RANGELAND BIOMASS UTILIZATION: MESQUITE (*PROSOPIS SPP.*) AS A MODEL FOR ENERGY, FOOD AND FODDER IN CENTRAL AND SOUTH TEXAS.

by

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ABSTRACT

This study is a descriptive study of Mesquite (*Prosopis spp*.) as a useful crop in bio-energy and agroforestry and landowner interest in the utilization of mesquite. Mesquite historically had been seen as a useful plant until sometime after the 1980's attitudes shifted to it being a noxious invader of arid and semi-arid grasslands of the Southwestern United States. These attitudes combined with lack of knowledge by landowners in the Southern United States of native biomass and wood based biomass feedstocks for energy production lead to landowners being unlikely or neutral about the utilization of mesquite. As the United States government wants to shift to more sustainable "green energy", mesquite is poised to be an energy crop in Texas and with the world population ever expanding poised to be a source of energy and protein for both animal and human consumption.

CHAPTER I

INTRODUCTION

Background and Setting

Mesquite is native to arid and semi-arid regions of the world and is rapidly expanding it range in which includes 56 million of Texas from the Panhandle to the Gulf Coast excluding only far eastern Texas (Rodgers, 2000). Prior to settlement by European many Native peoples in the Southwest United States used mesquite as a source of food, grinding the beans into flour, in places that would not support the growth of traditional crops. Throughout the 1950s up until to the early 1980s research was done to explore many uses of mesquite wood and bean pods in a multitude of industries including animal production and energy. Seemingly, interest into mesquite passed to the wayside as oil embargos were lifted and economies recovered making conventional grains less expensive. Research interests picked up again in the 1990s-2000s worldwide with articles published out of a number of countries including Brazil, India and Australia looking into mesquite pods as sources of digestible protein and energy in animal production. This research also brought to light another aspect of feeding mesquite to animals, replacement of higher priced grains and bran with an inexpensive natural food source.

European interests have been seeking biomass for fuel to replace fossil sources; mesquite wood chips have fallen in to a favorable source of biomass produced electricity. In November of 2013 Green Heart Energy LLC based out of the Czech Republic began harvesting mesquite wood chips in a 100 mile area near the Port of Corpus Christi for

shipment to a number of European Union countries for electricity generation (Hendricks, 2013). According to Green Heart Energy mesquite chips contain the equivalent energy of brown and black coal and allow power plants to begin to sell air pollution permits back to the respective governments of the countries in which these power plants using mesquite wood chips are located (Hendricks, 2013). A missed opportunity if local energy producers did not take advantage of mesquite as a resource before outside interests begin to lease lands and develop harvest contracts with land owners. Felker, 1982 developed revenue calculation for the 15 mile area surrounding mesquite operation at around $67 million per year.

In Central and South Texas, water availability and climate limit stocking rates, vegetation productivity and grazing capacity. This area is well suited for animal production over crop production both in wet years and lean in dry years. Recent droughts have brought to light the connection between rainfall and food prices in the U.S. Consumer markets. Lack of rain leads to a reduction in herds, as well as grain and pasture production to support those animals. Mesquite could replace up to 20% of livestock diets. (Sawal et al., 2004) and in aquaculture rations (Sena et al, 2012) without need for further supplementation especially in very dry years. Mesquite grows and produces biomass even in the driest years, adapted to the climate of arid and semi-arid regions of the world. In dry years, mesquite produces more bean pods while other vegetation is dormant, allowing for more dispersal of seed by grazing and browsing animals with few options in their diets other than mesquite bean pods and less competition from forbs and grasses for resources (i.e. sunlight and minerals) for seedlings.

Purpose of this study

This study uses a three legged stool approach for utilization of mesquite for energy, food and fodder in Texas. The three legs of the stool will be 1) current and historical use of mesquite developed and expressed by current and historical literature, 2) suitability of mesquite as an agroforestry crop in Texas which will be developed and expressed from literature where production and processing could occur and 3) A survey of landowner interest in the utilization of mesquite and landowner knowledge and perceptions of mesquite and wood based bio-energy in two counties in Texas

Limitations of this study

Any and all production and nutritional values are third party information, tracked down through review of literature. This study assesses perceptions of landowners' in two counties in Texas regarding mesquite utilization.

The survey results had limitations due Ag-Exempt tax status data from county database and landowners with the size properties of interest lacked access to and literacy of computers and the internet which limited response data and rate.

Implications of this Study

The world of sustainable renewable food and energy is constantly looking for the next big corn or oil solution but missing out on the microcosm of localized solutions that can reduce the dependence on and extend the life of fossil based energy as well as move animal and food production toward a more secure and sustainable future. Results will show land owners' and land managers' opinion of mesquite, willingness to utilize mesquite as a resource and barriers to adopting mesquite as a niche crop rather than

allocation of resources to eradication. This study will open doors on how to remove the negative view of mesquite that is currently costing the economy money to eradicate and change it to that of a positive resource, mesquite could be contributing to the economy in a positive manor. This study is not limited just to mesquite rather a starting point for many other resources that currently are underutilized throughout the world.

Research Questions

1. Can Mesquite be a source of biomass feedstock for bio-energy in Texas?
2. Can Mesquite be utilized in agroforestry production Texas?
3. Do landowners in Guadalupe and Hays County perceive value in mesquite as a crop or biomass feedstock?

CHAPTER II

LITERATURE REVIEW

Biology and Distribution of *Prosopis* genus.

Prosopis genus is made up by 44 species, easy to recognize but difficult to distinguish between individual species and hybrids due to ease of hybridization between species. Regions where species are native or naturalized, they are the center of biodiversity (Riveros, 1992). North American distribution ranges of *Prosopis spp.* from Kansas south into Northern Mexico and west to California (Stubbendieck et al. 2003). In the more arid southwestern United States, seven species of mesquite exist, of which four have a very wide distribution from California to Texas and north to Oklahoma and Colorado (Rogers, 2000). These species, unlike like the rest of the genus, have a fairly uniform appearance. Five of seven species thrive in Texas in all but the eastern reaches of the state (Rogers, 2000). Worldwide the genus *Prosopis* is native to or has been introduced to every continent except Europe and Antarctica. (Rogers, 2000; Riveros, 1992).

Woody plant abundance has increased in many parts of the world in the last century; in South Texas and Northern Mexico shifted to subtropical thorny woodlands, dominated by *Prosopis spp.* and *Acacia spp*. from the natural grasslands (Archer, 1988). The cause of the conversion of grasslands to woodlands can be attributed to fire suppression, changes in atmospheric carbon dioxide that favors C_3 woody plants over C_4 grasses, livestock grazing and accelerated seed dispersal by livestock (Ansley et al., 2010). Early settlers to the Southwest, even today modern ranchers, believed mesquite

came to the area with Spanish cattle in the mid to late 14th century and spread rapidly during the days of large cattle drives after the American Civil War (Pierce, 2014). Spanish settlers to San Antonio area observed few woody plants in the area around San Pedro springs but by the 1800's the area was overgrown by thick pockets of mesquite (Pierce, 2014).

Mesquite, *P. glandulosa*, is described as a small tree or shrub with multiple trunks; many branched, growing beginning in late spring until October (Stubbendieck et al. 2003). *P. glandulosa* lives to 217 years old with the majority of trees currently under 100 years old (Archer, 1988). *P. glandulosa* reproduces both from seed and shoots, flowering in May and fruiting June-August (Stubbendieck et al. 2003). Mesquite is well adapted to life in arid and semi-arid regions, utilizing soil moisture held by high matric forces, as low as -4.0 MPa and deep underground water tables between 4-8m. (Wan & Sosebee, 1991). In addition, individual trees are able to thicken leaf cuticles, reduce leaf surface area and cease growth in response to water availability to maintain photosynthesis and limit transporational losses. (Wan & Sosebee, 1991). Mesquite highest average daily transpiration rate has been shown much lower than cultivated pasture (Wan & Sosebee, 1991). Mesquite also keeps its leaf surface much closer to or above ambient temperature, indicating the plant is conservative in water use. (Wan & Sosebee, 1991). Mesquite also employs other strategies to combat heat and water stress, changing leaf angle parallel to sun to reduce solar radiation increasing wax and pubescence throughout growing season especially near the stomata to reduce evaporative losses, the waxes being highly hydrophobic, increasing leaf thickness but reduction in overall size allowing for reduction in canopy size and allowing for more heat dispersal via air turbulence (Wan & Sosebee,

1991). The final strategy mesquite uses to combat heat and water stress is a reduction in canopy development. Mesquite leaves appear in two stages: first leaves emerge with the spring bud break and mature mid-May about half way into a growing season, second stage after May and mature at the end of the growing season. (Wan & Sosebee, 1991) In times of water and heat stress this second stage of leaf growth and development can be limited or ceased all together, allowing for a reduction in canopy and avoidance of dehydration due to high evapotransporational losses. (Wan & Sosebee, 1991)

Historical use of Mesquite in Texas

Dating back to pre-European settlement Mesquite had many uses among the natives who utilized the deserts and grasslands of the Southwestern United States. Uses ranged from flour in breads and sweets to fuel and structural wood. (Riveros, 1992; Rodgers, 2000; Wright, 1998). Archeological evidence from the studies along the Rio Grande and Pecos show that between 800 B.C. and 500 A.D native people consumed flowers of mesquite tree regularly (Pierce, 2014). Native people encountering Spanish expeditions in to Texas in the 1500 and 1600's offered mesquite flour as nourishment (Pierce, 2014). Early white Texans saw economic potential and considered mesquite a sign of an undeveloped site (Pierce, 2014). Early pioneers to Bexar and Comal county areas found mesquite to be incredibly useful, uses ranging from livestock feed to building material in small vessels, homes, fences and hubs and spokes for horse and ox drawn wagons (Wright, 1998). When promoting settlement of Texas, Stephen F. Austin mentioned a tree he called Meskite as excellent fencing and firewood (Pierce, 2014). In the 1870s the gum of mesquite was thought to be the replacement for other gums. Thousands of pounds were collected throughout the 1870s-1900s exported to Mexico and

shipped to the north for use in many industries including pharmaceutical and confectionary (Wright, 1998). The Austin Weekly Democratic Statesman said of mesquite in an article in the 1890s that mesquite gum would replace other gums as a thickening agent and would be a profitable venture with prices around 15 cents per pound (Pierce. 2014). In 1880s the streets of San Antonio, Texas were paved with mesquite wood blocks (Rogers, 2000). Throughout the late 1800's-1900's newspaper articles in Austin, Dallas, McKinney, San Marcos and San Saba remarked on the usefulness of the rapidly expanding mesquite population for building material, food, firewood, fencing, fabric dyes and shade trees (Pierce, 2014).

Mesquite as a possible crop in Texas.

Mesquite is native to Texas, naturalized to the climate of local area. As far back as 1840s early farmers and cattlemen noted in times of heavy rains the mesquite barely produced a crop of beans but in dry years when the grass struggles, mesquites are overwhelmed with the amount of bean pods produced (Wright, 1998). Worldwide the *Prosopis* genus is used to combat desertification of arid lands, even converting hyper-arid and arid lands into more productive grazing lands (Rogers, 2000). Mesquite and the microorganisms supported by mesquite can also be used to reclaim poor, eroded land. Native leguminous trees demonstrated restoration of severely eroded desert lands was possible (Bashan et al. 2012). As a legume, mesquite can fix about 66 lbs of nitrogen per acre per year into the soil. (Sherif et al. 1982) Roots are hosts to large colonies of *arbuscular mycorrhizae* fungi and root nods host N_2 fixing bacteria (Bainbridge & Virginia, 1990). This microbial community is very sensitive to inorganic nitrogen,

reducing the effectiveness of node nitrogen fixation and microbial development around mesquite, making fertilization unnecessary for production (Jerrel et al, 1982).

Bean pod production begins in the third year following planting, yields as high as 10 tons/ha/year with average being 6 tons/ha/year to 8.5 tons/ha/year in the United States as compared to corn the yields on average 400 kg/ha (Riveros, 1992). Pod begins in 3-4 year old trees with production peaking in trees 15-20 years old (Sawal et al 2004). *P. juliflora* pods are available in May-June and September-October (Sawal et al 2004); whereas *P. glandulosa* are available June-August (Stubbendieck et al, 2003). In Mexico a commercial market was established in seven states for mesquite bean pods for human and animal consumption; this market has seen 300-500 tons of pods on average sold. (Silbert, 1998).

Mesquite wood could be used as a source of energy and/or chemical feedstock. Assuming a value of $2 per million BTU delivered to a power plant for fuel, mesquite wood has a delivered value of $34/t for fuel. (Felker, 1996). European interests have estimated the yield of mesquite on 500,000 acres within 100 miles of Corpus Christi, Texas to be 19 million tons of wood chips per year (Hendricks, 2013). These wood chips should provide 13.9 GJ per metric ton at a moisture level of 20% with 65mm average chip size (Greenheart Energy, 2013).Greenheart Energy is interested in the above ground portion of the mesquite tree which averages about 20% moisture year round in mesquite harvested in the Gulf of Mexico area (Greenheart Energy, 2013). Net heat value per pound from these chips is 6584 BTU (Smith, 1982). A medium infestation of mesquite should yield 8.6 tons/acre when green and when dried 5.3 tons/acre. This yield would require only 6.556 acres of mesquite per year to fuel a 6MW power plant (Smith, 1982).

Risk and cost limit European and United States companies' willingness to invest in biomass for energy production. Currently traditional fuels like oil, gas and coal are more cost effective but less sustainable (Hendricks, 2013). Farming biomass like mesquite would be a large job creator and with the needs of machinery and chemicals another revenue stream would open up for producers (Felker et al., 1982; Biomass Power Association, 2013; Greenheart Energy, 2013). In Maine and California, the two largest users of biomass energy facilities, the large biomass plants are the largest taxpayer and employer for the areas where the plant is located (Biomass Power Association, 2013). In a 2009 study in Mississippi an estimated 318 million gallons of bio-fuel could be produced each year from forest and mill residues, urban wastes and small diameter trees (Grebner et al. 2009). Grebner et al. 2009 states the only limitation to bio-energy feedstock from Southern forests is availability of bio-energy producers. That very same statement can be said for native rangeland, mesquite leading the way, in Texas. As barbecue chips and chunks, current wholesale prices for mesquite packaged in 2 kg plastic bags for the grocery trade are about $400/ton (Felker, 1996). An infrastructure model already exists through the charcoal trade along the Northern Mexico-Arizona border, where mesquite charcoal was imported from 1990-2002 (Taylor, 2008). This mesquite charcoal was harvested from the state of Sonora in Mexico and funneled through the US border crossing at Nogales, Arizona (Taylor, 2008).

