127	2,734	26,371	256	412	21,548	256	2,322	4,823	0
654	3,235	884	10,192	100	121	8,593	100	763	1,599	0
656	548	572	2,542	32	158	1,704	33	414	838	- 1
658	3,792	2,551	14,771	267	378	10,278	272	2,173	4,495	- 5

Table 9.16 (Cont.)

Watershed	Area (acres)	Baseline Scenario			Maximum Brush Control			Difference		
		GW-Use	ET	Runoff	GW-Use	ET	Runoff	GW-Use	ET	Runoff
660	3,922	1,118	12,394	128	190	10,438	129	928	1,956	- 1
662	2,561	940	8,484	219	203	6,950	222	737	1,534	- 3
664	3,194	1,122	10,430	123	186	8,439	124	936	1,991	- 1
666	448	266	1,689	45	67	1,273	46	199	416	- 1
668	2,771	656	8,424	111	44	7,170	110	612	1,254	1
670	4,449	1,936	15,180	303	439	12,000	306	1,497	3,180	- 3
SUM	109,781	36,520	346,287	3,884	6,003	283,151	3,911	30,517	63,136	- 27
Central Sector										
672	8,866	3,389	29,133	627	883	23,959	625	2,506	5,174	2
674	5,916	997	16,973	265	263	15,364	263	734	1,609	2
676	1,709	875	6,081	147	255	4,796	147	620	1,285	0
686	3,546	587	9,817	90	85	8,789	90	502	1,028	0
688	2,327	362	6,361	59	78	5,801	58	284	560	1
690	5,852	960	16,173	141	131	14,498	140	829	1,675	1
692	2,598	441	7,228	65	73	6,474	65	368	754	0
694	3,105	435	8,650	94	111	8,028	93	324	622	1
696	4,316	1,336	13,826	148	100	11,215	148	1,236	2,611	0
698	254	45	750	35	15	689	35	30	61	0
700	6,717	1,429	19,714	192	288	17,353	191	1,141	2,361	1
702	6,518	1,572	20,025	207	220	17,208	207	1,352	2,817	0
704	4,420	887	13,093	162	194	11,677	161	693	1,416	1
706	2,007	383	5,844	90	118	5,311	90	265	533	0
708	1,997	773	6,603	74	178	5,381	73	595	1,222	1
710	3,423	723	10,196	129	242	9,212	129	481	984	0
712	787	205	2,408	35	63	2,111	35	142	297	0
714	2,870	860	9,110	117	206	7,743	117	654	1,367	0
716	128	59	438	10	7	332	10	52	106	0
718	2,056	420	6,075	94	137	5,492	93	283	583	1
720	3,563	1,380	11,726	206	284	9,465	204	1,096	2,261	2
722	11,834	5,957	41,622	851	1,556	32,559	854	4,401	9,063	- 3
724	8,813	1,538	25,449	362	560	23,310	361	978	2,139	1
726	2,747	1,115	9,143	179	201	7,267	179	914	1,876	0
728	5,131	6,738	26,442	289	1,802	16,270	299	4,936	10,172	- 10
730	3,322	1,899	12,327	247	93	8,425	255	1,806	3,902	- 8
732	699	700	3,183	201	221	2,214	205	479	969	- 4
734	2	2	9	0	1	6	0	1	3	0
SUM	105,523	36,067	338,399	5,116	8,365	280,949	5,127	27,702	57,450	- 11
South Sector										
1124	9,166	5,794	35,328	457	280	23,465	476	5,514	11,863	- 19
1125	15,479	4,976	48,298	503	519	39,156	503	4,457	9,142	0
1126	23,007	4,634	66,168	405	691	58,061	401	3,943	8,107	4
1127	38,674	7,308	109,605	602	1,712	97,579	597	5,596	12,026	5
1128	6,165	1,036	17,258	237	212	15,394	238	824	1,864	- 1
1129	12,817	2,325	35,691	176	452	31,205	176	1,873	4,486	0
1130	6,277	2,739	21,437	122	1,448	18,476	120	1,291	2,961	2
1131	32,660	8,299	98,361	973	1,168	82,481	976	7,131	15,880	- 3
1132	22,357	9,975	77,177	365	2,587	61,523	360	7,388	15,654	5
1133	12,795	2,429	38,025	320	812	34,566	312	1,617	3,459	8
1134	12,322	6,357	44,699	391	668	32,607	392	5,689	12,092	- 1
1135	20,021	11,095	73,624	760	518	50,306	787	10,577	23,318	- 27
SUM	211,740	66,967	665,671	5,311	11,067	544,819	5,338	55,900	120,852	- 27
County Totals										
	551,137	172,228	1,726,255	19,094	36,322	1,439,006	19,155	135,906	287,249	- 61

The maximum brush control scenario resulted in a simulated vegetation consisting of mostly grassland throughout Goliad County, with scattered large live oak trees and low to medium density pecan-oak woodlands along drainages. Under these conditions and with a moderate rainfall regime, there would be a positive net water yield county-wide. A 97% ET/rainfall ratio indicates that the net annual yield would be 3% of annual rainfall, on average, or about 45,000 acre-feet per year (0.3 inch per acre). Once the soil profile was recharged to field capacity, this amount of water would recharge into groundwater or move laterally into creeks and the river. Eventually, the water table would increase (by about 3 inches per year, assuming 50% average pore space) until it reached an approximate elevation equal to the elevation of the waterways, at which point the annual surplus would move into the creeks and rivers as lateral flow.

This 0.3-inch average annual recharge under the maximum brush control scenario compares to a simulated 5.2-inch annual deficit under conditions of current vegetation. Both of these values are based on the county receiving moderate rainfall regime for 25 years. Above average rainfall would produce more recharge under the maximum brush control scenario and less of a deficit under current conditions. Similarly, a dry regime would produce less recharge and a higher deficit. Regardless of which rainfall regime would occur, there would be major fluctuations in recharge or deficit from year to year.

Enhancement of water yield from the maximum brush control scenario would not be uniform across the county. It would be higher in areas with heavier stands of woody species and lower in areas with lighter stands. Enhancement also varies in response to difference in soils (e.g., texture and depth) and species of woody species present in the vegetation (e.g., mesquite and live oak are deep-rooted species, whereas hackberry and blackbrush have shallower root systems; Appendix Table D.9).

Simulated maximum potential water yield enhancement was calculated for each watershed (Table 9.17) as the difference in ET between baseline and maximum brush control scenarios minus difference in runoff between the two scenarios (Table 9.16). It is unlikely that brush control treatments (with or without conversion to improved pasture or cultivated land) would, in practice, be applied to an entire watershed. Instead, applications are likely to be applied to only parts of a particular watershed. Although the enhanced water yield that would occur from a brush control operation will vary even within a watershed because of differences in vegetation, soils, and topography within the watershed, expressing potential water yield enhancement on a per acre basis provides a useful metric to compare potential benefits among watersheds.

Table 9.17 Maximum potential annual water yield enhancement and decrease in groundwater use by vegetation (GW-Use) resulting from the maximum brush control scenario using the Goliad County EDYS model. ET values are average annual decreases and runoff values are average annual increases (net yield = decreased ET + increased runoff).

Watershed	Area (acres)	Watershed Total (acre-feet)			Per Acre Basis (inches/acre)	Decrease in GW-Use ¹ (acre-feet) (inches/acre)	
		ET	Runoff	Net Yield			
Northeast Sector							
1101	10,392	3,359	3	3,362	3.88	1,674	1.93
1102	28,956	7,282	4	7,286	3.02	3,572	1.14
1103	9,076	4,360	- 1	4,359	5.76	2,154	2.85
1105	11,398	4,500	- 1	4,499	4.74	2,130	2.24
1106	14,382	5,045	2	5,047	4.21	2,328	1.94
1108	24,500	11,912	- 10	11,902	5.83	5,388	2.55
1136	18,068	6,921	4	6,925	4.60	3,376	2.24
1137	7,321	2,432	3	2,435	3.99	1,165	1.91
SUM	124,093	45,811	4	45,815	4.43	21,787	2.11
West Sector							
594	62	35	0	35	6.77	17	3.29
602	295	237	0	237	9.64	117	4.76
604	277	232	0	232	10.05	113	4.90
606	3,567	1,275	1	1,276	4.29	617	2.08
608	224	174	0	174	9.32	83	4.45
610	2,452	1,406	- 2	1,404	6.87	686	3.36
612	7,502	4,437	- 2	4,435	7.09	2,162	3.46
614	9,962	2,757	1	2,758	3.32	1,342	1.62
616	2,930	2,215	- 2	2,213	9.06	1,087	4.45
618	358	118	0	118	3.96	57	1.91
620	6,606	3,970	- 1	3,969	7.06	1,949	3.54
622	2,089	1,418	- 1	1,417	8.14	681	3.91
624	9,236	6,073	0	6,073	7.89	2,944	3.83
626	1,188	337	0	337	3.40	157	1.59
628	4,600	3,051	0	3,051	7.96	1,469	3.83
630	366	242	0	242	7.93	116	3.80
632	982	1,039	- 3	1,036	12.66	512	6.26
634	3,298	835	0	835	3.04	415	1.51
636	1,262	769	- 1	768	7.30	381	3.62
638	4,362	2,281	- 1	2,280	6.27	1,103	3.03
640	5,490	2,737	- 1	2,736	5.98	1,336	2.92
648	1,766	757	0	757	5.14	369	2.51
650	7,860	4,655	- 1	4,654	7.11	2,223	3.39
652	8,127	4,823	0	4,823	7.12	2,322	3.43
654	3,235	1,599	0	1,599	5.93	763	2.83
656	548	838	- 1	837	18.33	414	9.07
658	3,792	4,495	- 5	4,490	14.21	2,173	6.88
660	3,922	1,956	- 1	1,955	5.98	928	2.84
662	2,561	1,534	- 3	1,531	7.17	737	3.45
664	3,194	1,991	- 1	1,990	7.48	936	3.52
666	448	416	- 1	415	11.12	199	5.31
668	2,771	1,254	1	1,255	5.44	612	2.65
670	4,449	3,180	- 3	3,177	8.57	1,497	4.04
SUM	109,781	63,136	- 27	63,109	6.90	30,517	3.34
Central Sector							
672	8,866	5,174	2	5,176	7.01	2,506	3.39
674	5,916	1,609	2	1,611	3.27	734	1.49
676	1,709	1,285	0	1,285	9.02	620	4.35
686	3,546	1,028	0	1,028	3.48	502	1.70
688	2,327	560	1	561	2.89	284	1.46
690	5,852	1,675	1	1,676	3.44	829	1.70
692	2,598	754	0	754	3.10	368	1.70

Table 9.17 (Cont.)

Watershed	Area (acres)	Watershed Total (acre-feet)			Per Acre Basis (inches/acre)	Decrease in GW-Use ¹	
		ET	Runoff	Net Yield		(acre-feet)	(inches/acre)
694	3,105	622	1	623	2.41	324	1.25
696	4,316	2,611	0	2,611	7.26	1,611	4.48
698	254	61	0	61	2.88	30	1.42
700	6,717	2,361	1	2,362	4.22	1,141	2.04
702	6,518	2,817	0	2,817	5.19	1,352	2.50
704	4,420	1,416	1	1,417	3.85	693	1.88
706	2,007	533	0	533	3.19	265	1.58
708	1,997	1,222	1	1,223	7.35	595	3.58
710	3,423	984	0	984	3.45	481	1.69
712	787	297	0	297	4.53	142	2.17
714	2,870	1,367	0	1,367	5.72	654	3.08
716	128	106	0	106	9.93	52	4.88
718	2,056	583	1	584	3.40	283	1.65
720	3,563	2,261	2	2,263	7.62	1,096	3.69
722	11,834	9,063	- 3	9,060	9.19	4,401	4.46
724	8,813	2,139	1	2,140	2.91	978	1.33
726	2,747	1,876	0	1,876	8.20	914	3.99
728	5,131	10,172	- 10	10,162	23.74	4,936	11.54
730	3,322	3,902	- 8	3,894	14.07	1,806	6.52
732	699	969	- 4	965	16.58	479	8.22
734	2	3	0	3	16.50	1	5.50
SUM	105,523	57,450	- 11	57,439	6.53	27,702	3.15
South Sector							
1124	9,166	11,863	- 19	11,844	15.51	5,514	7.22
1125	15,479	9,142	0	9,142	7.09	4,457	3.46
1126	23,007	8,107	4	8,111	4.23	3,943	2.06
1127	38,674	12,026	5	12,031	3.73	5,596	1.74
1128	6,165	1,864	- 1	1,863	3.63	824	1.60
1129	12,817	4,486	0	4,486	4.20	1,873	1.75
1130	6,277	2,961	2	2,963	5.66	1,291	2.47
1131	32,660	15,880	- 3	15,877	5.83	7,131	2.62
1132	22,357	15,654	5	15,659	8.40	7,388	3.97
1133	12,795	3,459	8	3,467	3.25	1,617	1.52
1134	12,322	12,092	- 1	12,091	11.78	5,689	5.54
1135	20,021	23,318	- 27	23,291	13.96	10,577	6.34
SUM	211,740	120,852	- 27	120,825	6.85	55,900	3.17
County Totals							
	551,137	287,249	- 61	287,188	6.62	135,906	2.96

¹ Groundwater use amounts are included in the ET amounts (i.e., groundwater-use is part of the plant transpiration).

Maximum potential enhancement of water yield from brush control was 6.62 inches per acre annually when averaged over the entire county, with a low of 2.41 inches in Watershed 694 in the north-central part of the county and high of 23.74 inches in Watershed 728 along the river in the eastern part of the county (Table 9.17). Potential yields tended to be higher in watersheds located along the river and lower in watersheds located in more upland areas (Fig. 9.4).

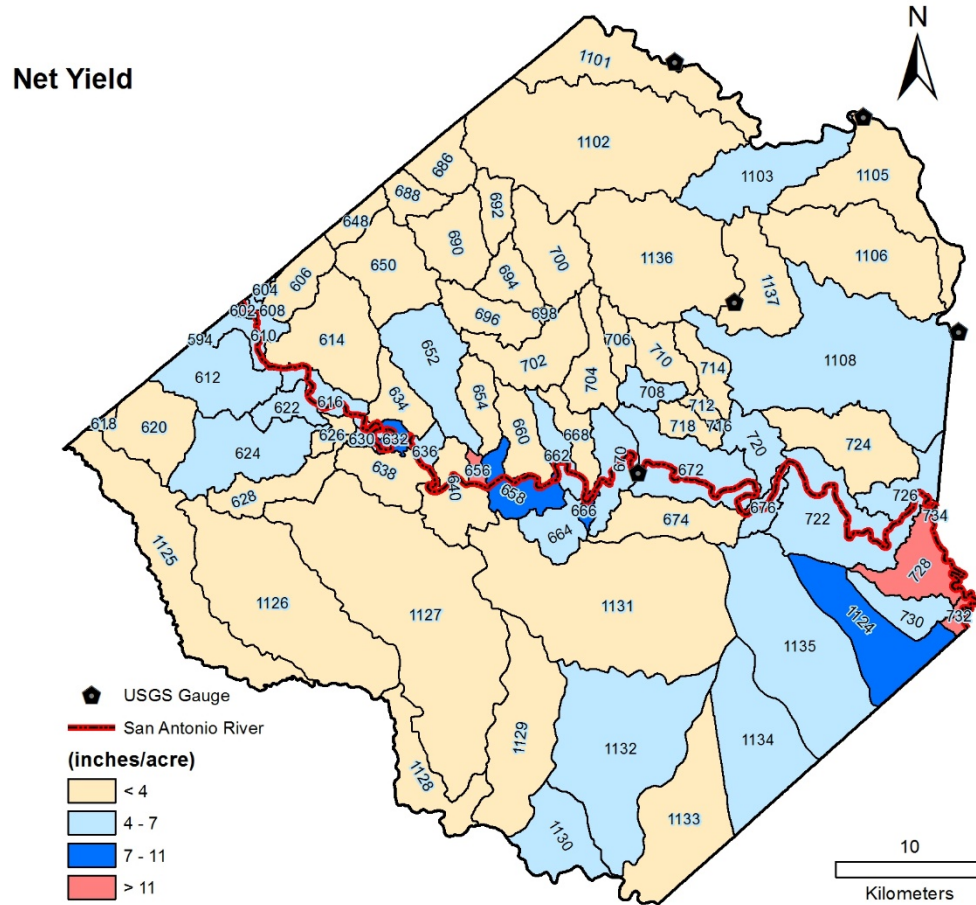


Figure 9.4 Maximum potential increased annual water yield (inches/acre) from brush control based on 25-year simulations of the Goliad EDYS model using the moderate rainfall regime.

Potential increase in water yield from brush control is the result of two primary factors: 1) decreased ET because of less, and different types of, vegetation and 2) lower groundwater use because of a reduction in amount of deep-rooted woody species. Overall, about 45% of the potential increase in water yield in the simulations occurred from lower groundwater use (Table 9.17). Although the proportion of potential increased water yield contributed by reduction in use of groundwater remained fairly constant among the watersheds, the amount of groundwater reduction varied substantially among watersheds (Fig. 9.5).

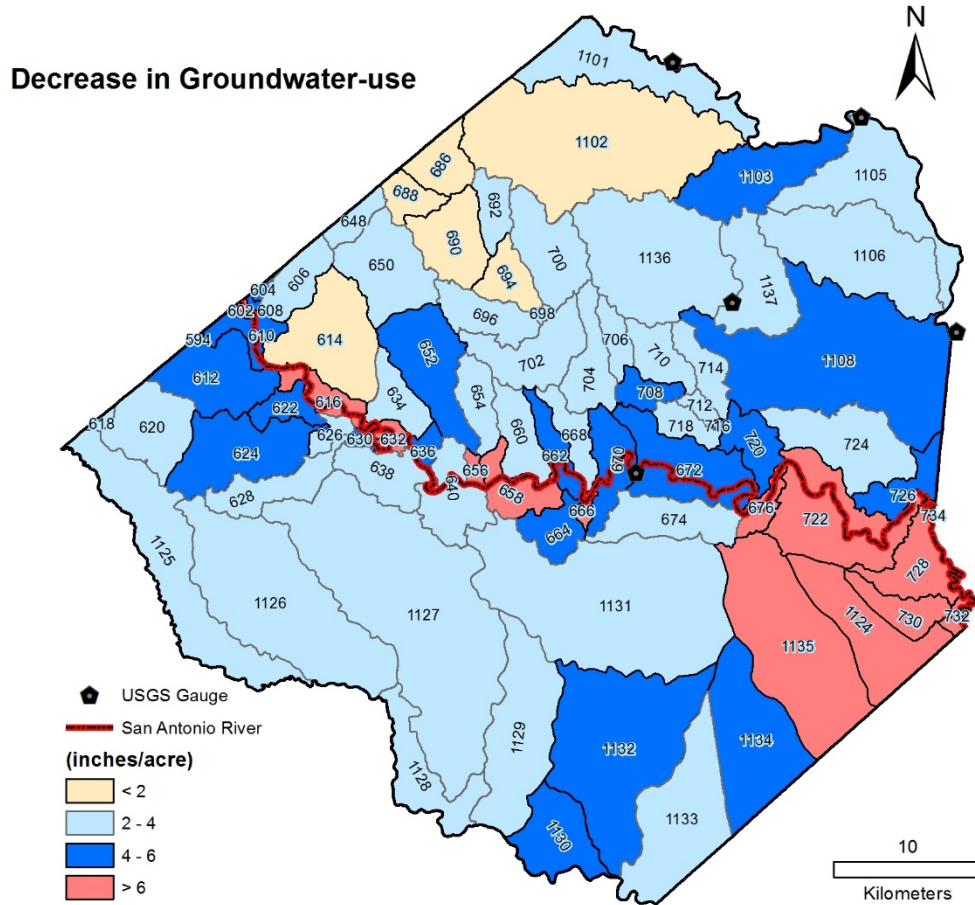


Figure 9.5 Decrease in annual groundwater use by vegetation (inches/acre) from maximum brush control based on 25-year simulations of the Goliad EDYS model using the moderate rainfall regime.

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APPENDIX A PRECIPITATION DATA

Appendix Table A.1 Annual precipitation (PPT; inches) data for Goliad, Texas, 1912-2015.

Year	PPT	Year	PPT	Year	PPT	Year	PPT	Year	PPT	Year	PPT
				1920	24.30	1930	25.94	1940	38.30	1950	18.69
				1921	31.23	1931	40.06	1941	38.05	1951	37.52
				1922	26.34	1932	35.17	1942	41.08	1952	37.22
		1913	34.21	1923	45.35	1933	31.67	1943	33.49	1953	28.50
		1914	42.19	1924	22.38	1934	41.93	1944	32.05	1954	16.14
		1915	21.47	1925	28.78	1935	38.32	1945	29.43	1955	25.27
		1916	19.99	1926	32.86	1936	36.55	1946	45.98	1956	19.49
		1917	9.73	1927	22.47	1937	26.78	1947	30.91	1957	51.52
		1918	32.34	1928	29.59	1938	27.30	1948	26.74	1958	43.05
		1919	47.25	1929	44.62	1939	21.66	1949	35.44	1959	32.35
		SUM	207.18	SUM	307.92	SUM	325.38	SUM	351.47	SUM	309.75
		MEAN	29.60	MEAN	30.79	MEAN	32.54	MEAN	35.15	MEAN	30.98
1960	48.23	1970	30.17	1980	35.59	1990	32.81	2000	37.11	2010	41.38
1961	29.01	1971	39.61	1981	59.48	1991	47.41	2001	45.91	2011	17.24
1962	31.68	1972	52.87	1982	26.22	1992	40.94	2002	42.40	2012	28.99
1963	23.59	1973	51.12	1983	36.56	1993	37.95	2003	34.47	2013	27.76
1964	25.16	1974	38.25	1984	28.39	1994	43.26	2004	47.94	2014	25.63
1965	44.00	1975	39.36	1985	38.08	1995	33.58	2005	28.92	2015	49.63
1966	37.63	1976	55.35	1986	-----	1996	23.93	2006	32.75		
1967	44.08	1977	38.56	1987	-----	1997	53.82	2007	51.84		
1968	42.10	1978	29.48	1988	-----	1998	51.52	2008	22.55		
1969	35.44	1979	40.77	1989	22.66	1999	22.96	2009	35.98		
SUM	360.92	SUM	415.54	SUM	246.98	SUM	388.18	SUM	379.87	SUM	190.63
MEAN	36.09	MEAN	41.55	MEAN	35.28	MEAN	38.82	MEAN	37.99	MEAN	31.77

Overall mean (1913-2015, excluding incomplete years) = 34.84

APPENDIX B SOILS

Appendix Table B.1 Soil units occurring in Goliad County (Wiedenfeld 2010) and corresponding composite units used in the Goliad County EDYS model.

Symbol	NRCS Soil Unit	EDYS Soil Unit
AnA	Ander fine sandy loam, 0-1% slopes	Ander fine sandy loam
AnB	Ander fine sandy loam, 1-3% slopes	Ander fine sandy loam
BnB	Blanca loma fine sand, 0-2% slopes	Ander fine sandy loam
BsA	Buchel clay, 0-1% slopes, occasionally flooded	Buchel clay
BuA	Buchel clay, 0-1% slopes, frequently flooded	Buchel clay
CnA	Cieno loam, 0-1% slopes	Cieno loam
CrA	Clareville sandy clay loam, 0-1% slopes, rarely flooded	Weesatche sandy clay loam
CrB	Clareville sandy clay loam, 1-3% slopes, rarely flooded	Weesatche sandy clay loam
CsC	Colibro sandy clay loam, 3-5% slopes	Pernitas sandy clay loam
CsD	Colibro loam, 5-12% slopes	Pernitas sandy clay loam
CyB	Coy clay loam, 1-3% slopes	Coy clay loam
CyC	Coy clay loam, 3-5% slopes	Coy clay loam
DaA	Dacosta sandy clay loam, 0-1% slopes	Laewest clay
DcA	Dacosta-Contee complex, 0-1% slopes	Laewest clay
DeC	Devine very gravelly fine sandy loam, 1-5% slopes	Pettus loam
EbA	Edna fine sandy loam, 0-1% slopes	Wyick fine sandy loam
EdA	Edroy clay, 0-1% slopes	Edroy clay
EnB	Elmendorf-Denhawken complex, 1-3% slopes	Monteola clay
FdA	Faddin fine sandy loam, 0-1% slopes	Telferner fine sandy loam
GdB	Goliad fine sandy loam, 1-3% slopes	Weesatche fine sandy loam
GoB	Goliad sandy clay loam, 1-3% slopes	Weesatche sandy clay loam
GrA	Greta fine sandy loam, 0-1% slopes	Greta fine sandy loam
ImA	Imogene fine sandy loam, 0-1% slopes	Ander fine sandy loam
InA	Inari fine sandy loam, 0-1% slopes	Telferner fine sandy loam
InB	Inari fine sandy loam, 1-3% slopes	Telferner fine sandy loam
KyB	Kuy fine sand, 1-3% slopes	Kuy fine sand
LaA	Laewest clay, 0-1% slopes	Laewest clay
LaB	Laewest clay, 1-3% slopes	Laewest clay
LaD	Laewest clay, 3-8% slopes	Laewest clay
LmB	Leming loamy fine sand, 0-3% slopes	Raisin loamy fine sand
MbB	Milby fine sand, 0-2% slopes	Nusil fine sand
MeA	Meguina silty clay loam, 0-1% slopes, occasionally flooded	Sinton sandy clay loam
MgA	Meguina silty clay loam, 0-1% slopes, frequently flooded	Sinton sandy clay loam
MoA	Monteola clay, 0-1% slopes	Monteola clay
MoB	Monteola clay, 1-3% slopes	Coy clay loam
MoC	Monteola clay, 3-5% slopes	Coy clay loam
NuC	Nusil fine sand, 1-5% slopes	Nusil fine sand
OdA	Odem-Riverwash complex, 0-1% slopes, frequently flooded	Sinton sandy clay loam
OmD	Olmedo very gravelly loam, 1-8% slopes	Olmedo very gravelly loam
OrA	Orelia fine sandy loam, 0-1% slopes	Telferner fine sandy loam
PaB	Papalote loamy sand, 0-3% slopes	Raisin loamy fine sand
PbA	Papalote fine sandy loam, 0-1% slopes	Ander fine sandy loam
PbB	Papalote fine sandy loam, 1-3% slopes	Ander fine sandy loam
PrB	Parrita sandy clay loam, 0-3% slopes	Parrita sandy clay loam
PtC	Pernitas sandy clay loam, 2-5% slopes	Pernitas sandy clay loam
PuC	Pettus loam, 2-5% slopes	Pettus loam
RaB	Raisin loamy fine sand, 0-3% slopes	Raisin loamy fine sand
RaC	Raisin loamy fine sand, 3-5% slopes	Raisin loamy fine sand
RaC2	Raisin loamy fine sand, 2-5% slopes, moderately eroded	Raisin loamy fine sand
RnB	Raisin fine sandy loam, 1-3% slopes	Weesatche fine sandy loam
RoA	Realitos clay, 0-1% slopes	Realitos clay
RsC	Rhymes fine sand, 1-5% slopes	Nusil fine sand
RuB	Runge fine sandy loam, 1-3% slopes	Weesatche fine sandy loam
RyA	Rydolph silty clay, 0-1% slopes, frequently flooded	Sinton sandy clay loam
ScB	Sarco coarse sand, 0-2% slopes	Sarco coarse sand
SnC	Sarnosa fine sandy loam, 1-5% slopes	Pernitas sandy clay loam
SnD	Sarnosa fine sandy loam, 5-8% slopes	Pernitas sandy clay loam
StC	Schattel sandy clay loam, 1-5% slopes	Schattel sandy clay loam
SwA	Sinton sandy clay loam, 0-1% slopes, occasionally flooded	Sinton sandy clay loam
TeA	Telferner fine sandy loam, 0-1% slopes	Telferner fine sandy loam
TeB	Telferner fine sandy loam, 1-3% slopes	Telferner fine sandy loam
ToA	Tiocano clay, 0-1% slopes	Realitos clay
UsB	Ustarents, loamy, 0-3% slopes	Olmedo very gravelly loam

Appendix Table B.1 (Cont.)

Symbol	NRCS Soil Unit	EDYS Soil Unit
VdA	Vidauri fine sandy loam, 0-1% slopes	Wyick fine sandy loam
VwA	Vidauri-Wyick complex, 0-1% slopes	Wyick fine sandy loam
WcC	Weesatche fine sandy loam, 2-5% slopes	Weesatche fine sandy loam
WeA	Weesatche sandy clay loam, 0-1% slopes	Weesatche sandy clay loam
WeB	Weesatche sandy clay loam, 1-3% slopes	Weesatche sandy clay loam
WeB2	Weesatche sandy clay loam, 1-3% slopes, moderately eroded	Weesatche sandy clay loam
WeC	Weesatche sandy clay loam, 3-5% slopes	Weesatche sandy clay loam
WoA	Woodsboro loam, 0-1% slopes, rarely flooded	Greta fine sandy loam
WyA	Wyick fine sandy loam, 0-1% slopes	Wyick fine sandy loam
ZaA	Zalco sand, 0-1% slopes, occasionally flooded	Zalco sand
ZcA	Zalco sand, 0-1% slopes, frequently flooded	Zalco sand
ZkA	Zunker fine sandy loam, 0-1% slopes, occasionally flooded	Sinton sandy clay loam
ZnA	Zunker fine sandy loam, 0-1% slopes, frequently flooded	Sinton sandy clay loam

APPENDIX C VEGETATION

Appendix Table C.1 NRCS range sites, associated soils, and corresponding EDYS plant communities (mid-seral) used in the Goliad County EDYS model.

Range Site	Soils	EDYS Plant Community
Blackland, RG Plains	EnB MoA	huisache-mesquite-purple threeawn
Blackland, Coastal	DaA DcA LaA LaB LaD	huisache-mesquite-buffalograss
Clayey bottomland	BsA BuA	mesquite-hackberry-ragweed
Clay loam	CrA CrB GoB WeA WeB WeB2 WeC	mesquite-huisache-silver bluestem
Claypan prairie	EbA VdA VwA WyA	huisache-little bluestem-knotroot bristle
Claypan savannah	ScB	post oak-mesquite-little bluestem
Deep sand	KyB	live oak-little bluestem-ragweed
Gravelly ridge	DeC PuC	blackbrush-purple threeawn-buffalograss
Gray sandy loam	CsC CsD PtC SnC SnD	mesquite-huisache-hooded windmillgrass
Lakebed, RG Plains	RoA ToA	huisache-longtom-knotroot bristlegrass
Lakebed, Coastal	EdA	huisache-longtom-flatsedge
Loamy bottomland	MeA MgA OdA RyA SwA ZkA ZnA	live oak-little bluestem-trichloris
Loamy prairie	FdA InA InB OrA TeA TeB	huisache-mesquite-little bluestem
Loamy sand	LmB PaB RaB RaC RaC2	live oak-mesquite-little bluestem
Lowland, Coastal	CnA	huisache-seacoast bluestem-longtom
Rolling blackland	CyB CyC MoB MoC	mesquite-silver bluestem-buffalograss
Salty prairie	GrA WoA	huisache-gulf cordgrass-sea oxeye
Sandy	MbB NuC RsC	mesquite-live oak-little bluestem
Sandy bottomland	ZaA ZcA	live oak-little bluestem-Virginia wildrye
Sandy loam	GdB RnB RuB WcC	mesquite-live oak-silver bluestem
Shallow ridge	OmD	blackbrush-ragweed-Texas wintergrass
Shallow sandy loam	PrB	mesquite-silver bluestem-little bluestem
Sloping clay loam	StC	mesquite-huisache-little bluestem
Tight sandy loam	AnA AnB BnB ImA PbA PbB	mesquite-silver bluestem-trichloris

Determination of species composition and initial biomass (Appendix Table C.2)

In Appendix Table C.2, species composition under light grazing (late-seral conditions) was taken from data in Appendix Tables C.3-C.6. Species composition under moderate (mid-seral) grazing was based on data from Appendix Tables C.7-C.18.

Total grass aboveground biomass under mid-seral conditions was estimated at 70% of late-seral levels (Appendix Table C.22) and total forb aboveground biomass was estimated at 38% of grass levels (Box 1961, Powell and Box 1967, Box and White 1969, Smeins and Diamond 1983, McLendon and Finch unpublished data, McLendon 2015a, 2015b; Appendix Tables C.7-C.11).

For woody species, the values are relative composition (%) of woody plant cover. Herbaceous standing crop biomass is decreased as woody plant cover increases, using the relationship:

$$\text{amount} = (\text{amount at 0\% woody cover})[(1.00 - 0.008(\% \text{ woody cover})]$$

based on data from Appendix Table C.23.

Appendix Table C.2 Adjustment of plant species composition to account for level of livestock grazing in plant communities in Goliad County. Amounts are clippable biomass (g/m²) for herbaceous species and relative cover for woody species. Mid-seral herbaceous biomass = 70% of late-seral (Appendix Table C.21).

Range Type	Woody Species	Relative Cover (%)	Grasses	Biomass		Forbs	Biomass	
				Late	Mid		Late	Mid
Blackland, RG Plains								
	huisache	40	purple threeawn	--	45	ragweed	3	55
	hackberry	1	silver bluestem	28	30	wild indigo	7	15
	mesquite	25	sideoats grama	28	2	old-mans beard	--	5
	live oak	1	hairy grama	--	3	bundleflower	3	2
	whitebrush	6	buffalograss	--	80	sunflower	--	15
	blackbrush	6	hooded windmill	--	25	coneflower	3	3
	granjeno	10	trichloris	73	4	ruellia	3	4
	agarito	2	Arizona cottontop	22	1			
	prickly pear	9	Texas cupgrass	20	2			
			vine-mesquite	20	3			
			little bluestem	73	4			
			plains bristle	22	36			
			indiangrass	45	1			
			Johnsongrass	--	5			
			tall dropseed	22	5			
			Texas wintergrass	20	15			
			Total grasses	373	261	Total forbs	19	99
Blackland, Coastal								
	huisache	41	big bluestem	93	3	ragweed	13	50
	hackberry	1	purple threeawn	--	52	wild indigo	13	44
	mesquite	26	silver bluestem	--	36	old-mans beard	--	50
	live oak	1	sideoats grama	75	4	bundleflower	13	6
	whitebrush	5	hairy grama	--	10	sunflower	--	40
	blackbrush	6	buffalograss	--	151	ruellia	--	8
	granjeno	9	hooded windmill	--	42			
	agarito	1	trichloris	--	5			
	prickly pear	10	vine-mesquite	73	7			
			switchgrass	93	10			
			brownseed paspalum	93	30			
			little bluestem	76	30			
			knotroot bristle	--	16			
			plains bristle	74	47			
			indiangrass	93	7			
			Johnsongrass	--	26			
			tall dropseed	75	18			
			Texas wintergrass	--	28			
			Total grasses	745	522	Total forbs	39	198
Clayey Bottomland								
	huisache	5	bushy bluestem	--	30	ragweed	--	15
	pecan	5	silver bluestem	--	20	giant ragweed	--	40
	hackberry	15	sideoats grama	--	4	spiny aster	--	5
	mesquite	30	buffalograss	22	44	wild indigo	20	8
	live oak	10	hooded windmill	--	10	old-mans beard	--	15
	whitebrush	5	trichloris	34	17	bundleflower	9	5
	baccharis	5	Virginia wildrye	67	20	frogfruit	--	6
	granjeno	10	vine-mesquite	22	10	snoutbean	10	4
	prickly pear	5	switchgrass	39	2	ruellia	--	3
	mustang grape	10	brownseed paspalum	62	30	bush sunflower	--	8
			little bluestem	45	15			
			knotroot bristle	22	30			
			plains bristle	62	25			
			indiangrass	34	1			
			Johnsongrass	--	28			
			Total grasses	409	286	Total forbs	39	109

Appendix Table C.2 (Cont.)

Range Type	Woody Species	Relative Cover (%)	Grasses	Biomass		Forbs	Biomass	
				Late	Mid		Late	Mid
Clay Loam								
	huisache	15	purple threeawn	--	26	ragweed	--	24
	mesquite	30	silver bluestem	90	45	broomweed	--	20
	blackbrush	10	sideoats grama	22	5	wild indigo	5	4
	whitebrush	10	hairy grama	--	3	old-mans beard	--	10
	baccharis	5	buffalograss	22	45	bundleflower	4	3
	granjeno	15	hooded windmill	--	72	sunflower	--	10
	wolfberry	3	trichloris	67	7	frogfruit	--	8
	agarito	2	Arizona cottontop	28	4	coneflower	--	4
	prickly pear	10	vine-mesquite	--	2	snoutbean	4	4
			brownseed paspalum	11	5	ruellia	--	4
			little bluestem	67	7	bush sunflower	5	10
			knotroot bristle	--	3	orange zexmenia	5	8
			plains bristle	90	43			
			indiangrass	11	1			
			Johnsongrass	--	10			
			tall dropseed	--	5			
			Texas wintergrass	--	3			
			Total grasses	408	286	Total forbs	23	109
Claypan Prairie								
	huisache	30	big bluestem	56	3	ragweed	7	80
	live oak	10	bushy bluestem	--	26	wild indigo	8	30
	baccharis	10	bermudagrass	--	36	Texas doveweed	7	18
	McCartn rose	45	switchgrass	95	4	bundleflower	7	6
	rattlepod	5	longtom	56	55	frogfruit	--	10
			brownseed paspalum	56	35			
			little bluestem	95	85			
			knotroot bristle	56	50			
			indiangrass	78	15			
			smutgrass	--	30			
			littletooth sedge	50	20			
			flatsedge	--	20			
			Total grasses	542	379	Total forbs	29	144
Claypan Savanna								
	mesquite	30	purple threeawn	--	30	ragweed	--	40
	post oak	50	silver bluestem	46	50	broomweed	--	28
	granjeno	15	sideoats grama	46	23	Texas doveweed	--	12
	prickly pear	5	hairy grama	--	20	sunflower	--	20
			red grama	--	5	snoutbean	--	6
			hooded windmill	22	44	bush sunflower	--	10
			trichloris	46	23			
			Arizona cottontop	46	12			
			little bluestem	106	71			
			plains bristle	24	18			
			indiangrass	101	10			
			Total grasses	437	306	Total forbs	--	116
Deep Sand								
	mesquite	5	purple threeawn	--	36	ragweed	--	55
	post oak	25	silver bluestem	--	2	partridge pea	--	2
	live oak	50	hairy grama	--	2	Texas doveweed	4	10
	mustang grape	20	sandbur	--	18	bundleflower	3	3
			hooded windmill	--	5	sunflower	--	10
			brownseed paspalum	62	29	coneflower	3	2
			thin paspalum	57	60	snoutbean	3	1
			little bluestem	83	56	bush sunflower	4	9
			plains bristle	67	22			
			indiangrass	78	8			
			tall dropseed	--	5			
			Total grasses	347	243	Total forbs	17	92

Appendix Table C.2 (Cont.)

