STAKEHOLDER PERCEPTIONS ON BETTER MANAGEMENT OF CROSS-TIMBERS FOREST RESOURCES

By

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STAKEHOLDER PERCEPTIONS ON BETTER

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RESOURCES

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Abstract: The Cross-timbers ecoregion represents the broad ecotone between the Eastern Deciduous Forest and the Tallgrass Prairie. The region is threatened by both natural and anthropogenic factors including urban development, increasing climate variability, and the encroachment of eastern redcedar (*Juniperus virginiana*). In particular, the exclusion of fire has dramatically changed the composition and structure of the Cross-timbers forests, which historically experienced multiple fires per decade. Active management practices such as prescribed fire, timber thinning, and fuels reduction are largely absent in the region. These management practices are further limited by a lack of a forest resource market. This study utilized a mixed-mode data collection method, which involved focus group meetings as well as an online version of the survey to determine how stakeholders perceived both active management and market opportunities within the Cross-timbers. The requisite data were analyzed using the strengths, weaknesses, opportunities, and threats (SWOT)-Analytic Network Process (ANP) framework. The results suggested that the presence of healthy and resilient forests and the opportunities associated with increased revenue could be the driving forces in active Cross-timbers management. In addition, the availability of a variety of natural resources and the restoration of ecosystem services could be the key to developing a sustainable market within the Cross-timbers. However, stakeholders across-the-board revealed that the financial burden of management and the risk of uncontrolled fire were the major obstacles in these efforts. Further, uncertain markets, lack of enthusiasm from manufacturers, and low quality resources may be what currently hinder the market potential of the Cross-timbers.

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CHAPTER I

INTRODUCTION

The Cross-timbers ecoregion is a mosaic of oak forest, savanna, and prairie historically covering approximately 4.8 million hectares, located just north of Denton, Texas, up through central Oklahoma, and into southeastern Kansas (Küchler 1965, Clark and Hallgren 2003). Prior to European settlement, the Cross-timbers were frequently burned by Native Americans, creating a more open savanna-like structure. However, changing attitudes towards fire and lack of desire to actively manage the landscape have resulted in the suppression of fire, which has led to the densification of oak savannas into closed-canopy forests (DeSantis and Hallgren 2011), particularly through the increase of eastern redcedar (*Juniperus virginiana*) and mesic hardwoods (Hoff et al. 2018b). These structural changes have proliferated the risk of wildfire through increased fuel loads (Stambaugh et al. 2014, Hoff et al. 2018a), have suppressed the herbaceous layer, and reduced wildlife habitat and grazing opportunities (Engle et al. 2006). In addition to wildfire, the region is threatened by a variety of both natural and anthropogenic factors including population pressures, land use change, and climate variability (Karki and Hallgren 2015).

Fortunately, reintroducing fire and other forms of active management such as herbicide use and timber thinning into the landscape can help restore the Cross-timbers forests to their historical structure and allow for sustainable use of their resources (Engle et al. 2006, Allen and Palmer 2011, Hallgren et al. 2012). In addition, several other opportunities present themselves with active management in the region. For example, healthy and resilient forests, improved wildlife habitat, reduced risk of wildfire, and improved aesthetics are all benefits that can come with active management (Hallgren et al. 2012, Stambaugh et al. 2014). Further, attracting investment into the region, financial assistance from federal/state agencies, seasonal job creation, and increased revenue are all additional opportunities that may result from employing active management (Dillard et al. 2006, Porter et al. 2006). However, the threat of uncontrolled fire, the financial burden of management, a limited market, and liability and health hazards may deter these efforts (Elmore et al. 2009b).

While active management using prescribed fire, thinning, and herbicides can help restore the open structure and species composition of the Cross-timbers forest resources, these activities come at a cost to landowners (Drake and Todd 2002). These costs not only require monetary inputs but additional investments in labor and capital resources as well (Mayer and Tikka 2006). The Cross-timbers forests are dominated by relatively short stature and poor quality (~15m tall) post oak (*Quercus stellata*) and blackjack oak (*Q. marilandica*), which suffer from insufficient valuation, as there are no traditional forestry markets for these slower growing and relatively small diameter tree species (Johnson and Risser 1974). In addition, poor quality soils, frequent drought, and a steep rocky terrain in places have further limited productivity and access to many of these forest resources in the Cross-timbers (Hallgren et al. 2012). With the forest resources of the Cross-timbers being of poor quality and not suitable for commercial forestry (Johnson and Risser 1975, Therrell and Stahle 1998), landowners may not be able to justify the cost of employing an active management strategy (Gold et al. 2005).