According to a survey in 1995 by the Texas Forestry Service, there are around 250 people or companies operating sawmills or cooking wood operations that utilize mesquite wood (Rodgers, 2000). On average sawmills processing mesquite lumber yield 250 to 300 board feet of lumber from each cord of mesquite, which is low compared to

other hardwoods (Rodgers, 2000). Mesquite logs are usually cut into two to three foot sections with a diameter between six to ten inches by portable band saws for cooking wood or one to two inch lumber for the woodworking (Rogers, 2000). Mesquite grows about .015 radial inches per year and can reach harvest size in about 60 years (Larson & Sodjoudee, 1982.). Most mesquite harvested is used for cooking wood, trucks loaded with eight to ten cords of logs are sent to a processing sites that hold thousands of cords of wood for sale to supermarket chains and grocery wholesaler brokers (Rogers, 2000). The cooking wood industry processed 12,000 cords of mesquite in 1996 (Rogers, 2000). As lumber, mesquite wood is unique and aesthetically pleasing. Hard, heavy and close grained, hardwood is gray to brown and sapwood is a thin yellow band (Larson & Sodjoudee, 1982). One of the best woods in the world for fine woodworking like flooring and furniture (Rodgers, 2000). Mesquite lumber would be favorable for use in furniture, manufactured lumber and specialty woodworking items in the southwest (Larson & Sodjoudee, 1982). It weighs 46 pound per cubic foot when green (Rogers, 2000), has an average density of 45 lbs. /ft^3, average bending strength of 1,380,000 lbs., an average side hardiness of 2,336 lbs. (Rogers, 2000) and average specific gravity of .68 (Larson & Sodjoudee, 1982). Mesquite wood is dimensionally stable, does not shrink or swell as much as other hardwoods meaning when boards are cut and squared mesquite will hold its shape even in severe moisture conditions (Rodgers, 2000). Extractive content of 14% in mesquite compared to other hardwoods that contain 5-6% extractive content give mesquite its dimensional strength and unique wood-smoke flavor (Rogers, 2000). Comparing to cherry, walnut, and oak at $3,000/thousand board feet, mesquite would be less expensive at $1700/thousand board feet. (Felker, 1996). The aesthetic quality of

mesquite wood is unique to the growing site of the trees harvested, drier sites with slower growth yield heavy, tight-grained wood grain with narrow growth rings, whereas wetter sites yield a light, softer wood grain with wide growth rings both of which the mesquite woodworking enterprises in Texas value (Rodgers, 2000). Use of mesquite like chipping and harvest of above ground biomass seems to be beneficial to the growth of the plant; a study in the Rolling Plains of Texas, showed an increase in biomass accumulation between 28 and 66% in the 2-5 years following mechanical shredding (Herndon, 1975). Table 2.1 below offers a list species of mesquite indicted from literature with potential as agroforestry crops.

Table 2.1 Mesquite (*Prosopis spp.*) Species as crops.

Species	*Reason for Interest*
P. alba	Best biomass producer
P. chilensis	Second best biomass producer
P.juliflora	Worldwide distribution and studied in many Agriculture applications worldwide
P.glandulosa var. glandulosa	Most common in semi-arid and arid regions of North America
P. glandulosa var.torreyana	Best native pod producer in California
P. tamarugo	Can move atmospheric moisture to soil moisture and high salt tolerance
P. velutina	Best native pod producer in Arizona
P. articulate	High salt tolerance and high biomass
P.alba X P.velutina	High sugar content of pods

Developed from Felker et al, 1982, Riveros, 1991, Rogers, 2000, and Stubbendiek et al., 2003

Nutrition composition of Mesquite

Whole mesquite pods contain 68.8% digestible dry matter (Silva et al., 1989) and 4,340 kcal/kg gross energy (Silva et al., 1990).Pericarp meal made from mesquite pods contains 65.6% digestible dry matter (Silva et al., 1989) and 4,291 kcal/kg gross energy (Silva et al 1990). Protein varies between 7.3% and 12.7 % of dry matter (Sharma et al. 1994). On a dry weight basis seed contained the most protein at 39.34% while pericarp was lowest at 7.02% protein (Zolfaghari & Harden, 1982). The most limited amino acid was methionine and lysine the most prevalent amino acid (Morangoni and Alli, 1988). Sucrose makes up 75% of sugars and linoleic acid the most common unsaturated fatty acid (Morangoni and Alli, 1988). Both Macro and Micro Minerals in pods are available in sufficient amounts for livestock production (Sawal et al. 2004, Zolfaghari & Hardan, 1982). Macro and trace minerals are equal to or richer in mesquite pods compared to other legumes (Zolfaghari & Hardan, 1982). See table 2.2-2.5 below for illustration of nutritional composition and mineral composition from reviewed literature.

Table 2.2 Energy and Fiber Composition of Mesquite from various literature.

Source	*Plant or fruit part studied*	*Digestible Dry Matter*	*Crude Fiber % of Dry Matter*	*Gross Energy kcal/kg*	*Digestible Energy kcal/kg*	*Metabolizable Energy Kcal/kg*	*Nitrogen Corrected Metabolizable Energy Kcal/kg*	*Mesquite species studied*
Becker, 1982	Seeds		7					*velutina,juliflora and pubescens*
	Whole Pods		17-30					*velutina,juliflora and pubescens*
	Pericarp							*velutina,juliflora and pubescens*
Baptisa & Launchbaugh, 2001	Leaves	59.6-68.6%		4082-4385				*glandulosa*
Chopra & Hooda, 2001	Pericarp		57.06					*juliflora*
	Seeds		6.67					*juliflora*
Meyer et al., 1982	Milled Exo-Mesocarp		18					*velutina*
	Milled Endocarp		36					*velutina*
	Milled Endosperm splits		10					*velutina*
	Cotyledon		1					*velutina*
	Whole Pods		22					*velutina*
Mendes, 1986	Seeds							*juliflora*
Morangoni & Alli, 1988	Seeds							*juliflora*
	Pods							*juliflora*

Table 2.2 Continued

Source	*Plant or fruit part studied*	*Digestible Dry Matter*	*Crude Fiber % of Dry Matter*	*Gross Energy kcal/kg*	*Digestible Energy kcal/kg*	*Metabolizable Energy Kcal/kg*	*Nitrogen Corrected Metabolizable Energy Kcal/kg*	*Mesquite species studied*
Richardson et al. 1982	Ground biomass	73.94%						*glandulosa*
Silva et al,1989	Whole Pods	68.80%			2880	2682	2642	*juliflora*
	Pericarp Meal	65.60%			2675	2466	2432	*juliflora*
Silva et al,1990	Whole Pods		18.55	4340				*juliflora*
	Pericarp			4291				*juliflora*
Sharma et al. ,1994	Whole Pods		24.73					*juliflora*
Talpeda & Shukla, 1988	Whole Pods		18.99					*juliflora*
Talpeda et al., 2002	Whole Pods		20.9					*juliflora*
Zolfaghari & Harden, 1982	Seeds		6.86					*glandulosa and velutina*
	Immature pods		35.33					*glandulosa and velutina*
	Mature pods		24.73					*glandulosa and velutina*
	Pericarp		29.63					*glandulosa and velutina*

Table 2.3 Protein and Fat composition of Mesquite from various literature

Source	*Plant or fruit part studied*	*Protein*	*Crude Protein % of Dry Matter*	*Protein n x6.25*	*Digestible Protein % of Dry Matter*	*Dominate Amino Acid*	*Limiting Amino Acid*	*Crude Fat % of Dry weight*	*Dominate Fatty Acid*	*Mesquite species studied*
Becker, 1982	Seeds			26-31%		Leucine	Methionine and Cystine			*velutina ,juliflora and pubescens*
	Whole Pods			11-17%						
	Pericarp			5-8%						
Baptisa & Launchbaugh, 2001	Leaves			11.5-12.2%						*glandulosa*
Chopra and Hooda, 2001	Pericarp		8.96							*juliflora*
	Seeds		33.7							
Meyer et al., 1982	milled Exo-Mesocarp		11					2.5		*velutina*
	milled Endocarp		6					5		
	milled Endosperm splits		8							
	Cotyledon		56					10		*velutina*
	Whole Pods		11.9					2.5		
Mendes, 1986	Seeds		34-39							*juliflora*
Morangoni and Alli, 1988	Seeds		35			Lysine	Methionine			
	Pods		10						Linoleic	*juliflora*

Table 2.3 continued

Source	*Plant or fruit part studied*	*Protein*	*Crude Protein % of Dry Matter*	*Protein nX6.25*	*Digestible Protein % of Dry Matter*	*Dominate Amino Acid*	*Limiting Amino Acid*	*Crude Fat % of Dry weight*	*Dominate Fatty Acid*	*Mesquite species studied*
Richardson et al. 1982	Ground biomass		12.09							*glandulosa*
Silva et al,1989	Whole Pods				2.6					*juliflora*
	Pericarp Meal									
Silva et al,1990	Whole Pods		8.48							*juliflora*
	Pericarp									
Sharma et al. ,1994	Whole Pods	7.3-12.7% of Dry Matter	12.16							*juliflora*
Talpeda & Shukla, 1988	Whole Pods		12.29							*juliflora*
Talpeda et al., 2002	Whole Pods		13.5							*juliflora*
Zolfaghari & Harden, 1982	Seeds			39.34		Arginine	Tryptophan	4.91		*glandulosa and velutina*
	Immature pods			13.26		Leucine	Methionine	2.23		
	Mature pods			13.35		Leucine	Methionine	2.87		
	Pericarp			7.02		Leucine	Cystenine	2.08		

Table 2.4 Macro Mineral Composition of Mesquite from various literature

Source	*Plant or fruit part studied*	*Mesquite Species Studied*	*Ca*	*Na*	*Mg*	*P*	*K*
Chopra & Hooda, 2002	Seed	*juliflora*	0.21%		0.13%	0.34%	0.43%
Morangoni & Alli, 1988	Seed	*juliflora*		0.05%			0.32%
Talpada & Shukla, 1988	Whole Pod	*juliflora*	0.44%			0.17%	
Zolfaghari & Harden, 1982	Seeds	*glandulosa and velutina*	260 mg/100g	7.2 mg/100g	210 mg/100g	310 mg/100g	865 mg/100g
	Immature pods	*glandulosa and velutina*	530 mg/100g	9.1 mg/100g	120 mg/100g	110 mg/100g	1560 mg/100g
	Mature pods	*glandulosa and velutina*	430 mg/100g	8.2 mg/100g	90 mg/100g	130 mg/100g	1495 mg/100g
	Pericarp	*glandulosa and velutina*	440 mg/100g	10.4 mg/100g	80 mg/100g	80 mg/100g	2150 mg/100g

Table 2.5 Micro Mineral Composition of Mesquite from various literature

Source	*Plant or fruit part studied*	*Mesquite Species Studied*	*Fe*	*Cu*	*Mn*	*Co*	*Se*	*Cr*	*Zn*
Chopra and Hooda, 2002	Seeds	*juliflora*	255.3 ppm	25 ppm	45.8 ppm				48.1 ppm
Morangoni and Alli, 1988	Seeds	*juliflora*	142 ppm	27 ppm	31 ppm				64 ppm
Zolfaghari & Harden, 1982	Seeds	*glandulosa and velutina*	156 µg/g	17.24 µg/g	27.8 µg/g	1.26 µg/g	0.59 µg/g	0.19 µg/g	108 µg/g
	Immature pods	*glandulosa and velutina*	42 µg/g	6.74 µg/g	20.06 µg/g	0.66 µg/g	2.72 µg/g	0.19µg/g	26 µg/g
	Mature pods	*glandulosa and velutina*	31 µg/g	7.71 µg/g	11.4 µg/g	0.78 µg/g	3.31 µg/g	0.08 µg/g	26 µg/g
	Pericarp	*glandulosa and velutina*	15 µg/g	6.55 µg/g	9.95 µg/g	0.58 µg/g	3.92 µg/g	0.09 µg/g	19 µg/g

Mesquite in animal diets

In Texas, mesquite is an important mast producing plant in the diet of a wide variety of wildlife species including white-tail deer (*Odocoileus virginianus)*, collared peccaries (*Pecari tanjacu)*, wild turkeys (*Meleagros gallopavo),* wild boar/feral hogs (*Sus scrofa*) and raccoons (*Procyon lotor*) (Elston and Hewitt, 2010). White-tail deer in the Rolling Plains of Texas diet consisted of 11% mesquite (Simpson, 2008). White tail Deer are both ecologically and economically important to South Texas (Conover, 1997). Early cattlemen and pioneers to Texas readily fed mature mesquite pods to animals especially in drought years, noting when grass was in short supply due to lack of rains, mesquite usually were burdened by the weight of pods produced. (Wright, 1998) For livestock on rangelands in late summer, mesquite can be an important source of vitamin A and nitrogen as herbaceous plants begin to seed out and go dormant (Baptisa & Launchbaugh, 2001). Cattle (dairy and beef), sheep, goats, chicken and tilapia all showed equal or improvements in productivity when mesquite pods were implemented into the diet between 20-50% substitution of conventional grains; with an increase in profitability in dairy cattle and egg laying hens. (Sawal et al, 2004; Sena et al., 2012). Mesquite bran could replace 100% of wheat bran in the diet of laying hens by without effect on egg production, 30% of ingredients in the ration of lactating dairy cattle can be replaced with mesquite pods without effect on milk production or feed conversion (Sawal et al. 2004). Less than 30% of concentrate diet in sheep could be made from mesquite pods and less than 85% of goat diet can be mesquite pods without effect on growth and weight gain (Sawal et al. 2004).

When 20% of dry matter in the diet of cattle was mesquite pods, rumen microbes showed indications of low ammonia nitrogen production, efficient utilization of sugars and available nitrogen for growth. (Talpada et al, 2002) In an 85 day study Richardson et al. 1982 found that adding mesquite treated or untreated with sulfur dioxide or ozone had no significant effect on average daily gain of lambs and suggested treated mesquite could be added to the rations of ruminants. The nutritional values of mesquite bean pods are an excellent source of carbohydrates and digestible protein. Mesquite's nutritional values have been found to rival that of corn, currently used in supplemental feeding programs for domesticated animals and wildlife. (Sena et al, 2012) Pericarp though low in protein is high in fiber and has a unique taste (Becker, 1982). Studies have been conducted by a number of organizations throughout the world concerning the use of mesquite bean pods in domesticated animal production to reduce costs of production and increase sustainability in arid to semi-arid regions (Riveros, 1992; Sawal et al, 2004; Sena et al, 2012).

In nontraditional agriculture, mesquite can also be useful. In aquaculture, Nile tilapia showed no difference in feed intake, weight gain, feed conversion and survival rate no matter the level of inclusion of mesquite bean bran up to 20% of the diet when compared to control feed that did not contain any mesquite bean bran. (Sena et al, 2012) In beekeeping, mesquite can be of importance to bees and honey production with 160 bee species known to use mesquite in the Southwestern United States (Simpson et al. 1977).

Problems in animal production using mesquite pods as feed.

Mesquite as sole source of feed is a detriment to livestock. Consuming immature pods leading to many ill effects including weight loss, reduced appetite and death in

ruminate animals (Felker and Waines, 1977; Gabar, 1986; Sawal et al, 2004). Cattle feed over 50% of diet and goats fed over 60% of diet as mesquite pods resulted in a number of digestive and neurological dysfunctions, loss of protozoa in rumen and changes in blood chemistry (Sawal et al, 2004). Feed mixtures containing more than 40% mesquite pods in the diet of growing calves and 75% of diet of sheep showed a negative balance for phosphorus, suggesting a need for phosphorous supplementation or feeding less than 40% and 75% ,respectively, of feed mixture (Talpada et al, 1979; Sharma, 1997). Swine production is the only animal production industry mesquite pods were found unsuitable for feed replacement. Back fat, meat: fat ratio was reduced when mesquite replaced traditional grains in diet (Pinheira et al. 1993). Low to moderate levels of trypsin inhibitors and hemeagglutin are present in mesquite pods (Becker, 1982). Trypsin was inhibited by the proteins in mesquite pods but did not inhibit human salivary or porcine pancreatic alpha amylase (Sawal et al., 2004). The activity of trypsin inhibitor was less than half of that of black eyed beans and could be lowered by autoclaving for 15 minutes (Zolfaghari & Harden, 1982). Sugar content of the pods declined with increases in rainfall (Sharma et al., 1994). High amounts of fiber in mesquite pods can interfere with some mineral bioavailability especially phytate (Zolfaghari & Harden, 1982). Substitution of mesquite pods of more than 40% of corn lowers average body weight of chicks which suggests an upper limit on use of mesquite pods in chicken diets (Becker, 1982). Seed gums of mesquite, even after dried, interferes with the digestion in rats and chickens by increasing water binding capacity and bulking effect (Becker, 1982). Over 10% of mesquite biomass offered to lambs decreased feed intake of lambs due to alleochemicals in plant material (Baptisa & Launchbaugh, 2001). Mesquite is healthy as a

supplement in the rations of ruminate animals (e.g. 20%) but not healthy as sole source of nutrition.

Failure to innovate in Agriculture.