Range Type	Woody Species	Relative Cover (%)	Grasses		Biomass		Forbs	Biomass	
			Late	Mid	Late	Mid		Late	Mid
Gravelly Ridge									
	mesquite	15	purple threeawn	39	46	ragweed	8	30	
	guajillo	25	silver bluestem	52	26	broomweed	3	17	
	blackbrush	40	sideoats	52	4	lazydaisy	4	6	
	granjeno	10	red grama	6	8	dogweed	5	15	
	agarito	5	buffalograss	34	42				
	prickly pear	5	hooded windmill	22	28				
			Arizona cottontop	27	2				
			green sprangletop	16	2				
			Texas bristlegrass	6	10				
			Texas wintergrass	--	10				
			Total grasses	254	178	Total forbs	20	68	
Gray Sandy Loam									
	huisache	25	purple threeawn	--	24	ragweed	--	30	
	mesquite	35	sideoats grama	38	10	broomweed	--	15	
	whitebrush	5	hairy grama	11	15	partridge pea	4	4	
	blackbrush	10	buffalograss	38	50	Texas doveweed	--	17	
	granjeno	15	sandbur	--	10	bundleflower	3	3	
	prickly pear	10	hooded windmill	36	50	sunflower	--	15	
			trichloris	91	30	coneflower	3	4	
			Arizona cottontop	28	4	snoutbean	4	5	
			green sprangletop	17	2	bush sunflower	6	12	
			thin paspalum	--	10				
			plains bristle	91	35				
			Texas bristlegrass	--	5				
			sand dropseed	22	15				
			Total grasses	372	260	Total forbs	20	105	
Lakebed, RG Plains									
	huisache	60	bushy bluestem	34	40	ragweed	4	44	
	mesquite	30	buffalograss	8	16	spiny aster	--	5	
	rattlepod	10	bermudagrass	--	12	wild indigo	3	5	
			vine-mesquite	34	15	bundleflower	1	1	
			switchgrass	101	10	sunflower	--	20	
			longtom	49	75	frogfruit	2	8	
			brownseed paspalum	90	70	ruellia	1	2	
			knotroot bristle	34	53	curly dock	2	15	
			Johnsongrass	--	30	bulltongue	2	5	
			littletooth sedge	11	15				
			flatsedge	22	30				
			cattail	11	10				
			Total grasses	394	276	total forbs	15	105	
Lakebed, Coastal									
	huisache	80	bushy bluestem	--	40	ragweed	3	52	
	mesquite	10	buffalograss	--	5	broomweed	2	10	
	rattlepod	10	bermudagrass	--	15	spiny aster	--	10	
			switchgrass	90	2	wild indigo	2	5	
			longtom	92	80	bundleflower	2	3	
			brownseed paspalum	90	40	sunflower	--	10	
			knotroot bristle	67	50	frogfruit	2	5	
			Johnsongrass	--	40	ruellia	2	5	
			flatsedge	67	60	curly dock	2	10	
			spikerush	22	15	bulltongue	2	5	
			cattail	3	3				
			Total grasses	431	350	Total forbs	17	115	

Appendix Table C.2 (Cont.)

Range Type	Woody Species	Relative Cover (%)	Grasses	Biomass		Forbs	Biomass	
				Late	Mid		Late	Mid
Loamy Bottomland								
	huisache	15	big bluestem	78	10	ragweed	6	36
	pecan	5	bushy bluestem	--	15	giant ragweed	--	30
	hackberry	15	silver bluestem	11	18	spiny aster	--	10
	mesquite	10	sideoats grama	45	25	partridge pea	6	6
	live oak	20	buffalograss	24	30	old-mans beard	6	30
	whitebrush	5	trichloris	78	45	bundleflower	5	4
	baccharis	5	bermudagrass	--	10	sunflower	--	15
	granjeno	5	Virginia wildrye	34	15	frogfruit	--	6
	mustang grape	20	Texas cupgrass	6	3	snoutbean	6	6
			vine-mesquite	22	15	ruellia	5	6
			switchgrass	78	25	greenbriar	10	15
			brownseed paspalum	22	25			
			little bluestem	90	55			
			knotroot bristle	11	15			
			plains bristle	45	25			
			Johnsongrass	--	30			
			Texas wintergrass	22	20			
			littletooth sedge	22	20			
			flatsedge	28	30			
			Total grasses	616	431	Total forbs	44	164
Loamy Prairie								
	huisache	30	big bluestem	34	4	ragweed	--	80
	mesquite	30	bushy bluestem	--	16	wild indigo	10	20
	live oak	10	purple threeawn	--	15	bundleflower	10	12
	McCartn rose	30	bermudagrass	--	4	sunflower	--	20
			Virginia wildrye	21	8	bush sunflower	11	24
			switchgrass	28	4			
			longtom	22	28			
			brownseed paspalum	22	22			
			thin paspalum	23	28			
			little bluestem	370	220			
			knotroot bristle	20	24			
			indiangrass	28	5			
			smutgrass	--	20			
			littletooth sedge	17	12			
			Total grasses	585	410	Total forbs	31	156
Loamy Sand								
	mesquite	35	purple threeawn	--	20	ragweed	2	51
	live oak	40	silver bluestem	17	24	partridge pea	5	6
	granjeno	10	sideoats grama	78	30	Texas doveweed	--	24
	prickly pear	5	hairy grama	--	8	bundleflower	3	4
	mustang grape	10	sandbur	--	12	coneflower	2	3
			hooded windmill	17	20	snoutbean	3	6
			Arizona cottontop	17	4	bush sunflower	6	18
			switchgrass	90	8			
			brownseed paspalum	78	58			
			thin paspalum	17	25			
			little bluestem	90	78			
			plains bristle	17	8			
			Total grasses	421	295	Total forbs	21	112

Appendix Table C.2 (Cont.)

Range Type	Woody Species	Relative Cover (%)	Grasses	Biomass		Forbs	Biomass	
				Late	Mid		Late	Mid
Lowland Coastal								
	huisache	80	big bluestem	126	8	ragweed	--	40
	baccharis	15	bushy bluestem	28	40	wild indigo	13	68
	rattlepod	5	bermudagrass	--	60	bundleflower	7	10
			switchgrass	127	8	frogfruit	--	18
			longtom	28	62	bush sunflower	13	34
			brownseed paspalum	26	42			
			little bluestem	127	102			
			knotroot bristle	26	34			
			indiangrass	126	27			
			smutgrass	--	36			
			littletooth sedge	25	20			
			flatsedge	--	8			
			Total grasses	639	447	Total forbs	33	170
Rolling Blackland								
	huisache	20	purple threeawn	--	24	ragweed	4	33
	mesquite	45	silver bluestem	40	42	broomweed	--	20
	whitebrush	10	sideoats grama	51	6	wild indigo	8	12
	granjeno	20	hairy grama	--	8	bundleflower	3	4
	agarito	5	buffalograss	29	52	sunflower	--	12
			hooded windmill	--	10	frogfruit	--	8
			trichloris	46	37	coneflower	3	4
			Arizona cottontop	43	4	ruellia	3	6
			Texas cupgrass	35	2			
			vine-mesquite	46	20			
			plains bristle	46	15			
			Texas wintergrass	35	40			
			Total grasses	371	260	Total forbs	21	99
Salty Prairie								
	huisache	90	bermudagrass	--	10	spiny aster	--	6
	mesquite	10	saltgrass	11	18	sea oxeye	39	53
			switchgrass	8	1	frogfruit	--	10
			longtom	11	12	glasswort	--	4
			common reed	6	4			
			little bluestem	7	4			
			knotroot bristle	12	20			
			indiangrass	7	2			
			gulf cordgrass	683	520			
			Total grasses	745	591	Total forbs	39	73
Sandy								
	mesquite	30	purple threeawn	--	25	ragweed	6	48
	live oak	30	sandbur	--	15	wild indigo	6	12
	baccharis	5	hooded windmill	17	25	partridge pea	6	12
	granjeno	10	switchgrass	53	4	Texas doveweed	--	29
	prickly pear	5	brownseed paspalum	53	25	snoutbean	6	12
	mustang grape	20	thin paspalum	18	27			
			little bluestem	210	160			
			indiangrass	53	4			
			tall dropseed	20	12			
			Total grasses	424	297	Total forbs	24	113

Appendix Table C.2 (Cont.)

Range Type	Woody Species	Relative Cover (%)	Grasses	Biomass		Forbs	Biomass	
				Late	Mid		Late	Mid
Sandy Bottomland								
	huisache	5	big bluestem	90	4	ragweed	--	48
	hackberry	15	hairy grama	--	6	giant ragweed	--	30
	mesquite	5	sandbur	--	12	partridge pea	22	20
	live oak	55	bermudagrass	--	20	sunflower	--	30
	mustang grape	20	trichloris	--	10	snoutbean	11	12
			Virginia wildrye	78	53			
			guineagrass	--	40			
			switchgrass	95	8			
			thin paspalum	--	20			
			little bluestem	96	80			
			knotroot bristle	78	72			
			plains bristle	--	8			
			indiangrass	90	6			
			Johnsongrass	--	25			
			tall dropseed	--	5			
			Total grasses	527	369	Total forbs	33	140
Sandy Loam								
	mesquite	35	purple threeawn	--	22	ragweed	7	37
	live oak	30	silver bluestem	67	90	broomweed	--	62
	whitebrush	10	red grama	--	4	partridge pea	6	4
	blackbrush	5	sandbur	--	12	Texas doveweed	--	2
	granjeno	15	hooded windmill	54	60	bundleflower	1	2
	prickly pear	5	trichloris	119	40	coneflower	2	3
			Arizona cottontop	66	4	snoutbean	4	6
			brownseed paspalum	--	18	bush sunflower	7	12
			little bluestem	120	70			
			plains bristle	62	22			
			Total grasses	488	342	Total forbs	27	128
Shallow Ridge								
	mesquite	15	purple threeawn	--	14	ragweed	5	23
	guajillo	30	sideoats grama	42	12	broomweed	4	22
	blackbrush	50	hairy grama	--	12	dogweed	2	6
	prickly pear	5	red grama	--	6			
			hooded windmill	--	14			
			trichloris	13	6			
			Arizona cottontop	38	4			
			green sprangletop	34	4			
			little bluestem	40	18			
			Texas bristlegrass	12	16			
			sand dropseed	12	10			
			Texas wintergrass	--	18			
			Total grasses	191	134	Total forbs	11	51
Shallow Sandy Loam								
	huisache	40	purple threeawn	--	15	ragweed	10	24
	mesquite	50	silver bluestem	68	43	broomweed	3	20
	prickly pear	10	hairy grama	--	4	bundleflower	2	3
			buffalograss	--	12	sunflower	3	8
			hooded windmill	29	32	coneflower	2	3
			trichloris	--	15	snoutbean	4	6
			Arizona cottontop	50	5	bush sunflower	12	16
			little bluestem	67	32			
			plains bristle	56	20			
			sand dropseed	30	20			
			Texas wintergrass	--	12			
			Total grasses	300	210	Total forbs	36	80

Appendix Table C.2 (Cont.)

Range Type	Woody Species	Relative Cover (%)	Grasses	Biomass		Forbs	Biomass	
				Late	Mid		Late	Mid
Sloping Clay Loam								
	huisache	20	purple threeawn	--	23	ragweed	5	24
	mesquite	40	silver bluestem	--	18	broomweed	--	17
	blackbrush	20	sideoats grama	54	12	bundleflower	2	3
	granjeno	15	hairy grama	--	10	sunflower	--	8
	prickly pear	5	red grama	--	4	coneflower	2	3
			buffalograss	28	40	snoutbean	2	4
			hooded windmill	--	12	ruellia	2	4
			trichloris	54	18	bush sunflower	2	8
			Arizona cottontop	50	5			
			plains bristle	52	14			
			Texas wintergrass	27	30			
			Total grasses	265	186	Total forbs	15	71
Tight Sandy Loam								
	mesquite	45	purple threeawn	--	31	ragweed	6	30
	live oak	20	silver bluestem	82	90	broomweed	--	24
	blackbrush	15	sideoats grama	82	16	partridge pea	6	6
	granjeno	15	hairy grama	--	10	Texas doveweed	--	15
	prickly pear	5	red grama	--	5	bundleflower	1	2
			sandbur	--	15	coneflower	1	2
			hooded windmill	36	40	snoutbean	3	6
			trichloris	82	60	bush sunflower	6	23
			Arizona cottontop	80	4			
			plains bristle	45	14			
			Total grasses	407	285	Total forbs	23	108

Appendix Table C.3 Species composition (% cover for woody species, g/m² annual aboveground production for herbaceous species, average rainfall) on **clay and clay loam** NRCS range sites under late-seral (excellent range condition) conditions in Goliad County (x = species occurs in early- or mid-seral).

Species	Blackland RG Plains	Blackland Coastal	Clayey Bottomland	Clay Loam	Loamy Bottomland	Rolling Blackland
Huisache	x	x	x	x	---	---
Pecan	---	---	5	---	5	---
Hackberry	2	1	10	---	5	---
Mesquite	x	1	x	2	x	x
Post oak	---	---	---	---	---	---
Live oak	3	2	10	---	10	---
Whitebrush	---	---	---	---	---	x
Baccharis	---	---	x	x	---	---
Granjeno	x	x	---	1	---	x
Wolfberry	---	---	---	1	---	---
Agarito	x	x	---	---	---	x
Greenbriar	---	---	---	---	5	x
Mustang grape	---	---	---	---	10	---
Big bluestem	---	93	---	---	78	---
Bushy bluestem	---	---	x	---	x	---
Purple threeawn	x	x	---	x	---	x
Silver bluestem	28	---	---	90	11	40
Sideoats grama	28	75	---	22	45	51
Hairy grama	x	x	---	x	---	x
Red grama	---	x	---	---	---	x
Buffalograss	x	x	22	22	24	29
Hooded windmillgrass	x	---	---	---	---	x
Trichloris	73	---	34	67	78	46
Arizona cottontop	22	---	---	28	---	43
Virginia wildrye	---	---	67	---	34	---
Texas cupgrass	20	---	---	---	6	35
Vine-mesquite	20	73	22	---	22	46
Switchgrass	---	93	39	---	78	---
Brownseed paspalum	---	93	62	11	22	---
Little bluestem	73	76	45	67	90	---
Knotroot bristlegrass	---	---	22	---	11	---
Plains bristlegrass	22	74	62	90	45	46
Indiangrass	45	93	34	11	---	---
Tall dropseed	22	75	---	x	---	---
Texas wintergrass	20	---	---	x	22	35
Littletooth sedge	---	---	---	---	22	---
Flatsedge	---	---	---	---	28	---
Ragweed	3	13	x	x	6	4
Annual broomweed	---	---	---	x	---	---
Spiny aster	---	---	x	---	x	---
Wild indigo	7	13	20	5	---	8
Partridge pea	---	---	---	---	6	---
Old-mans beard	---	---	---	---	6	---
Bundleflower	3	13	9	4	5	3
Sumpweed	---	---	x	---	---	---
Prairie coneflower	3	---	---	x	---	3
Snoutbean	---	---	10	4	6	---
Ruellia	3	---	---	---	5	3
Bush sunflower	---	---	---	5	---	---
Orange zexmenia	---	---	---	5	---	---
Total herbaceous	392	784	448	431	650	392

Appendix Table C.4 Species composition (% cover for woody species, g/m² annual aboveground production for herbaceous species, average rainfall) on **sandy and sandy loam** NRCS range sites under late-seral (excellent range condition) conditions in Goliad County (x = species occurs in early- or mid-seral).

Species	Gray Sandy Loam	Loamy Sand	Sandy	Sandy Loam	Tight Sandy Loam	Claypan Savannah	Claypan Prairie	Deep Sand	Loamy Prairie	Sandy Bottomland
Huisache	x	---	---	---	---	---	x	---	x	x
Sugar hackberry	---	---	---	---	---	---	---	---	---	5
Mesquite	5	2	2	x	3	x	---	---	---	x
Post oak	---	---	---	---	---	60	---	5	---	---
Live oak	---	2	2	---	---	---	x	10	x	15
Whitebrush	1	---	---	x	---	---	---	---	---	---
Blackbrush	1	---	---	5	---	---	---	---	---	---
Baccharis	---	---	x	---	---	---	x	---	---	---
Granjeno	3	x	---	x	2	x	---	---	---	---
McCartney rose	---	---	---	---	---	---	x	---	x	---
Rattlepod	---	---	---	---	---	---	x	---	---	---
Mustang grape	---	---	---	---	---	---	---	10	---	---
Prickly pear	1	x	x	---	---	x	---	---	---	---
Big bluestem	---	---	---	---	---	---	56	---	34	90
Bushy bluestem	---	---	---	---	---	---	x	---	x	---
Purple threeawn	x	x	---	x	---	---	---	x	---	---
Silver bluestem	---	17	---	67	82	46	---	---	---	---
Sideoats grama	38	78	---	---	82	46	---	---	---	---
Hairy grama	11	x	---	---	x	x	---	---	---	x
Red grama	---	---	---	x	x	x	---	---	---	---
Buffalograss	38	---	---	---	---	---	---	---	---	---
Sandbur	x	x	x	x	x	---	---	---	---	x
Hooded windmill	36	17	17	54	36	22	---	x	---	---
Trichloris	91	---	---	119	82	46	---	---	---	---
Bermudagrass	---	---	---	---	---	---	x	---	x	---
Arizona cottontop	28	17	---	66	80	46	---	---	---	---
Virginia wildrye	---	---	---	---	---	---	---	---	21	78
Green sprangletop	17	---	---	---	---	---	---	---	---	---
Switchgrass	---	90	53	---	---	---	95	---	28	95
Longtom	---	---	---	---	---	---	56	---	22	---
Brownseed paspalum	---	78	53	x	---	---	56	62	22	---
Thin paspalum	---	17	18	---	---	---	---	57	23	x
Little bluestem	---	90	210	120	---	106	95	83	370	96
Knotroot bristle	---	---	---	---	---	---	56	---	20	78
Plains bristlegrass	91	17	---	62	45	24	---	67	---	---
Indiangrass	---	---	53	---	---	101	78	78	28	90
Tall dropseed	---	---	20	---	---	---	---	---	---	---
Smutgrass	---	---	---	---	---	---	x	---	x	---
Sand dropseed	22	---	---	---	---	---	---	---	---	---
Littletooth sedge	---	---	---	---	---	---	50	---	17	---
Ragweed	x	2	6	7	6	---	7	---	---	---
Annual broomweed	x	---	---	x	x	x	---	---	---	---
Wild indigo	---	---	6	---	---	---	8	---	10	---
Partridge pea	4	5	6	6	6	---	---	---	---	22
Texas doveweed	x	x	x	x	x	x	7	4	---	---
Bundleflower	3	3	---	1	1	---	7	3	10	---
Prairie coneflower	3	2	---	2	1	---	---	3	---	---
Snoutbean	4	3	6	4	3	---	---	3	---	11
Bush sunflower	6	6	---	7	6	---	---	4	11	---
Total herbaceous	392	442	448	515	430	437	571	364	616	560

Appendix Table C.5 Species composition (% cover for woody species, g/m² annual aboveground production for herbaceous species, average rainfall) on **shallow** NRCS range sites under late-seral (excellent range condition) conditions in Goliad County (x = species occurs in early- or mid-seral).

Species	Gravelly Ridge	Shallow Ridge	Shallow Sandy Loam	Sloping Clay Loam
Mesquite	x	---	---	x
Guajillo	10	5	---	---
Blackbrush	15	5	---	5
Granjeno	x	---	---	---
Agarito	x	---	---	---
Prickly pear	x	---	---	x
Purple threeawn	39	x	---	x
Silver bluestem	52	---	68	---
Sideoats grama	52	42	---	54
Hairy grama	---	x	---	x
Red grama	6	x	---	x
Buffalograss	34	---	---	28
Hooded windmill	22	x	29	---
Trichloris	---	13	---	54
Arizona cottontop	27	38	50	50
Green sprangletop	16	34	---	---
Little bluestem	---	40	67	---
Plains bristlegrass	---	---	56	52
Texas bristlegrass	6	12	---	---
Sand dropseed	---	12	30	---
Texas wintergrass	---	---	---	27
Forbs	20	11	36	15
Total herbaceous	274	202	336	280

Appendix Table C.6 Species composition (% cover for woody species, g/m² annual aboveground production for herbaceous species) on **wetland** NRCS range sites under late-seral (excellent range condition) conditions in Goliad County (x = species occurs in early- or mid-seral).

Species	Lakebed RG Plains	Lakebed Coastal	Lowland Coastal	Salty Prairie
Huisache	x	x	x	x
Mesquite	x	---	---	---
Baccharis	---	---	x	---
Sea oxeye	---	---	---	39
Rattlepod	x	---	x	---
Big bluestem	---	---	126	---
Bushy bluestem	34	---	28	---
Buffalograss	8	---	---	---
Bermudagrass	x	---	---	x
Saltgrass	---	---	---	11
Vine-mesquite	34	---	---	---
Switchgrass	101	90	127	8
Longtom	49	92	28	11
Brownseed paspalum	90	90	26	---
Common reed	---	---	---	6
Little bluestem	---	---	127	7
Knotroot bristlegrass	34	67	26	12
Indiangrass	---	---	126	7
Gulf cordgrass	---	---	---	683
Smutgrass	---	---	x	---
Littletooth sedge	11	---	25	---
Flatsedge	22	67	---	---
Spikerush	---	22	---	---
Cattail	11	3	---	---
Ragweed	4	3	---	---
Annual broomweed	---	2	---	---
Spiny aster	x	---	---	---
Wild indigo	3	2	13	---
Bundleflower	1	2	7	---
Frogfruit	2	2	---	---
Ruellia	1	2	---	---
Curly dock	2	2	---	---
Bulltongue	2	2	---	---
Glasswort	---	---	---	x
Bush sunflower	---	---	13	---
Total herbaceous	409	448	672	784

Appendix Table C.7 Comparison of vegetation data from literature sources for clay and clay loam sites in South Texas.

Species	Box & White (1969)		Box (1961)		Powell &	Buckley	Dodd &	Johnston	
	Relative	Absolute	Victoria	Orelia	Box 1967	& Dodd	Holtz	(1963)	
					Victoria	1969 clay	(1972)		
			Welder Wildlife Refuge				Webb	Goliad	Kleberg
<i>Acacia farnesiana</i>	10.0	4.7	5.5	1.3	x				
<i>Acacia rigidula</i>	9.0	4.2	18.4	0.5	x				
<i>Acacia tortuosa</i>	t	t	2.9	1.3					
<i>Berberis trifoliolata</i>	4.1	1.9	6.4	t	x				
<i>Celtis pallida</i>	5.0	2.4	1.2	---	x				
<i>Condalia obovata</i>	2.0	0.9	0.9	---	x				
<i>Diospyros texana</i>	1.0	0.5	---	---					
<i>Lycium berlandieri</i>	1.0	0.5	---	---					
<i>Opuntia leptocaulis</i>	4.7	2.2	---	---					
<i>Opuntia linheimeri</i>	8.4	3.7	t	52.3		x			
<i>Parkinsonia aculeata</i>						x			
<i>Prosopis glandulosa</i>	43.2	20.3	53.0	38.2	x	x			
<i>Prosopis reptans</i>	4.6	2.2	---	---					
<i>Varilla texana</i>						x			
<i>Zanthoxylum fagara</i>	3.8	1.8	3.9	1.3	x				
<i>Zizyphus obtusifolia</i>	2.5	1.2	7.8	5.1					
Total woody (abs cover)		46.5	19.6	39.4	48.6				
<i>Aristida roemeriana</i>	3.3	5.4	14.3	7.6	2.3			2%	
<i>Aristida spp.</i>							6.4		
<i>Bothriochloa saccharoides</i>	8.7	14.1	0.6	0.5	4.5		1.7		
<i>Bouteloua curtipendula</i>							8.3		
<i>Bouteloua rigidiseta</i>					0.3				
<i>Bouteloua trifida</i>						2.3			
<i>Buchloe dactyloides</i>	24.4	39.8	27.6	11.3	28.6			30%	
<i>Cenchrus ciliaris</i>						4.0			
<i>Cenchrus incertus</i>	---	---	0.1	7.3		1.9		2%	
<i>Chloris cucullata</i>							1.2		
<i>Chloris verticillata</i>	1.4	2.2	2.5	25.0	1.6			15%	
<i>Cynodon dactylon</i>					0.6				
<i>Digitaria californica</i>	---	---	0.3	0.1					
<i>Eragrostis lugens</i>					3.9				
<i>Eriochloa contracta</i>	---	---	0.4	t	3.9	0.3			
<i>Hilaria belangeri</i>	t	t	16.9	20.9	1.0	27.8		20%	
<i>Leptochloa dubia</i>						6.6			
<i>Leptochloa nealleyi</i>					2.2				
<i>Leptoloma cognatum</i>	---	---	0.1	0.1			0.6		
<i>Panicum filipes</i>	3.0	4.8	10.6	2.3	6.9			5%	
<i>Panicum hallii</i>						78.2			
<i>Panicum obtusum</i>	1.4	2.2	2.0	t	2.2				
<i>Paspalum pubiflorum</i>	3.9	6.4	0.4	0.6	6.0				
<i>Schedonnardus paniculatus</i>	0.3	0.4	---	---				2%	
<i>Schizachyrium scoparium</i>							1.2		
<i>Setaria geniculata</i>	0.9	1.5	0.4	0.5	5.3				
<i>Setaria leucopila</i>	0.8	1.3	17.8	15.0	20.2		1.2		
<i>Sporobolus asper</i>	2.5	4.0	---	---	1.4				
<i>Sporobolus cryptandrus</i>							0.6		
<i>Sporobolus pyramidatus</i>	0.4	0.7	0.2	4.5	1.7	14.4			
<i>Stipa leucotricha</i>	5.3	8.6	0.9	0.9	5.8		1.7		
<i>Tridens albescens</i>	2.1	3.5	0.7	t	1.4				
<i>Tridens congestus</i>	1.5	2.5	---	---					
<i>Tridens eragrostoides</i>	---	---	t	0.5					
<i>Tridens texensis</i>							2.3		
Other grasses (4)	0.2	0.3	0.2	0.2			6.4		
<i>Carex spp.</i>							9.9		
Total grasses (g/m ²)	60.1	97.7			99.8	135.5	41.5		
Total grasses (% cover)			96.0	97.3					
<i>Ambrosia psilostachya</i>	4.9	8.6	---	---	20.4				
<i>Cienfuegosia sulphurea</i>	0.3	0.4	---	---					

Appendix Table C.7 (Cont.)

Species	Box & White (1969)		Box (1961)		Powell & Box 1967	Buckley & Dodd 1969 clay	Dodd & Holtz (1972)	Johnston (1963)
	Relative	Absolute	Victoria	Orelia	Victoria			
<i>Commelina erecta</i>	1.6	2.7	0.1	t				
<i>Croton monanthogynus</i>	2.8	4.5	0.9	t				
<i>Desmanthus virgatus</i>	2.1	3.5	---	---				5%
<i>Euphorbia albomarginata</i>								2%
<i>Evolvulus sericeus</i>								2%
<i>Lythrum californicum</i>	0.1	0.2	---	---				
<i>Malvastrum aurantiacum</i>	0.2	0.3	---	---				
<i>Phyla incisa</i>	0.5	0.9	t	t				
<i>Portulaca pilosa</i>	0.5	0.9	---	---				
<i>Ratibida columnaris</i>	0.1	0.2	0.6	t				
<i>Ruellia</i> sp.	7.6	12.3	0.8	t				
<i>Solanum eleagnifolium</i>	1.6	2.6	---	---				
<i>Verbesina microptera</i>	2.1	3.5	---	---				
<i>Xanthocephalum texanum</i>	15.0	24.5	0.1	0.5	20.4			
Other forbs (11)	0.5	0.8	1.0	t				
Total forbs	39.9	65.9	3.5	0.5	40.8		104.2	
Total herbaceous (g/m ²)	100.0	163.6			140.6		145.7	
Total herbaceous (% cover)			99.5	97.8				

Box and White (1969) was a chaparral community on Victoria clay. Box (1961) is % relative basal cover. Victoria communities are an average of mesquite and chaparral communities and Orelia community is a prickly pear site.

Appendix Table C.8 Basal cover (%) and composition (% relative basal cover) on late-successional Fayette Prairie clay and clay loam sites (Smeins and Diamond 1983).

Species	Basal Cover		Composition	
	Upland	Lowland	Upland	Lowland
<i>Andropogon gerardii</i>	3	t	2.0	t
<i>Bouteloua curtipendula</i>	6	0	3.7	0.0
<i>Coelorachis cylindrica</i>	3	0	2.0	0.0
<i>Dichanthelium sphaerocarpon</i>	2	0	1.0	0.0
<i>Eragrostis intermedia</i>	1	0	0.3	0.0
<i>Eriochloa sericea</i>	2	0	1.0	0.0
<i>Muhlenbergia capillaris</i>	3	0	1.7	0.0
<i>Panicum virgatum</i>	0	18	0.0	22.0
<i>Paspalum floridanum</i>	4	5	2.7	6.1
<i>Paspalum plicatulum</i>	7	0	4.3	0.0
<i>Paspalum setaceum</i>	3	0	1.7	0.0
<i>Schizachyrium scoparium</i>	59	t	39.0	t
<i>Sorghastrum nutans</i>	11	10	7.3	12.2
<i>Sporobolus asper</i>	4	2	2.7	2.4
<i>Stipa leucotricha</i>	3	0	2.0	0.0
<i>Tripsacum dactyloides</i>	12	41	7.7	50.0
<i>Carex microdonta</i>	4	t	2.7	t
<i>Eleocharis montevidensis</i>	2	3	1.0	3.7
<i>Fimbristylis puberula</i>	2	0	1.3	0.0
<i>Scleria ciliata</i>	2	0	1.3	0.0
<i>Argythamnia humilis</i>	2	0	1.0	0.0
<i>Biforia americana</i>	1	0	0.7	0.0
<i>Cacalia plantaginea</i>	3	0	1.7	0.0
<i>Desmanthus illinoensis</i>	0	2	0.0	2.4
<i>Dyschoriste linearis</i>	2	0	1.3	0.0
<i>Echinacea angustifolia</i>	1	0	0.7	0.0
<i>Krigia occidentalis</i>	2	0	1.3	0.0
<i>Marshallia caespitosa</i>	4	0	2.7	0.0
<i>Physotegia intermedia</i>	3	1	1.7	1.2
<i>Rudbeckia hirta</i>	2	0	1.3	0.0
<i>Ruellia nudiflora</i>	2	0	1.3	0.0
Grasses			79.1	92.7
Grass-likes			6.3	3.7
Forbs			13.7	3.6

Appendix Table C.9 Comparison of vegetation data from literature sources for sandy and sandy loam sites in South Texas. Values are percent composition unless otherwise noted.

Species	Box (1961) Nueces fs	Drawe & Box (1969) Zavala fsl (g/m ²)	& Smeins (1984) Alfisols (%)	Diamond	Bovey et al. (1972) Katy sl	McLendon & DeYoung (1976)	McLendon (2014) Aransas (g/m ²)	McLendon (2015) Goliad (g/m ²)	McLendon (2015) Karnes (g/m ²)
<i>Ampelopsis arborea</i>	----	----	----	---	----	----	----	22.7	----
<i>Baccharis glutinosa</i>	----	----	----	---	----	2.7	----	----	----
<i>Quercus virginiana</i>	----	----	----	---	114.2	8.6	----	----	----
<i>Vitis mustangensis</i>	----	----	----	---	----	----	27.0	----	----
<i>Andropogon glomeratus</i>	----	----	----	---	----	4.3	----	----	----
<i>Aristida purpurescens</i>	1.2	----	----	6	x	----	----	----	----
<i>Bothriochloa ischaemum</i>	----	----	----	---	----	----	----	34.7	----
<i>Bothriochloa saccharoides</i>	----	----	----	---	----	----	----	----	96.0
<i>Bouteloua curtipendula</i>	----	----	----	---	----	----	----	----	1.1
<i>Bouteloua hirsuta</i>	1.8	----	----	---	----	----	----	----	----
<i>Brachiaria ciliatissima</i>	3.2	22.0	9.3	---	----	----	----	----	----
<i>Cenchrus incertus</i>	13.7	23.1	9.7	---	----	2.0	1.1	----	----
<i>Chloris cucullata</i>	4.2	----	----	---	----	----	----	----	17.1
<i>Cynodon dactylon</i>	----	----	----	---	----	3.0	----	----	17.2
<i>Dichanthelium acuminatum</i>	----	----	----	---	----	----	6.1	----	8.0
<i>Dichanthelium langinosum</i>	----	----	----	---	----	3.0	----	----	----
<i>Dichanthelium oligosanthes</i>	----	----	----	4	----	4.0	----	----	----
<i>Dichanthelium sphaerocarpon</i>	----	----	----	---	----	3.7	----	----	----
<i>Digitaria texana</i>	----	----	----	---	----	2.7	----	----	----
<i>Elyonurus tripsacoides</i>	3.1	30.0	12.3	---	----	----	57.4	----	----
<i>Eragrostis secundiflora</i>	1.2	----	----	x	----	----	----	----	----
<i>Eragrostis trichodes</i>	----	----	----	---	----	----	----	----	29.0
<i>Eustachys petraea</i>	----	----	----	---	----	1.6	----	----	----
<i>Leptoloma cognatum</i>	2.1	----	----	---	----	----	----	----	----
<i>Panicum capillare</i>	----	----	----	---	----	----	----	0.8	----
<i>Panicum hallii</i>	----	----	----	---	----	----	----	----	0.4
<i>Panicum maximum</i>	----	----	----	---	----	----	----	67.1	----
<i>Paspalum floridanum</i>	----	----	----	3	----	----	5.0	----	----
<i>Paspalum monostachyum</i>	----	----	----	---	----	11.5	----	----	----
<i>Paspalum plicatulum</i>	0.4	----	----	10	x	5.8	----	----	----
<i>Paspalum setaceum</i>	4.4	----	----	3	----	3.6	3.6	----	18.2
<i>Schizachyrium scoparium</i>	----	----	----	41	x	----	----	33.5	3.7
<i>Schizachyrium littoralis</i>	20.7	13.8	5.7	---	----	3.4	388.6	----	----
<i>Setaria firmula</i>	19.8	33.4	14.0	---	x	----	----	----	----
<i>Setaria leucopila</i>	----	----	----	---	----	----	----	----	22.4
<i>Sorghastrum nutans</i>	----	----	----	7	x	----	----	----	----
<i>Sporobolus asper</i>	----	----	----	3	----	----	----	1.1	1.2
<i>Stipa leucotricha</i>	----	----	----	---	----	----	----	28.5	21.5
<i>Tridens strictus</i>	----	----	----	1	----	----	----	----	----
Other grasses	----	40.4	16.9	---	----	----	----	----	----
Grasses (% cover)				78					
Grasses (relative cover)	75.8		67.9			48.6			
Grasses (g/m ²)		162.7			184.7		488.8	165.7	235.8
<i>Carex</i> spp.	----	----	----	---	----	7.0	----	----	----
<i>Fimbristylis puberula</i>	----	----	----	3	----	----	----	----	----
<i>Rhynchospora</i> spp.	----	----	----	1	----	----	----	----	----
<i>Acacia hirta</i>	----	----	----	1	----	----	----	----	----
<i>Acalypha radians</i>	----	----	----	---	----	----	0.4	----	----
<i>Allium</i> sp.	----	----	----	---	----	----	----	0.3	----
<i>Ambrosia psilostachya</i>	----	----	----	3	----	----	12.7	----	4.4
<i>Aster pratensis</i>	----	----	----	1	----	----	----	----	----
<i>Baptisia leucophaea</i>	----	----	----	---	----	3.6	----	----	----
<i>Commelina erecta</i>	0.8	----	----	---	----	3.4	2.5	----	----
<i>Croton capitatus</i>	1.5	9.1	3.7	---	----	----	----	----	----
<i>Croton dioicus</i>	----	----	----	---	----	----	----	----	1.2
<i>Croton punctatus</i>	----	----	----	---	----	5.0	----	----	----
<i>Croton texensis</i>	----	1.7	0.7	---	----	----	----	1.5	----
<i>Erigeron myrionactis</i>	----	----	----	---	----	4.4	----	----	----
<i>Eriogonum multiflorum</i>	1.4	----	----	---	----	----	----	----	----

Appendix Table C.9 (Cont.)

Species	Box (1961) Nueces fsl	Drawe & Box (1969) Zavala fsl (g/m ²)	(%)	Diamond & Smeins (1984) Alfisols	Bovey et al. (1972) Katy sl	McLendon & DeYoung (1976)	McLendon (2014) Aransas (g/m ²)	McLendon (2015) Goliad (g/m ²)	McLendon (2015) Karnes (g/m ²)
<i>Eustoma exaltatum</i>	----	----	----	---	----	3.9	----	----	----
<i>Gnaphalium obtusifolium</i>	----	----	----	---	----	----	1.7	----	----
<i>Gutierrezia texana</i>	----	----	----	---	----	----	----	----	69.8
<i>Heterotheca subaxillaris</i>	----	49.8	21.3	---	----	2.3	----	----	----
<i>Ibervillea lindheimeri</i>	----	----	----	---	----	----	----	0.5	----
<i>Iva angustifolia</i>	----	----	----	---	----	----	22.9	----	----
<i>Liatris</i> spp.	----	----	----	3	----	----	----	----	----
<i>Monarda citriodora</i>	----	----	----	---	----	----	2.4	----	----
<i>Nama hispidum</i>	6.6	----	----	---	----	----	----	----	----
<i>Parthenium hysterophorus</i>	----	----	----	---	----	3.5	----	----	----
<i>Phyla incisa</i>	0.3	----	----	---	----	----	0.7	----	----
<i>Physalis viscosa</i>	----	----	----	---	----	----	1.9	----	----
<i>Ratibida columnaris</i>	----	----	----	1	----	----	6.3	----	----
<i>Rhynchosia americana</i>	----	----	----	---	----	2.9	----	----	----
<i>Rhynchosia texana</i>	----	----	----	---	----	4.3	----	----	----
<i>Sarcostemma cynanchoides</i>	----	----	----	---	----	----	1.1	----	----
<i>Schrankia uncinata</i>	----	----	----	3	----	----	----	----	----
<i>Sida abutifolia</i>	----	----	----	---	----	----	----	----	1.3
<i>Solanum eleagnifolium</i>	----	----	----	---	----	----	----	----	0.5
<i>Tragia urticifolia</i>	----	----	----	1	----	----	----	----	----
<i>Verbesina enceloides</i>	7.8	10.0	4.0	---	----	----	----	----	----
<i>Verbena halei</i>	----	----	----	---	----	----	0.7	----	----
Other forbs	----	5.4	2.3	---	----	----	----	----	3.5
Forbs (% cover)	----	----	----	17	----	----	----	----	----
Forbs (relative cover)	18.4	----	32.0	---	----	33.3	----	----	----
Forbs (g/m ²)	----	76.0	----	---	18.5	----	53.3	2.3	80.7
Other species	5.8	----	----	---	----	----	----	----	----

Trace species from Diamond and Smeins (1984): *Andropogon gerardii*, *Aster ericoides*, *Buchloe dactyloides*, *Cacalia plantaginea*, *Carex microdonta*, *Cirsium undulatum*, *Eryngium yuccifolium*, *Hedyotis nigricans*, *Linum medium*, *Muhlenbergia capillaris*, *Oxalis dillenii*, *Panicum virgatum*, *Ruellia nudiflora*, *Sabatia campestris*, *Scleria ciliata*, *Silphium laciniatum*, *Sisyrinchium pruinosum*.