Despite these limitations, the Cross-timbers do possess a variety of additional resources that can be used to market several non-commodity benefits and specialty commodities in the region (Aguilar et al. 2014). While traditional forest commodity resources have a publicly available market price (Gold et al. 2004), non-commodity benefits and specialty commodities, such as the utilization of carbon sequestration through the trading of carbon credits, are yet to be explored on a commercial scale in the region (Kumar 2005). Therefore, a sustainable approach to actively managing the Cross-timbers could hinge on the exploration and development of the non-traditional market opportunities in the region.

Marketable resources available within the Cross-timbers include the utilization of eastern redcedar for uses such as particleboard, mulch, horse and dog bedding, oil, and furniture (Drake and Todd 2002), biomass production, carbon sequestration and carbon trading, and hunting/recreation (Dillard et al. 2006, Hallgren et al. 2012). Further, there is growing support for the uses and marketing of non-traditional and specialty commodities to stimulate economic activity and market-driven forest management in a region (Gold et al. 2004, Dawson 2010). Market-driven forest management encourages active management practices while offering landowners a meaningful financial return for investing in these efforts (Ebeling and Yasué 2009). In addition, market development can present several opportunities within the Cross-timbers forest region. Forage for cattle, the restoration of ecosystem services, reduced fuel loads, and support to related industries all provide a variety of benefits to the stewards of the Cross-timbers following market establishment (Engle et al. 2006, Craige et al. 2016, Hoff et al. 2018b). However, policy and market uncertainty, seemingly higher transportation costs, and lack of enthusiasm from manufacturers may present drawbacks to market development (Gold et al. 2004, Craige et al. 2016).

Thus far, limited research has been conducted to identify the social acceptance and opinions regarding the active management of these resources and the economic potential of a natural resource market in the Cross-timbers (Ramli et al. 2017). Most fundamentally, I am unaware of the current perception of landowners and other stakeholders regarding the aforementioned opportunities and drawbacks of actively managing the Cross-timbers and establishing such markets in the region. Consequently, my research aimed to adopt the strengths, weaknesses, opportunities, and threats (SWOT)-Analytic Network Process (ANP) approach to fill the knowledge gap on these issues.

The following thesis provides insights to better understand the perceptions of these stakeholders on active management and market establishment within the forests of the Cross-timbers ecoregion. The subsequent chapters of this thesis are organized as follows: chapter II discusses stakeholders’ opinions on adopting active management practices in the region, chapter III explores how similar stakeholders perceive market opportunities within the Cross-timbers, and finally, chapter IV summarizes the overall findings of my work.

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CHAPTER II

PERCEPTIONS REGARDING ACTIVE MANAGEMENT OF THE CROSS-TIMBERS FOREST RESOURCES OF OKLAHOMA, TEXAS, AND KANSAS: A SWOT-ANP ANALYSIS

ABSTRACT

The Cross-timbers ecoregion, which stretches from north-central Texas, through central Oklahoma, and up into southern Kansas, represents the broad ecotone between the eastern deciduous forest and the grasslands of the southern Great Plains. The region is threatened by both natural and anthropogenic factors including climate variability, eastern redcedar (*Juniperus virginiana*) encroachment, and urbanization. In particular, fire exclusion has dramatically changed the structure and composition of the Cross-timbers forests, which historically experienced multiple fires per decade. Active management practices such as prescribed fire, timber thinning, and fuels reduction are largely absent in the Cross-timbers forested ecosystems. This study utilized a mixed-mode data collection method, which involved focus group meetings as well as an online version of the survey, to determine how stakeholders perceive active management in the Cross-timbers forests. The requisite data were analyzed using the strengths, weaknesses, opportunities, and threats (SWOT)-Analytic Network Process (ANP) framework. The results suggested that presence of healthy and resilient forests and the opportunities associated with increased revenue could be the driving forces in active Cross-timbers management. However, financial burden and uncontrolled fire were recognized as the major obstacles in these efforts. Tailoring appropriate outreach programs can help traditional and non-traditional stakeholders in identifying appropriate management solutions in the Cross-timbers.