In innovation there are more failures than successes but many of the successes are not only time and place but putting in the time to match consumer, stakeholder needs to the product from Smith & Wesson bicycles to new Coke, failures come because an innovation came to market without exploring the market climate first. Agriculture is no different. In 1990 Iowa State University and Hach Company began development on N-Trak soil testing kits. N-Trak was to make over-fertilization and wasted fertilizer a thing of the past, by allowing farmer to test 10 acre plots for fertility as corn reached six inches and have immediate results rather than wait on soil sample tests sent to a lab. (Rogers, 2003) Scientists, marketers and developers assumed the product would be innovative and all corn farmers would want it but by 1999 only 17 kits had sold when in 1990 projections put sales at least 1700 kits. (Rogers, 2003) The failure could have been avoided had those developing the N-Trak worked with the farmers they intended on helping and developed based on needs not perceived need (Rogers, 2003). In the 1960s in Nigeria, the US sent Dr. "Chicken" Davis, a leading expert in poultry production, to Nigeria to study production of eggs and chickens for sustainability and to make food more available to the people of Nigeria. (Rogers, 2003) The manner in which chickens were raised in Nigeria made egg production difficult but, Dr. Davis after spending time in country decided to bring American grown chickens and ideas on the production of eggs to the villages of Nigeria. As a disease swept through the newly developed westernized chicken farms, free range chickens were unaffected and continued to produce meat and

eggs. (Rogers, 2003) Davis' failure came in thinking modern ideas are superior to heritage knowledge so innovating chicken production in Nigeria ultimately failed and people continued with traditional production methods. (Rogers, 2003)

CHAPTER III

METHODS

Study Design

This study combines review of literature about the use of mesquite both current and historical and a survey of landowners in 2 potential counties for production and processing in I-35, I-10 corridor of Texas to explore mesquite's potential as a source of renewable energy and a low input crop in Texas. These items combine to develop a three legged stool supporting the utilization of mesquite in Texas.

Survey Design and Data Collected

In order to explore landowner perceived value in mesquite, this survey used "One mode prompt completion by another mode" (Dillman, 2000) and "Five Contact Points" described in Dillman et al. 2009 landowners were first sent an introduction mailing with instructions on how to access the survey, a thank you post card following completion of the electronic survey and periodically over the weeks of the study were sent reminder post cards and letters to non-respondents. Respondents were also entered into a random drawing for a $100 gift card to their chosen retailer as incentive to complete the survey.

A SurveyMonkey electronic survey consisting of 41questions sought to understand the willingness and views of landowners on the utilization of mesquite. The design of the survey was inspired by laddering of values (Reynolds and Gutman, 1988), ranking of values (Dillman, 2000), information derived from Hart (1987), Salant and Dillman (1994), Okazaki (2007), Johnson et al. (2008), Smith (2009), Jin (2011), Puleston (2011), Terhanian & Bremer,(2012) and questions modeled from a similar studies of wood biomass at Mississippi State University by Joshi et al. (2011), Joshi et al., (2013) and Gruchy et al. (2012)

2011. The survey was sent to a variety of farmers, ranchers and landowners in Guadalupe and Hays Counties which are central to I-35-I-10 corridor. Landowners were selected from property tax records indicating Ag-Exempt status of properties in the county. The survey asked respondents questions about their land, agricultural operation, willingness to support the harvest of mesquite for a biomass crop for energy production and in a portion of livestock diet, willingness to allocate resources to the use of mesquite as opposed to eradication and overall opinion of the mesquite.

Selection of study area and land owners

Using landowners based in Guadalupe and Hays County as target population for the survey will be the most efficient and effective method to determine the level of interest in the use and commercialization of mesquite and mesquite products in a niche market. All counties in the I-35, I-10 corridor within mesquite's natural range were considered for study with land owners from Guadalupe and Hays County selected. This area would give any business a logistical edge for moving a product around Texas, the nation and internationally. In 2013 population estimate Guadalupe County stood at 143,183, up 8.9% from 2010 census (U.S. Census Bureau, 2014). In Guadalupe County the Median age is 36.5 and median income is $63,889 (U.S. Census Bureau, 2012). An estimated 957 people in Guadalupe County Texas work in agriculture, forestry, fishing, hunting and mining industry (U.S. Census Bureau, 2012). As 2012 there were 2,241 farms in Guadalupe County covering 383,109 acres. Average size of a farm in Guadalupe County was 171 acres and Median size of 50 acres with an average farm value of $614,506. (National Agricultural Statistics Service, 2014). In Hays County, 274 farms received 2.2 million dollars in government payments. Agricultural goods account for

$61.5 million dollars in the economy of Guadalupe County at an average of $27,484 per farm (National Agricultural Statistics Service, 2014).Population of Hays County estimate stood at 176,026 in 2013 (U.S. Census Bureau, 2013) with Median age of 30.7 years and median income of $58,651. Agriculture, forestry, hunting and mining was 829 people report as occupation (U.S. Census Bureau, 2013.) Agriculture census showed 1490 farms covering 245,006 with average farm size 170 acres in Hays County of which 65 farms collected $469,000 in government payments (National Agricultural Statistics Service, 2014). Off farm income was reported by 972 farmers (National Agricultural Statistics Service, 2014). Average market value of farms in Hays County was reported $1,055,578 (National Agricultural Statistics Service, 2014). Agriculture goods were valued at $14.9 million to Hays county economy at an average of $10,403 per farm. (National Agricultural Statistics Service, 2014)

Criteria for selection for surveying interest in mesquite utilization was Agriculture Use Property Tax Exemption from each County Appraisal District and properties larger than 7 acres in size. Harvest of mesquite would be most efficient on 7 or more acres of land based on reading Smith (1982), Felker (1984), Ansley et al. (2010), Park et al. (2012), Joshi et al. (2013) and various other unpublished sources. Narrowing the results of Agriculture Use Exempt properties that matched the criteria for selection yielded a population size (n=) of 5974 in Guadalupe County and n= 912 in Hays County. Using Krejcie and Morgan (1970) and Dillman et al. (2009) 361 land owners (s=) in Guadalupe and s=269 in Hays, respectively that matched the criteria for selection from County Tax Appraisal District records and were sent an invitation to participate in the survey. In total

630 invitations to participate in the survey were sent to landowners in Guadalupe and Hays County.

Data Analysis

IBM SPSS 22, Microsoft Excel 2013 and SurveyMonkey analytical software were used to analyze response data collected by the survey. Responses were scored and means compared using a variety of descriptive statistics. Correlations between responses were made to build a larger picture of how land owners and managers view mesquite and its possible use in agriculture as a feed component, dietary supplement and crop for bio-energy feedstock.

Survey limitations

Population size was limited to landowners with a property size of seven acres or larger at current property values, age and income level of property owners could be a source of bias in the study. Contact information was obtained indirectly through County Appraisal District in Guadalupe and Hays County, introduction letters were sent only to landowner's address not situs address of the properties in all cases.

CHAPTER IV

SURVEY RESULTS

Survey Response

A total of 630 invitations to participate in the survey were sent out to Guadalupe and Hays County, 145 responses were received which yielded a 23% response rate. 109 participated in the survey, 106 fully completed the survey and 3 partially completed, which yielded 75% response rate to the survey. Thirty six declined to participate in the survey due to a number of reasons most commonly lack of access to or knowledge of computers and the internet.

Landowner Description in Guadalupe and Hays County

There were 73 male respondents and 33 female. Each Landowner in Guadalupe County owned one property between 11-20 acres in size, ideal for mesquite harvest. 80% of properties generated income for the landowner through farming (42.11%) or ranching (52.63%). Respondents in Guadalupe County in general were: college educated (67.79%) white (91.53%), male (61.02%), and 55-74 years old (59.32%), with an annual income between under $125,000 (66.1%). Agriculture was not their primary occupation of 88.14% of the respondents with the majority reporting 20 years or more of experience in agriculture. The majority of landowners reported less than 1/3 of their property covered by woody vegetation; spending $30,391 on removal of woody vegetation and $165,650 on range improvement each year in Guadalupe County. Each Landowner in Hays County

owned one property between 11-30 acres (28.58%) or 151-250 acres (18.37%) in size, like in Guadalupe county ideal for mesquite harvest operation. Properties did not generate income for 59.18% of respondents, while 40.82% did generate income for respondents through either ranching (62.5%) and/or leased the land for agricultural use (40.63%). Generally in Hays County Respondents were: college educated (78.73%), white (91.49%), male (74.47%) between 55-74 years old (61.9%) with an annual income of over $200,000 (38.8%) with agriculture not being their primary occupation (89.36%) with reporting 56% having experience in agriculture and 44% not having any experience in agriculture. The majority of landowners reported 1/3-75% of their property covered by woody vegetation; spending $88,750 on removal of woody vegetation and $57,800 on range improvement each year in Hays County.

Perceived Knowledge of Bio-energy and Biomass Feedstock

When asked about perceived knowledge of biomass and bioenergy respondents, see table 4.1 and 4.2 below, had some familiarity with biofuels as a source of energy (55.1% Hays County, 49.15% Guadalupe County). Perceived knowledge dropped when asked about native biomass as a source of energy and wood-based bio-energy most sharply in Guadalupe County compared to Hays County. Questions were weighted 1 being "Never Heard of" to 4 "Very familiar" for three questions. The first question mean ($\bar{x}$) for Guadalupe County was 2.42 with a standard deviation (SD) of 0.89 and for Hay County $\bar{x}$ = 2.61 with a SD = 0.78 indicating most landowners had familiarity with biofuels as energy. The next question was more exact asking about native biomass, $\bar{x}$ = 1.86 with SD= 0.91 for responses for Guadalupe County and for Hays County 2.14 with a SD= of 0.90 indicating more familiarity in Hays County than Guadalupe. Landowners in

Guadalupe seemed to have little or no familiarity of native biomass for bio-energy production. The final question asked familiarity with wood based bio-energy production, the mean ($\bar{x}$) for responses for Guadalupe County was 1.78 with a SD= of 0.83 and for Hays County $\bar{x}$= 2.08 with a SD= of 0.90. This showed again landowners in Hays County as with the prior question were more familiar with the subject but overall familiarity dropped the most in both counties when asked specifically about use of wood based bioenergy. Repeated from the prior question Guadalupe County landowners had little to no familiarity with wood based bio-energy.

Table 4.1 Perceived Knowledge of Bioenergy and Biofuels in Guadalupe County

Question	*Not at all*		*Heard of it but not too sure what it is*		*Some familiarity, Read about it in a publication (newspaper, journal, magazine, etc.) or on TV*		*Very familiar, Looked into it as a business opportunity or for general knowledge*		*Total responses*			
	n=	%	n=	%	n=	%	n=	%	n=	%	$\bar{x}$	*SD*
How familiar are you with biofuels as a source of energy?	12	20.34	14	23.73	29	49.15	4	6.78	59	100	2.42	0.89
How familiar are you with native biomass as a source of energy?	27	45.76	15	25.42	15	25.42	2	3.39	59	100	1.86	0.91
How familiar are you with wood based bio-energy as a source of energy?	28	47.46	18	30.51	12	20.34	1	1.69	59	100	1.76	0.83

Table 4.2 Perceived Knowledge of Bioenergy and Biofuels in Hays County

Question	*Not at all*		*Heard of it but not too sure what it is*		*Some familiarity, Read about it in a publication (newspaper, journal, magazine, etc.) or on TV*		*Very familiar, Looked into it as a business opportunity or for general knowledge*		*Total responses*			
	n=	%	n=	%	n=	%	n=	%	n=	%	$\bar{x}$	*SD*
How familiar are you with biofuels as a source of energy?	5	10.20	13	26.5	27	55.1	4	8.16	49	100	2.61	0.78
How familiar are you with native biomass as a source of energy?	15	30.61	14	28.57	18	36.73	2	4.08	49	100	2.14	0.90
How familiar are you with wood based bio-energy as a source of energy?	16	32.65	15	30.61	16	32.65	2	4.08	49	100	2.08	0.90

Likelihood of mesquite utilization

Landowners were asked a series of questions weighted 1-6, 1 not likely at all, 3 neutral and 6 very likely, about likelihood/unlikelihood of utilization based on specific criteria. Landowners were neutral about new crops, range of weighted response average was 2.90-3.51, and mean ($\bar{x}$) of 3.42 with as standard deviation (SD) of 0.23 but somewhat likely to preserve and improve wildlife habitat and rangeland condition, range of weighted response average was between 4.47 and 5.33 and $\bar{x}$ = 4.65 with a SD= 0.41. Landowners were neutral about using a native plant in their operation, range of weighted response averages was 3.10 and 3.69 and $\bar{x}$ = 3.32 with a SD= of 0.26.

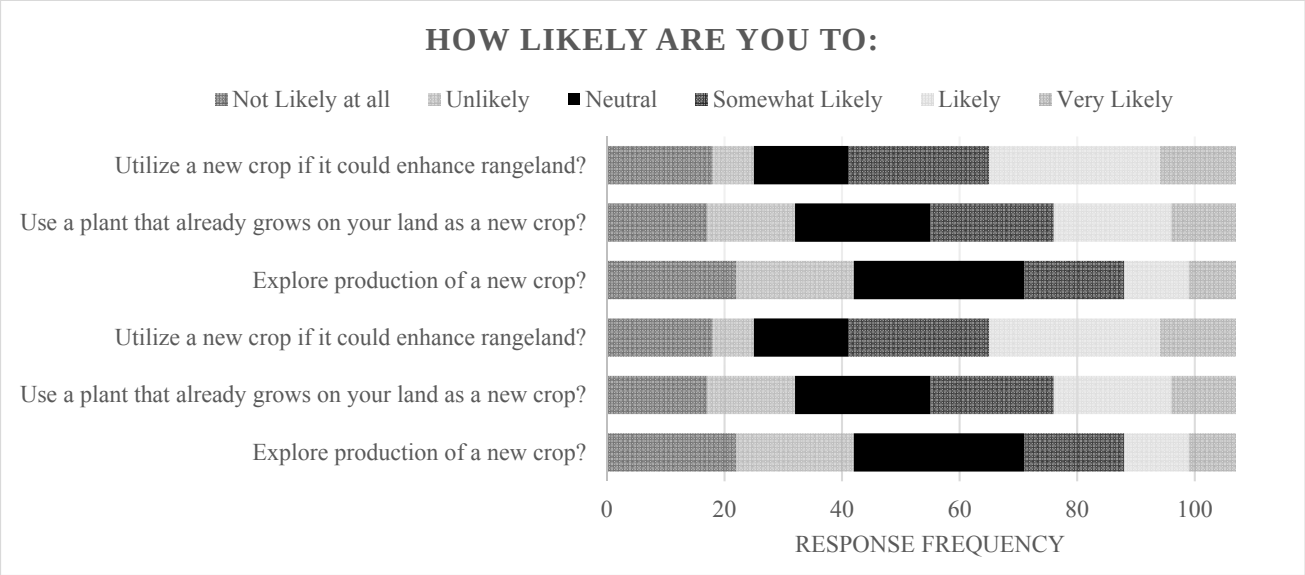
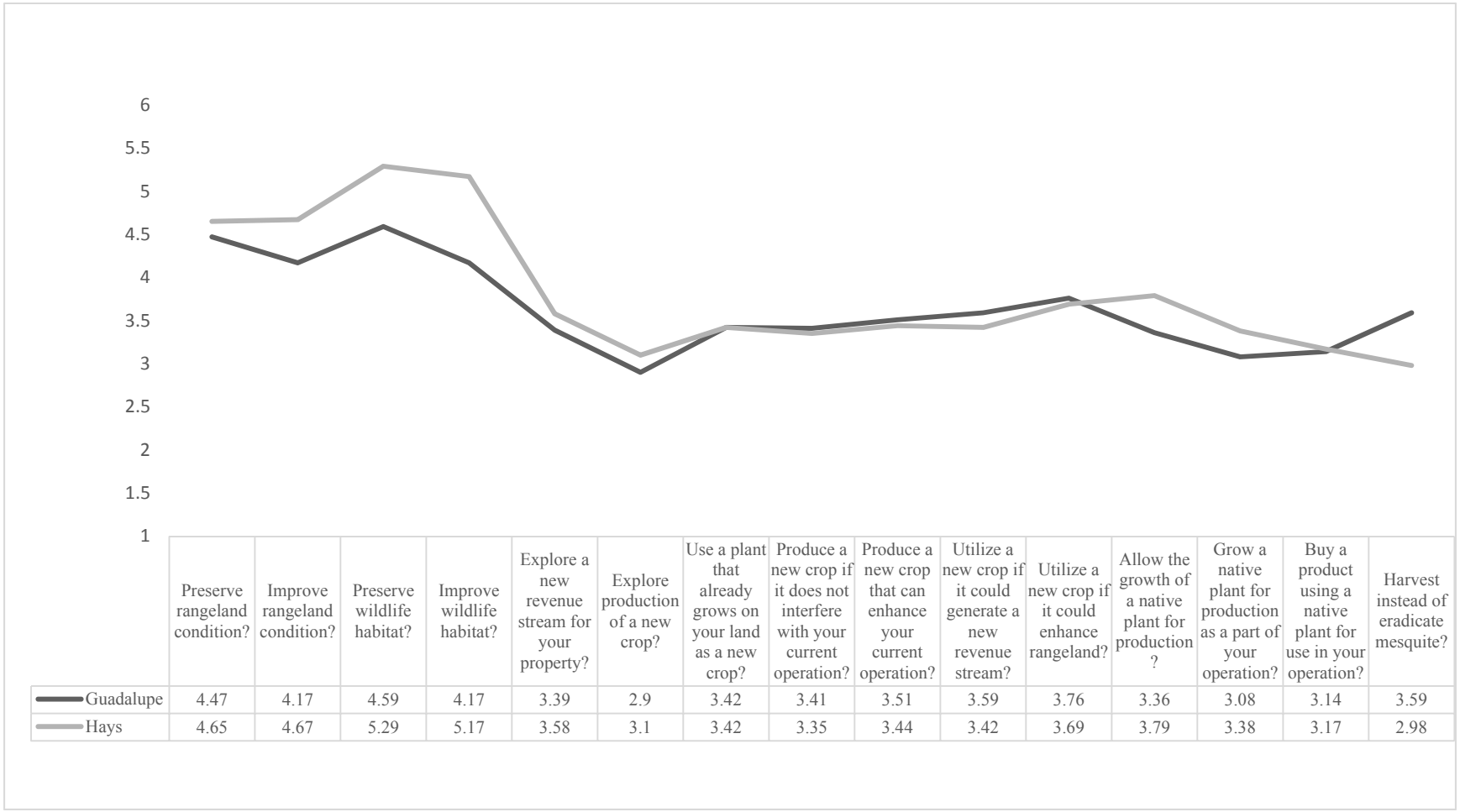