Appendix Table C.10 Mean frequency (%) of plant communities on Pat Welder Ranch, San Patricio County (McLendon and Dahl 1983).

Species	Mesquite- blackbrush- ragweed	Mesquite- blackbrush- knotroot bristlegrass	Mesquite- blackbrush- huisache	Mesquite- huisache- blackbrush	Mesquite- huisache- buffalograss	MEAN
<i>Prosopis glandulosa</i>	41	53	37	59	46	47
<i>Acacia farnesiana</i>			13	15	13	8
<i>Acacia rigidula</i>	20	17	33	18	12	20
<i>Celtis pallida</i>				12		2
<i>Agrostis hiemalis</i>					11	2
<i>Bothriochloa saccharoides</i>		10		11		4
<i>Buchloe dactyloides</i>	10		14	15	33	14
<i>Chloris verticillata</i>				11		2
<i>Paspalum plicatulum</i>				11		2
<i>Setaria geniculata</i>	19	61	49	12	10	30
<i>Stipa leucotricha</i>		10		17		3
<i>Ambrosia psilostachya</i>	65	79	30	86	23	57
<i>Chamaecrista fasciculata</i>				14	16	6
<i>Gutierrezia texana</i>	25	13	34	29	27	46
<i>Sida ciliaris</i>	23		18	17	27	17
<i>Oxalis dillenii</i>	10			35	20	13

Appendix Table C.11 Species composition of available forage (g/m²) on a grazed coastal prairie site (Lake Charles clay), Green Lake Ranch, Calhoun County, Texas, December 1973-April 1974 (Durham and Kothmann 1977).

Species	23 Dec	16 Jan	13 Feb	10 Mar	27 Mar	10 Apr	Mean
<i>Cynodon dactylon</i>	38	22	33	58	85	58	49
<i>Paspalum lividum</i>	19	37	63	91	54	60	54
<i>Paspalum plicatulum</i>	15	37	31	46	54	36	37
<i>Schizachyrium littoralis</i>	105	53	75	73	146	83	89
<i>Setaria geniculata</i>	83	31	15	8	8	6	25
<i>Sorghastrum nutans</i>	31	30	15	31	34	21	27
<i>Sporobolus indicus</i>	45	43	24	22	11	14	27
Other species	42	30	15	24	33	13	26
Total Grasses	378	283	271	353	425	291	334

Other grasses: *Bouteloua rigidiseta*, *Dichanthelium oligosanthes*, *Panicum virgatum*, *Paspalum dilatatum*.
The site was dominated by seacoast bluestem and McCartney rose (*Rosa bracteata*).

Appendix Table C.12 Mean aboveground biomass (g/m²) in grazed plots and exclusion plots on a heavily-grazed sandy rangeland in Brooks County, Texas, February-November 1980 (McLendon and Finch, unpublished data). Values are means of 8 plots per treatment per month for 8 months.

Species	Excluded Animals					Overall Mean
	None	Cattle	Cattle & Deer	Cattle, Deer, & Rabbits	Cattle, Deer, Rabbits, Gophers	
<i>Acacia greggii</i>	0.9	----	----	----	----	0.2
<i>Colubrina texensis</i>	0.3	*	----	----	*	0.1
<i>Opuntia leptocaulis</i>	----	----	0.6	----	1.7	0.5
<i>Opuntia lindheimeri</i>	1.5	12.5	----	17.8	1.4	6.6
<i>Prosopis glandulosa</i>	----	*	----	----	----	*
<i>Aristida purpurea</i>	10.3	18.3	12.2	21.0	23.1	17.0
<i>Aristida purpureascens</i>	25.8	31.8	38.9	31.8	26.1	30.9
<i>Bothriochloa saccharoides</i>	----	----	----	----	0.5	0.1
<i>Bouteloua hirsuta</i>	1.5	1.2	0.9	1.2	1.4	1.2
<i>Bracharia ciliatissima</i>	2.1	2.4	4.5	4.0	5.2	3.6
<i>Cenchrus incertus</i>	2.4	2.3	3.2	3.0	2.4	2.7
<i>Dichanthelium oligosanthes</i>	----	0.3	0.5	0.1	1.9	0.6
<i>Digitaria patens</i>	----	----	0.1	*	----	*
<i>Eragrostis secundiflora</i>	0.1	0.2	0.7	0.4	1.2	0.5
<i>Eragrostis sessilispica</i>	----	----	0.1	*	----	*
<i>Paspalum setaceum</i>	11.1	10.6	16.9	13.0	10.0	12.2
<i>Setaria firmula</i>	4.7	7.6	5.5	2.0	5.3	5.0
<i>Sporobolus cryptandrus</i>	0.1	0.3	0.6	0.3	1.0	0.5
<i>Acalypha radians</i>	0.8	1.2	0.9	1.0	1.4	1.1
<i>Allium runyonii</i>	----	----	----	*	*	*
<i>Ambrosia confertifolia</i>	2.6	7.1	6.1	5.7	3.8	5.1
<i>Aphanostephus kidder</i>	0.1	0.1	0.3	*	----	0.1
<i>Callirhoe involucrate</i>	0.1	0.3	----	0.1	0.3	0.2
<i>Carex</i> sp.	----	----	----	*	----	*
<i>Centaureium texense</i>	----	*	----	----	----	*
<i>Chamaecrista texana</i>	0.5	0.2	0.2	0.5	1.5	0.6
<i>Cnidocolus texanus</i>	----	----	----	*	----	*
<i>Commelina erecta</i>	0.7	0.3	0.2	0.4	0.4	0.4
<i>Croton argyranthemus</i>	1.5	1.8	3.3	2.4	1.8	2.2
<i>Croton capitatus</i>	7.5	3.3	2.8	3.4	3.3	4.1
<i>Eriogonum multiflorum</i>	*	1.2	0.9	0.6	0.1	0.6
<i>Evolvulus sericeus</i>	0.8	0.4	0.2	*	1.1	0.5
<i>Gaillardia pulchella</i>	2.0	1.8	1.2	0.9	2.4	1.7
<i>Gaura mckelveyae</i>	1.3	2.2	2.5	3.2	1.4	2.1
<i>Heterotheca subaxillaris</i>	16.2	19.6	21.4	24.1	22.2	20.7
<i>Lantana horrida</i>	0.1	0.2	0.6	----	----	0.2
<i>Lepidium lasiocarpum</i>	0.1	0.1	0.2	0.2	0.1	0.1
<i>Linum rigidum</i>	*	*	----	----	*	*
<i>Monarda punctata</i>	19.3	26.9	28.8	25.8	37.4	27.6
<i>Oenothera</i> sp.	----	*	----	----	----	*
<i>Oxalis dillenii</i>	2.5	1.0	1.8	1.4	0.7	1.5
<i>Palafoxia texana</i>	7.4	9.0	7.3	3.7	8.2	7.1
<i>Phlox drummondii</i>	0.5	----	----	*	----	0.1
<i>Physalis cinerascens</i>	0.4	0.4	0.8	1.3	0.3	0.6
<i>Plantago rhodosperma</i>	0.1	----	----	----	----	*
<i>Polygala alba</i>	----	0.1	*	----	*	*
<i>Ratibida peduncularis</i>	2.2	2.3	2.0	1.7	2.5	2.1
<i>Rhynchosia americana</i>	1.8	1.8	2.2	2.3	2.3	2.1
<i>Sida lindheimeri</i>	0.2	0.2	0.3	0.2	0.2	0.2
<i>Tephrosia lindheimeri</i>	6.3	7.1	2.5	8.3	4.3	5.7
Total Aboveground Biomass	135.8	175.5	171.2	181.8	176.9	168.4
Litter	89.9	101.1	150.8	110.2	133.4	117.1
Total Shrubs and Cacti	2.7	12.5	0.6	17.8	3.1	7.4
Total Grasses	58.1	74.4	84.1	76.8	78.1	74.3
Total Forbs	75.0	88.6	86.5	87.2	95.7	86.7

Dashed lines (----) indicate zero values. Astericks (*) indicate trace (< 0.05 g/m²) amounts.

Appendix Table C.13 Woody plant density (plants/ha) and basal cover (m²/ha) on Miguel and Papalote fine sandy loam soils on La Copita, Jim Wells County (Archer et al. 1988).

Species	Density			Cover Openings	Density of Plants > 2 m in Drainages
	Clusters	Openings	Drainages		
<i>Acacia farnesiana</i>		70	44	0.027	37
<i>Aloysia lycioides</i>		0	2189	0.000	0
<i>Bumelia</i> spp.	x	0	35	0.000	9
<i>Celtis pallida</i>	x	0	775	0.000	283
<i>Colubrina texensis</i>		30	582	0.001	0
<i>Condalia hookeri</i>	x	0	462	0.000	97
<i>Diospyros texana</i>	x	16	1101	0.001	106
<i>Lantana macropoda</i>	x	0	---	0.000	0
<i>Lycium berlandieri</i>	x	0	197	0.000	0
<i>Mahonia trifoliolata</i>	x	0	39	0.000	0
<i>Opuntia lindheimeri</i>	x	100	982	-----	0
<i>Opuntia leptocaulis</i>	x	30	---	-----	0
<i>Prosopis glandulosa</i>	x	350	764	0.022	295
<i>Salvia ballotaeflora</i>	x	0	339	0.000	0
<i>Schaefferia cuneifolia</i>	x	0	314	0.000	0
<i>Yucca treculeana</i>		0	---	0.000	---
<i>Zanthoxylum fagara</i>	x	30	3229	0.003	318
<i>Zizyphus obtusifolia</i>	x	0	218	0.000	0
TOTALS		626	11270	0.054	1145

Archer et al. (1988) sites were on Miguel and Papalote fine sandy loams on the La Copita, Jim Wells County. #/ha = number of woody plants per hectare, BC = basal cover (%).

Density of plants > 2 m in drainages included in the values for drainages overall.

Average cluster was 18 m².

Woody plant coverage averaged 13.0% in 1940 and 36.4% in 1983. This is an annual increase of 0.55 percentage points per year. At that rate, cover in 2013 would be 52.9% (36.4% + 16.5%).

Appendix Table C.14 Woody plant density (plants/ha) and canopy cover (m²/plant) in three plant communities on the Welder Wildlife Refuge, San Patricio County, Texas (Box 1961).

Species	Density			Cover		
	Mesquite	Chaparral	Prickly pear	Mesquite	Chaparral	Prickly pear
<i>Acacia farnesiana</i>	50	39	13	----	----	----
<i>Acacia rigidula</i>	3	193	56	11.75	3.69	0.87
<i>Acacia tortuosa</i>	13	34	13	----	----	----
<i>Celtis pallida</i>	t	19	t	----	----	----
<i>Condalia hookeri</i>	t	15	t	----	----	----
<i>Mahonia trifoliolata</i>	t	106	t	----	----	----
<i>Opuntia lindheimeri</i>	t	t	426	----	----	4.84
<i>Prosopis glandulosa</i>	364	174	2046	4.84	1.28	0.74
<i>Zanthoxylum fagara</i>	3	39	13	----	----	----
<i>Zizyphus obtusifolia</i>	14	116	56	----	----	----
TOTAL	447	735	2623			

Appendix Table C.15 Vegetation of the Welder Wildlife Refuge, San Patricio County (Drawe et al. 1978).

Mesquite-mixed grass community: Victoria clay

Moderate stands of mesquite (12-27% cover), with mottes of mixed brush; huisache is increasing (200-500 trees/ha). Interspaces with dense stands of grass: 17% Texas wintergrass, 8% meadow dropseed, 2% silver bluestem; little bluestem, plains bristlegrass, Texas cupgrass, lovegrass tridens, sourgrass (*Digitaria insularis*). Forbs (20%): prairie coneflower, western ragweed, ruellia, horsemint, one-seeded doveweed (*Croton monanthogynus*), bladderpod (*Lesquerella lindheimeri*), Texas broomweed. Depressions: vine-mesquite, pink tridens, white tridens, frogfruit, water clover (*Marsilea mucronata*). Swales: hackberry, longtom, sumpweed.

Chaparral-mixed grass community: drier clay and clay loam sites

Woody plant cover (34-55%): blackbrush (11%), mesquite, huisache, twisted acacia, agarito, creeping mesquite, granjeno, lotebush, brasil, Texas persimmon, colima. Areas root-plowed 30-35 years ago have brush 2-3 m tall. Mesquite and huisache have increased in height 1.0-1.5 m in 20-25 years and shrubs have increased 0.3-0.5 m. Understory in mottes: some plains bristlegrass and bunch cutgrass (*Leersia monandra*). Openings between mottes: similar to mesquite-mixed grass except more silver bluestem and little bluestem.

Chaparral-mixed grass community: sandy loam sites

Woody plant cover (25.7%): granjeno, colima, mesquite, huisache, blackbrush, agarito, lotebush, Texas persimmon, prickly pear (0.3%). Major grasses: silver bluestem, knotroot bristlegrass, plains bristlegrass, Texas cottontop.

Halophyte-shortgrass community: saline sites adjacent to temporary lakes or swales

Few, scattered mesquite. Padre Island dropseed, whorled dropseed, saltgrass, Texas willkommia (*Willkommia texana*), gulf cordgrass, shoregrass; sea oxeye, glasswort (*Salicornia virginica*), purslane, saltbush.

Paspalum-aquatic plant community: swales on clay soils

Sesbania and some scattered huisache. Almost pure stands of hairyseed paspalum (*Paspalum publiflorum*). Some canarygrass (*Phalaris canariensis*), arrowhead, and water clover. During dry periods, buffalograss and creeping lovegrass (*Neeragrostis reptans*) become abundant.

Gulf cordgrass community: frequently flooded clay swales

Upper clay loam sites: mesquite, granjeno, blackbrush, sea oxeye; bermudagrass, little barley
Upper sandy loam sites: huisache; bermudagrass, rescue grass, geranium
Mid-elevation sites: closed canopy of gulf cordgrass
Lower elevation sites: clubhead cutgrass (*Leersia hexandra*), cattail, and spikerush.

Huisache-mixed grass community: low swale areas

Dense stands of huisache. Understory under closed canopy: Texas wintergrass, canarygrass, Ozarkgrass, sixweeks fescue
Understory under open canopy: hairyseed paspalum, knotroot bristlegrass, vine-mesquite
Wetter areas: spiny aster and longtom; drier areas: more silver bluestem, lovegrass tridens, plains bristlegrass.

Bunchgrass-annual forb community: sandy and sandy loam soils

Open grassland with 25-40% grass cover. Relative cover = 75% grasses, 19% forbs, 6% shrubs.
Under light grazing: seacoast bluestem, big bluestem, Pan American balsamscale, tanglehead, switchgrass, Texasgrass (*Vaseochloa multinervosa*), trichloris, big sandbur, crinkleawn.
Under moderate grazing: increase in balsamscale and thin paspalum.
Under heavy grazing: sandbur and knotgrass (*Setaria formula*) are common.
Major forbs: skunk daisy (*Ximenesia encelioides*), Texas doveweed, woolly doveweed, wild buckwheat.
On sandy loam sites: increase in sideoats grama, brownseed paspalum, hooded windmillgrass, old-man's beard, and prickly pear.

Hogplum-bunchgrass community: sandy loam soils on river terraces

Stands of hogplum and old-man's beard, with scattered huisache and Texas kidneywood.
Hogplum dense on terraces, huisache dense in swales.
Understory: sideoats grama, brownseed paspalum, hooded windmillgrass, prickly pear.

Huisache-bunchgrass community: lower areas of Odem sandy loam soils

Moderate to dense stands of huisache and dense stands of old-man's beard.
Understory similar to bunchgrass-annual forb community, but with southwestern bristlegrass (*Setaria scheelei*), Texas wintergrass, Virginia wildrye, snoutbean, and ruellia.

Chittimwood-hackberry community: sandy loam soils

Dense stands of chittimwood (*Bumelia lanuginosa*) and hackberry. Small trees (3-7 m tall), with canopies extending to near the ground.
Sparse understory: southwestern bristlegrass and Turk's cap (*Malvavicus drummondii*).

Live oak-chaparral community: sandy and sandy loam soils

Overstory: scattered stands of old live oak, 2% canopy cover.
Mid-level: mesquite (30%; 3-5 m tall), colima (14%), Texas persimmon (6%), blackbrush (6%), granjeno (5%), agarito (5%), chittimwood, hackberry, anacua, chapatillo (*Amyris texana*), tickle-tongue.
Understory: seacoast bluestem, brownseed paspalum, tanglehead; some big bluestem, switchgrass, indiangrass, trichloris, southwestern bristlegrass.
Heavier grazing: windmillgrasses, brownseed paspalum, thin paspalum, sandbur.
Turk's cap, pigeon berry (*Rivina humilis*), mistflower, skunk daisy, doveweed.

Mesquite-bristlegrass community: poorly-drained sands and sandy loams

Open stands of mesquite, with granjeno, colima, lotebush, agarito.
Understory: knotroot bristlegrass, brownseed paspalum, Hall panicum, silver bluestem, gummy lovegrass; western ragweed

Riparian woodland community: riparian bottomlands

Stands of large trees: hackberry, anacua, cedar elm, pecan, with mustang grape.

Shrub understory: similar to that of live oak-chaparral community.

Herbaceous understory: southwestern bristlegrass, broadleaf uniola (*Chasmanthium latifolium*), Virginia wildrye, Turk's cap, velvet mallow (*Wissadula amplissima*).

Woodland-spiny aster community: mixed alluvial soils

Mixture of chaparral, western soapberry (*Sapindus saponaria*), and spiny aster.

Spiny aster-longtom community: low-lying areas where water stands for long periods following rains

Dense stands of spiny aster, with some longtom and little snoutbean (*Shynchosia minima*).

Lakes and Ponds

Submersed community: coontail (*Ceratophyllum demersum*), water nymph (*Najas quadalupensis*), water stargrass (*Heteranthera liebmanni*), wigeongrass (*Ruppia maritima*), sago pondweed (*Potamogeton pectinatus*), and muskgrass (*Chara* spp.).

Floating community: mostly lotus (*Nelumbo lutea*).

Lower marsh edges: bulrushes (*Scirpus* spp.), cattails, and sedges.

Upper marsh edges: clubhead cutgrass, longtom, sesbania.

As ponds dry: buffalograss, knotroot bristlegrass, creeping lovegrass.

Appendix Table C.16 Woody plants reported on other study sites in South Texas.

Species	Campbellton Bovey et al. 1970	Webb Co. Buckley & Dodd 1969	Goliad Co. Dodd & Holtz 1972
<i>Acacia farnesiana</i>	major		
<i>Acacia greggii</i>	scattered		
<i>Acacia rigidula</i>	major		308/ha
<i>Celtis pallida</i>	scattered		
<i>Colubrina texensis</i>	scattered		185/ha
<i>Diospyros texana</i>	scattered		124/ha
<i>Eysenhardtia texana</i>	scattered		
<i>Lycium berlandieri</i>	scattered		
<i>Mahonia trifoliolata</i>	scattered		62/ha
<i>Opuntia leptocaulis</i>	scattered		
<i>Opuntia linheimeri</i>	scattered	density = 1	
<i>Parkinsonia aculeata</i>		density = 4	
<i>Prosopis glandulosa</i>	scattered	density = 3	
<i>Varilla texana</i>		density = 2	
<i>Yucca treculeana</i>	scattered		
<i>Zizyphus obtusifolia</i>	scattered		62/ha
Other woody species			333/ha

Appendix Table C.17 Woody plant cover (%) at sites in South Texas.

Community	Woody Cover	Location	Reference
Blackbrush-mesquite	20.4	Welder WR, San Patricio Co.	Box (1961)
Blackbrush-mesquite	38.4	Welder WR, San Patricio Co.	Drawe et al. (1978)
Blackbrush-mesquite	48.6	Welder WR, San Patricio Co.	Powell & Box (1967)
Granjeno-colima	25.7	Welder WR, San Patricio Co.	Drawe et al. (1978)
Mesquite-buffalograss	18.6	Welder WR, San Patricio Co.	Box (1961)
Mesquite-huisache	47	Welder WR, San Patricio Co.	Box & White (1969)
Mesquite-mixed grass	20	Welder WR, San Patricio Co.	Drawe et al. (1978)
Mesquite-prickly pear	36.4	La Copita, Jim Wells Co.	Archer et al. (1988)
Prickly pear-mesquite	39.4	Welder WR, San Patricio Co.	Box (1961)

Appendix Table C.18 Species composition (%) in wetland communities on the Welder Wildlife Refuge, San Patricio County (Scifres et al. 1980).

Species	Clubhead cutgrass	Cattail-cutgrass	Cutgrass-spikerush	Cutgrass-longtom	Wetland Mean	Gulf cordgrass
<i>Borrichia frutescens</i>	0	1	t	0	t	2
<i>Cynodon dactylon</i>	2	5	t	5	3	t
<i>Leersia hexandra</i>	29	19	28	20	24	3
<i>Paspalum lividum</i>	20	14	14	29	19	4
<i>Setaria geniculata</i>	0	0	7	t	2	3
<i>Spartina spartinae</i>	0	0	t	t	t	65
<i>Echinodorus cordifolius</i>	9	4	6	7	6	2
<i>Eleocharis</i> spp	16	10	19	11	14	6
<i>Fimbristylis castanea</i>	6	5	8	3	5	5
<i>Typha domingensis</i>	t	32	t	0	8	0
<i>Iva annua</i>	0	0	0	6	2	0
<i>Phyla incisa</i>	t	t	6	t	2	t
<i>Polygonum ramosissimum</i>	0	0	2	7	2	1
<i>Rumex crispus</i>	4	1	2	9	2	4
<i>Sagittaria latifolia</i>	4	3	3	1	3	4

Appendix Table C.19 Non-quantified species lists for South Texas plant communities.

Species	Drawe (1994) Bluestem- cordgrass	McLendon (1994) Mesquite- granjeno-acacia	Smeins (1994a) Little bluestem- indiangrass	Smeins (1994b) Little bluestem- post oak	Archer (1990) La Copita Jim Wells Co.
<i>Acacia farnesiana</i>		common			
<i>Acacia rigidula</i>		common			
<i>Acacia tortuosa</i>		common			
<i>Aloysia lycioides</i>		common			
<i>Celtis laevigata</i>				common	
<i>Celtis pallida</i>		sub-dominant			common
<i>Condalia hookeri</i>		common			common
<i>Diospyros texana</i>		common			common
<i>Mahonia trifoliolata</i>		common			common
<i>Opuntia linheimeri</i>		common			
<i>Porlieria angustifolia</i>		common			
<i>Prosopis glandulosa</i>		dominant			dominant
<i>Quercus buckleyi</i>				common	
<i>Quercus marilandica</i>				common	
<i>Quercus stellata</i>				dominant	
<i>Quercus virginiana</i>				common	
<i>Rhus aromatic</i>				common	
<i>Schaefferia cuneifolia</i>					common
<i>Smilax bona-nox</i>				common	
<i>Symphoricarpos orbiculatus</i>				common	
<i>Zanthoxylum fagara</i>		common			common
<i>Zizyphus obtusifolia</i>		common			common
<i>Andropogon gerardii</i>				common	
<i>Andropogon glomeratus</i>	common				
<i>Andropogon tenarius</i>	common				
<i>Andropogon virginicus</i>	common				
<i>Aristida purpurea</i>	common	common	common	common	common
<i>Bothriochloa saccharoides</i>	common	common			
<i>Bouteloua curtipendula</i>		common	common	common	
<i>Bouteloua hirsuta</i>		common	common	common	
<i>Bouteloua rigidiseta</i>		common	common		common
<i>Bouteloua trifida</i>		common			common
<i>Buchloe dactyloides</i>	common	common	common	common	
<i>Cenchrus ciliaris</i>		common			
<i>Cenchrus incertus</i>		common			common
<i>Chloris cucullata</i>		common			common
<i>Chloris pluriflora</i>		common			
<i>Dichanthium annulatum</i>		common			
<i>Distichlis spicata</i>	common				
<i>Elyonurus tripsacoides</i>	common				
<i>Hilaria belangeri</i>		common			
<i>Panicum obtusum</i>		common			
<i>Pappophorum bicolor</i>		common			
<i>Paspalum plicatulum</i>	common				
<i>Paspalum lividum</i>	common				
<i>Paspalum setaceum</i>					common
<i>Schizachyrium littoralis</i>	dominant				
<i>Schizachyrium scoparium</i>	dominant		dominant	sub-dominant	
<i>Setaria leucopila</i>		common			
<i>Setaria texana</i>		common			
<i>Sorghastrum nutans</i>			sub-dominant	common	
<i>Spartina spartinae</i>	dominant				
<i>Sporobolus asper</i>	common		common	common	
<i>Sporobolus indicus</i>	common				
<i>Sporobolus tharpii</i>	common				
<i>Stipa leucotricha</i>	common		common	common	
<i>Tridens congestus</i>	common				
<i>Carex</i> spp.	common				
<i>Eleocharis</i> spp.	common				
<i>Fimbristylis</i> spp.	common				
<i>Scirpus</i> spp.	common				

Appendix Table C.19 (Cont.)

Species	Drawe (1994) Bluestem- Cordgrass	McLendon (1994) Mesquite- granjeno-acacia	Smeins (1994a) Little bluestem- indiangrass	Smeins (1994b) Little bluestem- post oak	Archer (1990) La Copita Jim Wells Co.
<i>Ambrosia psilostachya</i>	common				
<i>Amphiachyris dracunculoides</i>		common			
<i>Clematis drummondii</i>		common			
<i>Croton</i> spp.	common	common			
<i>Cynanchum leave</i>		common			
<i>Desmanthus virgatus</i>		common			
<i>Dichondra micrantha</i>	common				
<i>Ericameria texana</i>		common			
<i>Eriogonum multiflorum</i>	common				
<i>Eupatorium odoratum</i>		common			common
<i>Eupatorium incarnatum</i>		common			common
<i>Evolvulus</i> spp.					common
<i>Gnaphalium obtusifolium</i>		common			
<i>Iva annua</i>	common				
<i>Lantana horrida</i>		common			
<i>Parietaria texana</i>		common			
<i>Parthenium incanatum</i>		common			
<i>Ratibida columnaris</i>	common				
<i>Rhynchosia</i> spp.	common				
<i>Sagittaria latifolia</i>	common				
<i>Sarcostemma cynanchoides</i>		common			
<i>Verbesina</i> spp.					common
<i>Zexmenia hispida</i>		common			common

Remnants of the bluestem-cordgrass prairie remain as the Goliad Prairie, McFaddin Prairie (near Victoria), and east of Tivoli (Drawe 1994).

Appendix Table C.20 Effect of range condition or seral stage on forage production.

Type	Location	Units	Excellent	Good	Fair	Poor	Reference
Bluestem prairie	LA	lbs/ac	2828	3239	3351		Duvall & Linnartz (1967)
Bluestem prairie	OK	lbs/ac	3767			3172	Hazell (1967)
Bluestem prairie	NE	% comp	83	46	11		Jensen & Schumacher (1969)
Bluestem prairie	TX	g/m ²	489				McLendon (2014): Aransas NWR
Bluestem prairie	TX	g/m ²			236		McLendon (2015a): Stieren Ranch
Bluestem prairie	TX	g/m ²			208		McLendon et al. (2001): Fort Hood
Bluestem prairie	TX	g/m ²				176	McLendon (2015b): Brooks County
Bluestem prairie	TX	g/m ²				163	Drawe & Box (1969): Welder WR
Bluestem prairie	TX	g/m ²				172	McLendon (1977): Dimmit County

Appendix Table C.21 Effect of grazing intensity on forage production.

Type	Location	Units	Ungrazed	Light	Medium	Heavy	Reference
Black grama grassland	NM	basal	0.73	1.00	0.69	0.57	Paulsen & Ares 1962
Tobosa grassland	NM	basal	0.51	1.00	1.09	0.94	Paulsen & Ares 1962
Blue grama stony hills	NM	g/m ²	62.7		52.6		Pieper 1968
Blue grama loam upland	NM	g/m ²	72.8		61.6		Pieper 1968
Blue grama bottomland	NM	g/m ²	68.3		18.0		Pieper 1968

Appendix Table C.22 Calculation of change in aboveground grass biomass with change in range condition, seral stage, or grazing intensity. Ratios based on data in Appendix Tables C.20 and C.22.

Bluestem prairie	LA	Good = 1.15(Excellent)	Fair = 1.18(Excellent)		
Bluestem prairie	OK			Poor = 0.84(Excellent)	
Bluestem prairie	NE	Good = 0.55(Excellent)	Fair = 0.13(Excellent)		
Bluestem prairie	TX		Fair = 0.45(Excellent)	Poor = 0.35(Excellent)	
Tobosa grassland	NM	Light = 1.96(Ungrazed)	Medium = 2.14(Ungrazed)	Heavy = 1.84(Ungrazed)	
Black grama	NM	Light = 1.37(Ungrazed)	Medium = 0.95(Ungrazed)	Heavy = 0.78(Ungrazed)	
Blue grama	NM		Medium = 0.64(Ungrazed)		
Means:		Good = 0.85(Excellent)	Fair = 0.59(Excellent)	Poor = 0.60(Excellent)	
		Light = 1.67(Ungrazed)	Medium = 1.25(Ungrazed)	Heavy = 1.31(Ungrazed)	
			Medium = 0.75(Light)	Heavy = 0.78(Light)	
Summary:		1.00	----> 0.85	----> 0.75	----> 0.59
			----> 0.69		
Range Condition:		Excellent	Good	High-Fair	Low-Fair
Seral Stage:		Late		Mid	
Grazing Intensity:		Light		Moderate	Heavy

Appendix Table C.23 Aboveground biomass (g/m²) for woody species in the Goliad County EDYS model (values based on 100% canopy cover of the respective woody species).

Species	Common Name	Trunk	Stems	Leaves	Total
<i>Acacia farnesiana</i>	huisache	5,000	1,460	260	6,720
<i>Carya illinoensis</i>	pecan	23,650	3,890	330	27,870
<i>Celtis laevigata</i>	sugar hackberry	11,820	1,950	330	14,100
<i>Prosopis glandulosa</i>	mesquite	7,240	1,000	300	8,540
<i>Quercus stellata</i>	post oak	12,240	1,920	190	14,350
<i>Quercus virginiana</i>	live oak	24,270	3,830	380	28,480
<i>Acacia berlandieri</i>	guajillo	500	1,100	500	2,100
<i>Acacia rigidula</i>	blackbrush	630	1,300	440	2,370
<i>Aloysia lycioides</i>	whitebrush	700	1,500	400	2,600
<i>Baccharis texana</i>	prairie baccharis	1,240	1,240	260	2,740
<i>Borrhchia frutescens</i>	sea oxeye	150	100	250	500
<i>Celtis pallida</i>	granjeno	1,060	1,070	350	2,480
<i>Lycium berlandieri</i>	wolfberry	810	810	250	1,870
<i>Mahonia trifoliolata</i>	agarito	70	120	70	260
<i>Rosa bracteata</i>	McCartney rose	1,200	3,600	900	5,700
<i>Sesbania drummondii</i>	rattlepod	250	1,000	100	1,350
<i>Vitis mustangensis</i>	mustang grape	1,200	200	400	1,800
<i>Opuntia lindheimeri</i>	prickly pear	350	2,000	10	2,360

Appendix Table C.24 Effect of woody cover on grass production on two rangelands in Texas.

	Mesquite Canopy (%)				Huisache Canopy (%)							
	2-3	7-8	13	24	00	10	20	30	40	50	60	70
Production (g/m ²):	126	135	145	96	415	425	365	320	290	235	190	135
Proportion of lowest:	1.00	1.07	1.15	0.76	1.00	1.02	0.88	0.77	0.70	0.57	0.46	0.33

Mesquite = Rolling Plains near Vernon (McDaniel et al. 1982); huisache = Welder Wildlife Refuge, San Patricio County (Scrifers et al. 1982).

Approximate grass production = (amount at 0% cover)[1.00 – (0.8)(woody plant cover)].

Appendix Table C.25. Species composition and initial biomass values for land-use types in the Goliad County EDYS model. Values for woody species are in % of total woody cover and impervious surfaces are % of total area. Values for herbaceous species are g/m².

Species	Urban Houses	Buildings Industrial	Disturbed Areas	Caliche Pits	Tilled Fields	Orchard	Oil Pads
Huisache	---	30	30	10	---	---	---
Pecan	5	---	---	---	---	100	---
Hackberry	---	30	20	---	---	---	---
Mesquite	40	20	30	20	---	---	---
Live oak	55	---	---	---	---	---	---
Blackbrush	---	---	---	30	---	---	---
Whitebrush	---	---	---	10	---	---	---
Baccharis	---	20	10	10	---	---	---
Granjeno	---	---	10	20	---	---	---
Purple threeawn	---	20	25	20	---	---	---
King Ranch bluestem	---	50	20	10	---	---	---
Silver bluestem	---	10	5	20	---	---	---
Sandbur	---	10	10	10	---	---	---
Hooded windmillgrass	---	10	10	20	---	---	---
Bermudagrass	500	100	10	10	---	50	---
Johnsongrass	---	150	20	10	---	20	---
Milo	---	---	---	---	20	---	---
Ragweed	---	50	20	20	---	10	---
Sunflower	---	50	20	10	10	10	---
Impervious surface	50%	90%	0%	10%	0%	0%	100%

Appendix Table C.26 Species composition and aboveground herbaceous production (clippable biomass) in improved pasture by soil series in Goliad County.

NRCS Range Site	Woody Species Relative Composition (%)	Herbaceous Species Initial Aboveground Biomass (g/m ²)				
		BOIS	CYDA	PACO	SOHA	AMPS
Clay Soils						
Blackland RG Plains	huisache 50; mesquite 40; baccharis 10	30	0	544	30	19
Blackland Coastal	huisache 50; McCart rose (40); bacchrs 10	60	0	1089	60	39
Clayey Bottomland	huisache 60; mesquite 30; hackberry 10	33	0	597	33	39
Rolling Blackland	huisache 20; mesquite 60; baccharis 20	30	0	541	30	21
Clay Loam Soils						
Clay Loam	huisache 50; mesquite 40; baccharis 10	33	0	596	33	23
Loamy Bottomland	huisache 60; mesquite 30; hackberry 10	50	0	898	50	44
Sandy Loam Soils						
Claypan Prairie	huisache 50; McCartney rose 50	32	576	0	32	29
Claypan Savanna	huisache 30; mesquite 70	26	464	0	26	15
Gray Sandy Loam	huisache 50; mesquite 40; whitebrush 10	22	395	0	22	20
Loamy Prairie	huisache 50; McCart rose 40; mesquite 10	34	621	0	35	31
Sandy Loam	huisache 50; mesquite 50	29	518	0	29	27
Tight Sandy Loam	huisache 50; mesquite 50	24	432	0	24	23
Sandy Soils						
Deep Sand	huisache 30; mesquite 40; live oak 30	20	369	0	20	17
Loamy Sand	huisache 30; mesquite 50; live oak 20	25	447	0	25	21
Sandy	huisache 40; mesquite 40; baccharis 20	25	450	0	25	24
Sandy Bottomland	huisache 40; mesquite 40; hackberry 20	31	560	0	31	33
Shallow Soils						
Gravelly Ridge	mesquite 20; blackbrush 60; granjeno 20	15	270	0	15	20
Shallow Ridge	mesquite 30; blackbrush 70	11	203	0	11	11
Shallow Sandy Loam	huisache 50; mesquite 50	18	319	0	17	36
Sloping Clay Loam	huisache 30; mesquite 50; blackbrush 20	16	282	0	15	15
Wetland Soils						
Lakebed RG Plains	huisache 70; mesquite 20; baccharis 10	11	418	0	36	15
Lakebed Coastal	huisache 80; mesquite 10; rattlepod 10	13	458	0	38	17
Lowland Coastal	huisache 80; baccharis 10; rattlepod 10	19	629	0	56	33
Salty Prairie	huisache 90; mesquite 10	44	791	0	44	39

BOIS = King Ranch bluestem; CYDA = bermudagrass; PACO = kleingrass; SOHA = Johnsongrass; AMPS = ragweed. Annual aboveground production (g/m²) of three forage species, adjusted to mean annual precipitation for Goliad County (34.8 inches), are 576 for bermudagrass, 794 for kleingrass, and 866 for King Ranch bluestem (McCawley 1978, Kapinga 1982) on Orelia fine sandy loam soils. Compared to production from native species (sandy loam = 488 g/m²), there are 1.18 for bermudagrass, 1.62 for kleingrass, and 1.77 for King Ranch bluestem. Total forage biomass of improved pastures was estimated by multiplying these respective factors by total grass production under excellent range condition (Table C.2). Major improved pasture species are assumed to be determined by soil texture and soil depth: clays and clay loams = kleingrass; sands, sandy loams, shallow soils, and wetlands = bermudagrass. King Ranch bluestem and Johnsongrass are each considered to constitute 5% of the forage biomass on all improved pastures.

Appendix Table C.27 Initial vegetation plot types, including separation by woody plant coverage (%), used in the Goliad County EDYS model.