Keywords: SWOT-ANP, Cross-timbers, resource management, stakeholder perceptions

1. INTRODUCTION

The Cross-timbers ecoregion is a mosaic of oak forest, savanna, and prairie historically occupying approximately 4.8 million hectares, from just north of Denton, Texas, through central Oklahoma, and up into southern Kansas (Küchler 1965, Clark and Hallgren 2003). The forested areas were characterized by a steep rocky terrain and poor soils dominated by relatively short (<15 m tall) post oak (*Quercus stellata*) and blackjack oak (*Q. marilandica*) and therefore these forests were often overlooked by settlers for agricultural activities. Consequently, the Cross-timbers may contain some of the largest tracts of old growth forests in the eastern United States (Therrell and Stahle 1998). Prior to European settlement, the Cross-timbers were frequently burned by Native Americans. However, changing attitudes towards fire and lack of desire to actively manage the landscape has resulted in the exclusion of fire and densification of these oak savannas and other forests (DeSantis and Hallgren 2011, Hoff et al. 2018a)

In addition to fire exclusion, the region is threatened by both natural and anthropogenic factors including urban development, increasing climate variability, and the encroachment of eastern redcedar (*Juniperus virginiana*) (Karki and Hallgren 2015, Hoff et al. 2018b). The change in historic fire regimes has dramatically altered the structure and composition of the Cross-timbers forested ecosystems, which previously experienced multiple fires per decade (Hallgren et al. 2012, Toledo et al. 2013). Hoff et al. (2018a) recently documented that Cross-timbers forests are undergoing densification due to increased post oak basal area development, encroachment by eastern redcedar, and mesophication due to the proliferation of fire-intolerant hardwood trees such as hackberries (*Celtis spp*.) and Elm (*Ulmus spp*.). Densification of the Cross-timbers forest suppresses the herbaceous layer and reduces wildlife habitat and grazing opportunities (Engle et al. 2006). In addition, the introduction of the highly flammable eastern redcedar increases the risk of wildfire (Hoff et al. 2018b). Furthermore, fragmentation of the Cross-timbers further decreases the intensity and frequency of fires needed to decrease redcedar encroachment (Briggs et al. 2002). Reintroducing fire and other forms of active management such as herbicide use into the landscape can help restore the Cross-timbers forests to their historical structure and allow for sustainable use of their resources (Engle et al. 2006, Allen and Palmer 2011, Hallgren et al. 2012).

Currently, the Cross-timbers forests are faced with a more hands-off management approach. This may be attributed to the amount of poor quality, non-commercial timber resources and limited markets (Therrell and Stahle 1998, Johnson et al. 2010). The trees of the Cross-timbers are of low value and often described as densely packed and gnarled (Hoagland et al. 1999). However, despite low-quality timber, the Cross-timbers forests provide ecosystem services, including but not limited to, recreation, carbon sequestration and storage, water supply, and wildlife resources (Dillard et al. 2006, Hallgren et al. 2012). Since the Cross-timbers generally are not commercially viable timber sources, sustaining these ecosystem services can serve as a primary objective in forest management (Johnson et al. 2010).

Several research efforts have examined the approximate mix of management practices that can help revive the condition of the Cross-timbers, particularly how to effectively manage for both forest and grassland resources. For example, Engle et al. (1991) studied the effects of two herbicides (tebuthiuron and triclopyr) on understory vegetation and found that grass production greatly increased following the application of tebuthiuron, and forbs and woody browse increased with triclopyr application. In a similar study, Bernardo et al. (1992) found that land managed primarily for cattle production benefits most by utilizing herbicides such as tebuthiuron that promote grass production. Land under multiple use objectives (e.g. cattle (*Bos taurus*) and white-tailed deer (*Odocoileus virginianus*) management), however, is best managed by two different herbicide treatments along with prescribed fire. In a later study, Engle et al. (2006) found that combination of herbicide and prescribed fire can reduce hardwood overstory and re-establish herbaceous understory.

Likewise, research efforts aimed to understand the management of important woody vegetation has also been conducted in the Cross-timbers. In particular, Burton et al. (2010) studied fire effects on forest composition and structure in the eastern Cross-timbers. They found that two low-intensity winter burns per decade reduced mesophytic shade and fire-intolerant species and had no effect on oak saplings. These results suggest that by reintroducing fire into the landscape, the mesophication of the Cross-timbers forests may be reversed and allow for recruitment of oaks into the forest canopy by reducing competition. In a similar study, DeSantis and Hallgren (2011) studied how fire affects oak regeneration in the Cross-timbers. Consistent with Burton et al. (2010), the authors determined that regeneration of post oak and blackjack oak was best facilitated by low-intensity, dormant season burns.