Figure 4.1 Likelihood of utilization of a new crop.



	Preserve rangeland condition?	Improve rangeland condition?	Preserve wildlife habitat?	Improve wildlife habitat?	Explore a new revenue stream for your property?	Explore production of a new crop?	Use a plant that already grows on your land as a new crop?	Produce a new crop if it does not interfere with your current operation?	Produce a new crop that can enhance your current operation?	Utilize a new crop if it could generate a new revenue stream?	Utilize a new crop if it could enhance rangeland?	Allow the growth of a native plant for production ?	Grow a native plant for production as a part of your operation?	Buy a product using a native plant for use in your operation?	Harvest instead of eradicate mesquite?
Guadalupe	4.47	4.17	4.59	4.17	3.39	2.9	3.42	3.41	3.51	3.59	3.76	3.36	3.08	3.14	3.59
Hays	4.65	4.67	5.29	5.17	3.58	3.1	3.42	3.35	3.44	3.42	3.69	3.79	3.38	3.17	2.98

Figure 4.2 Mean of response frequency of “How likely/unlikely would you:”

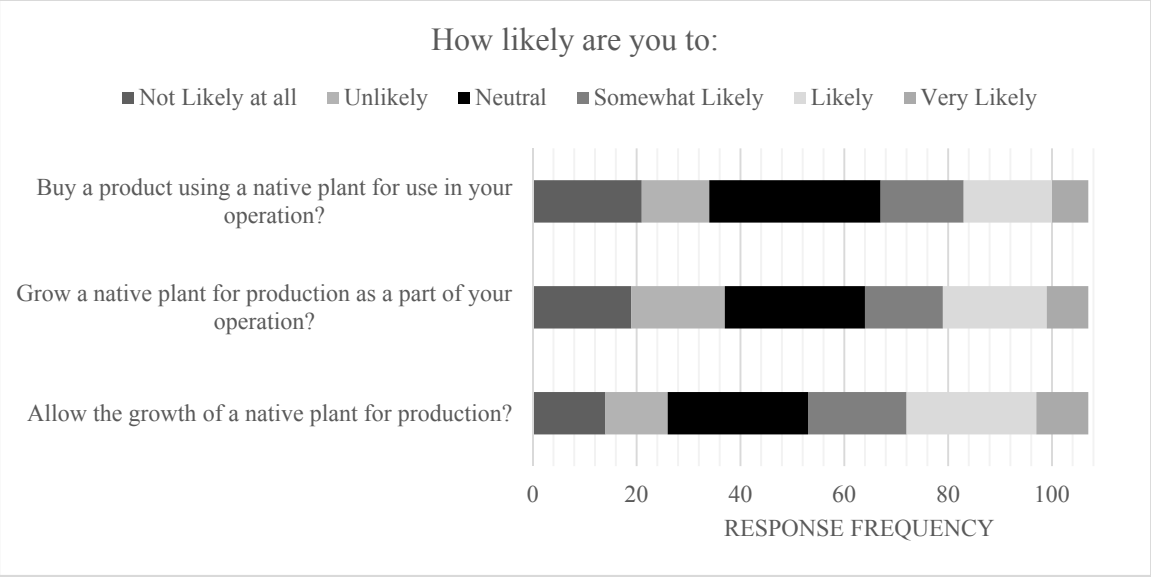


Figure 4.3 Likelihood of utilization of a native plant.

When asked Likelihood of Mesquite utilization based on current knowledge landowners were unlikely to neutral. When asked if given more information about mesquite there was a small uptick in likelihood but still remained neutral in utilization of mesquite. When comparing counties Guadalupe was more unlikely to utilize mesquite than Hays; Hays County landowners being neutral in likelihood of utilization of mesquite and Guadalupe County landowners unlikely to utilize mesquite. Landowners in both Guadalupe and Hays County who were like or very likely to harvest mesquite rather than eradicate were more like likely to utilize mesquite based on current knowledge mean ($\bar{x}$) range for the items asked were from 3.40-5.17 with $\bar{x}$ = 4.33 and standard deviation (SD) of 0.51. Sample size of these landowners (n) was 32; 20 from Guadalupe and 12 from Hays, respectively. In analysis a small outlier in the data showed, landowners in Hays County with more than 75% of their property were most likely to utilize with mean range between 4.33 and 5.00, $\bar{x}$ = 4.67 and SD = 0.28 for in all items in both current knowledge and if given additional information about mesquite question lines. Only 3 landowners in Hays County reported property being more than 75% of the property being covered by woody vegetation and was not repeated in Guadalupe County data with the same number of landowners reporting 75% or more of their property covered by woody vegetation.

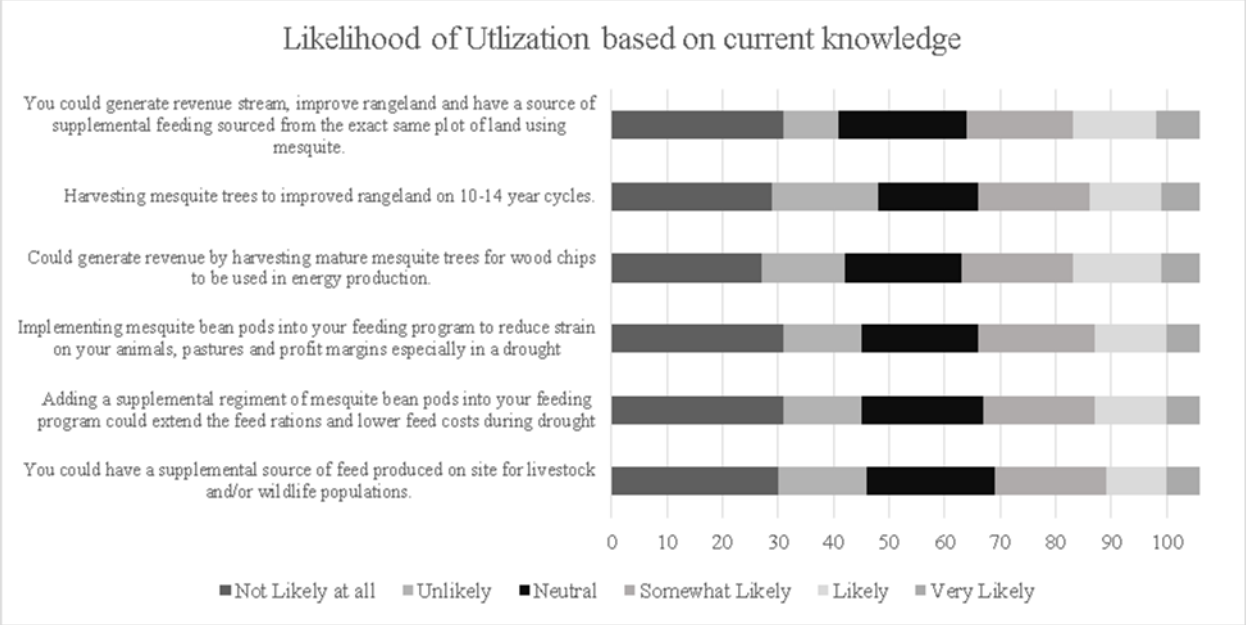


Figure 4.4 Likelihood of utilization based on current knowledge.

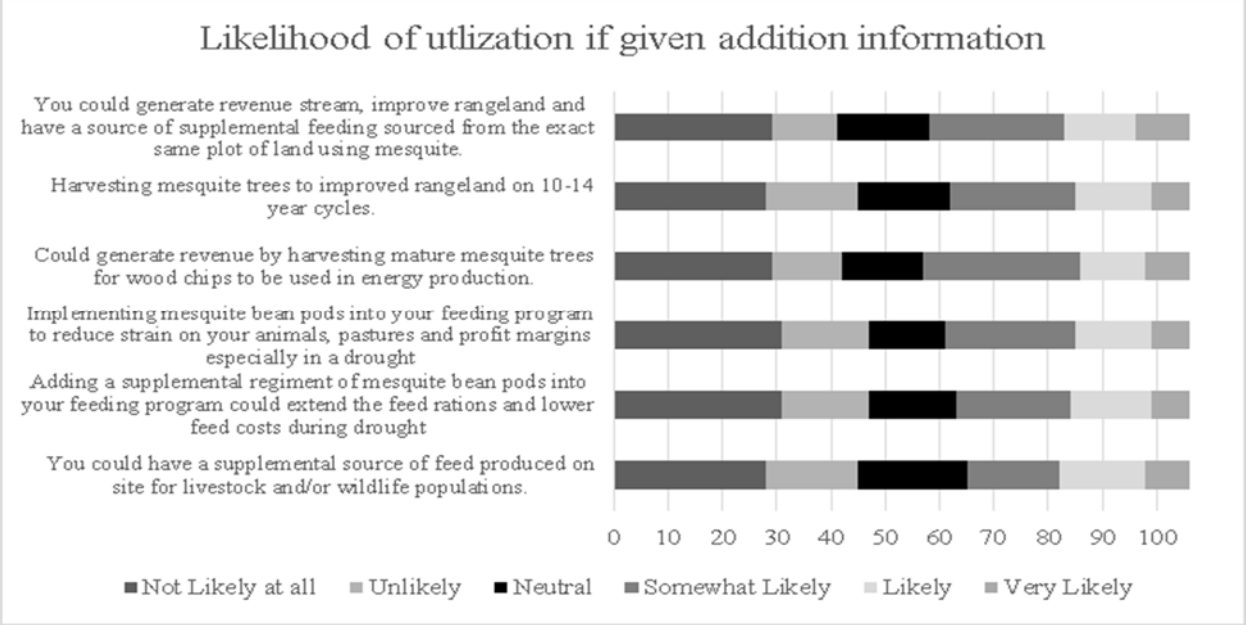
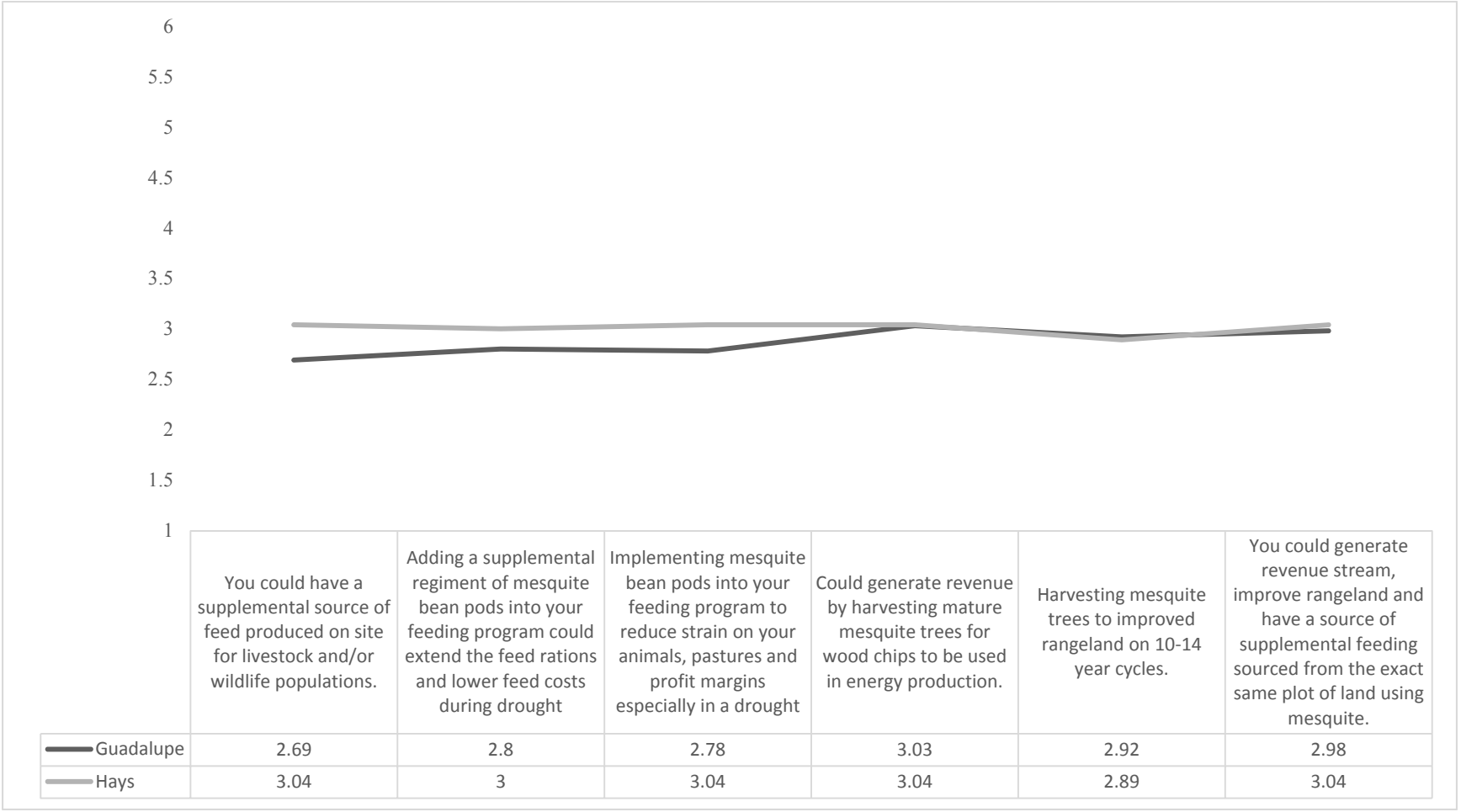
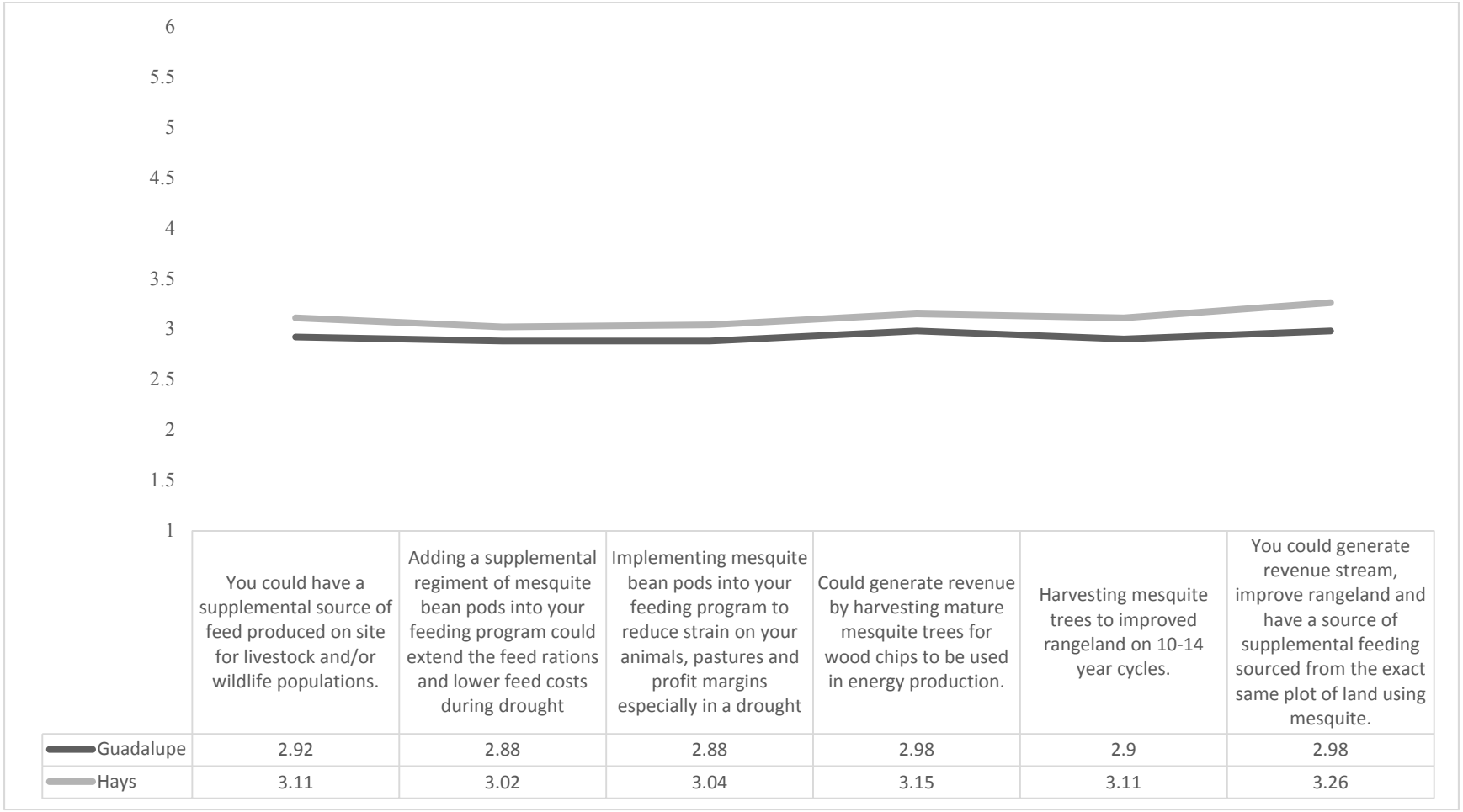