Plot Type	Range Type	Woody Coverage	Number of Cells	Plot Type	Range Type	Woody Coverage	Number of Cells
4501	Blackland Coastal	0-1	507	12101	Loamy Prairie	0-1	105
4601	Blackland Coastal	1-10	1389	12201	Loamy Prairie	1-10	354
4701	Blackland Coastal	10-25	67	12301	Loamy Prairie	10-25	657
4801	Blackland Coastal	25-50	240	12401	Loamy Prairie	25-50	702
4901	Blackland Coastal	50-75	310	12501	Loamy Prairie	50-75	7
5001	Blackland Coastal	75-90	174	12601	Loamy Prairie	75-90	1783
5101	Blackland Coastal	90-100	15				
				8701	Loamy Sand	0-1	2052
4201	Blackland RG Plains	25-50	1639	8801	Loamy Sand	1-10	8600
4301	Blackland RG Plains	50-75	2770	8901	Loamy Sand	10-25	3482
4401	Blackland RG Plains	75-90	1348	9001	Loamy Sand	25-50	5942
				9101	Loamy Sand	50-75	7509
13401	Clay Loam	0-1	22332	9201	Loamy Sand	75-90	1248
13501	Clay Loam	1-10	6905	9301	Loamy Sand	90-100	15
13601	Clay Loam	10-25	9175				
13701	Clay Loam	25-50	14636	1301	Lowland Coastal	0-1	287
13801	Clay Loam	50-75	2546	1401	Lowland Coastal	1-10	466
13901	Clay Loam	75-90	22	1501	Lowland Coastal	10-25	235
14001	Clay Loam	90-100	211	1601	Lowland Coastal	25-50	144
				1701	Lowland Coastal	50-75	458
801	Clayey Bottomland	1-10	3	1801	Lowland Coastal	75-90	80
901	Clayey Bottomland	25-50	135				
1001	Clayey Bottomland	50-75	712	1901	Rolling Blackland	1-10	25
1101	Clayey Bottomland	75-90	19	2001	Rolling Blackland	10-25	66
1201	Clayey Bottomland	90-100	135	2101	Rolling Blackland	25-50	338
				2201	Rolling Blackland	50-75	575
14101	Claypan Prairie	0-1	514	2301	Rolling Blackland	75-90	21
14201	Claypan Prairie	1-10	1524	2401	Rolling Blackland	90-100	45
14301	Claypan Prairie	10-25	3368				
14401	Claypan Prairie	25-50	1033	3001	Salty Prairie	0-1	114
14501	Claypan Prairie	50-75	6	3101	Salty Prairie	1-10	589
14601	Claypan Prairie	75-90	43	3201	Salty Prairie	10-25	507
14701	Claypan Prairie	90-100	306	3301	Salty Prairie	25-50	61
				3401	Salty Prairie	50-75	1529
10101	Claypan Savannah	0-1	1	3501	Salty Prairie	75-90	18
10201	Claypan Savannah	1-10	331				
10301	Claypan Savannah	10-25	133	5201	Sandy	0-1	343
10401	Claypan Savannah	25-50	210	5301	Sandy	1-10	415
10501	Claypan Savannah	50-75	543	5401	Sandy	10-25	578
10601	Claypan Savannah	75-90	833	5501	Sandy	25-50	633
				5601	Sandy	50-75	846
3601	Deep Sand	0-1	199	5701	Sandy	75-90	209
3701	Deep Sand	1-10	141	5801	Sandy	90-100	6
3801	Deep Sand	10-25	101				
3901	Deep Sand	25-50	41	14801	Sandy Bottomland	0-1	597
4001	Deep Sand	50-75	723	14901	Sandy Bottomland	1-10	1211
4101	Deep Sand	75-90	495	15001	Sandy Bottomland	10-25	1732
				15101	Sandy Bottomland	25-50	1221
8001	Gravelly Ridge	0-1	13	15201	Sandy Bottomland	50-75	342
8101	Gravelly Ridge	1-10	117	15301	Sandy Bottomland	75-90	525
8201	Gravelly Ridge	10-25	185	15401	Sandy Bottomland	90-100	43
8301	Gravelly Ridge	25-50	84				
8401	Gravelly Ridge	50-75	141	12701	Sandy Loam	0-1	5836
8501	Gravelly Ridge	75-90	89	12801	Sandy Loam	1-10	2174
8601	Gravelly Ridge	90-100	10	12901	Sandy Loam	10-25	2125
				13001	Sandy Loam	25-50	2737
7301	Gray Sandy Loam	0-1	41	13101	Sandy Loam	50-75	640
7401	Gray Sandy Loam	1-10	144	13201	Sandy Loam	75-90	99
7501	Gray Sandy Loam	10-25	246	13301	Sandy Loam	90-100	36
7601	Gray Sandy Loam	25-50	4337				
7701	Gray Sandy Loam	50-75	3713	5901	Shallow Ridge	0-1	649
7801	Gray Sandy Loam	75-90	505	6001	Shallow Ridge	1-10	1086
7901	Gray Sandy Loam	90-100	151	6101	Shallow Ridge	10-25	824
				6201	Shallow Ridge	25-50	1375

Appendix Table C.27 (Cont.)

Plot Type	Range Type	Woody Coverage	Number of Cells	Plot Type	Range Type	Woody Coverage	Number of Cells
2501	Lakebed Coastal	0-1	178	6301	Shallow Ridge	50-75	1387
2601	Lakebed Coastal	1-10	9	6401	Shallow Ridge	75-90	21
2701	Lakebed Coastal	10-25	129	6501	Shallow Ridge	90-100	30
2801	Lakebed Coastal	25-50	247				
2901	Lakebed Coastal	50-75	8	6601	Shallow Sandy Loam	0-1	602
				6701	Shallow Sandy Loam	1-10	1219
9401	Lakebed RG Plains	0-1	23	6801	Shallow Sandy Loam	10-25	851
9501	Lakebed RG Plains	1-10	212	6901	Shallow Sandy Loam	25-50	921
9601	Lakebed RG Plains	10-25	11	7001	Shallow Sandy Loam	50-75	1133
9701	Lakebed RG Plains	25-50	11	7101	Shallow Sandy Loam	75-90	88
9801	Lakebed RG Plains	50-75	10	7201	Shallow Sandy Loam	90-100	62
9901	Lakebed RG Plains	75-90	175				
10001	Lakebed RG Plains	90-100	20	10701	Sloping Clay Loam	0-1	70
				10801	Sloping Clay Loam	1-10	166
11401	Loamy Bottomland	0-1	107	10901	Sloping Clay Loam	10-25	24
11501	Loamy Bottomland	1-10	34	11001	Sloping Clay Loam	25-50	104
11601	Loamy Bottomland	10-25	320	11101	Sloping Clay Loam	50-75	30
11701	Loamy Bottomland	25-50	1598	11201	Sloping Clay Loam	75-90	259
11801	Loamy Bottomland	50-75	159	11301	Sloping Clay Loam	90-100	3
11901	Loamy Bottomland	75-90	503				
12001	Loamy Bottomland	90-100	64	101	Tight Sandy Loam	0-1	1564
				201	Tight Sandy Loam	1-10	9342
				301	Tight Sandy Loam	10-25	3337
				401	Tight Sandy Loam	25-50	4501
				501	Tight Sandy Loam	50-75	7014
				601	Tight Sandy Loam	75-90	1304
				701	Tight Sandy Loam	90-100	216

Appendix Table C.28 Weighted mean woody plant cover (%) by plot type and overall used as initial input values into the Goliad County EDYS model. Means are weighted by area (number of cells) in each woody coverage category.

Range Type	Number of Cells	(Number of Cells)(Woody Coverage)	Mean Woody Cover
Blackland Coastal	13,321	3,063.23	23.00
Blackland RG Plains	5,875	3,532.60	60.13
Clay Loam	308,678	129,654.43	42.00
Clayey Bottomland	15,355	10,177.73	66.28
Claypan Prairie	90,749	10,258.11	11.30
Claypan Savanna	67,511	31,659.33	46.90
Deep Sand	4,750	1,966.86	41.41
Gravelly Ridge	4,593	2,004.61	43.64
Gray Sandy Loam	44,025	24,683.23	56.07
Lakebed Coastal	833	193.65	23.25
Lakebed RG Plains	2,171	872.34	40.18
Loamy Bottomland	48,961	27,599.67	56.37
Loamy Prairie	35,503	9,443.67	26.60
Loamy Sand	165,968	53,239.76	32.08
Lowland Coastal	1,678	479.74	28.59
Rolling Blackland	11,634	6,475.47	55.66
Salty Prairie	36,184	2,638.58	10.06
Sandy	26,558	9,932.44	37.40
Sandy Bottomland	24,786	13,898.80	56.08
Sandy Loam	55,761	10,550.01	18.92
Shallow Ridge	40,668	14,410.55	35.42
Shallow Sandy Loam	46,612	30,670.13	65.80
Sloping Clay Loam	2,790	867.24	31.08
Tight Sandy Loam	207,904	73,877.55	35.53
Improved Pasture	25,794	350.92	1.36
Total	1,288,662	471,500.65	
Overall Weighted Mean			36.59

Appendix Table C.29 Forage consumption (C; g/m²) by cattle on a seacoast bluestem-McCartney rose pasture in Calhoun County, Texas. Values are from utilization (U; %) x available forage (F; g/m²). Data taken from Durham and Kothmann (1977).

Species	Dec 22			Jan 14			Feb 11			Mar 08			Mar 25			Apr 08		
	U	F	C	U	F	C	U	F	C	U	F	C	U	F	C	U	F	C
McCartney rose	6	101	6.1	9	44	4.0	6	94	5.8	5	36	1.8	2	90	1.8	0	--	1.3
Bermudagrass	35	38	13.3	31	22	6.8	40	33	13.2	27	58	15.7	20	85	17.0	31	58	18.0
Longtom	15	19	2.9	33	37	12.2	32	63	20.2	25	91	22.8	22	54	11.9	11	60	6.6
Brownseed paspalum	28	15	4.2	26	37	9.6	38	31	11.8	25	46	11.5	17	54	9.2	14	36	5.0
Seacoast bluestem	10	105	10.5	16	53	8.5	29	75	21.8	22	73	16.1	22	146	32.1	24	83	19.9
Knotroot bristle	12	83	10.0	3	31	0.9	30	15	4.5	24	8	1.9	27	8	2.2	40	6	2.4
Indiangrass	7	31	2.2	4	30	1.2	25	15	3.8	18	31	5.6	14	34	4.8	33	21	7.0
Smutgrass	37	45	16.7	44	43	18.9	55	24	13.2	46	22	10.1	36	11	4.0	14	14	2.0
Other grasses	5	42	2.1	14	30	4.2	15	15	2.3	14	24	3.4	24	33	8.0	20	13	2.6
Total			68.0			66.3			96.6			88.9			91.0			64.8

Consumption of McCartney rose was calculated from botanical composition of diet data.

Appendix Table C.30 Calculation of forage disappearance, animal unit basis, by cattle on a seacoast bluestem-McCartney rose pasture in Calhoun County, Texas. Data taken from Durham and Kothmann (1977).

Total forage utilization over 110 days (22 Dec-10 Apr) = 475.6 g/m² (Appendix Table C.27) = 4.32 g/m² per day.

Total area grazed = 7.2 ha = 72,000 m² = 17.8 acres.

Area was grazed by four cows. Assume cows were 1000 lbs = 4 AU.

Average daily consumption = (72,000 m²)(4.32 g/m²/d)/4 AU = 77,760 g/AUD = 171.28 lbs/AUD

Total forage production = forage utilized + forage remaining = (475.6 – 20.8) + 291 = 746 g/m²

Utilization rate = 455/746 = 0.610

ADDITIONAL PLANT AND VEGETATION DATA

Bovey, R.W., R.E. Meyer, and H.L. Morton. 1972. Herbage production following brush control with herbicides in Texas. Journal of Range Management 25:136-142.

Victoria County, Katy gravelly sandy loam.

Live oak-little bluestem community (shrub live oak = 2 m tall): live oak, little bluestem, brownseed paspalum, indiagrass, threeawns, lovegrasses, knotroot bristlegrass, bitter sneezeweed, Lindheimer doveweed.

Oct 1967 herbaceous biomass = 185 g/m² grasses + 18 g/m² forbs

Area bulldozed in Jul 1963 and harvested in Apr 1970 = 114 g/m² live oak regrowth + 2 g/m² grasses + 2 g/m² forbs

Victoria 1967 PPT = 33.90 inches = 86.1 cm Oct 1966-Sep 1967 = 28.18 inches = 71.6 cm

PUE = 203 g/m²/71.6 cm = 2.84 g/m²/cm + live oak production

Box, Thadis W. and Richard S. White. 1969. Fall and winter burning of South Texas brush ranges. Journal of Range Management 22:373-376.

Chaparral community, Welder Wildlife Refuge. Mesquite-huisache-blackbrush community

Sampled Aug 1967

Herbaceous production (24% buffalograss, 9% silver bluestem, 8% ruellia, 15% Texas broomweed):

163.6 g/m² = 97.7 g/m² grasses + 65.9 g/m² forbs

Buckley, P.E. and J.D. Dodd. 1969. Heavy precipitation influences saline clay flat vegetation. Journal of Range Management 22:405-407.

18 mi NNE of Zapata. Prickly pear-saladillo-mesquite community. Root plowed in 1962.

Sampled in Nov 1967 following Beulah.

Herbaceous production (56% Hall panicum, 20% curly mesquite, 10% whorled dropseed): 136 g/m²

1967 PPT at study site = 26.39 inches = 67.0 cm

PUE = 136 g/m²/67.0 cm = 2.03 g/m²/cm + shrub production

Dodd, J.D. and S.T. Holtz. 1972. Integration of burning with mechanical manipulation of South Texas grassland. Journal of Range Management 25:130-136.

Cartwright Ranch, Goliad County. Blackbrush-Texas persimmon-hogplum community.

Sampled Jun 1968.

Herbaceous production = 145 g/m² = 41 g/m² grass (24% sedge, 20% Texas grama, 16% threeawns) +

104 g/m² forbs (8% orange zexmenia, 4% Texas broomweed)

Jun 1967-May 1968 PPT at Goliad = 54.45 inches = 138.3 cm

PUE = 145 g/m²/138.3 cm = 1.05 g/m²/cm + shrub production

Drawe, D. Lynn and Thadis W. Box. 1969. High rates of nitrogen fertilization influence coastal prairie range. Journal of Range Management 22:32-36.

Bunchgrass-annual forb community on Zavala fine sandy loam, Welder Wildlife Refuge.

21% camphorweed, 14% knotgrass, 12% balsamscale, 10% sandbur, 9% signalgrass, 6% seacoast
Sampled in August of each year.

	1965	1966	1967	
Herbaceous production (g/m ²):	237	228	252	
Grasses (g/m ²):	159	137	192	
Forbs (g/m ²):	78	91	60	
Sep-Aug PPT (cm):	68.5	101.3	65.2	Refugio PPT(0.904)
PUE (g/m ² /cm):	3.46	2.25	3.87	Mean = 3.20

Jan 1964-Sep 1965 PPT Refugio = 50.59 inches

Jan 1964-Sep 1965 PPT WWR = 45.74 inches 45.74/50.59 = 0.904

Powell, Jeff and Thadis W. Box. 1967. Mechanical control and fertilization as brush management practices affect forage production in South Texas. Journal of Range Management 20:227-236.

Chaparral-bristlegrass community, Victoria clay, Welder Wildlife Refuge.

Blackbrush-huisache-mesquite (49% brush cover).

Herbaceous: plains bristlegrass (15%), buffalograss (11%), ragweed, Texas broomweed (31% forbs)

Forage production: 101 g/m² in 1964; 162 g/m² in 1965

Oct 1963-Sep 1964 PPT = 0.904(Refugio) = 0.904(33.37) = 30.17 inches = 76.6 cm

Oct 1964-Sep 1965 PPT = 0.904(Refugio Oct-Dec) + 17.44 inches = 0.904(7.03) + 17.44 = 60.5 cm

1964 PUE = 101 g/m²/76.6 cm = 1.32 g/m²/cm 1965 PUE = 162 g/m²/60.5 cm = 2.68 g/m²/cm

APPENDIX D ANIMALS

Appendix Table D.1 Estimation of cattle stocking rates (moderate level) for vegetation plot types in the Goliad County EDYS model. Values assume fair range condition and no woody plant cover.

Range Type	Annual Forage (g/m ²)	Available Forage (g/m ²)	AU Forage Requirement (g/AUD)(365 d)	Stocking Rate (m ² /AU) (ac/AU)
Blackland RG Plains	261	131	5,634,870	43,014 10.63
Blackland Coastal	522	261	5,634,870	21,580 5.33
Clayey Bottomland	286	143	5,634,870	39,405 9.73
Clay Loam	286	143	5,634,870	39,405 9.73
Claypan Prairie	379	190	5,634,870	29,657 7.33
Claypan Savanna	306	153	5,634,870	36,829 9.10
Deep Sand	243	122	5,634,870	46,188 11.41
Gravelly Ridge	178	89	5,634,870	63,313 15.64
Gray Sandy Loam	260	130	5,634,870	43,345 10.71
Lakebed RG Plains	276	138	5,634,870	40,832 10.09
Lakebed Coastal	350	175	5,634,870	32,199 7.95
Loamy Bottomland	431	216	5,634,870	26,087 6.94
Loamy Prairie	410	205	5,634,870	27,487 6.79
Loamy Sand	295	148	5,634,870	38,074 9.41
Lowland Coastal	447	224	5,634,870	25,156 6.21
Rolling Blackland	260	130	5,634,870	43,345 10.71
Salty Prairie	520	260	5,634,870	21,673 5.35
Sandy	297	149	5,634,870	37,818 9.34
Sandy Bottomland	369	185	5,634,870	30,459 7.52
Sandy Loam	342	171	5,634,870	32,952 8.14
Shallow Ridge	134	67	5,634,870	84,103 20.78
Shallow Sandy Loam	210	105	5,634,870	53,665 13.26
Sloping Clay Loam	186	93	5,634,870	60,590 14.97
Tight Sandy Loam	285	143	5,634,870	39,405 9.73
Improved Pasture	566	283	5,634,870	19,911 4.92
Mean				9.67

Annual forage = fair range condition (Appendix Table C.2).

Available forage = (Annual Forage)(0.5), where 0.5 is proper management harvest rate.

AU Forage Requirement = 15,438 g/AUD = (Table 6.1). Stocking Rate = (AU Forage Requirement)/(Available Forage).

Appendix Table D.2 Estimation of cattle stocking rates (moderate level) for vegetation plot types, adjusted for woody plant cover, in the Goliad County EDYS model. Values assume fair range condition.

Range Type	Woody Cover (%)	Annual Forage (g/m ²)	Available Forage (g/m ²)	Forage Requirement (g/AU)	Stocking Rate (m ² /AU)	(ac/AU)
Blackland RG Plains	0	261	131	5,634,870	43,104	10.63
Blackland RG Plains	38	182	91	5,634,870	61,922	15.30
Blackland RG Plains	63	130	65	5,634,870	86,690	21.42
Blackland RG Plains	83	87	44	5,634,870	128,065	31.64
Blackland Coastal	0	522	261	5,634,870	21,580	5.33
Blackland Coastal	5	501	250	5,634,870	22,539	5.57
Blackland Coastal	18	447	223	5,634,870	25,268	6.24
Blackland Coastal	38	364	182	5,634,870	30,961	7.65
Blackland Coastal	63	261	130	5,634,870	43,345	10.71
Blackland Coastal	83	174	87	5,634,870	64,769	16.00
Blackland Coastal	95	63	31	5,634,870	181,770	44.90
Clayey Bottomland	0	286	143	5,634,870	39,405	9.73
Clayey Bottomland	5	275	137	5,634,870	41,130	10.16
Clayey Bottomland	38	200	100	5,634,870	56,349	13.92
Clayey Bottomland	63	143	71	5,634,870	79,364	19.61
Clayey Bottomland	83	95	47	5,634,870	119,891	29.62
Clay Loam	0	286	143	5,634,870	39,405	9.73
Clay Loam	5	275	137	5,634,870	41,130	10.16
Clay Loam	18	245	122	5,634,870	46,187	11.41
Clay Loam	38	200	100	5,634,870	56,349	13.92
Clay Loam	63	143	71	5,634,870	79,364	19.61
Clay Loam	83	95	47	5,634,870	119,891	29.62
Clay Loam	95	69	34	5,634,870	165,731	40.94
Claypan Prairie	0	379	190	5,634,870	29,657	7.33
Claypan Prairie	5	364	182	5,634,870	30,961	7.65
Claypan Prairie	18	324	162	5,634,870	34,783	8.59
Claypan Prairie	38	265	132	5,634,870	42,688	10.55
Claypan Prairie	63	189	94	5,634,870	59,945	14.81
Claypan Prairie	83	129	64	5,634,870	88,045	21.75
Claypan Prairie	95	91	45	5,634,870	125,217	30.93
Claypan Savanna	0	306	153	5,634,870	36,829	9.10
Claypan Savanna	5	294	147	5,634,870	38,333	9.47
Claypan Savanna	18	262	131	5,634,870	43,014	10.63
Claypan Savanna	38	214	107	5,634,870	52,662	13.01
Claypan Savanna	63	153	76	5,634,870	74,143	18.32
Claypan Savanna	83	102	51	5,634,870	110,488	27.29
Deep Sand	0	243	122	5,634,870	46,187	11.41
Deep Sand	5	233	116	5,634,870	48,577	12.00
Deep Sand	18	208	104	5,634,870	54,181	13.38
Deep Sand	38	170	85	5,634,870	66,293	16.38
Deep Sand	63	121	60	5,634,870	93,915	23.20
Deep Sand	83	81	40	5,634,870	140,872	34.80
Gravelly Ridge	0	178	89	5,634,870	63,313	15.64
Gravelly Ridge	5	171	85	5,634,870	66,293	16.38
Gravelly Ridge	18	152	76	5,634,870	74,143	18.32
Gravelly Ridge	38	124	62	5,634,870	90,885	21.45
Gravelly Ridge	63	89	45	5,634,870	125,217	30.93
Gravelly Ridge	83	59	29	5,634,870	194,306	48.00
Gravelly Ridge	95	43	21	5,634,870	268,327	66.29
Gray Sandy Loam	0	260	130	5,634,870	43,345	10.71
Gray Sandy Loam	5	250	125	5,634,870	45,079	11.14
Gray Sandy Loam	18	223	111	5,634,870	50,765	12.54
Gray Sandy Loam	38	182	91	5,634,870	61,922	15.30
Gray Sandy Loam	63	130	65	5,634,870	86,690	21.42
Gray Sandy Loam	83	86	43	5,634,870	131,043	32.37
Gray Sandy Loam	95	62	31	5,634,870	181,770	44.90
Lakebed RG Plains	0	276	138	5,634,870	40,832	10.09
Lakebed RG Plains	5	265	132	5,634,870	42,688	10.55
Lakebed RG Plains	18	236	118	5,634,870	47,753	11.80
Lakebed RG Plains	38	193	96	5,634,870	58,697	14.50
Lakebed RG Plains	63	138	69	5,634,870	81,665	20.17
Lakebed RG Plains	83	92	46	5,634,870	122,497	30.26
Lakebed RG Plains	95	74	37	5,634,870	152,294	37.62
Lakebed Coastal	0	350	175	5,634,870	32,199	7.95

Appendix Table D.2 (Cont.)

Range Type	Woody Cover (%)	Annual Forage (g/m ²)	Available Forage (g/m ²)	Forage Requirement (g/AU)	Stocking Rate (m ² /AU)	(ac/AU)
Lakebed Coastal	5	336	168	5,634,870	33,451	8.26
Lakebed Coastal	18	300	150	5,634,870	37,566	9.28
Lakebed Coastal	38	245	122	5,634,870	46,187	11.41
Lakebed Coastal	63	168	84	5,634,870	67,082	16.57
Loamy Bottomland	0	431	216	5,634,870	26,087	6.94
Loamy Bottomland	5	414	207	5,634,870	27,222	6.72
Loamy Bottomland	18	369	184	5,634,870	30,624	7.57
Loamy Bottomland	38	300	150	5,634,870	37,566	9.28
Loamy Bottomland	63	215	107	5,634,870	52,662	13.01
Loamy Bottomland	83	143	71	5,634,870	79,364	19.61
Loamy Bottomland	95	103	51	5,634,870	110,488	27.29
Loamy Prairie	0	410	205	5,634,870	27,487	6.79
Loamy Prairie	5	394	197	5,634,870	28,603	7.07
Loamy Prairie	18	351	175	5,634,870	32,199	7.95
Loamy Prairie	38	286	143	5,634,870	39,405	9.73
Loamy Prairie	63	205	102	5,634,870	55,244	13.65
Loamy Prairie	83	136	68	5,634,870	82,866	20.47
Loamy Sand	0	295	148	5,634,870	38,074	9.41
Loamy Sand	5	283	141	5,634,870	39,964	9.87
Loamy Sand	18	253	126	5,634,870	44,721	11.05
Loamy Sand	38	206	103	5,634,870	54,707	13.51
Loamy Sand	63	147	73	5,634,870	77,190	19.07
Loamy Sand	83	98	49	5,634,870	114,997	28.41
Loamy Sand	95	71	35	5,634,870	160,996	39.77
Lowland Coastal	0	447	224	5,634,870	25,156	6.21
Lowland Coastal	5	429	214	5,634,870	26,331	6.50
Lowland Coastal	18	383	191	5,634,870	29,502	7.29
Lowland Coastal	38	312	156	5,634,870	36,121	8.92
Lowland Coastal	63	223	111	5,634,870	50,765	12.54
Lowland Coastal	83	149	74	5,634,870	76,147	18.81
Rolling Blackland	0	260	130	5,634,870	43,345	10.71
Rolling Blackland	5	250	125	5,634,870	45,079	11.14
Rolling Blackland	18	223	111	5,634,870	50,765	12.54
Rolling Blackland	38	182	91	5,634,870	61,922	15.30
Rolling Blackland	63	130	65	5,634,870	86,690	21.42
Rolling Blackland	83	86	43	5,634,870	131,043	32.37
Rolling Blackland	95	62	31	5,634,870	181,770	44.90
Salty Prairie	0	520	260	5,634,870	21,673	5.35
Salty Prairie	5	499	249	5,634,870	22,630	5.59
Salty Prairie	18	445	222	5,634,870	25,382	6.27
Salty Prairie	38	364	182	5,634,870	30,961	7.65
Salty Prairie	63	260	130	5,634,870	43,345	10.71
Salty Prairie	83	172	86	5,634,870	65,522	16.19
Sandy	0	297	149	5,634,870	37,818	9.34
Sandy	5	285	142	5,634,870	39,682	9.80
Sandy	18	254	127	5,634,870	44,369	10.96
Sandy	38	207	103	5,634,870	54,707	13.51
Sandy	63	148	74	5,634,870	76,147	18.81
Sandy	83	99	49	5,634,870	114,997	28.41
Sandy	95	71	35	5,634,870	160,996	39.77
Sandy Bottomland	0	369	185	5,634,870	30,459	7.52
Sandy Bottomland	5	354	177	5,634,870	31,835	7.86
Sandy Bottomland	18	316	158	5,634,870	35,664	8.81
Sandy Bottomland	38	258	129	5,634,870	43,666	10.79
Sandy Bottomland	63	184	92	5,634,870	61,249	15.13
Sandy Bottomland	83	123	61	5,634,870	92,375	22.82
Sandy Bottomland	95	89	44	5,634,870	128,065	31.64
Sandy Loam	0	342	171	5,634,870	32,952	8.14
Sandy Loam	5	328	164	5,634,870	34,359	8.49
Sandy Loam	18	293	146	5,634,870	38,595	9.56
Sandy Loam	38	238	119	5,634,870	47,352	11.70
Sandy Loam	63	171	85	5,634,870	66,293	16.38
Sandy Loam	83	114	57	5,634,870	98,857	24.42
Sandy Loam	95	82	41	5,634,870	137,436	33.95
Shallow Ridge	0	134	67	5,634,870	84,103	20.78
Shallow Ridge	5	129	64	5,634,870	88,045	21.75

Appendix Table D.2 (Cont.)

Range Type	Woody Cover (%)	Annual Forage (g/m ²)	Available Forage (g/m ²)	Forage Requirement (g/AU)	Stocking Rate (m ² /AU)	(ac/AU)
Shallow Ridge	18	115	57	5,634,870	98,857	24.42
Shallow Ridge	38	93	46	5,634,870	122,497	30.26
Shallow Ridge	63	67	33	5,634,870	170,754	42.18
Shallow Ridge	83	44	22	5,634,870	256,130	63.27
Shallow Ridge	95	32	16	5,634,870	352,179	87.00
Shallow Sandy Loam	0	210	105	5,634,870	53,665	13.26
Shallow Sandy Loam	5	202	101	5,634,870	55,791	13.78
Shallow Sandy Loam	18	180	90	5,634,870	62,610	15.47
Shallow Sandy Loam	38	147	73	5,634,870	77,190	19.07
Shallow Sandy Loam	63	105	52	5,634,870	108,363	26.77
Shallow Sandy Loam	83	70	35	5,634,870	160,996	39.77
Shallow Sandy Loam	95	50	25	5,634,870	225,395	55.68
Sloping Clay Loam	0	186	93	5,634,870	60,590	14.97
Sloping Clay Loam	5	179	89	5,934,870	63,313	15.63
Sloping Clay Loam	18	159	79	5,934,870	71,327	17.62
Sloping Clay Loam	38	130	65	5,634,870	86,690	21.42
Sloping Clay Loam	63	93	46	5,634,870	122,497	30.26
Sloping Clay Loam	83	62	31	5,634,870	181,770	44.90
Sloping Clay Loam	95	45	22	5,634,870	256,130	63.27
Tight Sandy Loam	0	285	143	5,634,870	39,405	9.73
Tight Sandy Loam	5	274	137	5,634,870	41,130	10.16
Tight Sandy Loam	18	244	122	5,634,870	46,187	11.41
Tight Sandy Loam	38	199	99	5,634,870	56,918	14.06
Tight Sandy Loam	63	142	71	5,634,870	79,364	19.61
Tight Sandy Loam	83	95	47	5,634,870	119,891	29.62
Tight Sandy Loam	95	68	34	5,634,870	165,731	40.94
Improved Pasture	0	566	283	5,634,870	19,911	4.92
Improved Pasture	5	543	271	5,634,870	20,793	5.14
Improved Pasture	18	484	242	5,634,870	23,285	5.75
Caliche Pit	0	100	50	5,634,870	112,697	27.84
Caliche Pit	5	96	48	5,634,870	117,393	29.00
Caliche Pit	18	86	43	5,634,870	131,043	32.37
Caliche Pit	38	70	35	5,634,870	160,996	39.77
Disturbed Site	0	100	50	5,634,870	112,697	27.84
Disturbed Site	5	96	48	5,634,870	117,393	29.00
Disturbed Site	18	86	43	5,634,870	131,043	32.37
Disturbed Site	38	70	35	5,634,870	160,996	39.37
Orchard	0	70	35	5,634,870	160,996	39.37
Orchard	5	67	33	5,634,870	170,754	42.18
Orchard	18	60	30	5,634,870	187,829	46.40
Orchard	38	49	24	5,634,870	234,786	58.00
Urban/Housing	0	500	250	5,634,870	22,539	5.57
Urban/Housing	5	480	240	5,634,870	23,479	5.80
Urban/Housing	18	428	214	5,634,870	26,331	6.50
Urban/Housing	38	348	174	5,634,870	32,384	8.00
Urban/Housing	63	250	125	5,634,870	45,079	11.14
Industrial	0	350	175	5,634,870	32,199	7.95
Industrial	5	336	168	5,634,870	33,541	8.26
Industrial	18	300	150	5,634,870	37,566	9.28
Industrial	38	245	122	5,634,870	46,187	11.41
Oil Pad	0	0	0	5,634,870	-----	-----
Oil Pad	5	0	0	5,634,870	-----	-----
Oil Pad	18	0	0	5,634,870	-----	-----

Annual forage = fair range condition (Appendix Table C.2).

Available forage = (Annual Forage)(0.5), where 0.5 is proper management harvest rate.

AU Forage Requirement = 15,438 g/AUD (Table 6.1).

Stocking rate = (AU Forage Requirement)(Available Forage)[1.00 – 0.8(percent woody plant cover/100)]; Appendix Table C.24.

APPENDIX E PLANT PARAMETERS

Appendix Table E.1 General species characteristics for species used in the Goliad County EDYS model.

Common Name	Growth Form	Legume	Biennial
Huisache	Deciduous Tree	1	No
Pecan	Deciduous Tree	0	No
Sugar hackberry	Deciduous Tree	0	No
Mesquite	Deciduous Tree	1	No
Post oak	Deciduous Tree	0	No
Live oak	Evergreen Tree	0	No
Guajillo	Evergreen Shrub	1	No
Blackbrush	Deciduous Shrub	1	No
Whitebrush	Deciduous Shrub	0	No
Prairie baccharis	Deciduous Shrub	0	No
Sea oxeye	Deciduous Shrub	0	No
Granjeno	Deciduous Shrub	0	No
Carolina wolfberry	Deciduous Shrub	0	No
Agarito	evergreen shrub	0	No
McCartney rose	Deciduous Shrub	0	No
Rattlepod	Deciduous Shrub	1	No
Mustang grape	Deciduous Vine	0	No
Texas prickly pear	Cacti	0	No
Big bluestem	Perennial Grass	0	No
Bushy bluestem	Perennial Grass	0	No
Purple threeawn	Perennial Grass	0	No
King Ranch bluestem	Perennial Grass	0	No
Silver bluestem	Perennial Grass	0	No
Sideoats grama	Perennial Grass	0	No
Hairy grama	Perennial Grass	0	No
Red grama	Perennial Grass	0	No
Buffalograss	Perennial Grass	0	No
Sandbur	Perennial Grass	0	No
Hooded windmillgrass	Perennial Grass	0	No
Trichloris	Perennial Grass	0	No
Bermudagrass	Perennial Grass	0	No
Arizona cottontop	Perennial Grass	0	No
Saltgrass	Perennial Grass	0	No
Virginia wildrye	Perennial Grass	0	No
Texas cupgrass	Perennial Grass	0	No
Green sprangletop	Perennial Grass	0	No
Kleingrass	Perennial Grass	0	No
Guineagrass	Perennial Grass	0	No
Vine-mesquite	Perennial Grass	0	No
Switchgrass	Perennial Grass	0	No
Longtom	Perennial Grass	0	No
Brownseed paspalum	Perennial Grass	0	No

Appendix Table E.1 (Cont.)

Common Name	Growth Form	Legume	Biennial
Thin paspalum	Perennial Grass	0	No
Common reed	Perennial Grass	0	No
Little bluestem	Perennial Grass	0	No
Knotroot bristlegrass	Perennial Grass	0	No
Plains bristlegrass	Perennial Grass	0	No
Texas bristlegrass	Perennial Grass	0	No
Indiangrass	Perennial Grass	0	No
Johnsongrass	Perennial Grass	0	No
Gulf cordgrass	Perennial Grass	0	No
Tall dropseed	Perennial Grass	0	No
Sand dropseed	Perennial Grass	0	No
Smutgrass	Perennial Grass	0	No
Texas wintergrass	Perennial Grass	0	No
Milo	Annual Grass	0	No
Wheat	Annual Grass	0	No
Corn	Annual Grass	0	No
Littletooth sedge	Perennial Grasslike	0	No
Flatsedge	Perennial Grasslike	0	No
Cattail	Perennial Grasslike	0	No
Ragweed	Perennial Forb	0	No
Lazydaisy	Perennial Forb	0	No
Spiny aster	Perennial Forb	0	No
Whitestem wild indigo	Perennial Forb	0	No
Old-mans beard	Perennial Forb	0	No
Bundleflower	Perennial Forb	1	No
Frogfruit	Perennial Forb	0	No
Prairie coneflower	Perennial Forb	0	No
Snoutbean	Perennial Forb	1	No
Ruellia	Perennial Forb	0	No
Curly dock	Perennial Forb	1	No
Bulltongue	Perennial Forb	1	No
Glasswort	Perennial Forb	0	No
Bush sunflower	Perennial Forb	0	No
Green briar	Perennial Forb	0	No
Texas verbena	Perennial Forb	0	No
Orange zexmenia	Perennial Forb	0	No
Giant ragweed	Annual Forb	0	No
Annual broomweed	Annual Forb	0	No
Partridge pea	Annual Forb	1	No
Texas doveweed	Annual Forb	0	No
Sunflower	Annual Forb	0	No
Dogweed	Annual Forb	0	No

Appendix Table E.2 Tissue allocation in mature plants, by plant part (proportion of total), and root:shoot ratio (R:S) for species included in the Goliad County EDYS model.

Common Name	CRoot	FRoot	Trunk	Stems	Leaves	Seeds
Huisache	0.34	0.12	0.38	0.11	0.05	0.00
Pecan	0.32	0.11	0.40	0.12	0.05	0.00
Sugar hackberry	0.16	0.06	0.55	0.17	0.06	0.00
Mesquite	0.14	0.10	0.39	0.28	0.09	0.00
Post oak	0.20	0.07	0.51	0.16	0.06	0.00
Live oak	0.24	0.08	0.48	0.15	0.05	0.00
Guajillo	0.27	0.12	0.34	0.18	0.09	0.00
Blackbrush	0.27	0.12	0.34	0.18	0.09	0.00
Whitebrush	0.26	0.12	0.34	0.19	0.09	0.00
Prairie baccharis	0.26	0.12	0.34	0.19	0.09	0.00
Sea oxeye	0.32	0.15	0.28	0.19	0.06	0.00
Granjeno	0.28	0.12	0.33	0.18	0.09	0.00
Carolina wolfberry	0.25	0.10	0.21	0.23	0.21	0.00
Agarito	0.35	0.14	0.28	0.15	0.08	0.00
McCartney rose	0.32	0.15	0.28	0.19	0.06	0.00
Rattlepod	0.27	0.11	0.34	0.19	0.09	0.00
Mustang grape	0.23	0.10	0.35	0.17	0.15	0.00
Texas prickly pear	0.16	0.08	0.37	0.38	0.01	0.00
Big bluestem	0.24	0.24	0.10	0.21	0.21	0.00
Bushy bluestem	0.23	0.36	0.13	0.16	0.12	0.00
Purple threeawn	0.33	0.32	0.07	0.14	0.14	0.00
King Ranch bluestem	0.31	0.30	0.08	0.16	0.15	0.00
Silver bluestem	0.25	0.25	0.10	0.20	0.20	0.00
Sideoats grama	0.31	0.31	0.08	0.15	0.15	0.00
Hairy grama	0.18	0.18	0.21	0.06	0.37	0.00
Red grama	0.18	0.18	0.21	0.06	0.37	0.00
Buffalograss	0.28	0.27	0.12	0.05	0.28	0.00
Sandbur	0.26	0.39	0.12	0.08	0.15	0.00
Hooded windmillgrass	0.23	0.24	0.14	0.05	0.34	0.00
Trichloris	0.25	0.25	0.10	0.20	0.20	0.00
Bermudagrass	0.28	0.27	0.15	0.05	0.25	0.00
Arizona cottontop	0.23	0.24	0.11	0.21	0.21	0.00
Saltgrass	0.23	0.36	0.13	0.16	0.12	0.00
Virginia wildrye	0.23	0.23	0.11	0.22	0.21	0.00
Texas cupgrass	0.26	0.26	0.10	0.19	0.19	0.00
Green sprangletop	0.23	0.23	0.11	0.22	0.21	0.00
Kleingrass	0.23	0.24	0.11	0.21	0.21	0.00
Guineagrass	0.23	0.24	0.11	0.21	0.21	0.00
Vine-mesquite	0.23	0.23	0.11	0.22	0.21	0.00
Switchgrass	0.25	0.25	0.10	0.20	0.20	0.00
Longtom	0.36	0.35	0.08	0.03	0.18	0.00
Brownseed paspalum	0.22	0.33	0.10	0.16	0.19	0.00

Appendix Table E.2 (Cont.)

Common Name	CRoot	FRoot	Trunk	Stems	Leaves	Seeds
Thin paspalum	0.22	0.21	0.17	0.06	0.34	0.00
Common reed	0.18	0.18	0.18	0.26	0.20	0.00
Little bluestem	0.31	0.31	0.08	0.15	0.15	0.00
Knotroot bristlegrass	0.26	0.26	0.14	0.05	0.29	0.00
Plains bristlegrass	0.31	0.46	0.03	0.12	0.08	0.00
Texas bristlegrass	0.19	0.19	0.19	0.06	0.37	0.00
Indiangrass	0.37	0.36	0.05	0.11	0.11	0.00
Johnsongrass	0.35	0.34	0.06	0.13	0.12	0.00
Gulf cordgrass	0.31	0.46	0.03	0.12	0.08	0.00
Tall dropseed	0.26	0.26	0.10	0.19	0.19	0.00
Sand dropseed	0.24	0.23	0.11	0.21	0.21	0.00
Smutgrass	0.31	0.46	0.03	0.12	0.08	0.00
Texas wintergrass	0.28	0.28	0.13	0.04	0.27	0.00
Milo	0.25	0.25	0.10	0.20	0.20	0.00
Wheat	0.23	0.24	0.11	0.21	0.21	0.00
Corn	0.25	0.25	0.10	0.20	0.20	0.00
Littletooth sedge	0.28	0.27	0.13	0.05	0.27	0.00
Flatsedge	0.39	0.38	0.05	0.09	0.09	0.00
Cattail	0.39	0.38	0.05	0.09	0.09	0.00
Ragweed	0.28	0.28	0.09	0.18	0.17	0.00
Lazydaisy	0.29	0.29	0.08	0.17	0.17	0.00
Spiny aster	0.49	0.20	0.05	0.17	0.09	0.00
Whitestem wild indigo	0.24	0.25	0.09	0.15	0.27	0.00
Old-mans beard	0.29	0.28	0.08	0.09	0.26	0.00
Bundleflower	0.29	0.30	0.08	0.16	0.17	0.00
Frogfruit	0.16	0.17	0.20	0.07	0.40	0.00
Prairie coneflower	0.29	0.29	0.08	0.18	0.17	0.00
Snoutbean	0.21	0.20	0.17	0.06	0.36	0.00
Ruellia	0.19	0.19	0.19	0.06	0.37	0.00
Curly dock	0.20	0.05	0.19	0.09	0.47	0.00
Bulltongue	0.20	0.05	0.19	0.09	0.47	0.00
Glasswort	0.14	0.10	0.25	0.25	0.26	0.00
Bush sunflower	0.28	0.28	0.09	0.18	0.17	0.00
Green briar	0.25	0.25	0.15	0.18	0.16	0.00
Texas verbena	0.21	0.20	0.17	0.06	0.36	0.00
Orange zexmenia	0.28	0.28	0.09	0.18	0.17	0.00
Giant ragweed	0.16	0.17	0.13	0.27	0.27	0.00
Annual broomweed	0.19	0.19	0.12	0.25	0.25	0.00
Partridge pea	0.19	0.19	0.19	0.06	0.37	0.00
Texas doveweed	0.14	0.15	0.14	0.29	0.28	0.00
Sunflower	0.08	0.07	0.17	0.34	0.34	0.00
Dogweed	0.19	0.19	0.16	0.06	0.40	0.00

croot = coarse roots; froot = fine roots

Data Sources

Root:Shoot Ratios

Huisache: huisache seedling = 0.48 (Fulbright et al. 1997); *Leucaena leucocephala* seedling = 0.46 (Jones & Aliyu 1976; Huang et al. 1985); *Leucaena leucocephala* mature = 0.82 (Von Carlowitz & Wolf 1991); huisache mature = $0.82(0.48/0.46) = 0.85$

Pecan: Slow-growing hardwoods (Odum 1971:375)

Sugar hackberry: *Fagus* sp. (Garelkov 1973)

Texas persimmon Slow-growing hardwoods (Odum 1971:375)

Mesquite: Twice the value reported by Barth et al. (1982)

Post oak: Mean of *Quercus alba* (Nadelhoffer et al. 1985), *Q. rubra* (Nadelhoffer et al. 1985), *Q. robur* (Andersson 1970, Duvigneaud et al. 1971, Rodin & Bazilevich 1967), *Q. robus* (Duvigneaud et al. 1971), *Q. velutina* (Nadelhoffer et al. 1985)

Live oak: Mean of *Quercus alba* and *Q. velutina* (Nadelhoffer et al. 1985)

Coarse:Fine Root Ratios

Coarse:Fine 75:25 trees; 70:30 shrubs; 50:50 herbaceous

Aboveground Tissue Allocation (Trunk:Stem:Leaves)

Trees: 0.70:0.22:0.08
 Shrubs: 0.55:0.30:0.15
 Herbaceous (stemmy): 0.2:0.4:0.4
 Herbaceous (short): 0.3:0.1:0.6

Appendix Table E.3 Allocation of new biomass production by plant part (proportion of total) for species included in the Goliad County EDYS model.

Common Name	CRoot	FRoot	Trunk	Stems	Leaves	Seeds
Huisache	0.08	0.20	0.09	0.22	0.41	0.00
Pecan	0.11	0.32	0.15	0.08	0.34	0.00
Sugar hackberry	0.06	0.16	0.27	0.08	0.43	0.00
Mesquite	0.08	0.30	0.12	0.19	0.31	0.00
Post oak	0.07	0.20	0.25	0.08	0.40	0.00
Live oak	0.10	0.20	0.15	0.07	0.48	0.00
Guajillo	0.06	0.20	0.04	0.18	0.52	0.00
Blackbrush	0.05	0.20	0.05	0.20	0.50	0.00
Whitebrush	0.04	0.18	0.04	0.25	0.49	0.00
Prairie baccharis	0.05	0.20	0.05	0.20	0.50	0.00
Sea oxeye	0.14	0.40	0.10	0.15	0.21	0.00
Granjeno	0.04	0.18	0.04	0.22	0.52	0.00
Carolina wolfberry	0.08	0.25	0.20	0.22	0.25	0.00
Agarito	0.07	0.25	0.10	0.10	0.48	0.00
McCartney rose	0.14	0.40	0.10	0.15	0.21	0.00
Rattlepod	0.05	0.20	0.10	0.15	0.50	0.00
Mustang grape	0.03	0.20	0.10	0.15	0.52	0.00
Texas prickly pear	0.10	0.22	0.20	0.46	0.02	0.00
Big bluestem	0.10	0.24	0.05	0.30	0.31	0.00
Bushy bluestem	0.10	0.25	0.10	0.25	0.30	0.00
Purple threeawn	0.12	0.25	0.08	0.10	0.45	0.00
King Ranch bluestem	0.12	0.25	0.10	0.05	0.48	0.00
Silver bluestem	0.12	0.24	0.05	0.25	0.34	0.00
Sideoats grama	0.12	0.24	0.05	0.26	0.33	0.00
Hairy grama	0.09	0.18	0.10	0.06	0.57	0.00
Red grama	0.10	0.25	0.08	0.10	0.47	0.00
Buffalograss	0.16	0.27	0.10	0.12	0.35	0.00
Sandbur	0.02	0.40	0.10	0.15	0.33	0.00
Hooded windmillgrass	0.12	0.24	0.07	0.05	0.52	0.00
Trichloris	0.12	0.25	0.04	0.26	0.33	0.00
Bermudagrass	0.12	0.25	0.10	0.05	0.48	0.00
Arizona cottontop	0.12	0.24	0.05	0.30	0.29	0.00
Saltgrass	0.09	0.36	0.19	0.24	0.12	0.00
Virginia wildrye	0.12	0.23	0.05	0.30	0.30	0.00
Texas cupgrass	0.12	0.23	0.10	0.24	0.31	0.00
Green sprangletop	0.12	0.24	0.08	0.25	0.31	0.00
Kleingrass	0.11	0.24	0.05	0.30	0.30	0.00
Guineagrass	0.11	0.24	0.05	0.30	0.30	0.00
Vine-mesquite	0.11	0.21	0.06	0.30	0.32	0.00
Switchgrass	0.11	0.24	0.06	0.25	0.34	0.00
Longtom	0.13	0.25	0.08	0.22	0.32	0.00
Brownseed paspalum	0.10	0.22	0.08	0.30	0.30	0.00

Appendix Table E.3 (Cont.)

Common Name	CRoot	FRoot	Trunk	Stems	Leaves	Seeds
Thin paspalum	0.11	0.21	0.09	0.20	0.39	0.00
Common reed	0.15	0.25	0.10	0.20	0.30	0.00
Little bluestem	0.13	0.25	0.05	0.26	0.31	0.00
Knotroot bristlegrass	0.14	0.25	0.10	0.26	0.25	0.00
Plains bristlegrass	0.04	0.17	0.11	0.45	0.23	0.00
Texas bristlegrass	0.09	0.20	0.09	0.10	0.52	0.00
Indiangrass	0.10	0.24	0.05	0.30	0.31	0.00
Johnsongrass	0.12	0.23	0.05	0.30	0.30	0.00
Gulf cordgrass	0.04	0.17	0.11	0.45	0.23	0.00
Tall dropseed	0.11	0.24	0.05	0.30	0.30	0.00
Sand dropseed	0.12	0.24	0.06	0.30	0.28	0.00
Smutgrass	0.04	0.17	0.11	0.45	0.23	0.00
Texas wintergrass	0.10	0.20	0.05	0.40	0.25	0.00
Milo	0.10	0.20	0.05	0.25	0.40	0.00
Wheat	0.25	0.25	0.10	0.20	0.20	0.00
Corn	0.25	0.25	0.10	0.20	0.20	0.00
Littletooth sedge	0.14	0.27	0.07	0.10	0.42	0.00
Flatsedge	0.18	0.35	0.06	0.12	0.29	0.00
Cattail	0.20	0.20	0.04	0.28	0.28	0.00
Ragweed	0.15	0.20	0.10	0.30	0.25	0.00
Lazydaisy	0.10	0.25	0.10	0.15	0.40	0.00
Spiny aster	0.28	0.12	0.20	0.20	0.20	0.00
Whitestem wild indigo	0.04	0.18	0.26	0.26	0.26	0.00
Old-mans beard	0.15	0.28	0.10	0.24	0.23	0.00
Bundleflower	0.08	0.18	0.10	0.32	0.32	0.00
Frogfruit	0.08	0.17	0.10	0.30	0.35	0.00
Prairie coneflower	0.12	0.24	0.08	0.30	0.26	0.00
Snoutbean	0.10	0.20	0.10	0.30	0.30	0.00
Ruellia	0.15	0.25	0.15	0.05	0.40	0.00
Curly dock	0.05	0.15	0.20	0.10	0.50	0.00
Bulltongue	0.05	0.15	0.20	0.10	0.50	0.00
Glasswort	0.15	0.15	0.24	0.10	0.36	0.00
Bush sunflower	0.12	0.25	0.12	0.26	0.25	0.00
Green briar	0.15	0.15	0.15	0.30	0.25	0.00
Texas verbena	0.10	0.20	0.12	0.29	0.29	0.00
Orange zexmenia	0.13	0.25	0.12	0.25	0.25	0.00
Giant ragweed	0.16	0.17	0.13	0.27	0.27	0.00
Annual broomweed	0.19	0.19	0.12	0.25	0.25	0.00
Partridge pea	0.19	0.19	0.19	0.06	0.37	0.00
Texas doveweed	0.14	0.15	0.14	0.29	0.28	0.00
Sunflower	0.12	0.20	0.10	0.30	0.23	0.05
Dogweed	0.19	0.19	0.16	0.06	0.40	0.00

Appendix Table E.4 Allocation of biomass production in green-out months by plant part (proportion of total) for species included in the Goliad County EDYS model.

Common Name	CRoot	FRoot	Trunk	Stems	Leaves	Seeds
Huisache	0.00	0.23	0.00	0.04	0.73	0.00
Pecan	0.00	0.24	0.00	0.05	0.71	0.00
Sugar hackberry	0.00	0.12	0.00	0.06	0.82	0.00
Mesquite	0.00	0.15	0.00	0.10	0.75	0.00
Post oak	0.00	0.15	0.00	0.06	0.79	0.00
Live oak	0.00	0.18	0.00	0.05	0.77	0.00
Guajillo	0.00	0.20	0.00	0.20	0.60	0.00
Blackbrush	0.00	0.20	0.00	0.20	0.60	0.00
Whitebrush	0.00	0.19	0.00	0.20	0.61	0.00
Prairie baccharis	0.00	0.19	0.00	0.20	0.61	0.00
Sea oxeye	0.00	0.15	0.00	0.25	0.60	0.00
Granjeno	0.00	0.21	0.00	0.19	0.60	0.00
Carolina wolfberry	0.00	0.25	0.20	0.20	0.35	0.00
Agarito	0.00	0.26	0.00	0.37	0.37	0.00
McCartney rose	0.00	0.15	0.00	0.25	0.60	0.00
Rattlepod	0.00	0.19	0.00	0.30	0.51	0.00
Mustang grape	0.00	0.17	0.00	0.23	0.60	0.00
Texas prickly pear	0.10	0.15	0.05	0.69	0.01	0.00
Big bluestem	0.01	0.18	0.00	0.41	0.40	0.00
Bushy bluestem	0.00	0.00	0.00	0.33	0.67	0.00
Purple threeawn	0.00	0.19	0.00	0.03	0.78	0.00
King Ranch bluestem	0.01	0.19	0.00	0.04	0.76	0.00
Silver bluestem	0.00	0.18	0.00	0.41	0.41	0.00
Sideoats grama	0.01	0.18	0.00	0.41	0.40	0.00
Hairy grama	0.00	0.14	0.00	0.03	0.83	0.00
Red grama	0.00	0.19	0.00	0.05	0.76	0.00
Buffalograss	0.00	0.20	0.00	0.09	0.71	0.00
Sandbur	0.00	0.40	0.00	0.25	0.35	0.00
Hooded windmillgrass	0.00	0.18	0.00	0.03	0.79	0.00
Trichloris	0.00	0.19	0.00	0.40	0.41	0.00
Bermudagrass	0.01	0.19	0.00	0.03	0.77	0.00
Arizona cottontop	0.00	0.18	0.00	0.41	0.41	0.00
Saltgrass	0.00	0.35	0.00	0.38	0.27	0.00
Virginia wildrye	0.00	0.17	0.00	0.41	0.42	0.00
Texas cupgrass	0.00	0.17	0.00	0.42	0.41	0.00
Green sprangletop	0.00	0.18	0.00	0.41	0.41	0.00
Kleingrass	0.00	0.18	0.00	0.41	0.41	0.00
Guineagrass	0.00	0.18	0.00	0.41	0.41	0.00
Vine-mesquite	0.01	0.16	0.00	0.15	0.68	0.00
Switchgrass	0.00	0.18	0.00	0.41	0.41	0.00
Longtom	0.00	0.26	0.00	0.03	0.71	0.00
Brownseed paspalum	0.00	0.15	0.00	0.40	0.45	0.00

Appendix Table E.4 (Cont.)

Common Name	CRoot	FRoot	Trunk	Stems	Leaves	Seeds
Thin paspalum	0.00	0.16	0.00	0.05	0.79	0.00
Common reed	0.02	0.19	0.00	0.40	0.41	0.00
Little bluestem	0.01	0.18	0.00	0.40	0.41	0.00
Knotroot bristlegrass	0.01	0.19	0.00	0.05	0.75	0.00
Plains bristlegrass	0.00	0.15	0.00	0.53	0.32	0.00
Texas bristlegrass	0.00	0.15	0.00	0.05	0.80	0.00
Indiangrass	0.01	0.18	0.00	0.41	0.40	0.00
Johnsongrass	0.01	0.17	0.00	0.41	0.41	0.00
Gulf cordgrass	0.00	0.15	0.00	0.53	0.32	0.00
Tall dropseed	0.00	0.18	0.00	0.41	0.41	0.00
Sand dropseed	0.00	0.18	0.00	0.41	0.41	0.00
Smutgrass	0.00	0.15	0.00	0.53	0.32	0.00
Texas wintergrass	0.00	0.19	0.00	0.03	0.78	0.00
Milo	0.25	0.25	0.10	0.20	0.20	0.00
Wheat	0.25	0.25	0.10	0.20	0.20	0.00
Corn	0.25	0.25	0.10	0.20	0.20	0.00
Littletooth sedge	0.00	0.20	0.00	0.05	0.75	0.00
Flatsedge	0.00	0.26	0.00	0.20	0.54	0.00
Cattail	0.02	0.15	0.00	0.43	0.40	0.00
Ragweed	0.00	0.15	0.00	0.43	0.42	0.00
Lazydaisy	0.00	0.19	0.00	0.41	0.40	0.00
Spiny aster	0.00	0.10	0.00	0.52	0.38	0.00
Whitestem wild indigo	0.00	0.15	0.00	0.85	0.00	0.00
Old-mans beard	0.00	0.21	0.00	0.39	0.40	0.00
Bundleflower	0.00	0.14	0.00	0.43	0.43	0.00
Frogfruit	0.00	0.13	0.00	0.44	0.43	0.00
Prairie coneflower	0.00	0.18	0.00	0.41	0.41	0.00
Snoutbean	0.00	0.15	0.00	0.43	0.42	0.00
Ruellia	0.00	0.14	0.00	0.21	0.65	0.00
Curly dock	0.00	0.05	0.00	0.35	0.60	0.00
Bulltongue	0.00	0.05	0.00	0.35	0.60	0.00
Glasswort	0.00	0.10	0.15	0.05	0.70	0.00
Bush sunflower	0.00	0.19	0.00	0.41	0.40	0.00
Green briar	0.00	0.10	0.00	0.20	0.70	0.00
Texas verbena	0.00	0.15	0.00	0.43	0.42	0.00
Orange zexmenia	0.00	0.19	0.00	0.41	0.40	0.00
Giant ragweed	0.16	0.17	0.13	0.27	0.27	0.00
Annual broomweed	0.19	0.19	0.12	0.25	0.25	0.00
Partridge pea	0.19	0.19	0.19	0.06	0.37	0.00
Texas doveweed	0.14	0.15	0.14	0.29	0.28	0.00
Sunflower	0.16	0.17	0.13	0.27	0.27	0.00
Dogweed	0.19	0.19	0.16	0.06	0.40	0.00

General guidelines for greenout allocation:

Trees: coarse roots, trunks, and seeds = no allocation; fine roots and stems = 75% of new growth allocation; leaves = remainder of allocation

Shrubs, midgrasses, and perennial forbs: coarse roots, trunks, and seeds = no allocation; fine roots = 75% of new growth allocation; stems + leaves = remainder of allocation (exception = rhizomatous grasses, which have coarse roots = 10% of new growth allocation)

Shortgrasses: coarse roots, trunks, and seeds = no allocation; fine roots = 75% of new growth allocation; stems = 50% of new growth allocation; leaves = remainder of allocation (exceptions = rhizomatous grasses which have coarse roots = 10% of new growth allocation and stoloniferous grasses which have stems = 75% of new growth allocation)

Annuals = new growth allocations.

Appendix Table E.9 Root architecture, proportion of roots by maximum rooting depth, and maximum potential rooting depth (mm) for plant species included in the Goliad County EDYS model.

Common Name													Max Root
	0-1	1-5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	Depth (mm)
Huisache	6	11	14	18	15	12	8	6	4	3	2	1	5000
Pecan	4	9	14	20	13	5	6	6	2	6	8	7	6250
Sugar hackberry	2	9	14	20	15	5	6	6	2	6	8	7	6000
Mesquite	15	14	15	14	11	9	7	5	4	3	2	1	53400
Post oak	2	8	9	18	15	11	11	6	5	5	5	5	5700
Live oak	4	14	15	21	12	8	8	7	4	4	2	1	22000
Guajillo	3	10	13	18	13	11	9	8	5	5	3	2	5000
Blackbrush	3	9	13	19	15	12	9	7	4	4	3	2	5250
Whitebrush	2	10	16	19	14	12	9	6	5	4	2	1	2230
Prairie baccharis	1	5	9	12	18	17	11	11	7	6	2	1	1900
Sea oxeye	4	6	15	20	15	12	10	6	5	3	2	2	2000
Granjeno	4	13	14	17	14	12	10	6	4	3	2	1	6680
Carolina wolfberry	10	12	25	20	20	5	3	1	1	1	1	1	1500
Agarito	3	10	12	19	13	12	10	9	5	4	2	1	3000
McCartney rose	2	6	8	15	16	14	8	10	9	7	3	2	3700
Rattlepod	2	5	9	15	17	16	13	8	7	5	2	1	1380
Mustang grape	5	12	15	17	13	11	9	7	5	3	2	1	3660
Texas prickly pear	2	9	12	19	13	20	11	6	4	2	1	1	840
Big bluestem	15	18	20	15	9	7	5	4	3	2	1	1	3050
Bushy bluestem	5	10	20	20	15	12	10	3	2	1	1	1	720
Purple threeawn	4	7	10	15	18	15	14	8	5	2	1	1	1830
King Ranch bluestem	4	16	21	18	14	8	6	4	3	2	2	2	1200
Silver bluestem	12	22	20	20	8	6	3	3	2	2	1	1	2380
Sideoats grama	12	20	23	21	12	5	2	1	1	1	1	1	3960
Hairy grama	5	13	14	18	13	11	9	9	4	2	1	1	1070
Red grama	4	13	14	20	13	10	9	7	4	3	2	1	600
Buffalograss	8	23	24	20	8	5	4	3	2	1	1	1	2160
Sandbur	10	20	25	12	7	6	5	5	4	3	2	1	350
Hooded windmillgrass	4	12	13	21	12	11	11	4	3	3	3	3	990
Trichloris	10	14	16	17	10	8	8	6	4	4	2	1	2300
Bermudagrass	5	14	17	15	12	10	8	6	5	4	3	1	900
Arizona cottontop	3	12	13	21	12	10	8	6	5	4	3	3	1000
Saltgrass	10	20	22	20	10	6	4	3	2	1	1	1	720
Virginia wildrye	4	12	16	18	14	12	8	6	4	3	2	1	720
Texas cupgrass	4	15	17	19	12	7	7	5	4	4	4	3	1040
Green sprangletop	3	13	15	18	13	11	9	6	4	4	3	1	1150
Kleingrass	3	10	13	18	15	13	13	3	3	3	3	3	2280
Guineagrass	3	10	13	18	15	13	13	3	3	3	3	3	2280
Vine-mesquite	3	11	13	19	14	10	8	6	5	4	4	3	2020
Switchgrass	15	17	20	12	8	8	7	4	4	2	2	1	3350
Longtom	5	19	18	12	9	7	7	6	5	4	4	4	900
Brownseed paspalum	6	20	28	16	12	8	5	1	1	1	1	1	1000

Appendix Table E.9 (Cont.)

Common Name													Max Root
	0-1	1-5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	Depth (mm)
Thin paspalum	3	12	15	24	13	10	7	6	4	3	2	1	1660
Common reed	2	9	11	23	9	9	8	8	7	6	5	3	3500
Little bluestem	10	22	23	18	8	5	4	3	3	2	1	1	2440
Knotroot bristlegrass	4	14	16	18	14	10	8	6	5	2	2	1	1020
Plains bristlegrass	6	19	19	27	9	4	3	3	3	3	2	2	1600
Texas bristlegrass	3	13	14	21	12	11	9	6	4	3	2	2	930
Indiangrass	12	25	21	10	9	7	5	4	3	2	1	1	2430
Johnsongrass	3	12	17	18	14	10	9	7	5	3	1	1	2410
Gulf cordgrass	10	20	25	12	7	6	5	5	4	3	2	1	3960
Tall dropseed	4	15	17	20	11	8	6	5	5	4	4	1	2130
Sand dropseed	6	19	19	27	9	4	3	3	3	3	2	2	2700
Smutgrass	3	13	14	20	12	9	5	6	8	5	3	2	2100
Texas wintergrass	3	11	13	18	14	10	8	8	6	4	3	2	1950
Milo	2	6	9	18	17	14	12	9	7	3	2	1	1950
Wheat	2	5	7	15	16	15	13	10	8	5	3	1	3000
Corn	2	7	10	22	17	13	12	8	5	2	1	1	2400
Littletooth sedge	2	9	12	22	16	10	8	6	5	5	4	1	1310
Flatsedge	2	5	8	15	13	12	12	10	9	7	4	3	630
Cattail	3	12	13	18	10	9	8	8	7	6	4	2	1400
Ragweed	6	20	20	27	10	4	3	3	2	2	2	1	1830
Lazydaisy	2	5	8	13	12	11	11	12	10	7	5	4	600
Spiny aster	15	20	25	25	5	3	2	1	1	1	1	1	3100
Whitestem wild indigo	10	24	20	24	9	4	3	2	1	1	1	1	1700
Old-mans beard	3	9	13	24	16	9	7	6	4	3	3	3	1280
Bundleflower	3	9	14	23	12	5	4	5	9	7	6	3	2100
Frogfruit	2	6	8	14	12	11	14	11	11	5	4	2	690
Prairie coneflower	4	16	14	23	14	6	6	4	4	4	3	2	1830
Snoutbean	5	12	20	15	8	4	2	3	10	12	6	3	1350
Ruellia	4	4	7	19	20	14	11	7	6	4	3	1	1500
Curly dock	8	30	34	12	5	4	2	1	1	1	1	1	610
Bulltongue	8	30	34	12	5	4	2	1	1	1	1	1	610
Glasswort	8	16	16	24	12	8	6	4	2	2	1	1	457
Bush sunflower	10	14	18	23	11	6	5	4	3	3	2	1	2620
Green briar	4	12	13	25	8	5	5	5	6	6	6	5	1500
Texas verbena	2	8	10	15	14	13	8	8	8	6	5	3	1520
Orange zexmenia	3	8	13	30	11	8	7	7	5	4	3	1	2640
Giant ragweed	2	6	11	23	10	9	9	9	8	7	4	2	1970
Annual broomweed	4	17	9	17	12	14	8	7	4	3	3	2	1050
Partridge pea	2	8	10	15	14	10	8	11	8	6	5	3	850
Texas doveweed	3	13	8	16	13	14	10	7	5	4	4	3	320
Sunflower	6	24	6	9	12	16	10	7	2	3	3	2	3100
Dogweed	3	6	8	15	11	12	12	11	9	6	4	3	760

Data Sources

Root Architecture

Huisache	mean of <i>Leucaena leucocephala</i> (Toky & Bisht 1992) and <i>Prosopis glandulosa</i>
Pecan, sugar hackberry, Texas persimmon	<i>Acer saccharum</i> (Dawson 1993)
Mesquite	mean of Heitschmidt et al. (1988) and Montana et al. (1995)
Post oak	<i>Quercus havardii</i> (Sears et al. 1986)
Live oak	mean of <i>Acer saccharum</i> (Dawson 1993), <i>Leucaena leucocephala</i> (Toky & Bisht 1992), <i>Nothofagus antarctica</i> and <i>N. pumila</i> (Schulze et al. 1996), <i>Populus fremontii</i> (McLendon 2008), <i>Prosopis glandulosa</i> , <i>Quercus havardii</i> (Sears et al. 1986)
Guajillo	<i>Larrea tridentata</i> (Wallace et al. 1980; Moorhead et al. 1989; Montana et al. 1995; Ogle et al. 2004)
Blackbrush	mean of <i>Flourensia cernua</i> (Wallace et al. 1980) and <i>Larrea tridentata</i> (Wallace et al. 1980; Moorhead et al. 1989; Montana et al. 1995; Ogle et al. 2004)
Whitebrush	mean of <i>Krameria parvifolia</i> , <i>Lycium andersonii</i> , <i>L. pallidum</i> (Wallace et al. 1980), and <i>Tetradymia spinosa</i> (Branson et al. 1976)
Prairie baccharis	<i>Pulchea sericea</i> (Gary 1963)
Granjeno	mean of <i>Flourensia cernua</i> (Wallace et al. 1980) and <i>Prosopis glandulosa</i>
Agarito	mean of <i>Ephedra nevadensis</i> (Wallace et al. 1980), <i>Larrea tridentata</i> (Wallace et al. 1980; Moorhead et al. 1989; Montana et al. 1995; Ogle et al. 2004), <i>Tetradymia spinosa</i> (Branson et al. 1976)
Rattlepod	mean of <i>Leucaena leucocephala</i> (Toky & Bisht 1992) and <i>Pulchea sericea</i> (Gary 1963)
Mustang grape	mean of 25 shrubs
Prickly pear	mean of <i>Opuntia acanthocarpa</i> (Nobel & Bobich 2002), <i>O. humifusa</i> (Sperry 1935), and <i>O. polyacantha</i> (Dougherty 1986)
Big bluestem	Sperry (1935), Weaver & Zink (1946), Weaver & Darland (1949), Coupland & Bradshaw (1953); Hopkins (1953), Weaver (1954)
Purple threeawn	modified from Weaver & Clements (1938)
King Ranch bluestem	Coyne & Bradford (1986)
Silver bluestem	mean of <i>Bouteloua curtipendula</i> and <i>Schizachyrium scoparium</i>
Sideoats grama	Weaver & Darland (1949), Hopkins (1953), Weaver (1954)
Hairy grama	mean of <i>Aristida purpurea</i> (Weaver & Clements 1938) and <i>Bouteloua gracilis</i> (Weaver & Clements 1938; Weaver 1947, 1958; Weaver & Zink 1947; Weaver & Darland 1949; Hopkins 1953; Lorenz & Rogler 1967; Redente et al. 1989; Lee & Lauenroth 1994; Gill et al. 1999)
Buffalograss	Weaver & Clements (1938), Weaver & Darland (1949), Hopkins (1953)
Sandbur	mean of <i>Aristida purpurea</i> (Weaver & Clements 1938) and <i>Sporobolus cryptandrus</i> (Albertson 1937; Weaver & Darland 1949; Hopkins 1953)
Hooded windmill	mean of <i>Axonopus compressus</i> (Fiala & Herrera 1988) and <i>Sporobolus cryptandrus</i> (Albertson 1937; Weaver & Darland 1949; Hopkins 1953)
Trichloris	<i>Schizachyrium scoparium</i>
Bermudagrass	mean of <i>Axonopus compressus</i> (Fiala & Herrera 1988), <i>Distichlis spicata</i> (Seliskar 1983; Dahlgren et al. 1997; McLendon 2008), <i>Hilaria mutica</i> (Montana et al. 1995)
Arizona cottontop	mean of <i>Cenchrus ciliaris</i> (Chaieb et al. 1996), <i>Hilaria jamesii</i> (Moore & West 1973; Daddy 1985), <i>Sporobolus cryptandrus</i> (Albertson 1937; Weaver & Darland 1949; Hopkins 1953)
Virginia wildrye	mean of <i>Agropyron trachycaulum</i> and <i>Poa compressa</i> (McLendon 2001)
Clubhead cutgrass	mean of <i>Axonopus compressus</i> (Fiala & Herrera 1988), <i>Paspalum notatum</i> (Hernandez & Fiala 1992)
Kleingrass	Hons et al. (1979)
Vine-mesquite	mean of <i>Bouteloua curtipendula</i> (Weaver & Darland 1949; Hopkins 1953; Weaver 1954; Pettit & Jaynes 1971), <i>Distichlis spicata</i> (Seliskar 1983; Dahlgren et al. 1997; McLendon

	2008), <i>Hilaria mutica</i> (Montana et al. 1995)
Switchgrass	Weaver & Darland (1949), Hopkins (1953), Pettit & Jaynes (1971)
Longtom	mean of <i>Distichlis spicata</i> (Seliskar 1983; Dahlgren et al. 1997; McLendon 2008) and <i>Paspalum notatum</i> (Hernandez & Fiala 1992)
Thin paspalum	mean of <i>Andropogon gerardii</i> var. <i>paucipilus</i> (Weaver & Clements 1938), <i>Cenchrus ciliaris</i> (Chaieb et al. 1996), <i>Redfieldia flexuosa</i> (Weaver & Clements 1938), <i>Sporobolus cryptandrus</i> (Albertson 1937; Weaver & Darland 1949; Hopkins 1953), and <i>Schizachyrium scoparium</i>
Little bluestem	Sperry (1935), Weaver & Zink (1946), Weaver (1947, 1950, 1954, 1958), Weaver & Darland (1949), Coupland & Bradshaw (1953), Jurena & Archer (2003)
Knotroot bristlegrass	mean of <i>Bouteloua curtipendula</i> (Weaver & Darland 1949; Hopkins 1953; Weaver 1954; Pettit & Jayens 1971) and <i>Sporobolus airoides</i> (McLendon 2008)
Texas bristlegrass	mean of <i>Aristida purpurea</i> (Weaver & Clements 1938), <i>Axonopus compressus</i> (Fiala & Herrera 1988), <i>Digitaria commutata</i> (Chaieb et al. 1996), <i>Koeleria pyramidata</i> (Coupland & Bradshaw 1953), <i>Sporobolus cryptandrus</i> (Albertson 1937; Weaver & Darland 1949; Hopkins 1953)
Johnsongrass	mean of <i>Panicum virgatum</i> (Weaver & Darland 1949; Hopkins 1953; Pettit & Jaynes 1971) and <i>Zea mays</i> (Weaver & Clements 1938)
Tall dropseed	mean of <i>Muhlenbergia cuspidata</i> (Sperry 1935), <i>Schizachyrium scoparium</i> (Sperry 1935; Weaver & Zink 1946; Weaver 1947, 1950, 1954, 1958; Weaver & Darland 1949; Coupland & Bradshaw 1953; Jurena & Archer 2003), <i>Sporobolus cryptandrus</i> (Albertson 1937; Weaver & Darland 1949; Hopkins 1953)
Texas wintergrass	mean of <i>Stipa comata</i> (Melgoza & Nowak 1991), <i>S. lagascae</i> (Chaieb et al. 1996), <i>S. spartea</i> (Sperry 1935; Coupland & Bradshaw 1953)
Milo	mean of <i>Triticum aestivum</i> and <i>Zea mays</i>
Wheat	Weaver et al. (1924), Weaver & Clements (1938)
Corn	Weaver & Clements (1938)
Littletooth sedge	mean of <i>Carex douglasii</i> (Manning et al. 1989) and <i>C. varia</i> (Sperry 1935)
Flatsedge	mean of <i>Carex nebrascensis</i> (Manning et al. 1989; Svejcar & Trent 1995; Kauffman et al. 2004) and <i>Scirpus validus</i> (Weaver & Clements 1938)
Fimbry	mean of <i>Carex douglasii</i> (Manning et al. 1989), <i>C. nebrascensis</i> (Manning et al. 1989; Svejcar & Trent 1995; Kauffman et al. 2004), <i>C. lasiocarpa</i> , <i>C. rostrata</i> , <i>C. trichocarpa</i> (Bernard & Fiala 1986), <i>C. varia</i> (Sperry 1935), <i>Juncus balticus</i> (Manning et al. 1989), <i>Scirpus validus</i> (Weaver & Clements 1938)
Cattail	mean of <i>Carex nebrascensis</i> (Manning et al. 1989), <i>Distichlis spicata</i> (Seliskar 1983; Dahlgren et al. 1997; McLendon 2008), <i>Lepidium latifolium</i> (Renz et al. 1997), <i>Paspalum notatum</i> (Hernandez & Fiala 1992), <i>Scirpus validus</i> (Weaver & Clements 1938), <i>Spartina pectinata</i> (Sperry 1935)
Ragweed	Sperry (1935)
Old-mans beard	mean of <i>Achillea millefolium</i> and <i>Solidago decumbens</i> (Holch et al. 1941)
Bundleflower	mean of <i>Oxytropis lambertii</i> (Weaver & Clements 1938), <i>Petalostemum purpureum</i> (Sperry 1935), and <i>Potentilla diversifolis</i> and <i>P. gracilis</i> (Holch et al. 1941)
Frogfruit	mean of <i>Potentilla gracilis</i> (Holch et al. 1941), <i>Pycnanthemum tenuifolium</i> (Sperry 1935)
Prairie coneflower	<i>Ratibida pinnata</i> (Sperry 1935)
Snoutbean	<i>Petalostemum purpureum</i> (Sperry 1935)
Ruellia	<i>Ruellia humilis</i> (Sperry 1935)
Bush sunflower	<i>Helianthus scaberrimus</i> (Sperry 1935)
Texas verbena	mean of <i>Aster multiflorus</i> (Sperry 1935), <i>A. oblongifolius</i> (Sperry 1935), <i>Erysimum asperum</i> (Holch et al. 1941), <i>Gallardia aristata</i> (Holch et al. 1941), <i>Geranium fremontii</i> (Holch et al. 1941), <i>Silphium integrifolium</i> (Sperry 1935)
Orange zexmenia	mean of <i>Helianthus scaberrimus</i> and <i>Parthenium hispidum</i> (Sperry 1935)
Giant ragweed	mean of <i>Ambrosia psilostachya</i> and <i>Parthenium hispidum</i> (Sperry 1935)

Annual broomweed	mean of <i>Helianthus annuus</i> (Stone et al. 2001), <i>Grindelia squarrosa</i> (Holch et al. 1941)
Partridge pea	mean of <i>Erysimum asperum</i> (Holch et al. 1941), <i>Euphorbia corollata</i> (Sperry 1935)
Texas doveweed	mean of <i>Centaurea maculosa</i> (Marier et al. 1999), <i>Grindelia squarrosa</i> (Holch et al. 1941), <i>Helianthus annuus</i> (Stone et al. 2001)
Sunflower	Stone et al. (2001)
Duckweed	<i>Phacelia glandulosa</i> (Holch et al. 1941)
Texas bluebonnet	<i>Oxytropis lambertii</i> (Weaver & Clements 1938)
Dogweed	mean of <i>Aster multiflorus</i> (Sperry 1935), <i>A. oblongifolius</i> (Sperry 1935), <i>Eriogonum alatum</i> (Holch et al. 1941), and <i>Grindelia squarrosa</i> (Holch et al. 1941)

Maximum Potential Rooting Depth

Huisache	mean of <i>Chilopsis linearis</i> (Meinzer 1927), <i>Prosopis velutina</i> (Snyder & Williams 2003)
Pecan	mean of <i>Celtis laevigata</i> (Jackson et al. 1999), <i>Juglans nigra</i> (Canadell et al. 1996), <i>Ulmus americana</i> (Jackson et al. 1999), <i>Ulmus crassifolia</i> (Jackson et al. 1999)
Sugar hackberry	Jackson et al. (1999)
Texas persimmon	mean of <i>Malus pumila</i> (Weaver & Clements 1938), <i>Rhus glabra</i> (Weaver 1926)
Mesquite	Phillips (1963)
Post oak	mean of <i>Quercus durandii</i> (Jackson et al. 1999) and <i>Q. macrocarpa</i> (Biswell 1935)
Live oak	Jackson et al. (1999)
Guajillo	<i>Larrea tridentata</i> (Gile et al. 1998)
Blackbrush	mean of <i>Koeberlinia spinosa</i> (Gibbens & Lenz 2001), <i>Larrea tridentata</i> (Gile et al. 1998)
Whitebrush	mean of <i>Corylus americana</i> (Weaver 1919), <i>Fallugia paradoxa</i> (Foxy & Tierney 1986), <i>Lycium berlandieri</i> (Gibbens & Lenz 2001), <i>L. pallidum</i> (Yoder & Nowak 1999a)
Prairie baccharis	mean of <i>Baccharis glutinosa</i> (Gary 1963), <i>B. pilularis</i> (Wright 1928)
Granjeno	mean of <i>Arctostaphylos glandulosa</i> (Hellmers et al. 1955), <i>Celtis laevigata</i> (Jackson et al. 1999), <i>Flourensia cernua</i> (Gibbens & Lenz 2001), <i>Koeberlinia spinosa</i> (Gibbens & Lenz 2001), <i>Larrea tridentata</i> (Gile et al. 1998), <i>Lycium berlandieri</i> (Gibbens & Lenz 2001), <i>Sarcobatus vermiculatus</i> (Meinzer 1927)
Agarito	<i>Berberis repens</i> (Weaver 1919)
Rattlepod	mean of <i>Baccharis glutinosa</i> (Gary 1963), <i>Pulchea sericea</i> (Gary 1963), <i>Sesbania sesban</i> (Sekiya & Yano 2002)
Mustang grape	<i>Toxicodendron radicans</i> (Tolstead 1942)
Prickly pear	mean of <i>Opuntia imbricata</i> (Dittmer 1959), <i>O. polyacantha</i> (Tierney & Foxx 1987)
Big bluestem	Tomanek & Albertson (1957)
Purple threeawn	Albertson (1937)
King Ranch bluestem	Coyne & Bradford (1986)
Silver bluestem	mean of <i>Bouteloua curtipendula</i> (Tomanek & Albertson 1957), <i>Heteropogon contortus</i> (Cable 1980), <i>Schizachyrium scoparium</i> (Weaver & Fitzpatrick 1934), <i>Sporobolus asper</i> (Weaver & Albertson 1943)
Sideoats grama	Tomanek & Albertson (1957)
Hairy grama	Weaver (1926)
Buffalograss	Weaver & Clements (1938)
Sandbur	Dittmer (1959)
Hooded windmillgrass	mean of <i>Bouteloua hirsuta</i> (Weaver 1926), <i>Cenchrus incertus</i> (Dittmer 1959), <i>Digitaria californica</i> (Cable 1980), <i>Hilaria jamesii</i> (Weaver 1958), <i>Muhlenbergia torreyi</i> (Weaver 1958), <i>Scleropogon brevifolius</i> (Gibbens & Lenz 2001)
Trichloris	about 5% less than <i>Schizachyrium scoparium</i>
Bermudagrass	Garrot & Mancino (1994)
Arizona cottontop	Cable (1980)
Virginia wildrye	<i>Elymus canadensis</i> (Weaver 1958)
Clubhead cutgrass	mean of <i>Holcus lanatus</i> and <i>Nardus stricta</i> (Boggie et al. 1958)
Kleingrass	mean of <i>Eragrostis lehmanniana</i> (Gibbens & Lenz 2001) and <i>Panicum virgatum</i> (Weaver 1954)