Figure 4.5 Likelihood of utilization of give more information about mesquite.



	You could have a supplemental source of feed produced on site for livestock and/or wildlife populations.	Adding a supplemental regiment of mesquite bean pods into your feeding program could extend the feed rations and lower feed costs during drought	Implementing mesquite bean pods into your feeding program to reduce strain on your animals, pastures and profit margins especially in a drought	Could generate revenue by harvesting mature mesquite trees for wood chips to be used in energy production.	Harvesting mesquite trees to improved rangeland on 10-14 year cycles.	You could generate revenue stream, improve rangeland and have a source of supplemental feeding sourced from the exact same plot of land using mesquite.
Guadalupe	2.69	2.8	2.78	3.03	2.92	2.98
Hays	3.04	3	3.04	3.04	2.89	3.04

Figure 4.6 Mean of response frequency of “likelihood of utilization based on current knowledge”.



	You could have a supplemental source of feed produced on site for livestock and/or wildlife populations.	Adding a supplemental regiment of mesquite bean pods into your feeding program could extend the feed rations and lower feed costs during drought	Implementing mesquite bean pods into your feeding program to reduce strain on your animals, pastures and profit margins especially in a drought	Could generate revenue by harvesting mature mesquite trees for wood chips to be used in energy production.	Harvesting mesquite trees to improved rangeland on 10-14 year cycles.	You could generate revenue stream, improve rangeland and have a source of supplemental feeding sourced from the exact same plot of land using mesquite.
Guadalupe	2.92	2.88	2.88	2.98	2.9	2.98
Hays	3.11	3.02	3.04	3.15	3.11	3.26

Figure 4.7 Mean of response frequency of “likelihood of utilization if given more information”.

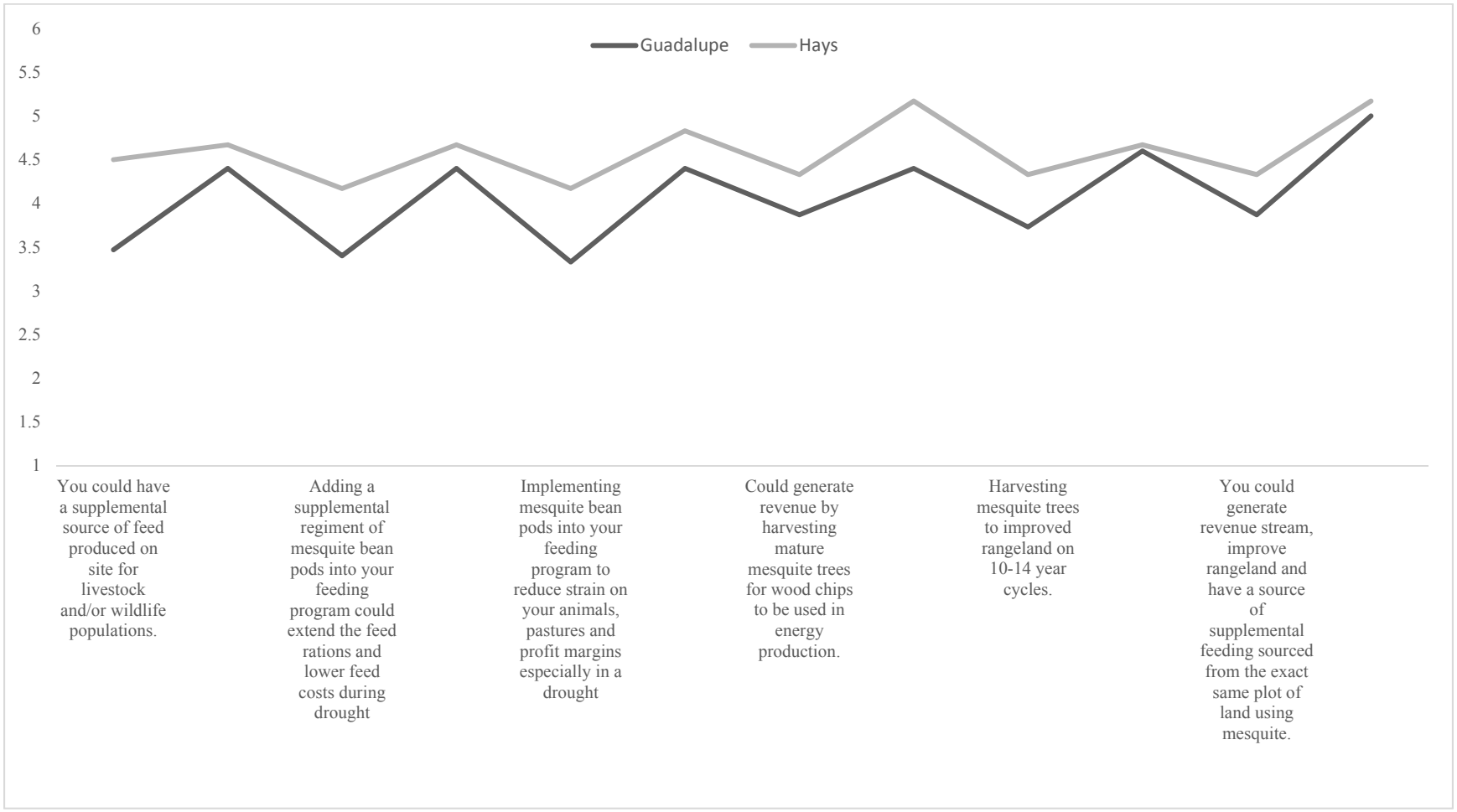


Figure 4.8 Mean frequency of utilization based on current knowledge of landowner likely to harvest mesquite rather than eradicate.

When ask if someone they knew was utilizing mesquite would they landowner opinion remained the similar other question lines. Selling land for mesquite production was least likely among landowners $\bar{x}$ = 1.54 with SD= 1.11 for Guadalupe County and $\bar{x}$ = 1.77 with SD= 1.22 in Hays County. Land owners in Guadalupe County were mostly likely to generate revenue using mesquite if someone else they knew was, $\bar{x}$ = 3.02 with SD=1.46 but still neutral. Hays County land owners were mostly to allow mesquite to mature for harvest if someone else they knew was, $\bar{x}$ = 3.13 with SD= 1.77, like Guadalupe County still neutral.

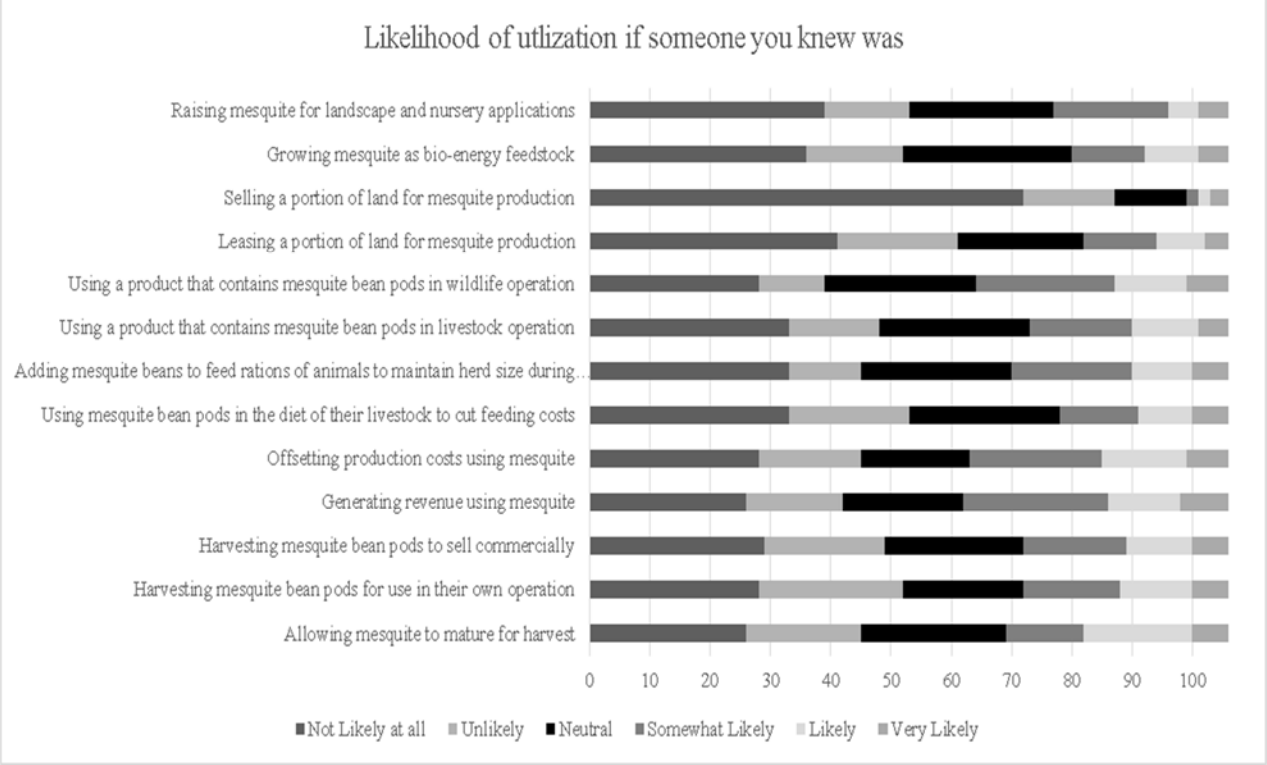
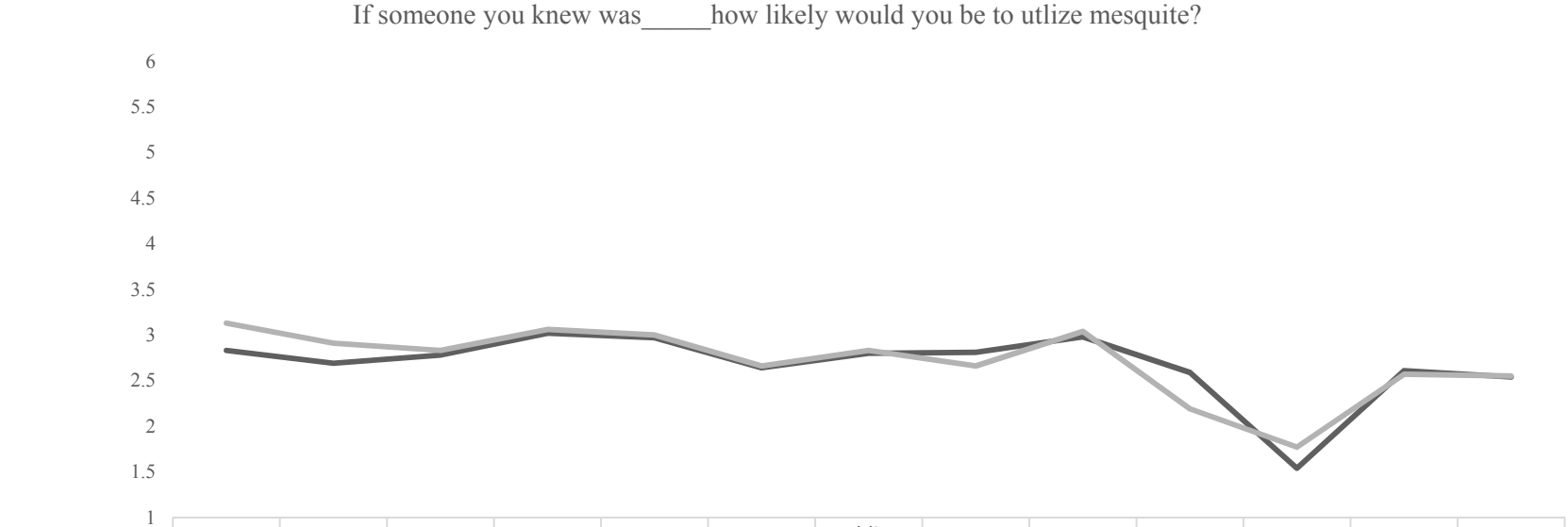


Figure 4.9 Likelihood of utilization of mesquite "If someone you knew was.."



	Allowing mesquite to mature for harvest	Harvesting mesquite bean pods for use in their own operation	Harvesting mesquite bean pods to sell commercially	Generating revenue using mesquite	Offsetting production costs using mesquite	Using mesquite bean pods in the diet of their livestock to cut feeding costs	Adding mesquite beans to feed rations of animals to maintain herd size during drought	Using a product that contains mesquite bean pods in livestock operation	Using a product that contains mesquite bean pods in wildlife operation	Leasing a portion of land for mesquite production	Selling a portion of land for mesquite production	Growing mesquite as bio-energy feedstock	Raising mesquite for landscape and nursery applications
Guadalupe	2.83	2.69	2.78	3.02	2.97	2.64	2.8	2.81	2.98	2.59	1.54	2.61	2.54
Hays	3.13	2.91	2.83	3.06	3	2.66	2.83	2.66	3.04	2.19	1.77	2.57	2.55

Figure 4.10 Mean frequency of responses to "If someone you knew was….."

Relating Perceived Knowledge and Likelihood of utilization of mesquite

Lastly looking at perceived knowledge levels' influence on the likelihood of utilization of mesquite. One-way ANOVA analysis showed significance between knowledge level and likelihood of utilization question lines. Table 4.3 illustrates the correlation of each perceived knowledge question to likelihood of utilization question lines and each utilization question line to one another. In general, landowner knowledge was low on all questions and declining when asked more direct questions about native biomass and lowest at knowledge of wood based bio-energy and overall likelihood of utilization of mesquite was unlikely to neutral; one would assume each item would have direct relationship to one another. For knowledge and "likelihood of" confidence interval was set 95% all variables had slight positive correlation coefficient with the strongest correlation with utilization of crop if it could enhance rangeland and each knowledge of bio-fuels, native biomass and wood based bio-energy knowledge questions. With confidence levels set at 99% slightly positive correlations can be found between "likelihood of" questions. The strongest correlations can be found between producing a crop that generates a new revenue stream and producing a crop that does not interfere with current operation. Table 4.4 and 4.5 illustrates correlation of perceived knowledge and utilization based on knowledge of mesquite and if given more information about mesquite. When looking at knowledge level and utilization based on current knowledge significance in correlation can only be found in a few variables, majority of the variables under familiarly of biofuels in which knowledge level was the highest reported among land owners surveyed. Strongest correlation between variables for can be found when looking at the two variable that ask about utilization of mesquite during drought for both

current knowledge of mesquite and if given more information about mesquite, respectively. Table 4.6 illustrates the correlation between knowledge and likelihood of utilization if someone else was. Strongest correlations can be found between harvesting mesquite pods, selling mesquite pods and offsetting cost of production using mesquite.

Table 4.3 Correlation table of Perceived Knowledge and Likelihood response

Correlations

		3. How familiar are you with biofuels as a source of energy? (Check one)	4. How familiar are you with native biomass as a source of energy? (Check one)	5. How familiar are you with wood based bio energy as a source of energy? (Check one)	Improve rangeland condition ?	Preserve wildlife habitat?	Improve wildlife habitat?	Explore a new revenue stream for your property?	Explore production of a new crop?	Allow the growth of a native plant for production?	Grow a native plant for production as a part of your operation ?	Buy a product using a native plant for use in your operation ?	Use a plant that already grows on your land as a new crop?	Produce a new crop if it does not interfere with your current operation ?	Produce a new crop that can enhance your current operation ?	Utilize a new crop if it could generate a new revenue stream?	Utilize a new crop if it could enhance rangeland ?	Harvest instead of eradicate mesquite ?
3. How familiar are you with biofuels as a source of energy? (Check one)	Pearson Correlation	1	.710**	.560**	.285**	.202*	.150	.321**	.259**	.259**	.340**	.317**	.312**	.289**	.341**	.357**	.382**	.166
	Sig. (2-tailed)		.000	.000	.003	.037	.124	.001	.007	.007	.000	.001	.001	.003	.000	.000	.000	.088
	N	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107
4. How familiar are you with native biomass as a source of energy? (Check	Pearson Correlation	.710**	1	.804**	.236*	.216*	.125	.235*	.228*	.197*	.259**	.225*	.235*	.195*	.285**	.250**	.298**	.058
	Sig. (2-tailed)	.000		.000	.014	.025	.199	.015	.018	.042	.007	.020	.015	.044	.003	.009	.002	.551
	N	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107
5. How familiar are you with wood based bio-energy as a source of	Pearson Correlation	.560**	.804**	1	.181	.184	.097	.156	.146	.199*	.190	.175	.312**	.159	.225*	.200*	.211*	.028
	Sig. (2-tailed)	.000	.000		.062	.058	.323	.109	.133	.040	.050	.072	.001	.101	.020	.039	.030	.775
	N	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107
Improve rangeland condition?	Pearson Correlation	.285**	.236*	.181	1	.458**	.570**	.447**	.493**	.378**	.483**	.440**	.471**	.516**	.571**	.520**	.606**	.281**
	Sig. (2-tailed)	.003	.014	.062		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.003
	N	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107
Preserve wildlife habitat?	Pearson Correlation	.202*	.216*	.184	.458**	1	.801**	.309**	.279**	.485**	.349**	.319**	.328**	.263**	.294**	.296**	.350**	.244*
	Sig. (2-tailed)	.037	.025	.058	.000		.000	.001	.004	.000	.000	.001	.001	.006	.002	.002	.000	.011
	N	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107
Improve wildlife habitat?	Pearson Correlation	.150	.125	.097	.570**	.801**	1	.435**	.413**	.532**	.497**	.465**	.442**	.416**	.439**	.423**	.480**	.303**
	Sig. (2-tailed)	.124	.199	.323	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.002
	N	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107
Explore a new revenue stream for your property?	Pearson Correlation	.321**	.235*	.156	.447**	.309**	.435**	1	.836**	.602**	.721**	.730**	.645**	.760**	.747**	.730**	.678**	.520**
	Sig. (2-tailed)	.001	.015	.109	.000	.001	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107
Explore production of a new crop?	Pearson Correlation	.259**	.228*	.146	.493**	.279**	.413**	.836**	1	.575**	.704**	.769**	.665**	.794**	.775**	.780**	.734**	.613**
	Sig. (2-tailed)	.007	.018	.133	.000	.004	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000	.000
	N	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107
Allow the growth of a native plant for production?	Pearson Correlation	.259**	.197*	.199*	.378**	.485**	.532**	.602**	.575**	1	.750**	.696**	.700**	.682**	.631**	.656**	.623**	.444**
	Sig. (2-tailed)	.007	.042	.040	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000	.000
	N	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107
Grow a native plant for production as a part of your operation?	Pearson Correlation	.340**	.259**	.190	.483**	.349**	.497**	.721**	.704**	.750**	1	.857**	.737**	.809**	.824**	.827**	.775**	.614**
	Sig. (2-tailed)	.000	.007	.050	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000	.000
	N	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107
Buy a product using a native plant for use in your operation?	Pearson Correlation	.317**	.225*	.175	.440**	.319**	.465**	.730**	.769**	.696**	.857**	1	.737**	.854**	.808**	.841**	.775**	.654**
	Sig. (2-tailed)	.001	.020	.072	.000	.001	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000	.000
	N	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107
Use a plant that already grows on your land as a new crop?	Pearson Correlation	.312**	.235*	.312**	.471**	.328**	.442**	.645**	.665**	.700**	.737**	.737**	1	.784**	.742**	.752**	.692**	.588**
	Sig. (2-tailed)	.001	.015	.001	.000	.001	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000	.000
	N	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107
Produce a new crop if it does not interfere with your current operation?	Pearson Correlation	.289**	.195*	.159	.516**	.263**	.416**	.760**	.794**	.682**	.809**	.854**	.784**	1	.899**	.932**	.867**	.684**
	Sig. (2-tailed)	.003	.044	.101	.000	.006	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000	.000
	N	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107
Produce a new crop that can enhance your current operation?	Pearson Correlation	.341**	.285**	.225*	.571**	.294**	.439**	.747**	.775**	.631**	.824**	.808**	.742**	.899**	1	.926**	.913**	.681**
	Sig. (2-tailed)	.000	.003	.020	.000	.002	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000	.000
	N	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107
Utilize a new crop if it could generate a new revenue stream?	Pearson Correlation	.357**	.250**	.200*	.520**	.296**	.423**	.730**	.780**	.656**	.827**	.841**	.752**	.932**	.926**	1	.912**	.725**
	Sig. (2-tailed)	.000	.009	.039	.000	.002	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000	.000
	N	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107
Utilize a new crop if it could enhance rangeland?	Pearson Correlation	.382**	.298**	.211*	.606**	.350**	.480**	.678**	.734**	.623**	.775**	.775**	.692**	.867**	.913**	.912**	1	.685**
	Sig. (2-tailed)	.000	.002	.030	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000		.000
	N	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107
Harvest instead of eradicate mesquite?	Pearson Correlation	.166	.058	.028	.281**	.244*	.303**	.520**	.613**	.444**	.614**	.654**	.588**	.684**	.681**	.725**	.685**	1
	Sig. (2-tailed)	.088	.551	.775	.003	.011	.002	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	
	N	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107	107

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4.4 Correlation table of Perceived Knowledge and Utilization based on current knowledge of mesquite.

Correlations

		3. How familiar are you with biofuels as a source of energy? (Check one)	4. How familiar are you with native biomass as a source of energy? (Check one)	5. How familiar are you with wood based bio-energy as a source of energy? (Check one)	You could have a supplemental source of feed produced on site for livestock and/or wildlife populations.	Adding a supplemental regiment of mesquite bean pods into your feeding program could extend the feed rations and lower feed costs during drought	Implementing mesquite bean pods into your feeding program to reduce strain on your animals, pastures and profit margins especially in a drought	Could generate revenue by harvesting mature mesquite trees for wood chips to be used in energy production.	Harvesting mesquite trees to improved rangeland on 10-14 year cycles.	You could generate revenue stream, improve rangeland and have a source of supplemental feeding sourced from the exact same plot of land using mesquite.
3. How familiar are you with biofuels as a source of energy? (Check one)	Pearson Correlation	1	.710	.560	.242	.265	.275	.232	.163	.229
	Sig. (2-tailed)		.000	.000	.012	.006	.004	.016	.093	.017
	N	107	107	107	107	107	107	107	107	107
4. How familiar are you with native biomass as a source of energy? (Check one)	Pearson Correlation	.710	1	.804	.144	.180	.193	.160	.114	.180
	Sig. (2-tailed)	.000		.000	.138	.063	.046	.100	.240	.063
	N	107	107	107	107	107	107	107	107	107
5. How familiar are you with wood based bio-energy as a source of energy? (Check one)	Pearson Correlation	.560	.804	1	.128	.168	.182	.163	.154	.170
	Sig. (2-tailed)	.000	.000		.189	.083	.060	.094	.113	.081
	N	107	107	107	107	107	107	107	107	107
You could have a supplemental source of feed produced on site for livestock and/or wildlife populations.	Pearson Correlation	.242	.144	.128	1	.942	.944	.789	.744	.841
	Sig. (2-tailed)	.012	.138	.189		.000	.000	.000	.000	.000
	N	107	107	107	107	107	107	107	107	107
Adding a supplemental regiment of mesquite bean pods into your feeding program could extend the feed rations and lower feed costs during drought	Pearson Correlation	.265	.180	.168	.942	1	.987	.764	.710	.808
	Sig. (2-tailed)	.006	.063	.083	.000		.000	.000	.000	.000
	N	107	107	107	107	107	107	107	107	107
Implementing mesquite bean pods into your feeding program to reduce strain on your animals, pastures and profit margins especially in a drought	Pearson Correlation	.275	.193	.182	.944	.987	1	.777	.728	.828
	Sig. (2-tailed)	.004	.046	.060	.000	.000		.000	.000	.000
	N	107	107	107	107	107	107	107	107	107
Could generate revenue by harvesting mature mesquite trees for wood chips to be used in energy production.	Pearson Correlation	.232	.160	.163	.789	.764	.777	1	.914	.919
	Sig. (2-tailed)	.016	.100	.094	.000	.000	.000		.000	.000
	N	107	107	107	107	107	107	107	107	107
Harvesting mesquite trees to improved rangeland on 10-14 year cycles.	Pearson Correlation	.163	.114	.154	.744	.710	.728	.914	1	.900
	Sig. (2-tailed)	.093	.240	.113	.000	.000	.000	.000		.000
	N	107	107	107	107	107	107	107	107	107
You could generate revenue stream, improve rangeland and have a source of supplemental feeding sourced from the exact same plot of land using mesquite.	Pearson Correlation	.229	.180	.170	.841	.808	.828	.919	.900	1
	Sig. (2-tailed)	.017	.063	.081	.000	.000	.000	.000	.000	
	N	107	107	107	107	107	107	107	107	107

Table 4.5 Correlation table of Perceived Knowledge and Utilization if given more information about mesquite.

Correlations

		3. How familiar are you with biofuels as a source of energy? (Check one)	4. How familiar are you with native biomass as a source of energy? (Check one)	5. How familiar are you with wood based bio-energy as a source of energy? (Check one)	You could have a supplemental source of feed produced on site for livestock and/or wildlife populations.	Adding a supplemental regiment of mesquite bean pods into your feeding program could extend the feed rations and lower feed costs in a drought	Implementing mesquite bean pods into your feeding program to reduce strain on your animals, pastures and profit margins especially in drought	Could generate revenue by harvesting mature mesquite trees for wood chips to be used in energy production.	Harvesting mesquite trees to improved rangeland on 10-14 year cycles.	You could generate revenue stream, improve rangeland and have a source of supplemental feeding sourced from the exact same plot of land using mesquite.
3. How familiar are you with biofuels as a source of energy? (Check one)	Pearson Correlation	1	.710	.560	.241	.251	.261	.225	.165	.205
	Sig. (2-tailed)		.000	.000	.012	.009	.007	.020	.089	.034
	N	107	107	107	107	107	107	107	107	107
4. How familiar are you with native biomass as a source of energy? (Check one)	Pearson Correlation	.710	1	.804	.162	.174	.174	.145	.140	.123
	Sig. (2-tailed)	.000		.000	.095	.074	.073	.137	.150	.207
	N	107	107	107	107	107	107	107	107	107
5. How familiar are you with wood based bio-energy as a source of energy? (Check one)	Pearson Correlation	.560	.804	1	.137	.147	.147	.129	.153	.103
	Sig. (2-tailed)	.000	.000		.159	.132	.130	.185	.116	.293
	N	107	107	107	107	107	107	107	107	107
You could have a supplemental source of feed produced on site for livestock and/or wildlife populations.	Pearson Correlation	.241	.162	.137	1	.953	.954	.860	.810	.882
	Sig. (2-tailed)	.012	.095	.159		.000	.000	.000	.000	.000
	N	107	107	107	107	107	107	107	107	107
Adding a supplemental regiment of mesquite bean pods into your feeding program could extend the feed rations and lower feed costs in a drought	Pearson Correlation	.251	.174	.147	.953	1	.995	.836	.756	.842
	Sig. (2-tailed)	.009	.074	.132	.000		.000	.000	.000	.000
	N	107	107	107	107	107	107	107	107	107
Implementing mesquite bean pods into your feeding program to reduce strain on your animals, pastures and profit margins especially in drought	Pearson Correlation	.261	.174	.147	.954	.995	1	.840	.761	.846
	Sig. (2-tailed)	.007	.073	.130	.000	.000		.000	.000	.000
	N	107	107	107	107	107	107	107	107	107
Could generate revenue by harvesting mature mesquite trees for wood chips to be used in energy production.	Pearson Correlation	.225	.145	.129	.860	.836	.840	1	.921	.945
	Sig. (2-tailed)	.020	.137	.185	.000	.000	.000		.000	.000
	N	107	107	107	107	107	107	107	107	107
Harvesting mesquite trees to improved rangeland on 10-14 year cycles.	Pearson Correlation	.165	.140	.153	.810	.756	.761	.921	1	.908
	Sig. (2-tailed)	.089	.150	.116	.000	.000	.000	.000		.000
	N	107	107	107	107	107	107	107	107	107
You could generate revenue stream, improve rangeland and have a source of supplemental feeding sourced from the exact same plot of land using mesquite.	Pearson Correlation	.205	.123	.103	.882	.842	.846	.945	.908	1
	Sig. (2-tailed)	.034	.207	.293	.000	.000	.000	.000	.000	
	N	107	107	107	107	107	107	107	107	107

CHAPTER V

DISCUSSION AND CONCLUSIONS

Research Question #1: Can Mesquite be a source of biomass feedstock for bio-energy in Texas?