Vine-mesquite	mean of <i>Distichlis spicata</i> (Shantz & Piemeisel 1940), <i>Hilaria mutica</i> (Cottle 1931), <i>Panicum virgatum</i> (Weaver 1954)
Switchgrass	Weaver (1954)
Longtom	mean of <i>Cynodon dactylon</i> (Garrot & Mancino 1994), <i>Distichlis spicata</i> (Shantz & Piemeisel 1940), and <i>Holcus lanatus</i> and <i>Nardus stricta</i> (Boggie et al. 1958)
Thin paspalum	mean of <i>Heteropogon contortus</i> (Cable 1980), <i>Muhlenbergia arenacea</i> (Gibbens & Lenz 2001), <i>Redfieldia flexuosa</i> (Weaver 1958), <i>Schizachyrium scoparium</i> (Weaver & Fitzpatrick 1934), <i>Sporobolus asper</i> (Weaver & Albertson 1943)
Little bluestem	Weaver & Fitzpatrick (1934)
Knotroot bristlegrass	mean of <i>Agrostis tenuis</i> (Boggie et al. 1958), <i>Dichanthelium scribnerianum</i> (Weaver 1954), <i>Muhlenbergia torreyi</i> (Weaver 1958), <i>Poa pratensis</i> (Weaver 1954)
Texas bristlegrass	mean of <i>Aristida purpurea</i> (Albertson 1937), <i>Bouteloua hirsuta</i> (Weaver 1926), <i>Cenchrus incertus</i> (Dittmer 1959), <i>Dichanthelium scribnerianum</i> (Weaver 1954), <i>Festuca ovina</i> (Boggie et al. 1958), <i>Koeleria pyramidata</i> (Wyatt et al. 1980), <i>Muhlenbergia porteri</i> (Gibbens & Lenz 2001), <i>Scleropogon brevifolius</i> (Gibbens & Lenz 2001)
Johnsongrass	mean of <i>Sorghastrum nutans</i> (Albertson 1937) and <i>Zea mays</i> (Weaver 1926)
Tall dropseed	Weaver & Albertson (1943)
Texas wintergrass	<i>Stipa comata</i> (Wyatt et al. 1980)
Milo	mean of <i>Pennisetum glaucum</i> (Payne et al. 1990) and <i>Zea mays</i> (Weaver 1926)
Wheat	Hamblin & Tennant (1987)
Corn	Weaver (1926)
Littletooth sedge	mean of <i>Carex filifolia</i> (Weaver 1920; Tolstead 1942), <i>C. geyerii</i> (Spence 1937), <i>C. varia</i> (Sperry 1935)
Flatsedge	mean of <i>Carex nebrascensis</i> (Chambers et al. 1999), <i>Juncus balticus</i> (Manning et al. 1989), <i>Scirpus validus</i> (Weaver & Clements 1938)
Fimbry	mean of <i>Juncus balticus</i> (Manning et al. 1989), <i>Scirpus validus</i> (Weaver & Clements 1938)
Cattail	mean of <i>Lepidium latifolium</i> (Renz et al. 1997), <i>Scirpus validus</i> (Weaver & Clements 1938), <i>Spartina pectinata</i> (Weaver 1958)
Ragweed	Weaver (1958)
Old-mans beard	mean of <i>Achillea millefolium</i> (Spence 1937), <i>Smilax rotundifolia</i> (Duncan 1935)
Bundleflower	<i>Desmanthus cooleyi</i> (Gibbens & Lenz 2001)
Frogfruit	mean of <i>Euphorbia albomarginata</i> (Gibbens & Lenz 2001), <i>Evolvulus nuttallianus</i> (Albertson 1937), <i>Hedyotis nigricans</i> (Albertson 1937)
Prairie coneflower	Hopkins (1951)
Snoutbean	mean of <i>Cassia bauhinioides</i> (Gibbens & Lenz 2001), <i>Desmanthus cooleyi</i> (Gibbens & Lenz 2001), <i>Hoffmanseggia drepanocarpa</i> (Gibbens & Lenz 2001), <i>Thermopsis rhombifolia</i> (Coupland & Johnson 1965), <i>Trifolium pretense</i> (Keim & Beadle 1927)
Ruellia	<i>Ruellia caroliniensis</i> (Sperry 1935)
Bush sunflower	mean of <i>Arnica pumila</i> (Holch et al. 1941), <i>Balsamorhiza sagittata</i> (Weaver 1958), <i>Chrysopsis villosa</i> (Weaver 1958), <i>Helianthus laetiflorus</i> (Weaver 1954), <i>Parthenium integrifolium</i> (Sperry 1935), <i>Veronica baldwinii</i> (Weaver 1919)
Texas verbena	<i>Verbena stricta</i> (Weaver 1958)
Orange zexmenia	mean of <i>Artemisia dracunculus</i> (Foxx & Tierney 1986), <i>Chrysopsis villosa</i> (Weaver 1958), <i>Helianthus laetiflorus</i> (Weaver 1954), <i>Machaeranthera pinnatifida</i> (Hopkins 1951), <i>Parthenium integrifolium</i> (Sperry 1935)
Giant ragweed	mean of <i>Ambrosia acanthicarpa</i> (Dittmer 1959), <i>A. artemisifolia</i> (Cole & Holch 1941), <i>Helianthus annuus</i> (Schwarzbach et al. 2001), <i>Kochia scoparia</i> (Foxx & Tierney 1986)
Annual broomweed	mean of <i>Croton pottsii</i> (Gibbens & Lenz 2001), <i>C. texensis</i> (Dittmer 1959)
Partridge pea	<i>Cassia bauhinioides</i> (Gibbens & Lenz 2001)

Texas doveweed	Dittmer (1959)
Sunflower	Schwarzbach et al. (2001)
Duckweed	mean of <i>Mimulus bigelovii</i> and <i>Polygonum aviculare</i> (Forseth et al. 1984)
Texas bluebonnet	mean of <i>Cassia bahinioides</i> (Gibbens & Lenz 2001), <i>Hoffmanseggia drepanocarpa</i> (Gibbens & Lenz 2001), <i>Medicago lupulina</i> (Cole & Holch 1941), <i>Lupinus caudatus</i> (Foxx & Tierney 1986)
Dogweed	mean of <i>Aphanostephus ramoissimus</i> (Gibbens & Lenz 2001), <i>Centaurea solstitialis</i> (Sheley & Larson 1994), <i>Croton texensis</i> (Dittmer 1959), <i>Erodium botrys</i> (McKell et al. 1962), <i>Lepidium densiflorum</i> (Allen & Knight 1984), <i>Linum australe</i> (Gibbens & Lenz 2001), <i>Verbena utricifolia</i> (Cole & Holch 1941)

Appendix Table E.11 Values for months when physiological responses occur in plant species included in the Goliad County EDYS model.

Common Name	Green-out	Seed-sprout	Seed-set	Dormancy		
Huisache	2	2	9	4	9	12
Pecan	3	3	9	4	9	10
Sugar hackberry	3	3	9	4	8	10
Mesquite	3	3	9	4	8	11
Post oak	3	3	7	4	8	11
Live oak	3	3	7	4	8	2
Guajillo	1	2	10	6	10	12
Blackbrush	2	2	10	6	10	12
Whitebrush	2	3	10	6	10	11
Prairie baccharis	2	2	10	2	10	11
Sea oxeye	4	3	9	4	8	10
Granjeno	3	2	10	4	8	11
Carolina wolfberry	3	3	9	4	9	11
Agarito	1	2	10	4	8	12
McCartney rose	1	3	9	4	8	1
Rattlepod	3	2	10	6	7	11
Mustang grape	2	3	9	6	10	12
Texas prickly pear	1	2	11	7	8	12
Big bluestem	3	4	8	8	8	11
Bushy bluestem	3	4	4	8	8	11
Purple threeawn	3	4	9	7	11	12
King Ranch bluestem	3	4	10	6	10	11
Silver bluestem	3	3	9	5	7	11
Sideoats grama	3	4	9	6	10	11
Hairy grama	3	4	10	6	10	11
Red grama	3	4	9	5	9	11
Buffalograss	3	3	9	5	10	11
Sandbur	3	4	9	7	8	11
Hooded windmillgrass	3	3	10	7	8	11
Trichloris	3	3	10	7	8	11
Bermudagrass	3	4	10	5	8	11
Arizona cottontop	3	3	9	5	7	11
Saltgrass	3	3	9	5	7	11
Virginia wildrye	10	10	6	5	7	6
Texas cupgrass	3	4	9	6	9	10
Green sprangletop	3	4	9	5	9	11
Kleingrass	3	3	9	5	7	11
Guineagrass	3	3	9	5	7	11
Vine-mesquite	3	4	10	5	10	12
Switchgrass	3	5	9	7	9	11
Longtom	3	3	10	8	10	11
Brownseed paspalum	3	3	8	8	10	10

Appendix Table E.11 (Cont.)

Common Name	Green-out	Seed-sprout	Seed-set	Dormancy		
Thin paspalum	3	3	10	8	9	11
Common reed	3	4	10	9	11	11
Little bluestem	3	5	9	7	9	11
Knotroot bristlegrass	3	3	10	5	8	12
Plains bristlegrass	3	3	9	5	8	11
Texas bristlegrass	2	2	11	5	8	12
Indiangrass	3	5	9	7	9	11
Johnsongrass	3	4	9	7	10	11
Gulf cordgrass	3	3	9	5	8	11
Tall dropseed	3	4	9	5	8	11
Sand dropseed	3	4	10	5	9	11
Smutgrass	3	3	9	5	8	11
Texas wintergrass	10	10	5	3	5	6
Milo	3	3	9	5	8	11
Wheat	10	10	4	4	5	5
Corn	4	4	9	5	8	11
Littletooth sedge	3	3	10	5	9	12
Flatsedge	2	3	10	4	9	12
Cattail	3	4	10	6	8	12
Ragweed	3	3	9	5	10	10
Lazydaisy	2	3	9	3	7	10
Spiny aster	3	4	9	6	8	9
Whitestem wild indigo	3	3	9	5	8	11
Old-mans beard	3	3	10	6	10	12
Bundleflower	3	4	9	5	10	11
Frogfruit	3	3	9	3	10	11
Prairie coneflower	2	2	8	4	8	10
Snoutbean	3	3	9	4	8	11
Ruellia	3	3	10	4	8	12
Curly dock	2	3	9	4	8	11
Bulltongue	2	3	9	4	8	11
Glasswort	2	3	8	5	9	10
Bush sunflower	3	3	9	5	9	11
Green briar	3	9	6	2	6	2
Texas verbena	2	2	9	4	8	12
Orange zexmenia	3	4	9	5	9	11
Giant ragweed	3	3	9	7	8	11
Annual broomweed	3	2	9	3	10	11
Partridge pea	3	3	9	6	7	11
Texas doveweed	3	2	9	4	8	11
Sunflower	2	2	10	5	9	11
Dogweed	3	3	9	4	9	11

Appendix Table E.13 Values for water use variables used in the Goliad County EDYS model.

Common Name	Maintenance (mm/g bio/mo)	New biomass maintenance	Water to production	Green-out water use
Huisache	0.000085	0.04	1.25	0.55
Pecan	0.000085	0.04	0.88	0.55
Sugar hackberry	0.000090	0.05	0.90	0.45
Mesquite	0.000085	0.04	1.10	0.50
Post oak	0.000080	0.04	0.90	0.45
Live oak	0.000080	0.03	0.80	0.45
Guajillo	0.000090	0.05	1.63	0.70
Blackbrush	0.000090	0.05	1.63	0.70
Whitebrush	0.000090	0.05	1.20	0.70
Prairie baccharis	0.000090	0.05	0.81	0.70
Sea oxeye	0.000100	0.05	1.87	0.50
Granjeno	0.000100	0.05	1.22	0.50
Carolina wolfberry	0.000085	0.04	1.25	0.65
Agarito	0.000080	0.04	1.47	0.60
McCartney rose	0.000090	0.05	1.00	0.65
Rattlepod	0.000250	0.07	0.64	0.75
Mustang grape	0.000090	0.05	0.90	0.70
Texas prickly pear	0.000080	0.04	0.30	0.80
Big bluestem	0.000280	0.05	0.83	0.80
Bushy bluestem	0.000280	0.05	1.30	0.80
Purple threeawn	0.000150	0.04	0.68	0.65
King Ranch bluestem	0.000150	0.04	0.70	0.67
Silver bluestem	0.000160	0.04	0.76	0.70
Sideoats grama	0.000160	0.04	0.87	0.65
Hairy grama	0.000150	0.03	0.60	0.60
Red grama	0.000140	0.03	0.56	0.60
Buffalograss	0.000150	0.04	0.74	0.64
Sandbur	0.0003910	0.05	0.47	0.80
Hooded windmillgrass	0.0003910	0.05	0.87	0.80
Trichloris	0.0003910	0.05	0.87	0.80
Bermudagrass	0.000160	0.04	0.91	0.70
Arizona cottontop	0.000160	0.04	0.63	0.70
Saltgrass	0.000160	0.04	0.78	0.70
Virginia wildrye	0.000160	0.04	1.24	0.70
Texas cupgrass	0.000170	0.05	0.82	0.75
Green sprangletop	0.000160	0.04	0.76	0.70
Kleingrass	0.000160	0.04	1.36	0.70
Guineagrass	0.000160	0.04	1.36	0.70
Vine-mesquite	0.000150	0.04	0.90	0.65
Switchgrass	0.000180	0.05	1.00	0.75
Longtom	0.000017	0.06	0.50	0.65
Brownseed paspalum	0.000017	0.06	0.95	0.65

Appendix Table E.13 (Cont.)

Common Name	Maintenance (mm/g bio/mo)	New biomass maintenance	Water to production	Green-out water use
Thin paspalum	0.000017	0.06	0.76	0.65
Common reed	0.000200	0.06	0.73	0.70
Little bluestem	0.000170	0.05	0.90	0.65
Knotroot bristlegrass	0.000120	0.04	0.90	0.70
Plains bristlegrass	0.000120	0.04	0.80	0.70
Texas bristlegrass	0.000120	0.04	0.61	0.70
Indiangrass	0.000175	0.05	0.89	0.75
Johnsongrass	0.000175	0.06	0.89	0.70
Gulf cordgrass	0.000120	0.04	0.60	0.70
Tall dropseed	0.000160	0.04	0.71	0.70
Sand dropseed	0.000140	0.04	0.85	0.65
Smutgrass	0.000120	0.04	0.60	0.70
Texas wintergrass	0.000120	0.03	0.99	0.65
Milo	0.000120	0.04	0.33	0.70
Wheat	0.000120	0.04	0.76	0.70
Corn	0.000120	0.04	0.37	0.70
Littletooth sedge	0.000200	0.06	0.79	0.67
Flatsedge	0.000200	0.06	0.73	0.70
Cattail	0.000225	0.06	0.85	0.70
Ragweed	0.000140	0.03	0.91	0.72
Lazydaisy	0.000140	0.03	0.67	0.70
Spiny aster	0.000100	0.04	0.50	0.78
Whitestem wild indigo	0.000187	0.05	1.10	0.67
Old-mans beard	0.000090	0.05	0.80	0.70
Bundleflower	0.000140	0.03	0.67	0.72
Frogfruit	0.000070	0.03	0.70	0.72
Prairie coneflower	0.000160	0.06	0.69	0.67
Snoutbean	0.000250	0.08	0.83	0.82
Ruellia	0.000250	0.08	0.60	0.82
Curly dock	0.000250	0.08	0.87	0.82
Bulltongue	0.000250	0.08	0.87	0.82
Glasswort	0.000190	0.06	0.80	0.67
Bush sunflower	0.000200	0.07	0.85	0.75
Green briar	0.000180	0.05	1.20	0.61
Texas verbena	0.000250	0.08	0.79	0.82
Orange zexmenia	0.000180	0.05	0.70	0.60
Giant ragweed	0.000070	0.03	0.53	0.72
Annual broomweed	0.000070	0.03	0.58	0.72
Partridge pea	0.000250	0.07	0.76	0.75
Texas doveweed	0.000250	0.08	0.56	0.82
Sunflower	0.000200	0.06	0.55	0.70
Dogweed	0.000070	0.03	0.50	0.72

Data Sources**Water to Production**

Huisache: mean of *Cercidium microphyllum* and *Prosopis velutina* (McGinnes & Arnold 1939)
 Pecan, sugar hackberry, Texas persimmon, post oak, live oak: *Populus fremontii* (Anderson 1982)
 Mesquite: Dwyer & DeGarmo (1970)

Guajillo and blackbrush: *Acacia greggii*, *Cercidium microphyllum*, *Prosopis velutina* (McGinnes & Arnold 1939)
 Whitebrush: mean of *Atriplex lentiformis* (Watson 1990), *Chrysothamnus nauseosus* (Donovan et al. 1996),
Sarcobatus vermiculatus (Donovan et al. 1996), *Simmondsia chinensis* (McGinnes & Arnold 1939)

Baccharis: 0.9(*Populus fremontii*) = *Baccharis salicifolia* (Glenn et al. 1998)

Granjeno: mean of *Atriplex canescens* (Watson 1990), *Larrea tridentata* (Dwyer & DeGarmo 1970), *Populus fremontii* (Anderson 1982)

Agarito: *Larrea tridentata* (mean of Dwyer & DeGarmo 1970; Lane et al. 1984)

Rattlepod: mean of *Atriplex lentiformis* (Watson 1990), *Baccharis salicifolia* (Glenn et al. 1998), *Salix goodingii* (Glenn et al. 1998)

Mustang grape: *Populus fremontii* (Anderson 1982)

Prickly pear: *Opuntia basilaris* (Nobel 1976)

Big bluestem: Weaver (1941)

Purple threeawn: McLendon et al. (unpublished)

KR bluestem: Coyne & Bradford (1986)

Silver bluestem: McGinnes & Arnold (1939)

Sidecoats grama: McGinnes & Arnold (1939)

Hairy grama: McGinnes & Arnold (1939)

Buffalograss: 90% of blue grama (Shantz & Piemeisel 1927)

Sandbur: *Cenchrus ciliaris*, mean of Khan (1971) and Kapinga (1982)

Hooded windmillgrass and trichloris: *Chloris gayana* (Kapinga 1982)

Bermudagrass: mean of McDonald & Hughes (1968) and Wiedenfeld (1988)

Arizona cottontop: McGinnes & Arnold (1939)

Virginia wildrye: *Leymus junceus*, mean of Hunt (1962), Power (1985), Frank & Berdahl (1999)

Clubhead cutgrass: *Phalaris aquatica* (Morison & Gifford 1984)

Kleingrass: mean of McCawley (1978) and Kapinga (1982)

Vine-mesquite: 90% of *Hilaria mutica* (Dwyer & DeGarmo 1970)

Switchgrass: mean of *Andropogon gerardii* (Weaver 1941), *Panicum antidotale* (Wright & Dobrenz 1970)

Longtom: *Paspalum vaginatum* (Biran et al. 1981)

Thin paspalum: mean of *Aristida purpurea* (McLendon et al., unpublished), *Bouteloua hirsuta* (McGinnes & Arnold), *Cenchrus ciliaris* (Kapinga 1982), *Eragrostis curvula* (Wiedenfeld 1988), *Heteropogon contortus* (McGinnes & Arnold 1939), *Schizachyrium scoparium* (Weaver 1941), *Sporobolus airoides* (Benton & Wester 1998), *Sporobolus flexuosus* (Dwyer & DeGarmo)

Little bluestem: mean of Weaver (1941) and McLendon et al. (unpublished)

Knotroot bristle: mean of *Spartina alterniflora* (Gallagher et al. 1980) and *Sporobolus wrightii* (Cox 1985)

Texas bristlegrass: mean of *Bothriochloa saccharoides* (McGinnes & Arnold), *Setaria italic* (Briggs & Shantz 1913), *Sporobolus flexuosus* (Dwyer & DeGarmo 1970)

Johnsongrass: mean of *Andropogon gerardii* (Weaver 1941), *Chloris gayana* (Kapinga 1982), *Panicum antidotale* (Wright & Dobrenz), *Phragmites australis* (Mueller et al. 2005), *Sorghum bicolor* (Briggs & Shantz 1913)

Tall dropseed: *Sporobolus flexuosus* (Dwyer & DeGarmo 1970)

Texas wintergrass: *Stipa viridula* (Fairbourn 1982)

Milo: Briggs & Shantz (1913), Peng & Krieg (1992)

Wheat: Briggs & Shantz (1913)

Corn: Briggs & Shantz (1913)

- Littletooth sedge: *Juncus roemerianus* (Giurgevich & Dunn 1978)
 Flatsedge: *Phragmites australis* (Mueller et al. 2005)
 Fimbry: *Phalaris arundinacea* (Mueller et al. 2005)
 Cattail: mean of *Juncus roemerianus* (Giurgevich & Dunn 1978), *Paspalum vaginatum* (Biran et al. 1981), *Phalaris aquatica* (Morison & Gifford 1984), *Phragmites australis* (Mueller et al. 2005), *Spartina alterniflora* (Gallagher et al. 1980)
- Ragweed: *Ambrosia artemisifolia* (Shantz & Piemeisel 1927)
 Old-mans beard: mean of *Ambrosia artemisifolia* and *Iva xanthifolia* (Shantz & Piemeisel 1927)
 Bundleflower: mean of *Lotus humistrutis* (McGinnes & Arnold 1939), *Melilotus alba* (Shantz & Piemeisel 1927)
 Frogfruit: mean of *Amaranthus retroflexus* (Briggs & Shantz 1913), *Plantago insularis* (McGinnes & Arnold 1939), *Polygonum aviculare* (Shantz & Piemeisel 1927)
 Priage coneflower: mean of *Ambrosia artemisifolia*, *Grindelia squarrosa*, *Helianthus petiolaris*, *Polygonum aviculare* (Shantz & Piemeisel 1927)
 Snoutbean: mean of *Glycine max* (Lawn 1982), *Lotus humistrutis* (McGinnes & Arnold 1939), *Pisum sativum* (Briggs & Shantz 1913)
 Ruellia: mean of *Fagopyrum fagopyrum* (Briggs & Shantz 1913), *Iva xanthifolia* (Shantz & Piemeisel 1927), *Plantago insularis* (McGinnes & Arnold 1939), *Polygonum aviculare* (Shantz & Piemeisel 1927), *Solanum tuberosum* (Briggs & Shantz 1913)
 Bush sunflower: mean of *Helianthus petiolaris* and *Polygonum aviculare* (Shantz & Piemeisel 1927)
 Texas verbena: mean of *Chenopodium album* (Shantz & Piemeisel 1927), *Erodium cicutarium* (McGinnes & Arnold 1939)
 Orange zexmenia: 0.8(bush sunflower)
- Giant ragweed: mean of *Amaranthus retroflexus* (Briggs & Shantz 1913), *Helianthus annuus* (mean of 4 studies), *Iva xanthifolia* (Shantz & Piemeisel 1927), *Polygonum aviculare* (Shantz & Piemeisel 1927)
 Annual broomweed: mean of *Fagopyrum fagopyrum* (Briggs & Shantz 1913), *Grindelia squarrosa* (Shantz & Piemeisel 1927)
 Sunflower: mean of Shantz & Piemeisel (1927), Morison & Gifford (1984), Larcher (1995), Mueller et al. (2005)
 Duckweed: mean of *Allenrolfea occidentalis* (Glenn et al. 1998), *Iva xanthifolia* (Shantz & Piemeisel 1927), *Phalaris aquatica* (Morison & Gifford 1984)
 Partridge pea: mean of *Astragalus cicer* (Fairbourn 1982), *Lotus humistrutis* (McGinnes & Arnold 1939), *Pisum sativum* (Briggs & Shantz 1913)
 Texas doveweed: mean of *Brassica napus* (Briggs & Shantz 1913), *Chenopodium album* (Shantz & Piemeisel 1927), *Fagopyrum fagopyrum* (Briggs & Shantz 1913),
 Texas bluebonnet: mean of *Astragalus cicer* (Fairbourn 1982), *Lotus humistrutis* (McGinnes & Arnold 1939), *Trifolium pretense* (Mueller et al. 2005)
 Dogweed: mean of *Boerhaavia torreyana* (McGinnes & Arnold 1939), *Pectocarya linearis* (McGinnes & Arnold 1939), *Salsola iberica* (Briggs & Shantz 1913)

Appendix Table E.14 Growth rate control factor values for plant species included in the Goliad County EDYS model.

Common Name	Max growth rate	Max biomass	Max plant height	Max old biomass drought loss
Huisache	1.10	5000	6000	0.20
Pecan	0.98	28000	42672	0.10
Sugar hackberry	1.10	14000	9144	0.10
Mesquite	0.90	6400	9144	0.05
Post oak	0.25	15000	9144	0.10
Live oak	0.40	29000	9144	0.10
Guajillo	0.28	2100	1500	0.35
Blackbrush	0.28	2400	1500	0.35
Whitebrush	1.00	2600	1500	0.35
Prairie baccharis	1.20	2800	1500	0.40
Sea oxeye	0.80	390	792	0.50
Granjeno	0.90	2500	792	0.50
Carolina wolfberry	0.50	1000	1500	0.25
Agarito	0.25	1200	792	0.10
McCartney rose	0.75	2000	792	0.30
Rattlepod	1.30	1400	792	0.70
Mustang grape	1.00	2000	1500	0.40
Texas prickly pear	0.05	2400	792	0.10
Big bluestem	3.00	800	792	0.80
Bushy bluestem	2.25	390	792	0.80
Purple threeawn	2.75	300	792	0.20
King Ranch bluestem	2.50	800	610	0.20
Silver bluestem	2.75	600	610	0.40
Sideoats grama	2.75	600	610	0.25
Hairy grama	1.75	250	610	0.20
Red grama	1.75	150	850	0.20
Buffalograss	1.71	350	610	0.30
Sandbur	2.20	1020	610	0.80
Hooded windmillgrass	1.75	250	610	0.80
Trichloris	2.25	600	610	0.80
Bermudagrass	2.50	600	396	0.25
Arizona cottontop	2.50	500	351	0.40
Saltgrass	2.30	1020	351	0.40
Virginia wildrye	2.75	600	351	0.40
Texas cupgrass	2.50	600	351	0.30
Green sprangletop	2.50	400	351	0.30
Kleingrass	2.00	800	351	0.40
Guineagrass	2.00	800	351	0.40
Vine-mesquite	2.75	450	351	0.30
Switchgrass	2.75	800	351	0.30
Longtom	2.75	500	610	0.40
Brownseed paspalum	2.40	780	990	0.40

Appendix Table E.14 (Cont.)

Common Name	Max growth rate	Max biomass	Max plant height	Max old biomass drought loss
Thin paspalum	2.25	400	610	0.40
Common reed	3.26	2100	850	0.15
Little bluestem	2.50	600	914	0.30
Knotroot bristlegrass	1.50	250	850	0.30
Plains bristlegrass	1.36	1080	850	0.30
Texas bristlegrass	1.50	100	850	0.30
Indiangrass	2.75	750	792	0.30
Johnsongrass	2.75	800	850	0.35
Gulf cordgrass	1.36	1080	2012	0.30
Tall dropseed	2.75	600	850	0.30
Sand dropseed	2.75	400	850	0.20
Smutgrass	1.36	1080	850	0.30
Texas wintergrass	2.00	300	1200	0.25
Milo	4.00	1000	1200	0.30
Wheat	2.00	350	1200	0.30
Corn	3.00	1200	1200	0.30
Littletooth sedge	1.25	250	1325	0.50
Flatsedge	1.50	500	351	0.30
Cattail	1.00	800	351	0.50
Ragweed	3.12	600	1035	0.20
Lazydaisy	2.00	60	1035	0.25
Spiny aster	3.50	1000	1325	0.30
Whitestem wild indigo	1.75	710	351	0.50
Old-mans beard	1.00	400	1400	0.35
Bundleflower	2.00	80	1035	0.20
Frogfruit	2.40	60	1035	0.10
Prairie coneflower	2.00	60	895	0.30
Snoutbean	2.00	80	1050	0.80
Ruellia	2.00	50	1050	0.80
Curly dock	1.50	450	1050	0.80
Bulltongue	1.50	450	1050	0.80
Glasswort	1.80	450	1050	0.40
Bush sunflower	1.75	300	1050	0.20
Green briar	0.40	800	792	0.40
Texas verbena	2.50	50	1050	0.80
Orange zexmenia	1.35	200	1050	0.15
Giant ragweed	4.00	1000	1035	0.10
Annual broomweed	3.00	300	1035	0.10
Partridge pea	1.50	200	1325	0.70
Texas doveweed	1.50	250	895	0.80
Sunflower	3.00	750	895	0.30
Dogweed	1.00	60	1035	0.10

Data Sources**Maximum Growth Rate**

Purple threeawn	<i>Aristida glabrata</i> (McGinnies & Arnold 1939)
Silver bluestem	McGinnies & Arnold (1939)
Sideoats grama	McGinnies & Arnold (1939)
Hairy grama	McGinnies & Arnold (1939)
Buffalograss	<i>Hilaria belangeri</i> (McGinnies & Arnold 1939)
Arizona cottontop	modified from McGinnies & Arnold (1939)
Thin paspalum	<i>Heteropogon contortus</i> (McGinnies & Arnold 1939)

Maximum Aboveground Biomass

King Ranch bluestem	<i>Dichanthium annuatum</i> (Kapinga 1982)
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Appendix Table E.15 Monthly growth rates (proportion of maximum potential growth rate, Appendix Table E.14) for plant species in the Goliad County EDYS model.

Common Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Huisache	0.10	0.20	0.70	0.90	1.00	1.00	1.00	1.00	0.80	0.50	0.20	0.10
Pecan	0.00	0.00	0.50	0.80	1.00	1.00	1.00	1.00	0.70	0.30	0.10	0.00
Sugar hackberry	0.00	0.00	0.60	0.90	1.00	1.00	1.00	1.00	0.70	0.30	0.10	0.00
Mesquite	0.00	0.10	0.80	1.00	1.00	1.00	1.00	1.00	0.80	0.50	0.20	0.05
Post oak	0.00	0.00	0.50	0.80	1.00	1.00	1.00	1.00	0.60	0.30	0.10	0.00
Live oak	0.30	0.40	0.80	0.90	1.00	1.00	1.00	1.00	0.80	0.60	0.40	0.30
Guajillo	0.05	0.10	0.50	0.90	1.00	1.00	1.00	1.00	0.80	0.50	0.10	0.05
Blackbrush	0.05	0.15	0.50	0.90	1.00	1.00	1.00	1.00	0.80	0.60	0.30	0.10
Whitebrush	0.20	0.40	0.90	1.00	1.00	1.00	1.00	1.00	0.80	0.50	0.30	0.20
Prairie baccharis	0.10	0.40	0.70	0.90	1.00	1.00	1.00	1.00	0.80	0.60	0.30	0.10
Sea oxeye	0.00	0.00	0.00	0.50	0.90	1.00	1.00	1.00	0.90	0.50	0.00	0.00
Granjeno	0.05	0.10	0.70	0.90	1.00	1.00	1.00	1.00	0.80	0.50	0.30	0.05
Carolina wolfberry	0.00	0.00	0.50	0.80	1.00	1.00	1.00	1.00	1.00	0.70	0.30	0.00
Agarito	0.10	0.20	0.70	0.90	1.00	1.00	1.00	1.00	0.90	0.70	0.20	0.10
McCartney rose	0.20	0.20	0.40	0.80	1.00	1.00	1.00	1.00	0.90	0.60	0.30	0.20
Rattlepod	0.05	0.20	0.40	0.70	1.00	1.00	1.00	1.00	0.90	0.70	0.40	0.05
Mustang grape	0.00	0.20	0.60	1.00	1.00	1.00	1.00	1.00	0.80	0.40	0.20	0.00
Texas prickly pear	0.10	0.10	0.60	0.90	1.00	1.00	1.00	1.00	1.00	0.70	0.30	0.10
Big bluestem	0.00	0.10	0.50	0.90	1.00	1.00	1.00	1.00	0.90	0.60	0.30	0.05
Bushy bluestem	0.00	0.00	0.30	0.60	0.90	1.00	1.00	1.00	0.75	0.40	0.05	0.00
Purple threeawn	0.10	0.20	0.80	1.00	1.00	1.00	1.00	1.00	0.85	0.60	0.20	0.10
King Ranch bluestem	0.10	0.20	0.60	0.90	1.00	1.00	1.00	1.00	0.80	0.50	0.20	0.10
Silver bluestem	0.10	0.15	0.50	0.80	1.00	1.00	1.00	1.00	0.80	0.50	0.20	0.10
Sideoats grama	0.10	0.15	0.60	0.80	1.00	1.00	1.00	1.00	0.60	0.30	0.20	0.10
Hairy grama	0.10	0.15	0.40	0.80	1.00	1.00	1.00	1.00	0.80	0.50	0.20	0.10
Red grama	0.10	0.15	0.40	0.80	1.00	1.00	1.00	1.00	0.80	0.50	0.20	0.10
Buffalograss	0.05	0.10	0.40	0.80	1.00	1.00	1.00	0.90	0.70	0.50	0.30	0.10
Sandbur	0.00	0.00	0.20	0.50	0.80	1.00	1.00	0.90	0.80	0.60	0.30	0.00
Hooded windmillgrass	0.00	0.01	0.40	0.80	0.90	1.00	1.00	0.90	0.70	0.50	0.20	0.00
Trichloris	0.10	0.10	0.50	0.70	1.00	1.00	1.00	0.90	0.70	0.50	0.20	0.10
Bermudagrass	0.00	0.05	0.20	0.50	1.00	1.00	1.00	1.00	0.90	0.60	0.20	0.00
Arizona cottontop	0.20	0.30	0.40	0.50	0.60	0.70	0.90	1.00	0.60	0.50	0.40	0.30
Saltgrass	0.10	0.20	0.60	1.00	1.00	0.90	0.80	0.70	0.80	0.40	0.20	0.10
Virginia wildrye	0.50	0.80	1.00	1.00	0.80	0.40	0.10	0.10	0.30	0.40	0.50	0.50
Texas cupgrass	0.00	0.10	0.60	0.90	1.00	1.00	1.00	1.00	0.80	0.60	0.30	0.10
Green sprangletop	0.05	0.10	0.40	0.80	1.00	1.00	1.00	1.00	0.90	0.40	0.10	0.05
Kleingrass	0.10	0.20	0.30	0.50	0.80	1.00	1.00	1.00	0.80	0.60	0.40	0.20
Guineagrass	0.10	0.20	0.30	0.50	0.80	1.00	1.00	1.00	0.80	0.60	0.40	0.20
Vine-mesquite	0.10	0.20	0.40	0.80	1.00	1.00	1.00	1.00	0.80	0.50	0.30	0.15
Switchgrass	0.05	0.10	0.40	0.80	1.00	1.00	1.00	1.00	0.80	0.50	0.30	0.10
Longtom	0.10	0.30	0.75	0.90	1.00	1.00	1.00	1.00	0.60	0.40	0.20	0.10
Brownseed paspalum	0.00	0.00	0.50	0.90	1.00	1.00	1.00	1.00	0.90	0.50	0.20	0.00

Appendix Table E.15 (Cont.)