Both biomass and bean pods could be utilized for bio-energy production. Both products can be utilized with current technologies for harvest and production. Wood chips can be produced with any number of cutting and chipping equipment available on the market today. Chemical feedstocks like alcohols and biogas could easily be fermented and produced from the biomass of the mesquite including the bean pods using existent equipment used for biomass corn, sorghum and switchgrass. Systems for electrical energy using wood biomass already exist in Lufkin and Nacogdoches, Texas that use municipal and industrial wood waste to produce clean, renewable bioenergy. In 2008, Texas House Bill 1090 allows the Texas Department of Agriculture to subsidize $20 per ton of bone dry wood used for energy production. The state also gives 1-2 cent credit per KwH given to utility companies for production of renewable energy.

With Europeans interested looking into large scale production, the U.S. government wanting a shift into more renewable energy source and a number of studies from 1970's-present; mesquite finds itself in a unique position again. First being for thousands of years a boon to native peoples and settlers alike then as the woody invasion of grasslands, mesquite becomes a noxious invader. Now again there is a chance to change again to a boon for the economy of Texas either for domestic production or exportation. Information

from studies by Felker, Park and Smith show utilizing mesquite 20 to 50 miles of harvest site would be economical with mesquite wood chips around 2mm in size at 20% moisture content producing 6584 BTU/lb. (Smith, 1982) using steam generation equipment those wood chips produce 4.5 KwH/kg (Park, 2012) at a cost between $31- 84 per ton delivered to a power plant (Park, 2012). In India a study of farmers showed that 35-60% of diesel could be replaced by bio-gas from native biomass in the generation of 20-30 Kw of electricity using 14-15 kg of wood per hour (Rangnekar, 1991). If pods were used in the production of ethanol, the most efficient portion would be the exo-mesocarp due to high amounts of sucrose found in a study by Meyer et al. (1982). Ideally, harvest of both wood chips and bean pods would occur on the same site with wood being harvested on a 7 to 14 year rotation and bean pods production starting after the third year of regrowth until the trees were harvested for wood chips.

Research Question #2: Can Mesquite be used in agroforestry production Texas?

In Texas drought is a very limiting factor on vegetation and crop productivity but mesquite is able to produce bean pods, often in the driest years weighed down by the number of bean pods produced. Literature dating to the 1800s note cattle producers in Texas using mesquite pods to feed animal especially in the driest years when mesquite was one of the few green plants on the range . With Texas now being seventh in the nation in dairy production according to the USDA in 2015, a bran made from mesquite could be utilized in dairy production. This is not novel dairy farmers in the Southwest used mesquite bran to replace more costly grains in production prior to World War II. Up to 30% of dairy cow ration could be mesquite bran without effect on milk yield (Sawal et

al 2004). In beef cattle anecdotal evidence from ranchers in Hays County and studies from 1970's-2000's state that cattle performance is not effected when mesquite bean pods and/or biomass does not exceed around 20-25% of the diet. In beef cattle no more than 60% of the animal's diet should be mesquite (beans or biomass) for longer than 60 days without high quality roughages (Hart et al., 2003). Ranchers in Hays County also say cattle, goats and horses enjoy leaves, shoots and bean pods all at different stages of plant maturity but caution after a rain the ripe bean pods can cause colic or bloat. Baptisa and Launchbaugh (2001) suggest breeding programs for range livestock in arid and semi-arid regions where mesquite is a dominate species to better adapt the animals to detoxify and utilize biomass of mesquite especially in late summer as herbaceous plants begin to decline. Stocking sheep and cattle together on lands with a high percentage of mesquite coverage is suggested to reduce cattle losses attributed to mesquite because sheep are able to consume more mesquite without adverse effects (Hart et al., 2003). Mesquite biomass and bean pods are also a significant portion of wildlife diets, bean pods are considered mast crops for many native species and the leaves and shoots provide browse even in the driest years. Protein and caloric values of native legumes like mesquite (*Prosopis spp*.) and huisache (*Acacia spp.*) are part of the equation when looking at antler development in prized South Texas bucks that so many hunters covet. In aquaculture production studies by Zuanon et al. 2006, Guimaraes et al. 2008, Sena et al. 2012 and Kitagima & Fracalossi 2011 show no difference overall in performance of channel catfish and nile tilapia with using mesquite bran up to 20% of dry matter of feed.

For human consumption, flours and brans made with ripe mesquite bean pods have been utilized for thousands of years. For thousands of years, people living in arid

and semi-arid regions of North and South America, Asia and Africa consumed *Prosopis* pods in their diet. Immature pods can be boiled and eaten like any other bean or pea, both flour and pods can be a source of dietary fiber and protein as demand for food rises across the globe. A number of studies look to native legumes as cheap source of nutrition for humans across the globe as population continues to rise. Mesquite flour has been named a "super food" by a number of producers based in Texas, Arizona and California. Mesquite flour has gained traction in modern diets for being organic, low glycemic and gluten free. Meyer et al (1982) suggested the endocarp due to high fiber content is best for inclusion in breads and cotyledon as protein supplement in both human and animal nutrition. A quick internet search for mesquite flour will show: currently the majority mesquite pods used for human consumption are advertised as imported from Chile, Peru and Argentina, leaving the domestic market nearly untapped for Texas mesquite.

Mesquite bean pods have protein content equivalent to soybeans, good source of many minerals in the diet and lack only sulfur containing amino acids, which are easy to supplement, according to Zolfaghari & Harden (1982).Most studies suggest the anti-nutritional factors can be autoclaved, heated or chemical removed or are a non-factor when mesquite pods or biomass does not exceed certain levels in the diet of animal species of interest. Richardson et al. (1982) concluded ground biomass of mesquite (P. *glandulosa*) is suitable treated or untreated with ozone or sulfur dioxide for inclusion in rations of ruminants up 40% without any effect on average daily gain. Problems being to emerge with more than 20-60% of the diet being mesquite pods and/or biomass for livestock species, wildlife has not be studied but it can be inferred it is nearly the same holds true for undomesticated ruminates with perhaps slightly higher tolerance level of mesquite in the

diet especially in species and subspecies that co-evolved with mesquites. Internet retail outlets sell mesquite flour for about $7-11 per pound which could make mesquite bean pods a profitable crop in both human and animal foods. Nutritionally mesquite can compete with alfalfa but not economically on a feedlot but for large ranches looking for better grass and forage production; harvest of mesquite could replace alfalfa especially because spraying and clearing mesquite requires removal of livestock from pastures for a period of time (Tock, 1982).

Harvest of mesquite requires no unique or novel equipment, only matching of equipment to product produced. Felker, 1999 describes a modified combine used to harvest small diameter mesquite. Roger, 2000 found producers of timber and cooking wood from mesquite harvest use portable band saws. In harvest of bean pods, a pecan harvester that shakes trees certainly could be utilized to collect ripe bean pods.

Research Question #3 Do landowners in Guadalupe and Hays County perceive value in mesquite as a crop or biomass feedstock?

Landowners in Guadalupe County perceived less value in mesquite than landowners in Hays County but both groups were overall neutral in converting resources spent on eradication to a harvest program. This comes as no surprise when looking a perceived knowledge of bio-energy and biomass feedstocks. Joshi (2011),Joshi (2013) and Gruchy, (2012) found in a similar studies that harvesting biomass for energy is not common in the South, so it comes as no surprise that landowners are not aware of the opportunity. This study finds the same; landowners are unaware of native biomass feedstocks and wood based bio-energy, hence likelihood of the utilization of mesquite among landowners is neutral at best.

Over $100,000 was spent per year, an average around $900 per landowner in both counties on the removal of woody vegetation if some of that money could be recovered through selling the cleared vegetation some landowners would begin to show interest. This study found that: landowners with a higher percentage of woody vegetation on their property might be more likely to utilize mesquite than those with a lower percentage of woody vegetation coverage based on a small frame size. This could be a starting point for the marketability of mesquite and the beginnings of more awareness of possibilities other than chemical control and/or burning mesquite. Development of a short course or workshop through a university or extension office targeting landowners with a high density of woody vegetation on their property or interested in improving rangeland and wildlife habitat would be ideal to increase awareness of opportunities other than removal for mesquite to landowners. This educational outlet would ideally offer information and literature on bio-energy, native bio-mass feedstocks and wood based bio-energy to landowners who are willing to allocate resources to the clearing and removal of mesquite.

Summary and Conclusions

View and perceptions of landowners about mesquite, which is often seen only as a vile pest to be eradicated, has limited its value on the agricultural market. It will never take over as a primary feed or energy source but can be added to animal diets. However, it can be utilized in small and lifestyle farm and ranch operations as supplemental feed and be a local alternative to fossil fuels. Early humans utilized mesquite as a plant with multiple uses, but since settlement times the plant utility has been disregarded. Many industries, current and historical, have made use of any portion of the mesquite tree and its biology allows these industries to rely less on external inputs and focus on a native

crop that only requires space and time to mature and become useful. Mesquite requires no irrigation or artificial chemical inputs for growth, though will respond if one was to include such in a production model. The plant is adapted to the majority of climates in Texas; this could be a boon to any number of industries interested in becoming more sustainable in the future. Many who have researched mesquite and similar resources have found the only limit to production is exposure to the market place. If farmers and ranchers knew what they were clearing was of more value than just firewood and charcoal on occasion, producers of animal feed and energy would have a valuable, sustainable resource to market, creating revenue and jobs into rural economies.

Mesquite is an available and underutilized resource in Texas. Lack of a market limits chance of mainstream utilization. Landowners and agriculture producers are unaware of the attributes of mesquite and not aware of bio-energy in general. Mesquite has been long labeled a pest, noxious weed (Wright, 1998) and an "extravagant" water user (Wan & Sosebee, 1991), these stigmas about the water usage and toxic effects have long promoted the eradication of a once valued resource. With the impending foreign interests into mesquite as a possible energy source it is time domestic energy producers capture the market before it reaches critical mass. Along with the energy market, harvest and growth cycles of the biomass can be utilized in other ways. Bean pods can easily be milled into a component of animal feeds, used to produce ethanol and bio-gas, the wood used to produce methanol and mesquite farm can be heavily grazed and/or leased for hunting during the regeneration cycle of above ground biomass. The Food and Drug Administration has not reviewed mesquite, so for human consumption it is considered generally safe but any claims to diagnosis or treatment of disease are unfounded by

accepted medical science. In animal consumption the United States Department of Agriculture lists all species of *Prosopis* genus as a forage for livestock.

Possibility for future study and research of the utilization of mesquite is limitless from food to energy. More research is beneficial to any field of study but in the case of mesquite more research is essential to overcome negative conclusions and information available to landowners currently. Mesquite is not the only organism that utilization over eradication could be possible, a number are mentioned throughout this thesis including Huisache (*Acacia spp.*), horse apple (suggested by local ranchers in Hays County), Ashe juniper and Salt Cedar (*Tamarix spp.*). Not only woody plants but herbaceous plants and some animals, invasive and unwanted, organisms like zebra mussels, feral hogs and bastard cabbage could be utilized the same way as mesquite.

For mesquite, a model vertically integrated farm could be developed with woody vegetation removed for pastures chipped, stored and used for electrical production on a scheduled program. During the regrowth period mesquite beans and biomass could be used to as supplemental feed to livestock of the ranch while the unutilized and re-growing portion of the property could be left for wildlife habitat, possibly leased for recreational use for additional income for the landowner.

APPENDIX SECTION

Appendix A: Survey Instrument

Mesquite Utilization,Land Owner Interest Assessment Survey

Welcome to Mesquite Utilization,Land Owner Interest Assessment Survey.

Your responses will be kept confidential, used only for scientific inquiry, and never sold for marketing or solicitation purposes.

Instructions:

1. Read item carefully and respond accordingly.

2. Be sure to indicate the gift card you would like at the end of the survey.

3. Survey must be completed by

Thank You for your time and participation!

Mesquite Utilization,Land Owner Interest Assessment Survey.

Property Information

* 1. Please list the property(s) you own or manage larger than 7 acres in _____ County Texas. If more than 3 please list the 3 largest properties.

	Size (in acres)	Do you own, manage or both
Property 1		
Property 2		
Property 3		

* 2. Do any of the properties listed above generate income/revenue for you or your business?

Mesquite Utilization,Land Owner Interest Assessment Survey

Revenue and Income from property.

Please approximate the income generated for you or your business from the properties listed previously.

* 3. Approximate Annual Revenue (if none put 0)

	$
Property 1	
Property 2	
Property 3	

* 4. What percentage of your income or your business' is generated from this/these property(s)?

	Percent
Property 1	
Property 2	
Property 3	

Mesquite Utilization,Land Owner Interest Assessment Survey.

Land Use

Please describe the current use of your property.

5. Which of the following best describes the current usage of Property 1?

- [ ] Farming (crops, hay, orchards, etc.)
- [ ] Ranching
- [ ] Leasing (Agricultural use)
- [ ] Leasing (Mineral/Timber) Ex oil/gas
- [ ] Leasing (Hunting or Recreation)

Other (please specify)

* 6. Do you own/manage another property larger than 7 acres in ____ County, Texas?

Mesquite Utilization,Land Owner Interest Assessment Survey

Land Use Continued

Please describe the current use of your property.

7. Which of the following best describes the current usage of Property 2?

- [ ] Farming (crops, hay, orchards, etc.)
- [ ] Ranching
- [ ] Leasing (Agricultural use)
- [ ] Leasing (Mineral/Timber) Ex oil/gas
- [ ] Leasing (Hunting or Recreation)

Other (please specify)

* 8. Do you own/manage another property larger than 7 acres in _____ County, Texas?

Mesquite Utilization,Land Owner Interest Assessment Survey

Land Use Continued

Please describe the current use of your property.

9. Which of the following best describes the current usage of Property 3?

- [ ] Farming (crops, hay, orchards, etc.)
- [ ] Ranching
- [ ] Leasing (Agricultural use)
- [ ] Leasing (Mineral/Timber) Ex oil/gas
- [ ] Leasing (Hunting or Recreation)

Other (please specify)

Mesquite Utilization,Land Owner Interest Assessment Survey

Goals and Purposes of Property

Please select one or more of the following that best describes the goals and/or purpose of the property(s) you own or manage in _____ County.

10. In general what are your goals for Property 1? (Check all that apply)

- [ ] Recreational Use
(Ex.hunting,bird watching, ATV/4x4, Trail Riding,etc.)

- [ ] Agricultural Use
(yourself or leased to others)

- [ ] Tax purposes
or
Investment

- [ ] Dream home

Other (please specify)

* 11. Do you own/manage another property larger than 7 acres in_____ County, Texas?

Mesquite Utilization,Land Owner Interest Assessment Survey

Goals and Purpose Continued

Please select one or more of the following that best describes the goals and/or purpose of the property you own or manage in _____ County.

12. In general what are your goals for Property 2? (Check all that apply)

- [ ] Recreational Use
(Ex.hunting,bird watching, ATV/4x4, Trail Riding,etc.)
- [ ] Agricultural Use
(yourself or leased to others)
- [ ] Tax purposes
or
Investment
- [ ] Dream home

Other (please specify)

* 13. Do you own/manage another property larger than 7 acres in_____ County, Texas?

Mesquite Utilization,Land Owner Interest Assessment Survey

Goals and Purpose Continued

Please select one or more of the following that best describes the goals and/or purpose of the property you own or manage in _____ County.