Common Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Thin paspalum	0.10	0.20	0.40	0.80	1.00	1.00	1.00	0.80	0.60	0.40	0.20	0.10
Common reed	0.00	0.10	0.50	0.90	1.00	1.00	1.00	1.00	1.00	0.70	0.30	0.10
Little bluestem	0.05	0.10	0.40	0.80	1.00	1.00	1.00	1.00	0.80	0.40	0.10	0.05
Knotroot bristlegrass	0.10	0.30	0.60	0.80	1.00	1.00	1.00	0.80	0.60	0.40	0.20	0.10
Plains bristlegrass	0.00	0.10	0.80	1.00	1.00	0.90	0.80	0.70	0.80	0.40	0.20	0.00
Texas bristlegrass	0.20	0.40	0.60	0.80	1.00	1.00	0.80	0.70	0.60	0.50	0.40	0.30
Indiangrass	0.05	0.10	0.40	0.70	1.00	1.00	1.00	1.00	0.80	0.40	0.20	0.05
Johnsongrass	0.00	0.00	0.50	0.90	1.00	1.00	1.00	1.00	0.80	0.40	0.20	0.05
Gulf cordgrass	0.10	0.30	0.80	1.00	1.00	0.90	0.80	0.70	0.80	0.40	0.20	0.10
Tall dropseed	0.10	0.20	0.40	0.80	1.00	1.00	1.00	0.90	0.70	0.40	0.20	0.10
Sand dropseed	0.05	0.10	0.50	0.90	1.00	1.00	1.00	1.00	0.80	0.40	0.20	0.05
Smutgrass	0.10	0.30	0.80	1.00	1.00	0.90	0.80	0.70	0.80	0.40	0.20	0.10
Texas wintergrass	0.70	0.80	1.00	1.00	0.70	0.40	0.10	0.00	0.20	0.40	0.60	0.70
Milo	0.00	0.10	0.90	1.00	1.00	1.00	1.00	0.80	0.50	0.20	0.00	0.00
Wheat	0.80	0.90	1.00	1.00	0.70	0.30	0.00	0.00	0.00	0.20	0.40	0.80
Corn	0.00	0.10	0.90	1.00	1.00	1.00	1.00	0.90	0.60	0.30	0.10	0.00
Littletooth sedge	0.10	0.25	0.50	0.90	1.00	1.00	1.00	0.90	0.70	0.50	0.30	0.10
Flatsedge	0.10	0.20	0.60	0.90	1.00	1.00	1.00	0.90	0.70	0.30	0.20	0.10
Cattail	0.10	0.20	0.40	0.80	1.00	1.00	1.00	1.00	0.80	0.40	0.20	0.10
Ragweed	0.00	0.10	0.50	0.90	1.00	1.00	1.00	0.90	0.50	0.30	0.10	0.10
Lazydaisy	0.00	0.50	0.90	1.00	1.00	1.00	1.00	0.80	0.40	0.20	0.10	0.00
Spiny aster	0.00	0.15	0.30	0.60	1.00	1.00	1.00	0.80	0.60	0.30	0.10	0.00
Whitestem wild indigo	0.00	0.10	0.60	1.00	1.00	1.00	1.00	1.00	0.80	0.20	0.10	0.00
Old-mans beard	0.10	0.20	0.40	0.80	1.00	1.00	1.00	0.90	0.70	0.50	0.30	0.20
Bundleflower	0.10	0.20	0.50	0.70	1.00	1.00	1.00	0.80	0.60	0.40	0.20	0.10
Frogfruit	0.10	0.20	0.50	0.70	1.00	1.00	1.00	0.80	0.60	0.40	0.20	0.10
Prairie coneflower	0.10	0.30	0.70	1.00	1.00	1.00	1.00	0.80	0.50	0.30	0.20	0.10
Snoutbean	0.10	0.15	0.60	0.90	1.00	1.00	1.00	1.00	0.80	0.40	0.20	0.10
Ruellia	0.10	0.20	0.70	0.90	1.00	1.00	1.00	1.00	0.80	0.40	0.20	0.10
Curly dock	0.10	0.10	0.40	0.80	1.00	1.00	1.00	1.00	0.90	0.40	0.20	0.10
Bulltongue	0.10	0.10	0.40	0.80	1.00	1.00	1.00	1.00	0.90	0.40	0.20	0.10
Glasswort	0.00	0.00	0.40	0.90	1.00	1.00	1.00	1.00	0.80	0.50	0.20	0.00
Bush sunflower	0.00	0.10	0.40	0.90	1.00	1.00	1.00	1.00	0.90	0.30	0.00	0.00
Green briar	0.10	0.30	0.80	1.00	1.00	1.00	1.00	0.90	0.70	0.50	0.40	0.10
Texas verbena	0.20	0.40	0.80	1.00	1.00	0.90	0.80	0.70	0.60	0.50	0.40	0.30
Orange zexmenia	0.00	0.10	0.50	0.90	1.00	1.00	1.00	1.00	0.90	0.30	0.00	0.00
Giant ragweed	0.10	0.20	0.50	0.90	1.00	1.00	1.00	0.80	0.60	0.40	0.20	0.00
Annual broomweed	0.10	0.20	0.40	0.80	1.00	1.00	0.90	0.70	0.50	0.30	0.10	0.00
Partridge pea	0.20	0.40	0.80	1.00	1.00	1.00	0.90	0.70	0.50	0.30	0.10	0.00
Texas doveweed	0.10	0.30	0.60	1.00	1.00	1.00	0.90	0.80	0.60	0.40	0.10	0.00
Sunflower	0.00	0.10	0.40	0.80	1.00	1.00	1.00	0.90	0.60	0.40	0.20	0.00
Dogweed	0.10	0.30	0.50	0.80	1.00	1.00	1.00	0.60	0.40	0.20	0.10	0.00

Data Sources

Purple threeawn	Modified from <i>Aristida divaricata</i> (McGinnies & Arnold 1939)
Silver bluestem	McGinnies & Arnold 1939
Sideoats grama	McGinnies & Arnold 1939
Hairy grama	McGinnies & Arnold 1939
Arizona cottontop	McGinnies & Arnold 1939

Appendix Table E.16 Plant part productivity rates (proportion of maximum photosynthetic rate) for plant species in the Goliad County EDYS model.

Common Name	CRoot	FRoot	Trunk	Stems	Leaves	Seeds
Huisache	0.00	0.00	0.00	0.05	1.00	0.00
Pecan	0.00	0.00	0.00	0.00	1.00	0.00
Sugar hackberry	0.00	0.00	0.00	0.00	1.00	0.00
Mesquite	0.00	0.00	0.00	0.02	1.00	0.00
Post oak	0.00	0.00	0.00	0.00	1.00	0.00
Live oak	0.00	0.00	0.00	0.00	1.00	0.00
Guajillo	0.00	0.00	0.00	0.02	1.00	0.00
Blackbrush	0.00	0.00	0.00	0.00	1.00	0.00
Whitebrush	0.00	0.00	0.00	0.05	1.00	0.00
Prairie baccharis	0.00	0.00	0.00	0.00	1.00	0.00
Sea oxeye	0.00	0.00	0.00	0.20	1.00	0.10
Granjeno	0.00	0.00	0.00	0.00	1.00	0.00
Carolina wolfberry	0.00	0.00	0.00	0.10	1.00	0.00
Agarito	0.00	0.00	0.00	0.02	1.00	0.00
McCartney rose	0.00	0.00	0.00	0.30	1.00	0.00
Rattlepod	0.00	0.00	0.00	0.05	1.00	0.00
Mustang grape	0.00	0.00	0.00	0.00	1.00	0.00
Texas prickly pear	0.00	0.00	0.02	1.00	0.00	0.00
Big bluestem	0.00	0.00	0.00	0.10	1.00	0.00
Bushy bluestem	0.00	0.00	0.00	0.10	1.00	0.00
Purple threeawn	0.00	0.00	0.05	0.20	1.00	0.00
King Ranch bluestem	0.00	0.00	0.05	0.30	1.00	0.00
Silver bluestem	0.00	0.00	0.00	0.20	1.00	0.00
Sideoats grama	0.00	0.00	0.05	0.10	1.00	0.00
Hairy grama	0.00	0.00	0.10	0.20	1.00	0.00
Red grama	0.00	0.00	0.05	0.20	1.00	0.00
Buffalograss	0.00	0.00	0.10	0.20	1.00	0.00
Sandbur	0.00	0.00	0.10	0.40	1.00	0.00
Hooded windmillgrass	0.00	0.00	0.10	0.20	1.00	0.00
Trichloris	0.00	0.00	0.01	0.20	1.00	0.00
Bermudagrass	0.00	0.00	0.10	0.20	1.00	0.00
Arizona cottontop	0.00	0.00	0.05	0.20	1.00	0.00
Saltgrass	0.00	0.00	0.00	0.10	1.00	0.00
Virginia wildrye	0.00	0.00	0.00	0.10	1.00	0.00
Texas cupgrass	0.00	0.00	0.05	0.20	1.00	0.00
Green sprangletop	0.00	0.00	0.05	0.20	1.00	0.00
Kleingrass	0.00	0.00	0.00	0.10	1.00	0.00
Guineagrass	0.00	0.00	0.00	0.10	1.00	0.00
Vine-mesquite	0.00	0.00	0.10	0.20	1.00	0.00
Switchgrass	0.00	0.00	0.00	0.10	1.00	0.00
Longtom	0.00	0.00	0.03	0.20	1.00	0.00
Brownseed paspalum	0.00	0.00	0.00	0.20	1.00	0.00

Appendix Table E.16 (Cont.)

Common Name	CRoot	FRoot	Trunk	Stems	Leaves	Seeds
Thin paspalum	0.00	0.00	0.05	0.20	1.00	0.00
Common reed	0.00	0.00	0.00	0.10	1.00	0.00
Little bluestem	0.00	0.00	0.00	0.10	1.00	0.00
Knotroot bristlegrass	0.00	0.00	0.10	0.20	1.00	0.00
Plains bristlegrass	0.00	0.00	0.00	0.30	1.00	0.00
Texas bristlegrass	0.00	0.00	0.10	0.20	1.00	0.00
Indiangrass	0.00	0.00	0.00	0.10	1.00	0.00
Johnsongrass	0.00	0.00	0.05	0.20	1.00	0.00
Gulf cordgrass	0.00	0.00	0.00	0.30	1.00	0.00
Tall dropseed	0.00	0.00	0.05	0.10	1.00	0.00
Sand dropseed	0.00	0.00	0.05	0.20	1.00	0.00
Smutgrass	0.00	0.00	0.00	0.30	1.00	0.00
Texas wintergrass	0.00	0.00	0.10	0.20	1.00	0.00
Milo	0.00	0.00	0.00	0.20	1.00	0.00
Wheat	0.00	0.00	0.02	0.20	1.00	0.00
Corn	0.00	0.00	0.00	0.20	1.00	0.00
Littletooth sedge	0.00	0.00	0.05	0.20	1.00	0.00
Flatsedge	0.00	0.00	0.00	0.20	1.00	0.00
Cattail	0.00	0.00	0.00	0.10	1.00	0.00
Ragweed	0.00	0.00	0.00	0.10	1.00	0.00
Lazydaisy	0.00	0.00	0.05	0.10	1.00	0.00
Spiny aster	0.00	0.00	0.00	0.60	1.00	0.00
Whitestem wild indigo	0.00	0.00	0.10	1.00	0.00	0.00
Old-mans beard	0.00	0.00	0.10	0.20	1.00	0.00
Bundleflower	0.00	0.00	0.10	0.10	1.00	0.00
Frogfruit	0.00	0.00	0.05	0.05	1.00	0.00
Prairie coneflower	0.00	0.00	0.00	0.05	1.00	0.00
Snoutbean	0.00	0.00	0.05	0.10	1.00	0.00
Ruellia	0.00	0.00	0.05	0.10	1.00	0.00
Curly dock	0.00	0.00	0.00	0.10	1.00	0.00
Bulltongue	0.00	0.00	0.00	0.10	1.00	0.00
Glasswort	0.00	0.00	0.10	0.20	1.00	0.00
Bush sunflower	0.00	0.00	0.05	0.10	1.00	0.00
Green briar	0.00	0.00	0.10	0.50	1.00	0.00
Texas verbena	0.00	0.00	0.05	0.10	1.00	0.00
Orange zexmenia	0.00	0.00	0.00	0.10	1.00	0.00
Giant ragweed	0.00	0.00	0.00	0.20	1.00	0.00
Annual broomweed	0.00	0.00	0.00	0.10	1.00	0.00
Partridge pea	0.00	0.00	0.00	0.10	1.00	0.00
Texas doveweed	0.00	0.00	0.00	0.05	1.00	0.00
Sunflower	0.00	0.00	0.05	0.20	1.00	0.00
Dogweed	0.00	0.00	0.00	0.20	1.00	0.00

Appendix Table E.17 Green-out plant part productivity conversion rates (proportion of biomass weight converted to new production at green-out) for plant species in the Goliad County EDYS model.

Common Name	CRoot	FRoot	Trunk	Stems	Leaves	Seeds
Huisache	0.02	0.00	0.01	0.05	1.00	0.00
Pecan	0.02	0.00	0.01	0.02	1.00	0.00
Sugar hackberry	0.01	0.00	0.01	0.03	1.00	0.00
Mesquite	0.02	0.00	0.01	0.05	1.00	0.00
Post oak	0.01	0.00	0.01	0.02	1.00	0.00
Live oak	0.01	0.00	0.01	0.02	1.00	0.00
Guajillo	0.02	0.00	0.02	0.05	1.00	0.00
Blackbrush	0.02	0.00	0.02	0.05	1.00	0.00
Whitebrush	0.04	0.00	0.04	0.10	1.00	0.00
Prairie baccharis	0.04	0.00	0.04	0.10	1.00	0.00
Sea oxeye	0.10	0.00	0.00	0.10	0.80	0.00
Granjeno	0.02	0.00	0.02	0.05	1.00	0.00
Carolina wolfberry	0.10	0.00	0.10	0.20	1.00	0.00
Agarito	0.02	0.00	0.02	0.05	1.00	0.00
McCartney rose	0.05	0.00	0.05	0.20	1.00	0.00
Rattlepod	0.02	0.00	0.05	0.10	1.00	0.00
Mustang grape	0.01	0.00	0.02	0.10	1.00	0.00
Texas prickly pear	0.01	0.00	0.02	0.00	0.00	0.00
Big bluestem	0.05	0.00	0.10	0.50	1.00	0.00
Bushy bluestem	0.00	0.00	1.00	1.00	1.00	0.00
Purple threeawn	0.05	0.00	0.05	0.50	1.00	0.00
King Ranch bluestem	0.05	0.00	0.10	0.50	1.00	0.00
Silver bluestem	0.05	0.00	0.10	0.50	1.00	0.00
Sideoats grama	0.10	0.00	0.10	0.50	1.00	0.00
Hairy grama	0.05	0.00	0.05	0.50	1.00	0.00
Red grama	0.05	0.00	0.05	0.50	1.00	0.00
Buffalograss	0.05	0.00	0.05	0.50	1.00	0.00
Sandbur	0.10	0.00	0.20	0.50	1.00	0.00
Hooded windmillgrass	0.05	0.00	0.05	0.50	1.00	0.00
Trichloris	0.05	0.00	0.10	0.50	1.00	0.00
Bermudagrass	0.10	0.00	0.10	0.50	1.00	0.00
Arizona cottontop	0.05	0.00	0.10	0.50	1.00	0.00
Saltgrass	0.10	0.00	0.10	0.50	1.00	0.00
Virginia wildrye	0.05	0.00	0.05	0.50	1.00	0.00
Texas cupgrass	0.05	0.00	0.05	0.50	1.00	0.00
Green sprangletop	0.05	0.00	0.05	0.50	1.00	0.00
Kleingrass	0.05	0.00	0.10	0.50	1.00	0.00
Guineagrass	0.05	0.00	0.10	0.50	1.00	0.00
Vine-mesquite	0.10	0.00	0.10	0.50	1.00	0.00
Switchgrass	0.05	0.00	0.10	0.50	1.00	0.00
Longtom	0.05	0.00	0.10	0.50	1.00	0.00
Brownseed paspalum	0.10	0.00	0.10	0.50	1.00	0.00

Appendix Table E.17 (Cont.)

Common Name	CRoot	FRoot	Trunk	Stems	Leaves	Seeds
Thin paspalum	0.05	0.00	0.05	0.50	1.00	0.00
Common reed	0.10	0.00	0.10	0.25	1.00	0.00
Little bluestem	0.05	0.00	0.10	0.50	1.00	0.00
Knotroot bristlegrass	0.10	0.00	0.10	0.50	1.00	0.00
Plains bristlegrass	0.10	0.00	0.10	0.50	1.00	0.00
Texas bristlegrass	0.05	0.00	0.05	0.50	1.00	0.00
Indiangrass	0.05	0.00	0.10	0.50	1.00	0.00
Johnsongrass	0.10	0.00	0.10	0.50	1.00	0.00
Gulf cordgrass	0.10	0.00	0.10	0.50	1.00	0.00
Tall dropseed	0.05	0.00	0.05	0.50	1.00	0.00
Sand dropseed	0.05	0.00	0.05	0.50	1.00	0.00
Smutgrass	0.10	0.00	0.10	0.50	1.00	0.00
Texas wintergrass	0.05	0.00	0.05	0.50	1.00	0.00
Milo	0.00	0.00	0.10	0.50	1.00	0.00
Wheat	0.00	0.00	0.10	0.50	1.00	0.00
Corn	0.00	0.00	0.10	0.50	1.00	0.00
Littletooth sedge	0.05	0.00	0.05	0.50	1.00	0.00
Flatsedge	0.10	0.00	0.10	0.50	1.00	0.00
Cattail	0.30	0.00	0.20	0.30	1.00	0.00
Ragweed	0.10	0.00	0.10	0.40	1.00	0.00
Lazydaisy	0.05	0.00	0.10	0.30	1.00	0.00
Spiny aster	0.00	0.00	0.20	0.50	1.00	0.00
Whitestem wild indigo	0.10	0.00	0.10	1.00	0.00	0.00
Old-mans beard	0.10	0.00	0.10	0.40	1.00	0.00
Bundleflower	0.05	0.00	0.10	0.40	1.00	0.00
Frogfruit	0.05	0.00	0.10	0.30	1.00	0.00
Prairie coneflower	0.10	0.00	0.10	0.30	1.00	0.00
Snoutbean	0.10	0.00	0.20	0.30	1.00	0.00
Ruellia	0.10	0.00	0.10	0.30	1.00	0.00
Curly dock	0.20	0.00	0.40	0.40	1.00	0.00
Bulltongue	0.20	0.00	0.40	0.40	1.00	0.00
Glasswort	0.10	0.00	0.10	0.50	1.00	0.00
Bush sunflower	0.10	0.00	0.20	0.40	1.00	0.00
Green briar	0.10	0.00	0.20	0.50	1.00	0.00
Texas verbena	0.05	0.00	0.10	0.30	1.00	0.00
Orange zexmenia	0.10	0.00	0.10	0.40	1.00	0.00
Giant ragweed	0.00	0.00	0.20	0.50	1.00	0.00
Annual broomweed	0.00	0.00	0.10	0.20	1.00	0.00
Partridge pea	0.00	0.00	0.20	0.40	1.00	0.00
Texas doveweed	0.00	0.00	0.10	0.20	1.00	0.00
Sunflower	0.00	0.00	0.20	0.50	1.00	0.00
Dogweed	0.00	0.00	0.20	0.30	1.00	0.00

Appendix Table E.18 Physiological control constants for plant species in the Goliad County EDYS model.

Common Name	Growing season max root:shoot	Growing season green- out shoot:root	Max 1-mo seed germination	Max 1st-mo seedling growth
Huisache	1.70	0.230	0.730	20.00
Pecan	1.50	0.670	0.730	5.00
Sugar hackberry	0.56	1.780	0.800	10.00
Mesquite	0.64	1.560	0.500	10.00
Post oak	0.72	0.130	0.950	8.00
Live oak	0.92	1.090	0.630	8.00
Guajillo	1.30	0.200	0.960	20.00
Blackbrush	1.30	0.200	0.960	20.00
Whitebrush	1.22	0.190	0.960	20.00
Prairie baccharis	1.22	0.820	0.940	10.00
Sea oxeye	1.80	0.280	0.750	15.00
Granjeno	1.32	0.200	0.750	15.00
Carolina wolfberry	1.10	0.463	0.720	20.00
Agarito	1.94	0.520	0.790	10.00
McCartney rose	5.10	0.097	0.480	20.00
Rattlepod	1.22	0.190	0.260	30.00
Mustang grape	1.00	1.000	0.640	10.00
Texas prickly pear	0.62	1.610	0.700	10.00
Big bluestem	1.72	0.230	0.540	20.00
Bushy bluestem	1.30	0.750	0.540	20.00
Purple threeawn	3.78	0.260	0.160	20.00
King Ranch bluestem	3.18	0.310	0.600	30.00
Silver bluestem	2.00	0.250	0.900	30.00
Sideoats grama	3.20	0.310	0.720	20.00
Hairy grama	1.12	0.890	0.390	20.00
Red grama	1.12	0.890	0.390	20.00
Buffalograss	2.40	0.270	0.618	30.00
Sandbur	2.00	0.249	0.440	15.00
Hooded windmillgrass	1.80	0.240	0.440	15.00
Trichloris	2.00	0.250	0.440	15.00
Bermudagrass	2.42	0.410	0.850	20.00
Arizona cottontop	1.80	0.240	0.900	30.00
Saltgrass	1.40	0.530	0.900	30.00
Virginia wildrye	1.68	0.230	0.900	30.00
Texas cupgrass	2.12	0.470	0.530	20.00
Green sprangletop	1.72	0.580	0.790	20.00
Kleingrass	1.80	0.240	0.900	30.00
Guineagrass	1.80	0.240	0.900	30.00
Vine-mesquite	1.70	0.590	0.370	20.00
Switchgrass	1.96	0.510	0.480	20.00
Longtom	5.00	0.360	0.530	30.00
Brownseed paspalum	2.40	0.210	0.530	30.00

Appendix Table E.18 (Cont.)

Common Name	Growing season max root:shoot	Growing season green- out shoot:root	Max 1-mo seed germination	Max 1st-mo seedling growth
Thin paspalum	1.52	0.220	0.530	30.00
Common reed	0.72	1.250	0.010	10.00
Little bluestem	3.26	0.310	0.480	20.00
Knotroot bristlegrass	2.20	0.260	0.580	25.00
Plains bristlegrass	3.40	0.220	0.580	25.00
Texas bristlegrass	1.20	0.190	0.580	25.00
Indiangrass	1.72	0.580	0.630	20.00
Johnsongrass	4.42	0.230	0.880	20.00
Gulf cordgrass	3.40	0.220	0.580	25.00
Tall dropseed	2.20	0.450	0.800	20.00
Sand dropseed	1.76	0.570	0.800	20.00
Smutgrass	3.40	0.220	0.580	25.00
Texas wintergrass	2.52	0.400	0.130	20.00
Milo	2.00	0.250	0.580	25.00
Wheat	1.76	0.570	0.940	20.00
Corn	2.00	0.250	0.580	25.00
Littletooth sedge	2.40	0.270	0.353	30.00
Flatsedge	6.66	0.170	0.460	20.00
Cattail	6.66	0.170	0.650	20.00
Ragweed	2.52	0.400	0.600	20.00
Lazydaisy	2.76	0.360	0.700	10.00
Spiny aster	2.30	0.350	0.950	40.00
Whitestem wild indigo	1.60	0.300	0.520	15.00
Old-mans beard	2.60	0.280	0.960	20.00
Bundleflower	2.92	0.350	0.420	20.00
Frogfruit	1.00	0.170	0.500	20.00
Prairie coneflower	2.76	0.360	0.500	20.00
Snoutbean	1.40	0.210	0.700	50.00
Ruellia	1.20	0.190	0.700	50.00
Curly dock	0.70	0.270	0.700	50.00
Bulltongue	0.70	0.270	0.700	50.00
Glasswort	3.90	0.129	0.990	30.00
Bush sunflower	2.52	0.400	0.380	20.00
Green briar	2.00	0.250	0.600	30.00
Texas verbena	1.40	0.210	0.700	50.00
Orange zexmenia	2.52	0.400	0.500	20.00
Giant ragweed	1.00	0.170	0.500	20.00
Annual broomweed	1.20	0.190	0.500	20.00
Partridge pea	1.20	0.190	0.260	30.00
Texas doveweed	0.80	0.140	0.700	50.00
Sunflower	0.34	2.940	0.820	30.00
Dogweed	1.20	0.190	0.600	30.00

Growing season max root:shoot ratio = twice the initial root:shoot ratio value (Appendix Table D.2). Examples of field root:shoot ratios include: *Quercus robur* 0.35 (Rodin & Bazilevich 1967); *Q. velutina* 0.54 (Nadelhoffer et al. 1985); *Larrea tridentata* 0.42 (Chew & Chew 1965), 1.08 (Wallace et al. 1974); *Bouteloua gracilis* 2.39 (Samuel & Hart 1992), 4.10 (Coupland & Johnson 1965), 6.90 (Vinton & Burke 1995); *Cynodon dactylon* 0.62 (Rodriguez et al. 2002), 1.60 (Hons et al. 1979), 2.90 (Beaty et al. 1975); *Distichlis spicata* 1.10 (Seliskar & Gallagher 2000); *Hilaria jamesii* 5.31 (Moore & West 1973); *Hilaria rigida* 0.57 (Robberecht et al. 1983); *Oryzopsis hymenoides* 2.62 (Orodho & Trlica 1990); *Paspalum notatum* 2.27 (Fiala et al. 1991), 2.50 (Beaty et al. 1975); *Schizachyrium scoparium* 2.76 (Cerligione et al. 1987); tallgrass prairie 0.90 Oklahoma (Sims & Singh 1978), 0.97 Missouri (Buyanovsky et al. 1987); Kansas midgrass prairie 1.76 (Sims & Singh 1978); shortgrass plains 1.87 Colorado (Sims & Singh 1978), 2.21 Texas (Sims & Singh 1978); *Carex nebrascensis* 5.62 (Manning et al. 1989); *Juncus roemerianus* 1.55 (Gallagher et al. 1977).

Growing season green-out shoot:root ratio = half the inverse of initial shoot:root ratio (Appendix Table D.2).

Appendix Table E.19 End of growing season dieback (proportion of tissue lost at onset of dormancy) for plant species in the Goliad County EDYS model.

Common Name	CRoot	FRoot	Trunk	Stems	Leaves	Seeds
Huisache	0.02	0.06	0.010	0.02	0.85	1.00
Pecan	0.01	0.05	0.005	0.01	1.00	1.00
Sugar hackberry	0.01	0.05	0.010	0.02	0.98	1.00
Mesquite	0.01	0.05	0.005	0.02	0.90	1.00
Post oak	0.01	0.05	0.010	0.02	1.00	1.00
Live oak	0.01	0.05	0.005	0.01	0.74	1.00
Guajillo	0.03	0.15	0.030	0.10	0.35	1.00
Blackbrush	0.03	0.15	0.020	0.10	0.40	1.00
Whitebrush	0.04	0.15	0.030	0.25	0.90	1.00
Prairie baccharis	0.04	0.15	0.050	0.15	0.85	1.00
Sea oxeye	0.01	0.05	0.010	0.03	1.00	1.00
Granjeno	0.03	0.15	0.020	0.05	0.80	1.00
Carolina wolfberry	0.05	0.15	0.050	0.20	1.00	1.00
Agarito	0.02	0.10	0.020	0.10	0.35	1.00
McCartney rose	0.03	0.10	0.020	0.20	0.35	1.00
Rattlepod	0.08	0.15	0.100	0.20	0.95	1.00
Mustang grape	0.04	0.15	0.010	0.08	0.95	1.00
Texas prickly pear	0.04	0.10	0.020	0.08	0.05	1.00
Big bluestem	0.03	0.09	0.030	0.90	0.99	1.00
Bushy bluestem	0.06	0.15	0.200	1.00	1.00	1.00
Purple threeawn	0.10	0.20	0.050	0.95	0.95	1.00
King Ranch bluestem	0.10	0.20	0.080	0.95	0.98	1.00
Silver bluestem	0.07	0.15	0.040	0.90	0.95	1.00
Sideoats grama	0.05	0.15	0.030	0.90	0.98	1.00
Hairy grama	0.15	0.30	0.080	0.95	0.90	1.00
Red grama	0.15	0.30	0.150	0.95	0.95	1.00
Buffalograss	0.15	0.30	0.150	0.85	0.90	1.00
Sandbur	0.10	0.20	0.050	1.00	1.00	1.00
Hooded windmillgrass	0.15	0.30	0.080	0.95	0.95	1.00
Trichloris	0.10	0.20	0.040	0.90	0.95	1.00
Bermudagrass	0.10	0.20	0.150	0.70	0.90	1.00
Arizona cottontop	0.10	0.20	0.050	0.95	0.95	1.00
Saltgrass	0.10	0.20	0.050	0.85	1.00	1.00
Virginia wildrye	0.12	0.25	0.100	0.95	0.99	1.00
Texas cupgrass	0.10	0.20	0.100	0.95	0.95	1.00
Green sprangletop	0.15	0.30	0.150	0.95	0.90	1.00
Kleingrass	0.18	0.40	0.150	0.95	0.95	1.00
Guineagrass	0.18	0.40	0.150	0.95	0.95	1.00
Vine-mesquite	0.10	0.20	0.050	0.90	0.95	1.00
Switchgrass	0.05	0.15	0.030	0.90	0.95	1.00
Longtom	0.15	0.30	0.060	0.80	0.95	1.00
Brownseed paspalum	0.10	0.20	0.050	0.90	1.00	1.00

Appendix Table E.19 (Cont.)

Common Name	CRoot	FRoot	Trunk	Stems	Leaves	Seeds
Thin paspalum	0.17	0.25	0.120	0.95	0.99	1.00
Common reed	0.03	0.10	0.050	0.80	0.90	1.00
Little bluestem	0.10	0.20	0.030	0.90	0.98	1.00
Knotroot bristlegrass	0.18	0.30	0.150	0.90	0.90	1.00
Plains bristlegrass	0.08	0.20	0.040	0.95	0.90	1.00
Texas bristlegrass	0.25	0.50	0.250	0.98	0.99	1.00
Indiangrass	0.05	0.15	0.030	0.90	0.95	1.00
Johnsongrass	0.10	0.20	0.100	0.90	0.95	1.00
Gulf cordgrass	0.08	0.20	0.040	0.95	0.90	1.00
Tall dropseed	0.10	0.20	0.050	0.95	0.97	1.00
Sand dropseed	0.15	0.30	0.100	0.90	0.95	1.00
Smutgrass	0.08	0.20	0.040	0.95	0.90	1.00
Texas wintergrass	0.15	0.30	0.150	0.95	0.95	1.00
Milo	1.00	1.00	1.000	1.00	1.00	1.00
Wheat	1.00	1.00	1.000	1.00	1.00	1.00
Corn	1.00	1.00	1.000	1.00	1.00	1.00
Littletooth sedge	0.15	0.30	0.200	0.90	0.95	1.00
Flatsedge	0.15	0.30	0.150	0.97	0.95	1.00
Cattail	0.10	0.20	0.050	0.95	0.90	1.00
Ragweed	0.18	0.35	0.200	0.95	0.99	1.00
Lazydaisy	0.20	0.40	0.150	0.80	0.99	1.00
Spiny aster	0.08	0.20	0.100	0.90	1.00	1.00
Whitestem wild indigo	0.10	0.20	0.050	0.95	1.00	1.00
Old-mans beard	0.15	0.30	0.120	0.60	0.90	1.00
Bundleflower	0.10	0.20	0.120	0.60	0.95	1.00
Frogfruit	0.20	0.30	0.200	0.80	0.95	1.00
Prairie coneflower	0.15	0.30	0.200	0.70	0.95	1.00
Snoutbean	0.05	0.15	0.050	0.40	0.95	1.00
Ruellia	0.18	0.30	0.100	0.60	0.80	1.00
Curly dock	0.50	0.60	0.500	0.90	0.90	1.00
Bulltongue	0.50	0.60	0.500	0.90	0.90	1.00
Glasswort	0.20	0.40	0.200	1.00	1.00	1.00
Bush sunflower	0.10	0.20	0.200	0.95	0.99	1.00
Green briar	0.08	0.20	0.100	0.40	1.00	1.00
Texas verbena	0.25	0.50	0.300	0.90	0.90	1.00
Orange zexmenia	0.10	0.20	0.200	0.95	0.98	1.00
Giant ragweed	1.00	1.00	1.000	1.00	1.00	1.00
Annual broomweed	1.00	1.00	1.000	1.00	1.00	1.00
Partridge pea	1.00	1.00	1.000	1.00	1.00	1.00
Texas doveweed	1.00	1.00	1.000	1.00	1.00	1.00
Sunflower	1.00	1.00	1.000	1.00	1.00	1.00
Dogweed	1.00	1.00	1.000	1.00	1.00	1.00

Data Sources

Weaver & Zink (1946); Caldwell & Camp (1974); Peet et al. (2005).

Appendix Table E.20 Shading effect on species included in the Goliad County EDYS model. Values are the proportional decreases in maximum potential production of the **shaded species** resulting from 100% cover of the **shading species**.

Common Name	Sugar							Prairie			
	Huisache	Pecan	hackberry	Mesquite	Post oak	Live oak	Guajillo	Blackbrush	Whitebrush	baccharis	Sea oxeye
Huisache	0.00	0.03	0.01	0.01	0.01	0.03	0.00	0.00	0.01	0.01	0.00
Pecan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sugar hackberry	0.00	0.02	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
Mesquite	0.00	0.06	0.01	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
Post oak	0.00	0.02	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Live oak	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Guajillo	0.03	0.03	0.02	0.02	0.02	0.03	0.00	0.01	0.02	0.02	0.00
Blackbrush	0.01	0.02	0.02	0.01	0.02	0.04	0.01	0.00	0.01	0.01	0.00
Whitebrush	0.01	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.00
Prairie baccharis	0.00	0.03	0.02	0.02	0.00	0.03	0.00	0.00	0.00	0.00	0.00
Sea oxeye	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Granjeno	0.01	0.01	0.01	0.01	0.01	0.02	0.00	0.00	0.01	0.01	0.00
Carolina wolfberry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agarito	0.00	0.04	0.03	0.01	0.00	0.03	0.00	0.00	0.00	0.01	0.00
McCartney rose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rattlepod	0.02	0.02	0.02	0.02	0.02	0.02	0.00	0.00	0.01	0.01	0.00
Mustang grape	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas prickly pear	0.00	0.04	0.02	0.01	0.00	0.04	0.00	0.00	0.00	0.01	0.00
Big bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bushy bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Purple threeawn	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
King Ranch bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Silver bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sideoats grama	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hairy grama	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Red grama	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Buffalograss	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sandbur	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hooded windmillgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trichloris	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bermudagrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arizona cottontop	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Saltgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Virginia wildrye	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas cupgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Green sprangletop	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kleingrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Guineagrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vine-mesquite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Switchgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Longtom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Brownseed paspalum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix Table E.20 (Cont.)

Common Name	Sugar									Prairie	
	Huisache	Pecan	hackberry	Mesquite	Post oak	Live oak	Guajillo	Blackbrush	Whitebrush	baccharis	Sea oxeye
Thin paspalum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common reed	0.00	0.02	0.01	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
Little bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Knotroot bristlegrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plains bristlegrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas bristlegrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Indiangrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Johnsongrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gulf cordgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tall dropseed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sand dropseed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Smutgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas wintergrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Milo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wheat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corn	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Littletooth sedge	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Flatsedge	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cattail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ragweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lazydaisy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spiny aster	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Whitestem wild indigo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Old-mans beard	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bundleflower	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Frogfruit	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prairie coneflower	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Snoutbean	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ruellia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Curly dock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bulltongue	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bush sunflower	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Green briar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas verbena	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Orange zexmenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Giant ragweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual broomweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Partridge pea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas doveweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sunflower	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dogweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix Table E.20 (Cont.)

Common Name	Carolina		McCartney		Mustang		Texas prickly		Bushy	Purple	King Ranch
	Granjeno	wolfberry	Agarito	rose	Rattlepod	grape	pear	Big bluestem	bluestem	threeawn	bluestem
Huisache	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
Pecan	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00
Sugar hackberry	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00
Mesquite	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00
Post oak	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
Live oak	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00
Guajillo	0.01	0.00	0.01	0.00	0.00	0.04	0.00	0.06	0.00	0.00	0.00
Blackbrush	0.01	0.00	0.00	0.00	0.00	0.04	0.00	0.04	0.00	0.00	0.00
Whitebrush	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Prairie baccharis	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00
Sea oxeye	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Granjeno	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
Carolina wolfberry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agarito	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00
McCartney rose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rattlepod	0.01	0.00	0.00	0.00	0.00	0.04	0.00	0.05	0.00	0.00	0.00
Mustang grape	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas prickly pear	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00
Big bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bushy bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Purple threeawn	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
King Ranch bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Silver bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00
Sideoats grama	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hairy grama	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Red grama	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Buffalograss	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.01	0.01
Sandbur	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hooded windmillgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.01	0.01
Trichloris	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00
Bermudagrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arizona cottontop	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00
Saltgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Virginia wildrye	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00
Texas cupgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Green sprangletop	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kleingrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00
Guineagrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00
Vine-mesquite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Switchgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Longtom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00
Brownseed paspalum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix Table E.20 (Cont.)

Common Name	Carolina		McCartney		Mustang		Texas prickly		Bushy	Purple	King Ranch
	Granjeno	wolfberry	Agarito	rose	Rattlepod	grape	pear	Big bluestem	bluestem	threeawn	bluestem
Thin paspalum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.01	0.00
Common reed	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
Little bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Knotroot bristlegrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.01	0.01
Plains bristlegrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas bristlegrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.02	0.02
Indiangrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Johnsongrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gulf cordgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tall dropseed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sand dropseed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Smutgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas wintergrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Milo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.06	0.06
Wheat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corn	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00
Littletooth sedge	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.02	0.01
Flatsedge	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cattail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ragweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lazydaisy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spiny aster	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Whitestem wild indigo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Old-mans beard	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00
Bundleflower	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Frogfruit	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.01	0.01
Prairie coneflower	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Snoutbean	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00
Ruellia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00
Curly dock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bulltongue	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bush sunflower	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Green briar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas verbena	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00
Orange zexmenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Giant ragweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00
Annual broomweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.01	0.00
Partridge pea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00
Texas doveweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.01	0.00
Sunflower	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dogweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.03	0.01

Appendix Table E.20 (Cont.)

Common Name	Silver	Sideoats	Hairy	Red	Buffalograss	Sandbur	Hooded		Bermudagrass	Arizona	
	bluestem	grama	grama	grama			windmillgrass	Trichloris		cottontop	Saltgrass
Huisache	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pecan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sugar hackberry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesquite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Post oak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Live oak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Guajillo	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Blackbrush	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Whitebrush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prairie baccharis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sea oxeye	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Granjeno	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carolina wolfberry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agarito	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
McCartney rose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rattlepod	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mustang grape	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas prickly pear	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Big bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bushy bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Purple threeawn	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
King Ranch bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Silver bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sideoats grama	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hairy grama	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Red grama	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Buffalograss	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00
Sandbur	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hooded windmillgrass	0.03	0.02	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.02	0.00
Trichloris	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bermudagrass	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arizona cottontop	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Saltgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Virginia wildrye	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas cupgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Green sprangletop	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kleingrass	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Guineagrass	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vine-mesquite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Switchgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Longtom	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Brownseed paspalum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix Table E.20 (Cont.)

Common Name	Silver	Sideoats	Hairy	Red	Buffalograss	Sandbur	Hooded		Bermudagrass	Arizona	
	bluestem	grama	grama	grama			windmillgrass	Trichloris		cottontop	Saltgrass
Thin paspalum	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00
Common reed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Little bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Knotroot bristlegrass	0.04	0.03	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
Plains bristlegrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas bristlegrass	0.04	0.03	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.02	0.00
Indiangrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Johnsongrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gulf cordgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tall dropseed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sand dropseed	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Smutgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas wintergrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Milo	0.09	0.08	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
Wheat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corn	0.08	0.07	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Littletooth sedge	0.04	0.03	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00
Flatsedge	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cattail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ragweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lazydaisy	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spiny aster	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Whitestem wild indigo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Old-mans beard	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
Bundleflower	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Frogfruit	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00
Prairie coneflower	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Snoutbean	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00
Ruellia	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00
Curly dock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bulltongue	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bush sunflower	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Green briar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas verbena	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.00
Orange zexmenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Giant ragweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual broomweed	0.06	0.05	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.02	0.00
Partridge pea	0.04	0.03	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.01	0.00
Texas doveweed	0.05	0.04	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.02	0.00
Sunflower	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dogweed	0.06	0.05	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.05	0.00

Appendix Table E.20 (Cont.)

Common Name	Virginia wildrye	Texas cupgrass	Green sprangletop	Kleingrass	Guineagrass	Vine- mesquite	Switchgrass	Longtom	Brownseed paspalum	Thin paspalum	Common reed
Huisache	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pecan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sugar hackberry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesquite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Post oak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Live oak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Guajillo	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
Blackbrush	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
Whitebrush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prairie baccharis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Sea oxeye	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Granjeno	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carolina wolfberry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agarito	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.07
McCartney rose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rattlepod	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mustang grape	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas prickly pear	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.08
Big bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bushy bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Purple threeawn	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.10
King Ranch bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.05
Silver bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
Sideoats grama	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.06
Hairy grama	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.10
Red grama	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.10
Buffalograss	0.01	0.00	0.00	0.04	0.00	0.00	0.08	0.00	0.00	0.02	0.00
Sandbur	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hooded windmillgrass	0.02	0.00	0.00	0.05	0.00	0.00	0.08	0.00	0.00	0.02	0.00
Trichloris	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00
Bermudagrass	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.02
Arizona cottontop	0.01	0.00	0.00	0.02	0.00	0.00	0.05	0.00	0.00	0.00	0.00
Saltgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Virginia wildrye	0.00	0.00	0.00	0.01	0.00	0.00	0.03	0.00	0.00	0.00	0.00
Texas cupgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.05
Green sprangletop	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.05
Kleingrass	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00
Guineagrass	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00
Vine-mesquite	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.02
Switchgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Longtom	0.01	0.00	0.00	0.01	0.00	0.00	0.05	0.00	0.00	0.00	0.00
Brownseed paspalum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix Table E.20 (Cont.)