14. In general what are your goals for Property 3? (Check all that apply)

- [ ] Recreational Use
(Ex.hunting,bird watching, ATV/4x4, Trail Riding,etc.)
- [ ] Agricultural Use
(yourself or leased to others)
- [ ] Tax purposes
or
Investment
- [ ] Dream home

Other (please specify)

Mesquite Utilization,Land Owner Interest Assessment Survey

Vegetation Coverage

Select from the following which best describes the coverage of Woody Vegetation (trees,bushes, shrubs, etc.) for the property(s) you own or manage in _____ County.

* 15. Which best describes the Woody Vegetation coverage on Property 1?

- Less than 10%
  Very little woody vegetation at all
- 10- 30%
  Scattered or some small-mid size thickets dot the property
- 31-50%
  Large thickets with open areas with few scattered trees
- 51-75%
  Property mostly wooded, open space limited with woody vegetation moving into open space.
- More than 75%
  Very little open ground, nearly or completely wooded property

* 16. Do you own/manage another property larger than 7 acres in _____ County, Texas?

Mesquite Utilization,Land Owner Interest Assessment Survey

Vegetation Coverage Continued

Select from the following which best describes the coverage of Woody Vegetation (trees,bushes, shrubs, etc.) for the property(s) you own or manage in _____ County.

* 17. Which best describes the Woody Vegetation coverage on Property 2?

- Less than 10%
  Very little woody vegetation at all
- 10- 30%
  Scattered or some small-mid size thickets dot the property
- 31-50%
  Large thickets with open areas with few scattered trees
- 51-75%
  Property mostly wooded, open space limited with woody vegetation moving into open space.
- More than 75%
  Very little open ground, nearly or completely wooded property

* 18. Do you own/manage another property larger than 7 acres in _____ County, Texas?

Mesquite Utilization,Land Owner Interest Assessment Survey

Vegetation Coverage Continued

Select from the following which best describes the coverage of Woody Vegetation (trees,bushes, shrubs, etc.) for the property(s) you own or manage in _____ County.

19. Which best describes the Woody Vegetation coverage on Property 3?

- ○ Less than 10%

Very little woody vegetation at all

- ○ 10- 30%

Scattered or some small-mid size thickets dot the property

- ○ 31-50%

Large thickets with open areas with few scattered trees

- ○ 51-75%

Property mostly wooded, open space limited with woody vegetation moving into open space.

- ○ More than 75%

Very little open ground, nearly or completely wooded property

Mesquite Utilization,Land Owner Interest Assessment Survey

Woody Vegetation Control and Vegetation Improvement

Please answer the following with an approximate whole dollar amount. Ex. 100

* 20. On an average annual basis how much do you spend on _____ ? (If none put 0)

Control and Removal of woody vegetation on your property(s)

Improving pasture/rangeland?

Mesquite Utilization,Land Owner Interest Assessment Survey

Vegetation Control Methods

* 21. What is your current mesquite control method? (Check all that apply)

- [ ] None
- [ ] Burn
- [ ] Mechanical (ex. cutting, grubbing, etc.)
- [ ] Chemical/Herbicide
- [ ] Other

Other (please specify)

Mesquite Utilization,Land Owner Interest Assessment Survey

Familiarity with Biofuels and Energy

The following statements are designed to evaluate your familiarity with Bioenergy,Feedstocks and Fuels

* 22. Evaluate the following statements.

	Not at all	Heard of it but not too sure what it is	Some familiarity, Read about it in a publication (newspaper, journal, magazine, etc.) or on TV	Very familiar, Looked into it as a business opportunity or for general knowledge.
3. How familiar are you with biofuels as a source of energy? (Check one)	○	○	○	○
4. How familiar are you with native biomass as a source of energy? (Check one)	○	○	○	○
5. How familiar are you with wood based bio-energy as a source of energy? (Check one)	○	○	○	○

Mesquite Utilization,Land Owner Interest Assessment Survey

Likelihood of Utilization of Mesquite.

Click the bubble on the scale to indicate the likelihood/unlikelihood for any of your properties. Click only one bubble for each statement.

* 23. How likely/unlikely are you to:

	Not Likely at all	Unlikely	Neutral	Somewhat Likely	Likely	Very Likely
Preserve rangeland condition?	○	○	○	○	○	○
Improve rangeland condition?	○	○	○	○	○	○
Preserve wildlife habitat?	○	○	○	○	○	○
Improve wildlife habitat?	○	○	○	○	○	○
Explore a new revenue stream for your property?	○	○	○	○	○	○
Explore production of a new crop?	○	○	○	○	○	○
Allow the growth of a native plant for production?	○	○	○	○	○	○
Grow a native plant for production as a part of your operation?	○	○	○	○	○	○
Buy a product using a native plant for use in your operation?	○	○	○	○	○	○
Use a plant that already grows on your land as a new crop?	○	○	○	○	○	○
Produce a new crop if it does not interfere with your current operation?	○	○	○	○	○	○
Produce a new crop that can enhance your current operation?	○	○	○	○	○	○
Utilize a new crop if it could generate a new revenue stream?	○	○	○	○	○	○
Utilize a new crop if it could enhance rangeland?	○	○	○	○	○	○
Harvest instead of eradicate mesquite?	○	○	○	○	○	○

Mesquite Utilization,Land Owner Interest Assessment Survey

Likihood of Utlization continued

Click the bubble on the scale to indicate the likelihood/unlikelihood for any of your properties. Click only one bubble for each statement

* 24. If someone you knew was _____. How likely/unlikely would you do the same?

	Not Likely at all	Unlikely	Neutral	Somewhat Likely	Likely	Very Likely
Allowing mesquite to mature for harvest	○	○	○	○	○	○
Harvesting mesquite bean pods for use in their own operation	○	○	○	○	○	○
Harvesting mesquite bean pods to sell commercially	○	○	○	○	○	○
Generating revenue using mesquite	○	○	○	○	○	○
Offsetting production costs using mesquite	○	○	○	○	○	○
Using mesquite bean pods in the diet of their livestock to cut feeding costs	○	○	○	○	○	○
Adding mesquite beans to feed rations of animals to maintain herd size during drought	○	○	○	○	○	○
Using a product that contains mesquite bean pods in livestock operation	○	○	○	○	○	○
Using a product that contains mesquite bean pods in wildlife operation	○	○	○	○	○	○
Leasing a portion of land for mesquite production	○	○	○	○	○	○
Selling a portion of land for mesquite production	○	○	○	○	○	○
Growing mesquite as bio-energy feedstock	○	○	○	○	○	○
Raising mesquite for landscape and nursery applications	○	○	○	○	○	○

Mesquite Utilization,Land Owner Interest Assessment Survey

Utilization based on Knowledge

Click the bubble on the scale to indicate the likelihood/unlikelihood for any of your properties. Click only one bubble for each statement.

* 25. Given your current understanding of Mesquite. How likely/unlikely you would to be utilize mesquite in your operation if:

	Not Likely at all	Unlikely	Neutral	Somewhat Likely	Likely	Very Likely
You could have a supplemental source of feed produced on site for livestock and/or wildlife populations.	○	○	○	○	○	○
Adding a supplemental regiment of mesquite bean pods into your feeding program could extend the feed rations and lower feed costs during drought	○	○	○	○	○	○
Implementing mesquite bean pods into your feeding program to reduce strain on your animals, pastures and profit margins especially in a drought	○	○	○	○	○	○
Could generate revenue by harvesting mature mesquite trees for wood chips to be used in energy production.	○	○	○	○	○	○
Harvesting mesquite trees to improved rangeland on 10-14 year cycles.	○	○	○	○	○	○
You could generate revenue stream, improve rangeland and have a source of supplemental feeding sourced from the exact same plot of land using mesquite.	○	○	○	○	○	○

Mesquite Utilization,Land Owner Interest Assessment Survey

Utilization based on Knowledge continued

Click the bubble on the scale to indicate the likelihood/unlikelihood for any of your properties. Click only one bubble for each statement.

* 26. If you had more information about Mesquite. How likely/unlikely you would to be utilize mesquite in your operation if:

	Not Likely at all	Unlikely	Neutral	Somewhat Likely	Likely	Very Likely
You could have a supplemental source of feed produced on site for livestock and/or wildlife populations.	○	○	○	○	○	○
Adding a supplemental regiment of mesquite bean pods into your feeding program could extend the feed rations and lower feed costs in a drought	○	○	○	○	○	○
Implementing mesquite bean pods into your feeding program to reduce strain on your animals, pastures and profit margins especially in drought	○	○	○	○	○	○
Could generate revenue by harvesting mature mesquite trees for wood chips to be used in energy production.	○	○	○	○	○	○
Harvesting mesquite trees to improved rangeland on 10-14 year cycles.	○	○	○	○	○	○
You could generate revenue stream, improve rangeland and have a source of supplemental feeding sourced from the exact same plot of land using mesquite.	○	○	○	○	○	○

Mesquite Utilization,Land Owner Interest Assessment Survey

Demographic Information

Please answer the following. All reponses will be kept confidentional and never sold for marketing or solicitation purposes.

* 27. Are you male or female?

- Male
- Female

* 28. What is your age?

- 18 to 24
- 25 to 34
- 35 to 44
- 45 to 54
- 55 to 64
- 65 to 74
- 75 or older

* 29. What is your approximate average household income?

- $0-$24,999
- $25,000-$49,999
- $50,000-$74,999
- $75,000-$99,999
- $100,000-$124,999
- $125,000-$149,999
- $150,000-$174,999
- $175,000-$199,999
- $200,000 and up

* 30. What is the highest level of education you have completed?

* 31. Which race/ethnicity best describes you? (Please choose only one.)

- ○ American Indian or Alaskan Native
- ○ Asian / Pacific Islander
- ○ Black or African American
- ○ Hispanic American
- ○ White / Caucasian
- ○ Multiple ethnicity / Other (please specify)

Mesquite Utilization,Land Owner Interest Assessment Survey

Demograhic Information continued

Please answer the following. All anwers will be kept confidentional and never sold for marketing or solicitation purposes.

* 32. Is Agriculture your primary field of experience? (Please select one)

Mesquite Utilization,Land Owner Interest Assessment Survey

Experience (Non-Ag)

33. What is your field of experience?

* 34. Do you have experience in Agriculture?

35. If yes. Years of Agriculture Experience.

- 0-5 years
- 6-10 years
- 11-20 years
- More than 20 years

Mesquite Utilization,Land Owner Interest Assessment Survey

Experience and Off the Farm Income

* 36. Years of Agriculture Experience.

- ○ 0-5 years
- ○ 6-10 years
- ○ 11-20 years
- ○ More than 20 years

* 37. Do you have off the farm income?

38. If yes. What percentage of your income comes from off the farm employment?

Mesquite Utilization,Land Owner Interest Assessment Survey

Retirement Status

* 39. Are you retired?

- Yes
- No

40. If yes. Do you collect a Pension,Retirement, Social Security etc.?

41. If yes. What percentage of your income is collect from a Pension, Retirement, Social Security, etc. ?

Appendix B: Example of Mailing sent to Landowners

Texas State University

Agriculture Department

ATTN: Charles Hoitt

601 University Drive

San Marcos, TX 78666

<Landowner>

Address Line

City, State Zip Code

Greetings <Landowner>,

My name is Charles Hoitt. I am an Agricultural Education Graduate Student at Texas State University. As part of my thesis completion requirements, I am conducting a study on the utilization of mesquite for bio-energy feedstock and animal feed supplementation. Because you are a land owner or manager, you have been selected to participate in this research; your input is essential to the completion of this project. Your password for the electronic survey along with instructions on how to access the survey are included with this letter. The survey that should take no more than 8 minutes to complete and should be completed by . To thank you for your participation in the survey you will be entered into a drawing for a $100 gift card of to your choice of Cabela's, Home Depot, Tractor Supply or Wal-Mart. Your answers and information will be kept confidential and will be used only in this study and never sold for marketing purposes.

Should you have any questions about this research please contact me through telephone at or by email at. This project complies with IRB policy at Texas State University

Again, thank you very much for your time and insight!

Sincerely,

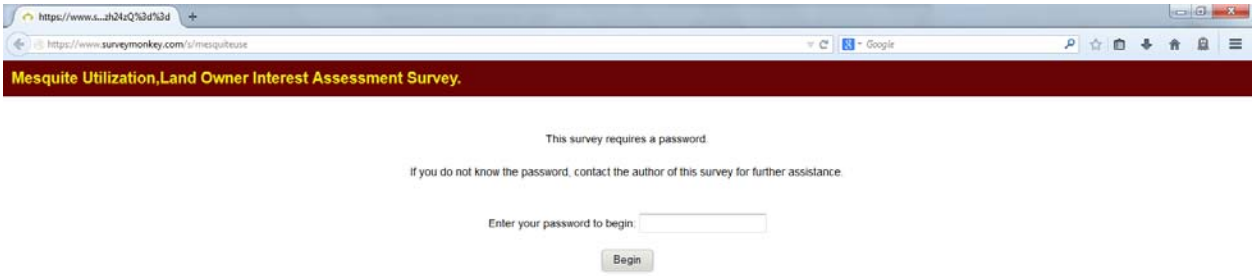
Charles Hoitt

Agricultural Education Graduate Student

Instructions for logging on to take the survey

1. Type the Website URL in to your internet browser's address bar.

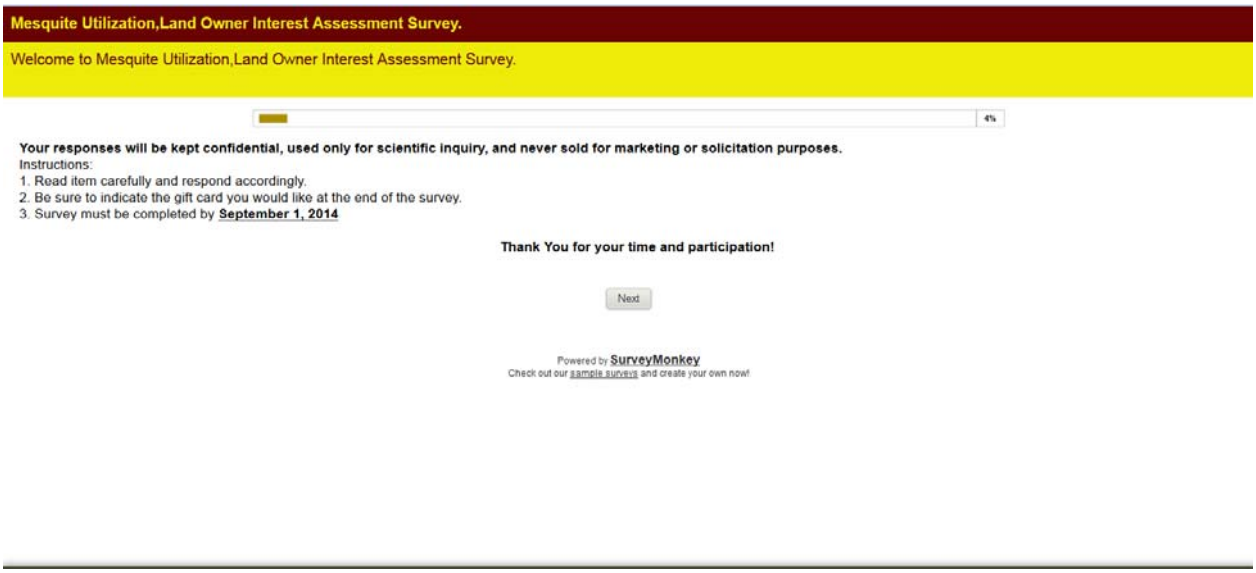
2. You should come to a screen that looks like the image below:



3. Type your password into the box

4. Click "Begin" to start the survey

5. You should come to a screen that looks like:



This is the survey. All you need to do now is navigate the questions/statements, this should take you no longer than 8 minutes to complete.

DO NOT SEARCH FOR THE SURVEY IN GOOGLE, BING, ETC. You have to input the web address into the URL bar as shown in the pictures.

Should you need further assistance or if you are interested in the results of this study.

Contact me through email at

ch1675@txstate.edu

Thank You for your participation and time.

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