Common Name	Virginia wildrye	Texas cupgrass	Green sprangletop	Kleingrass	Guineagrass	Vine- mesquite	Switchgrass	Longtom	Brownseed paspalum	Thin paspalum	Common reed
Thin paspalum	0.01	0.00	0.00	0.03	0.00	0.00	0.06	0.00	0.00	0.00	0.00
Common reed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Little bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.04
Knotroot bristlegrass	0.02	0.00	0.00	0.04	0.00	0.00	0.06	0.03	0.00	0.02	0.00
Plains bristlegrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas bristlegrass	0.02	0.00	0.00	0.05	0.00	0.00	0.10	0.01	0.00	0.03	0.00
Indiangrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Johnsongrass	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.02
Gulf cordgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tall dropseed	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.05
Sand dropseed	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.10
Smutgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas wintergrass	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.05
Milo	0.00	0.00	0.00	0.04	0.00	0.00	0.10	0.00	0.00	0.00	0.00
Wheat	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.10
Corn	0.00	0.00	0.00	0.02	0.00	0.00	0.09	0.00	0.00	0.00	0.00
Littletooth sedge	0.01	0.00	0.00	0.03	0.00	0.00	0.08	0.02	0.00	0.02	0.00
Flatsedge	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.02
Cattail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ragweed	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.05
Lazydaisy	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.10
Spiny aster	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Whitestem wild indigo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Old-mans beard	0.00	0.00	0.00	0.01	0.00	0.00	0.07	0.00	0.00	0.01	0.00
Bundleflower	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.10
Frogfruit	0.01	0.00	0.00	0.03	0.00	0.00	0.09	0.02	0.00	0.02	0.00
Prairie coneflower	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.10
Snoutbean	0.01	0.00	0.00	0.02	0.00	0.00	0.07	0.00	0.00	0.02	0.00
Ruellia	0.01	0.00	0.00	0.03	0.00	0.00	0.08	0.00	0.00	0.01	0.00
Curly dock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bulltongue	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bush sunflower	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.10
Green briar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas verbena	0.01	0.00	0.00	0.02	0.00	0.00	0.07	0.01	0.00	0.02	0.00
Orange zexmenia	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.10
Giant ragweed	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
Annual broomweed	0.01	0.00	0.00	0.05	0.00	0.00	0.10	0.00	0.00	0.04	0.00
Partridge pea	0.01	0.00	0.00	0.03	0.00	0.00	0.06	0.00	0.00	0.01	0.00
Texas doveweed	0.01	0.00	0.00	0.04	0.00	0.00	0.10	0.00	0.00	0.04	0.00
Sunflower	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.07
Dogweed	0.04	0.00	0.00	0.05	0.00	0.00	0.10	0.03	0.00	0.04	0.00

Appendix Table E.20 (Cont.)

Common Name	Little	Knotroot	Plains	Texas	Indiangrass	Johnsongrass	Gulf	Tall	Sand	Smutgrass	Texas
	bluestem	bristlegrass	bristlegrass	bristlegrass				dropseed	dropseed		wintergrass
Huisache	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pecan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sugar hackberry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesquite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Post oak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Live oak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Guajillo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Blackbrush	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Whitebrush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prairie baccharis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sea oxeeye	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Granjeno	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carolina wolfberry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agarito	0.01	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00
McCartney rose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rattlepod	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mustang grape	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas prickly pear	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Big bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bushy bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Purple threeawn	0.05	0.00	0.00	0.00	0.10	0.10	0.00	0.03	0.00	0.00	0.00
King Ranch bluestem	0.01	0.00	0.00	0.00	0.05	0.05	0.00	0.00	0.00	0.00	0.00
Silver bluestem	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sideoats grama	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Hairy grama	0.05	0.00	0.00	0.00	0.10	0.10	0.00	0.03	0.00	0.00	0.00
Red grama	0.05	0.00	0.00	0.00	0.10	0.10	0.00	0.03	0.00	0.00	0.00
Buffalograss	0.02	0.00	0.00	0.00	0.00	0.04	0.00	0.02	0.00	0.00	0.00
Sandbur	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hooded windmillgrass	0.05	0.00	0.00	0.00	0.00	0.04	0.00	0.02	0.00	0.00	0.00
Trichloris	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Bermudagrass	0.05	0.00	0.00	0.00	0.05	0.04	0.00	0.00	0.00	0.00	0.00
Arizona cottontop	0.02	0.00	0.00	0.00	0.00	0.03	0.00	0.01	0.00	0.00	0.00
Saltgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Virginia wildrye	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Texas cupgrass	0.01	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00
Green sprangletop	0.02	0.00	0.00	0.00	0.05	0.05	0.00	0.00	0.00	0.00	0.00
Kleingrass	0.03	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
Guineagrass	0.03	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
Vine-mesquite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Switchgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Longtom	0.04	0.00	0.00	0.00	0.00	0.03	0.00	0.01	0.00	0.00	0.00
Brownseed paspalum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix Table E.20 (Cont.)

Common Name	Little	Knotroot	Plains	Texas	Indiangrass	Johnsongrass	Gulf	Tall	Sand	Smutgrass	Texas
	bluestem	bristlegrass	bristlegrass	bristlegrass				dropseed	dropseed		wintergrass
Thin paspalum	0.03	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00
Common reed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Little bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Knotroot bristlegrass	0.04	0.00	0.00	0.00	0.00	0.02	0.00	0.02	0.00	0.00	0.00
Plains bristlegrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas bristlegrass	0.06	0.00	0.00	0.00	0.00	0.06	0.00	0.02	0.00	0.00	0.00
Indiangrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Johnsongrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gulf cordgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tall dropseed	0.01	0.00	0.00	0.00	0.03	0.03	0.00	0.00	0.00	0.00	0.00
Sand dropseed	0.03	0.00	0.00	0.00	0.05	0.05	0.00	0.03	0.00	0.00	0.00
Smutgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas wintergrass	0.01	0.00	0.00	0.00	0.05	0.05	0.00	0.00	0.00	0.00	0.00
Milo	0.06	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00
Wheat	0.05	0.00	0.00	0.00	0.10	0.10	0.00	0.05	0.00	0.00	0.00
Corn	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00
Littletooth sedge	0.05	0.00	0.00	0.00	0.00	0.04	0.00	0.02	0.00	0.00	0.00
Flatsedge	0.05	0.00	0.00	0.00	0.10	0.10	0.00	0.00	0.00	0.00	0.00
Cattail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ragweed	0.05	0.00	0.00	0.00	0.10	0.10	0.00	0.00	0.00	0.00	0.00
Lazydaisy	0.07	0.00	0.00	0.00	0.10	0.10	0.00	0.05	0.00	0.00	0.00
Spiny aster	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Whitestem wild indigo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Old-mans beard	0.03	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00
Bundleflower	0.07	0.00	0.00	0.00	0.10	0.10	0.00	0.04	0.00	0.00	0.00
Frogfruit	0.03	0.00	0.00	0.00	0.00	0.03	0.00	0.02	0.00	0.00	0.00
Prairie coneflower	0.03	0.00	0.00	0.00	0.10	0.10	0.00	0.02	0.00	0.00	0.00
Snoutbean	0.03	0.00	0.00	0.00	0.00	0.03	0.00	0.02	0.00	0.00	0.00
Ruellia	0.04	0.00	0.00	0.00	0.00	0.04	0.00	0.03	0.00	0.00	0.00
Curly dock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bulltongue	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bush sunflower	0.01	0.00	0.00	0.00	0.05	0.05	0.00	0.00	0.00	0.00	0.00
Green briar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas verbena	0.03	0.00	0.00	0.00	0.00	0.03	0.00	0.02	0.00	0.00	0.00
Orange zexmenia	0.02	0.00	0.00	0.00	0.05	0.05	0.00	0.00	0.00	0.00	0.00
Giant ragweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual broomweed	0.07	0.00	0.00	0.00	0.00	0.08	0.00	0.03	0.00	0.00	0.00
Partridge pea	0.04	0.00	0.00	0.00	0.00	0.04	0.00	0.02	0.00	0.00	0.00
Texas doveweed	0.05	0.00	0.00	0.00	0.00	0.07	0.00	0.04	0.00	0.00	0.00
Sunflower	0.01	0.00	0.00	0.00	0.05	0.05	0.00	0.00	0.00	0.00	0.00
Dogweed	0.08	0.00	0.00	0.00	0.00	0.08	0.00	0.07	0.00	0.00	0.00

Appendix Table E.20 (Cont.)

Common Name	Littletooth									Whitestem	Old-mans
	Milo	Wheat	Corn	sedge	Flatsedge	Cattail	Ragweed	Lazydaisy	Spiny aster	wild indigo	beard
Huisache	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pecan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sugar hackberry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesquite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Post oak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Live oak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Guajillo	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Blackbrush	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Whitebrush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prairie baccharis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sea oxeye	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Granjeno	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carolina wolfberry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agarito	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00
McCartney rose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rattlepod	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mustang grape	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas prickly pear	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
Big bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bushy bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Purple threeawn	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00
King Ranch bluestem	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00
Silver bluestem	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sideoats grama	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00
Hairy grama	0.00	0.00	0.00	0.00	0.03	0.10	0.05	0.00	0.00	0.00	0.00
Red grama	0.00	0.00	0.00	0.00	0.05	0.10	0.05	0.00	0.00	0.00	0.00
Buffalograss	0.00	0.00	0.05	0.00	0.01	0.03	0.03	0.00	0.00	0.00	0.03
Sandbur	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hooded windmillgrass	0.00	0.00	0.05	0.00	0.03	0.04	0.04	0.00	0.00	0.00	0.04
Trichloris	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bermudagrass	0.00	0.00	0.00	0.00	0.00	0.05	0.01	0.00	0.00	0.00	0.00
Arizona cottontop	0.00	0.00	0.04	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.01
Saltgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Virginia wildrye	0.00	0.00	0.05	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01
Texas cupgrass	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00
Green sprangletop	0.00	0.00	0.00	0.00	0.00	0.05	0.01	0.00	0.00	0.00	0.00
Kleingrass	0.00	0.00	0.04	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.01
Guineagrass	0.00	0.00	0.04	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.01
Vine-mesquite	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
Switchgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Longtom	0.00	0.00	0.03	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.03
Brownseed paspalum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix Table E.20 (Cont.)

Common Name	Littletooth									Whitestem	Old-mans
	Milo	Wheat	Corn	sedge	Flatsedge	Cattail	Ragweed	Lazydaisy	Spiny aster	wild indigo	beard
Thin paspalum	0.00	0.00	0.04	0.00	0.01	0.01	0.03	0.00	0.00	0.00	0.03
Common reed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Little bluestem	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
Knotroot bristlegrass	0.00	0.00	0.04	0.00	0.02	0.02	0.03	0.00	0.00	0.00	0.04
Plains bristlegrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas bristlegrass	0.00	0.00	0.04	0.00	0.04	0.04	0.06	0.00	0.00	0.00	0.05
Indiangrass	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Johnsongrass	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Gulf cordgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tall dropseed	0.00	0.00	0.00	0.00	0.00	0.05	0.01	0.00	0.00	0.00	0.00
Sand dropseed	0.00	0.00	0.00	0.00	0.00	0.10	0.03	0.00	0.00	0.00	0.00
Smutgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas wintergrass	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00
Milo	0.00	0.00	0.06	0.00	0.02	0.03	0.04	0.00	0.00	0.00	0.05
Wheat	0.00	0.00	0.00	0.00	0.03	0.10	0.05	0.00	0.00	0.00	0.00
Corn	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.00	0.00	0.00	0.05
Littletooth sedge	0.00	0.00	0.04	0.00	0.03	0.03	0.04	0.00	0.00	0.00	0.04
Flatsedge	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.00	0.00	0.00	0.00
Cattail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ragweed	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00
Lazydaisy	0.00	0.00	0.00	0.00	0.05	0.10	0.10	0.00	0.00	0.00	0.00
Spiny aster	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Whitestem wild indigo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Old-mans beard	0.00	0.00	0.01	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
Bundleflower	0.00	0.00	0.00	0.00	0.01	0.08	0.05	0.00	0.00	0.00	0.00
Frogfruit	0.00	0.00	0.01	0.00	0.01	0.01	0.03	0.00	0.00	0.00	0.05
Prairie coneflower	0.00	0.00	0.00	0.00	0.01	0.10	0.10	0.00	0.00	0.00	0.00
Snoutbean	0.00	0.00	0.02	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.05
Ruellia	0.00	0.00	0.02	0.00	0.01	0.02	0.03	0.00	0.00	0.00	0.06
Curly dock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bulltongue	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bush sunflower	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00
Green briar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas verbena	0.00	0.00	0.03	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.06
Orange zexmenia	0.00	0.00	0.00	0.00	0.00	0.08	0.02	0.00	0.00	0.00	0.00
Giant ragweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual broomweed	0.00	0.00	0.04	0.00	0.02	0.02	0.04	0.00	0.00	0.00	0.07
Partridge pea	0.00	0.00	0.02	0.00	0.00	0.01	0.03	0.00	0.00	0.00	0.05
Texas doveweed	0.00	0.00	0.04	0.00	0.02	0.02	0.04	0.00	0.00	0.00	0.06
Sunflower	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00
Dogweed	0.00	0.00	0.05	0.00	0.02	0.02	0.05	0.00	0.00	0.00	0.06

Appendix Table E.20 (Cont.)

Common Name	Prairie								Bush
	Bundleflower	Frogfruit	coneflower	Snoutbean	Ruellia	Curly dock	Bulltongue	Glasswort	sunflower
Huisache	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pecan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sugar hackberry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesquite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Post oak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Live oak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Guajillo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Blackbrush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Whitebrush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prairie baccharis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sea oxeye	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Granjeno	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carolina wolfberry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agarito	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
McCartney rose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rattlepod	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mustang grape	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas prickly pear	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Big bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bushy bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Purple threeawn	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
King Ranch bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Silver bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sideoats grama	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hairy grama	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
Red grama	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Buffalograss	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Sandbur	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hooded windmillgrass	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.02
Trichloris	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bermudagrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arizona cottontop	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Saltgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Virginia wildrye	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas cupgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Green sprangletop	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kleingrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Guineagrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vine-mesquite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Switchgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Longtom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Brownseed paspalum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix Table E.20 (Cont.)

Common Name	Prairie								Bush
	Bundleflower	Frogfruit	coneflower	Snoutbean	Ruellia	Curly dock	Bulltongue	Glasswort	sunflower
Thin paspalum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Common reed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Little bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Knotroot bristlegrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Plains bristlegrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas bristlegrass	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
Indiangrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Johnsongrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gulf cordgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tall dropseed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sand dropseed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Smutgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas wintergrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Milo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Wheat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Corn	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Littletooth sedge	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Flatsedge	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cattail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ragweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lazydaisy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Spiny aster	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Whitestem wild indigo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Old-mans beard	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bundleflower	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Frogfruit	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prairie coneflower	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Snoutbean	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Ruellia	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.03
Curly dock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bulltongue	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bush sunflower	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Green briar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas verbena	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
Orange zexmenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Giant ragweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual broomweed	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.04
Partridge pea	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.02
Texas doveweed	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.02
Sunflower	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dogweed	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.09

Appendix Table E.20 (Cont.)

Common Name	Green briar	Texas	Orange	Giant	Annual	Partridge	Texas	Sunflower	Dogweed
		verbena	zexmenia	ragweed	broomweed	pea	doveweed		
Huisache	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pecan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sugar hackberry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesquite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Post oak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Live oak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Guajillo	0.00	0.00	0.00	0.80	0.00	0.00	0.00	0.00	0.00
Blackbrush	0.00	0.00	0.00	0.70	0.00	0.00	0.00	0.00	0.00
Whitebrush	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00
Prairie baccharis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sea oxeye	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Granjeno	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00
Carolina wolfberry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agarito	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
McCartney rose	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rattlepod	0.00	0.00	0.00	0.80	0.00	0.00	0.00	0.10	0.00
Mustang grape	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas prickly pear	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Big bluestem	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.10	0.00
Bushy bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Purple threeawn	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
King Ranch bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Silver bluestem	0.00	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.00
Sideoats grama	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hairy grama	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.03	0.00
Red grama	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.04	0.00
Buffalograss	0.00	0.00	0.00	0.90	0.00	0.00	0.05	0.30	0.00
Sandbur	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hooded windmillgrass	0.00	0.00	0.00	0.95	0.01	0.00	0.05	0.60	0.00
Trichloris	0.00	0.00	0.00	0.60	0.00	0.00	0.00	0.20	0.00
Bermudagrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arizona cottontop	0.00	0.00	0.00	0.80	0.01	0.00	0.04	0.50	0.00
Saltgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Virginia wildrye	0.00	0.00	0.00	0.60	0.00	0.00	0.00	0.30	0.00
Texas cupgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Green sprangletop	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kleingrass	0.00	0.00	0.00	0.70	0.00	0.00	0.00	0.20	0.00
Guineagrass	0.00	0.00	0.00	0.70	0.00	0.00	0.00	0.20	0.00
Vine-mesquite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Switchgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Longtom	0.00	0.00	0.00	0.70	0.00	0.00	0.01	0.30	0.00
Brownseed paspalum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix Table E.20 (Cont.)

Common Name	Texas		Orange	Giant	Annual	Partridge	Texas		
	Green briar	verbena	zexmenia	ragweed	broomweed	pea	doveweed	Sunflower	Dogweed
Thin paspalum	0.00	0.00	0.01	0.80	0.01	0.00	0.04	0.60	0.00
Common reed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Little bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Knotroot bristlegrass	0.00	0.00	0.00	0.80	0.02	0.00	0.03	0.50	0.00
Plains bristlegrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas bristlegrass	0.00	0.00	0.00	0.90	0.01	0.00	0.02	0.50	0.00
Indiangrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Johnsongrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gulf cordgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tall dropseed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sand dropseed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Smutgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas wintergrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Milo	0.00	0.00	0.00	0.90	0.00	0.00	0.01	0.40	0.00
Wheat	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.05	0.00
Corn	0.00	0.00	0.00	0.80	0.00	0.00	0.00	0.30	0.00
Littletooth sedge	0.00	0.00	0.00	0.80	0.01	0.00	0.03	0.60	0.00
Flatsedge	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cattail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ragweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Lazydaisy	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.05	0.00
Spiny aster	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Whitestem wild indigo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Old-mans beard	0.00	0.00	0.00	0.70	0.00	0.00	0.00	0.30	0.00
Bundleflower	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.03	0.00
Frogfruit	0.00	0.00	0.00	0.40	0.01	0.00	0.02	0.30	0.00
Prairie coneflower	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.05	0.00
Snoutbean	0.00	0.00	0.00	0.80	0.01	0.00	0.03	0.50	0.00
Ruellia	0.00	0.00	0.00	0.80	0.01	0.00	0.02	0.40	0.00
Curly dock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bulltongue	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Glasswort	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bush sunflower	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Green briar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas verbena	0.00	0.00	0.01	0.80	0.02	0.00	0.04	0.50	0.00
Orange zexmenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Giant ragweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual broomweed	0.00	0.00	0.01	0.80	0.00	0.00	0.02	0.50	0.00
Partridge pea	0.00	0.00	0.00	0.70	0.00	0.00	0.01	0.20	0.00
Texas doveweed	0.00	0.00	0.00	0.90	0.01	0.00	0.00	0.50	0.00
Sunflower	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dogweed	0.00	0.01	0.04	0.99	0.04	0.06	0.06	0.80	0.00

Appendix Table E.21 Cattle preference factors for plant parts, by species, in the Goliad County EDYS model. Values are relative rankings (1 = highest, 30 = lowest). High rankings indicate the plant part and species are highly preferred by cattle.

Common Name	Croot	Froot	Trunk	Stems	Leaves	Seeds	SDStems	SDLeaves	SdlgRoot	SdlgShoot	SeedBank
Huisache	35	35	35	35	10	21	36	28	10	10	35
Pecan	20	19	22	16	11	19	19	13	8	7	19
Sugar hackberry	20	19	22	15	10	15	19	11	6	5	17
Mesquite	20	19	22	17	14	3	19	15	8	7	17
Post oak	35	35	35	35	25	34	35	31	25	25	34
Live oak	20	19	22	17	13	16	19	15	7	6	16
Guajillo	35	35	35	34	6	18	35	20	6	6	35
Blackbrush	35	35	35	35	12	21	35	29	12	12	35
Whitebrush	35	35	35	34	17	18	30	28	17	17	35
Prairie baccharis	29	29	29	26	10	10	31	20	6	6	12
Sea oxeye	29	29	29	26	10	10	31	20	6	6	12
Granjeno	35	35	35	34	16	16	31	29	16	16	36
Carolina wolfberry	29	29	29	26	10	10	31	20	6	6	12
Agarito	19	18	21	16	16	16	18	17	7	6	17
McCartney rose	29	29	29	26	10	10	31	20	6	6	12
Rattlepod	35	35	35	34	26	36	35	30	25	25	36
Mustang grape	19	18	21	16	9	4	18	11	6	5	17
Texas prickly pear	19	18	20	8	8	3	18	18	3	2	17
Big bluestem	11	11	3	1	1	1	11	9	1	1	34
Bushy bluestem	29	29	29	26	10	10	31	20	6	6	12
Purple threeawn	18	17	5	3	3	3	4	4	3	2	17
King Ranch bluestem	18	17	5	2	2	2	5	5	2	1	9
Silver bluestem	10	10	3	2	2	2	9	9	1	1	35
Sideoats grama	18	17	4	1	1	1	3	3	2	1	8
Hairy grama	18	17	4	2	2	2	3	3	3	2	8
Red grama	18	17	4	3	3	3	3	3	3	2	8
Buffalograss	8	8	2	1	1	1	2	2	1	1	35
Sandbur	6	6	6	1	1	1	5	5	1	1	5
Hooded windmillgrass	9	9	5	4	4	4	8	8	3	3	36
Trichloris	10	10	4	2	2	2	9	9	1	1	36
Bermudagrass	18	17	4	1	1	1	3	3	2	1	8
Arizona cottontop	10	10	3	1	1	1	9	9	1	1	36
Saltgrass	6	6	6	1	1	1	5	5	1	1	5
Virginia wildrye	10	10	4	2	2	2	9	9	1	1	35
Texas cupgrass	18	17	4	1	1	1	3	3	2	1	7
Green sprangletop	18	17	4	1	1	1	3	3	2	1	8
Kleingrass	10	10	4	2	2	2	9	9	1	1	35
Guineagrass	10	10	4	2	2	2	9	9	1	1	35
Vine-mesquite	18	17	4	1	1	1	3	3	2	1	6
Switchgrass	18	17	5	1	1	1	4	4	2	1	8
Longtom	9	8	3	2	2	2	8	8	1	1	34
Brownseed paspalum	7	7	7	2	2	2	5	5	1	1	5

Appendix Table E.21 (Cont.)

Common Name	Croot	Froot	Trunk	Stems	Leaves	Seeds	SDStems	SDLeaves	SdlgRoot	SdlgShoot	SeedBank
Thin paspalum	10	10	4	3	3	3	9	9	2	2	35
Common reed	7	7	7	2	2	2	5	5	1	1	5
Little bluestem	18	17	5	2	2	2	4	4	2	1	9
Knotroot bristlegrass	10	10	6	4	4	4	9	9	3	3	35
Plains bristlegrass	7	7	7	3	3	3	6	6	2	2	6
Texas bristlegrass	9	9	4	3	3	3	8	8	2	2	35
Indiangrass	18	17	5	1	1	1	4	4	2	1	3
Johnsongrass	7	7	7	3	3	3	6	6	2	2	6
Gulf cordgrass	7	7	7	3	3	3	6	6	2	2	6
Tall dropseed	18	17	5	2	2	2	4	4	3	2	8
Sand dropseed	18	17	4	2	2	2	3	3	2	1	8
Smutgrass	7	7	7	3	3	3	6	6	2	2	6
Texas wintergrass	18	17	4	1	1	1	3	3	3	2	9
Milo	10	10	9	3	2	2	11	9	1	1	3
Wheat	18	16	2	1	1	1	5	5	2	1	3
Corn	10	10	9	3	1	1	11	9	1	1	2
Littletooth sedge	9	9	6	5	5	5	9	9	4	4	35
Flatsedge	18	17	6	4	3	3	5	5	3	2	9
Cattail	18	17	9	9	6	9	18	8	4	3	10
Ragweed	18	17	11	9	9	9	16	16	5	3	8
Lazydaisy	18	17	4	3	3	3	5	5	3	2	8
Spiny aster	0	0	0	5	4	0	7	6	0	0	0
Whitestem wild indigo	7	7	7	3	3	3	6	6	2	2	6
Old-mans beard	16	16	15	14	14	14	16	16	13	13	36
Bundleflower	18	17	4	3	3	3	5	5	2	1	8
Frogfruit	14	14	12	11	11	11	13	13	10	10	35
Prairie coneflower	18	17	5	4	4	4	6	6	2	1	8
Snoutbean	13	13	12	11	11	11	12	12	10	10	34
Ruellia	14	14	13	12	12	12	13	13	11	11	34
Curly dock	20	20	20	12	12	12	20	20	10	10	11
Bulltongue	20	20	20	12	12	12	20	20	10	10	11
Glasswort	20	20	20	12	12	12	20	20	10	10	11
Bush sunflower	18	17	9	9	7	7	17	8	4	3	7
Green briar	29	29	29	26	10	10	31	20	6	6	12
Texas verbena	18	18	17	15	15	15	17	17	14	14	35
Orange zexmenia	18	17	5	3	3	3	4	4	2	1	7
Giant ragweed	30	30	29	27	25	25	33	32	24	24	35
Annual broomweed	31	31	31	30	28	27	32	31	27	27	36
Partridge pea	13	13	10	8	8	8	12	12	7	7	34
Texas doveweed	31	31	32	31	26	26	31	30	25	25	34
Sunflower	18	17	9	9	6	5	19	9	4	3	6
Dogweed	31	30	30	29	29	29	30	30	28	28	34

SDStems = standing dead stems; SDLeaves = standing dead leaves; SdlgRoot = seedling roots; SdlgShoot = seedling shoots

Appendix Table E.22 Cattle competition factors for plant parts, by species, in the Goliad County EDYS model. Values are relative rankings among competing herbivores for the respective plant material (1 = most competitive of the herbivores; 6 = least competitive).

Common Name	Croot	Froot	Trunk	Stems	Leaves	Seeds	SDStems	SDLeaves	SdlgRoot	SdlgShoot
Huisache	6	6	6	4	4	4	4	4	6	6
Pecan	6	6	6	5	5	5	5	5	6	6
Sugar hackberry	6	6	6	5	5	5	5	5	6	6
Mesquite	6	6	6	5	5	5	5	5	6	6
Post oak	6	6	6	4	4	4	4	4	6	6
Live oak	6	6	6	5	5	5	5	5	6	6
Guajillo	6	6	6	5	5	5	5	5	6	6
Blackbrush	6	6	6	5	5	5	5	5	6	6
Whitebrush	6	6	6	5	5	5	5	5	6	6
Prairie baccharis	5	5	5	4	4	4	4	4	5	5
Sea oxeye	5	5	5	4	4	4	4	4	5	5
Granjeno	6	6	6	5	5	5	5	5	6	6
Carolina wolfberry	5	5	5	4	4	4	4	4	5	5
Agarito	6	6	6	6	6	6	6	6	6	6
McCartney rose	5	5	5	4	4	4	4	4	5	5
Rattlepod	6	6	6	5	5	5	5	5	6	6
Mustang grape	6	6	6	5	5	5	5	5	6	6
Texas prickly pear	6	6	6	6	6	6	6	6	6	6
Big bluestem	6	6	6	6	6	5	6	6	6	6
Bushy bluestem	5	5	5	4	4	4	4	4	5	5
Purple threeawn	6	6	6	6	6	6	6	6	6	6
King Ranch bluestem	6	6	6	6	6	6	6	6	6	6
Silver bluestem	6	6	6	6	6	5	6	6	6	6
Sideoats grama	6	6	6	6	6	5	6	6	6	6
Hairy grama	6	6	6	6	6	6	6	6	6	6
Red grama	6	6	6	6	6	6	6	6	6	6
Buffalograss	6	6	6	6	6	6	6	6	6	6
Sandbur	5	5	5	5	5	5	5	5	5	5
Hooded windmillgrass	6	6	6	6	6	6	6	6	6	6
Trichloris	6	6	6	6	6	5	6	6	6	6
Bermudagrass	6	6	6	6	6	6	6	6	6	6
Arizona cottontop	6	6	6	6	6	5	6	6	6	6
Saltgrass	5	5	5	5	5	5	5	5	5	5
Virginia wildrye	6	6	6	6	6	5	6	6	6	6
Texas cupgrass	6	6	6	6	6	6	6	6	6	6
Green sprangletop	6	6	6	6	6	6	6	6	6	6
Kleingrass	6	6	6	6	6	5	6	6	6	6
Guineagrass	6	6	6	6	6	5	6	6	6	6
Vine-mesquite	6	6	6	6	6	6	6	6	6	6
Switchgrass	6	6	6	6	6	5	6	6	6	6
Longtom	6	6	5	5	5	5	5	5	5	5
Brownseed paspalum	5	5	5	5	5	5	5	5	5	5

Appendix Table E.22 (Cont.)

Common Name	Croot	Froot	Trunk	Stems	Leaves	Seeds	SDStems	SDLeaves	SdlgRoot	SdlgShoot
Thin paspalum	6	6	6	6	6	6	6	6	6	6
Common reed	5	5	5	5	5	5	5	5	5	5
Little bluestem	6	6	6	6	6	5	6	6	6	6
Knotroot bristlegrass	6	6	6	6	6	6	6	6	6	6
Plains bristlegrass	2	2	2	5	5	5	5	5	5	5
Texas bristlegrass	6	6	6	6	6	6	6	6	6	6
Indiangrass	6	6	6	6	6	5	6	6	6	6
Johnsongrass	2	2	2	5	5	5	5	5	5	5
Gulf cordgrass	2	2	2	5	5	5	5	5	5	5
Tall dropseed	6	6	6	6	6	5	6	6	6	6
Sand dropseed	6	6	6	6	6	6	6	6	6	6
Smutgrass	2	2	2	5	5	5	5	5	5	5
Texas wintergrass	6	6	6	6	6	6	6	6	6	6
Milo	6	6	6	6	6	6	6	6	6	6
Wheat	6	6	6	6	6	6	6	6	6	6
Corn	6	6	6	6	6	5	6	6	6	6
Littletooth sedge	6	6	6	6	6	6	6	6	6	6
Flatsedge	6	6	6	6	6	5	6	6	6	6
Cattail	6	6	5	5	5	5	5	5	5	5
Ragweed	6	6	6	6	6	5	6	6	6	6
Lazydaisy	6	6	6	6	6	6	6	6	6	6
Spiny aster	0	0	0	4	4	0	4	4	0	0
Whitestem wild indigo	2	2	2	5	5	5	5	5	5	5
Old-mans beard	6	6	6	6	5	5	6	5	6	6
Bundleflower	6	6	6	6	6	6	6	6	6	6
Frogfruit	6	6	6	6	6	6	6	6	6	6
Prairie coneflower	6	6	6	6	6	6	6	6	6	6
Snoutbean	6	6	6	6	6	6	6	6	6	6
Ruellia	6	6	6	6	6	6	6	6	6	6
Curly dock	5	5	5	5	5	5	5	5	5	5
Bulltongue	5	5	5	5	5	5	5	5	5	5
Glasswort	5	5	5	5	5	5	5	5	5	5
Bush sunflower	6	6	6	6	6	6	6	6	6	6
Green briar	5	5	5	4	4	4	4	4	5	5
Texas verbena	6	6	6	6	6	6	6	6	6	6
Orange zexmenia	6	6	6	6	6	6	6	6	6	6
Giant ragweed	6	6	6	6	6	5	6	6	6	6
Annual broomweed	6	6	6	6	6	6	6	6	6	6
Partridge pea	6	6	6	6	6	6	6	6	6	6
Texas doveweed	6	6	6	6	6	6	6	6	6	6
Sunflower	6	6	6	6	6	5	6	6	6	6
Dogweed	6	6	6	6	6	6	6	6	6	6

SDStems = standing dead stems; SDLeaves = standing dead leaves; SdlgRoot = seedling roots; SdlgShoot = seedling shoots

Appendix Table E.23 Accessibility of plant parts, by species, for consumption by cattle in the Goliad County EDYS model. Values are the percentage of standing crop biomass that could be accessed by cattle.

Common Name	CRoot	FRoot	Trunk	Stems	Leaves	Seeds	SDStems	SDLeaves	SdIlgRoot	SdIlgShoot	SeedBank
Huisache	0	0	1	10	10	5	10	10	10	40	20
Pecan	0	0	1	1	1	0	1	1	0	80	5
Sugar hackberry	0	0	1	2	2	1	2	2	0	25	0
Mesquite	0	0	1	10	10	10	10	10	0	40	2
Post oak	0	0	1	1	1	0	1	1	10	70	50
Live oak	0	0	1	5	5	4	5	5	0	50	2
Guajillo	1	1	90	99	99	99	99	99	10	60	30
Blackbrush	1	1	90	95	90	90	95	80	10	50	10
Whitebrush	0	0	90	99	95	75	95	80	5	40	0
Prairie baccharis	1	0	99	99	80	90	99	50	20	80	0
Sea oxeye	1	0	99	99	80	90	99	50	20	80	0
Granjeno	0	0	90	95	80	10	90	50	5	40	0
Carolina wolfberr	1	0	99	99	80	90	99	50	20	80	0
Agarito	0	0	80	95	95	95	95	95	0	5	0
McCartney rose	1	0	99	99	80	90	99	50	20	80	0
Rattlepod	0	0	95	99	95	95	95	80	10	70	20
Mustang grape	0	0	5	5	5	4	5	5	0	5	0
Texas prickly pear	0	0	50	95	95	95	95	95	0	5	0
Big bluestem	1	1	40	90	90	95	90	90	10	50	0
Bushy bluestem	1	0	99	99	80	90	99	50	20	80	0
Purple threeawn	0	0	5	95	95	90	95	95	0	5	0
King Ranch bluest	0	0	5	90	90	95	90	90	0	5	0
Silver bluestem	1	1	40	90	90	95	90	85	10	50	0
Sideoats grama	0	0	5	95	95	90	95	95	0	10	0
Hairy grama	0	0	2	90	90	90	90	90	0	2	0
Red grama	0	0	2	80	85	80	80	85	0	1	0
Buffalograss	1	1	20	80	75	40	80	70	5	20	0
Sandbur	10	0	40	70	80	95	70	80	40	50	0
Hooded windmillç	1	1	30	90	85	90	90	80	5	30	0
Trichloris	1	1	40	90	90	95	90	85	10	50	0
Bermudagrass	0	0	2	80	80	80	80	80	0	2	0
Arizona cottontop	1	1	30	90	90	95	90	85	10	50	0
Saltgrass	10	0	40	70	80	95	70	80	40	50	0
Virginia wildrye	1	1	40	90	90	95	90	85	10	50	0
Texas cupgrass	0	0	5	95	95	90	95	95	0	10	0
Green sprangletolç	0	0	5	95	95	95	95	95	0	10	0
Kleingrass	1	1	30	90	90	95	90	85	10	50	0
Guineagrass	1	1	30	90	90	95	90	85	10	50	0
Vine-mesquite	0	0	5	80	85	90	80	85	0	5	0
Switchgrass	0	0	5	95	95	95	95	95	0	10	0
Longtom	3	2	10	80	75	90	80	70	10	30	0
Brownseed paspa	10	0	40	80	80	95	80	80	40	50	0

Appendix Table E.23 (Cont.)

Common Name	CRoot	FRoot	Trunk	Stems	Leaves	Seeds	SDStems	SDLeaves	SdlgRoot	SdlgShoot	SeedBank
Thin paspalum	1	1	20	90	90	95	90	85	10	30	0
Common reed	10	0	40	80	80	95	80	80	40	50	0
Little bluestem	0	0	5	95	95	95	95	95	0	10	0
Knotroot bristlegr	1	1	10	80	75	90	80	70	5	20	0
Plains bristlegrass	5	0	50	80	80	95	80	80	50	50	0
Texas bristlegrass	1	1	10	90	80	90	90	75	5	20	0
Indiangrass	0	0	5	95	95	95	95	95	0	10	0
Johnsongrass	5	0	50	80	80	95	80	80	50	50	0
Gulf cordgrass	5	0	50	80	80	95	80	80	50	50	0
Tall dropseed	0	0	5	95	95	95	95	95	0	10	0
Sand dropseed	0	0	5	95	95	90	95	95	0	5	0
Smutgrass	5	0	50	80	80	95	80	80	50	50	0
Texas wintergrass	0	0	5	90	90	90	90	90	0	5	0
Milo	2	1	20	90	90	95	90	85	20	70	20
Wheat	0	0	5	95	95	95	95	95	0	10	1
Corn	2	1	30	90	90	95	90	85	30	80	70
Littletooth sedge	1	1	10	90	80	90	90	70	5	20	0
Flatsedge	0	0	5	90	85	90	90	85	0	5	0
Cattail	5	5	50	90	90	80	90	90	0	10	0
Ragweed	0	0	5	95	95	95	95	95	0	5	0
Lazydaisy	0	0	1	90	70	80	90	70	0	1	0
Spiny aster	0	0	0	100	100	0	100	100	0	0	0
Whitestem wild ir	5	0	50	80	80	95	80	80	50	50	0
Old-mans beard	1	1	10	70	80	80	70	70	5	20	0
Bundleflower	0	0	5	90	80	80	90	80	0	2	0
Frogfruit	1	1	5	70	50	70	70	40	5	10	0
Prairie coneflowe	0	0	2	90	70	90	90	70	0	5	0
Snoutbean	1	1	10	75	60	80	75	50	5	10	1
Ruellia	1	1	1	60	40	60	60	30	1	5	0
Curly dock	5	0	50	80	80	80	80	70	10	40	0
Bulltongue	5	0	50	80	80	80	80	70	10	40	0
Glasswort	5	0	50	80	80	80	80	70	10	40	0
Bush sunflower	0	0	5	90	85	95	90	85	0	5	0
Green briar	1	0	99	99	80	90	99	50	20	80	0
Texas verbena	1	1	5	80	70	90	80	60	5	10	0
Orange zexmenia	0	0	5	90	85	90	90	85	0	5	0
Giant ragweed	1	1	20	90	90	80	90	80	10	50	0
Annual broomwe	1	1	5	80	80	85	80	70	10	40	0
Partridge pea	1	1	5	80	70	70	80	60	10	30	1
Texas doveweed	1	1	5	85	90	90	85	80	10	20	0
Sunflower	0	0	5	95	95	90	95	95	0	5	0
Dogweed	1	1	1	80	60	90	80	50	1	10	0

SDStems = standing dead stems; SDLeaves = standing dead leaves; SdlgRoot = seedling roots; SdlgShoot = seedling shoots