While these efforts help better understand the ecological implications of management of Cross-timbers forests, little has been done to understand what the stewards of Cross-timbers woodlands and prairies— private landowners—think about those prescriptions, and more importantly, whether or not they would engage in these activities. To this end, Elmore et al. (2009a) designed a survey to understand public attitudes and perceptions toward fire and the associated encroachment of eastern redcedar in Oklahoma. The survey results suggested that while the majority of respondents were in support of prescribed fire, they were also concerned about liability issues. Likewise, Twidwell et al. (2013) analyzed how prescribed burn cooperatives have helped the general public overcome their traditional concerns related to prescribed burning in the Great Plains.

While these studies included some human insights into active land management research, no studies have directly documented landowner interest in the active management of the Cross-timbers or lack thereof. With nearly 90% of forested land in the South Central United States privately owned, landowners are essential stakeholders in implementing active forest management practices (Mullin and O'Brien 2011). Likewise, opinions of other stakeholders such as research scientists, government agency professionals, extension agents, and consulting foresters, which also provide important insights on the sustainability of these practices, are not documented. Therefore, I adopted the strengths, weaknesses, opportunities, and threats (SWOT)-Analytic Network Process (ANP) approach to fill the knowledge gap on these issues in the Cross-timbers.

2. METHODOLOGY

2.1 SWOT-ANP

Perception analysis has been identified as a useful tool in resource management, as it can reveal whether stakeholders have different opinions or have consensus concerning a given natural resource issue. This information can not only help engage extension and outreach efforts but also generate new research ideas. A widely adopted approach in natural resource management is strengths, weaknesses, opportunities, and threats (SWOT) methodology, which is used as an aid in decision-making analysis and allows one to determine the internal and external factors of a particular environment (Yüksel and Dagdeviren 2007). As a structural model, SWOT is useful for organizational strategy formulation. However, it is a qualitative social science tool and therefore cannot obtain quantifiable matrices that could be used to compare all four attributes (Pickton and Wright 1998). In order to determine the quantitative values of SWOT attributes, the Analytic Hierarchy Process (AHP) or Analytical Network Process (ANP) is the recommended procedure (Saaty 2006).

While AHP is a commonly used tool for determining the quantitative values for SWOT analysis, it operates on the assumption that elements function independently of one another in a hierarchical structure (Saaty 2006, Catron et al. 2013). This can be a stringent assumption to meet, particularly when attributes under consideration represent a convoluted situation. Instead, the Analytical Network Process (ANP) is well suited to analyze dependencies in decision problems that involve such complexities (Yüksel and Dagdeviren 2007). ANP has a feedback structure resembles an interdependent network where elements can be connected to one another (Saaty and Vargas 2012, Shahabi et al. 2014). Since active management of the Cross-timbers, with such varying stakeholder objectives and opinions, is itself a convoluted issue involving many complex elements, SWOT-ANP is deemed the better approach for this study.

The ANP, though frequently used for business management applications (Feglar et al. 2006, Mu 2006, Lin et al. 2009), is still an emerging methodology in natural resource management and only a handful of the studies have used it. For example, Catron et al. (2013) used SWOT-ANP to examine the forest-based bioenergy industry in Kentucky, USA while Dağdeviren and Eraslan (2008) utilized this model to determine strategic energy policies in Turkey. Wolfslehner et al. (2005) utilized both AHP and ANP to evaluate several strategic management strategies for Sustainable Forest Management in Europe. They reported that while the top strategy selected by stakeholders was the same when calculated with AHP and ANP, the ANP was better suited for strategy selection because it allowed for differences in priority values to become more apparent. Building on the theoretical foundation of SWOT-ANP, I aimed to understand how stakeholders perceive the implementation of active management in the Cross-timbers. This understanding will contribute additional insights to better engage stakeholders on how to best manage the forests in the Cross-timbers ecoregion.

2.2 Data Collection

A group of four experts familiar with the resources of the Cross-timbers was involved in a focus group to create a list of initial attributes. This guided discussion was directed toward determining a comprehensive list of SWOT factors to be involved in further discussion and review by an additional four experts. Following these meetings, the attributes were narrowed down to four factors in each SWOT category. The detailed outline of SWOT factors is described in table 2.1. A survey was then developed and administered to a variety of stakeholders, which included landowners, industry professionals, academics, federal/state agency professionals, and employees of Non-Governmental Organizations (NGOs) located in the Cross-timbers region of Kansas, Oklahoma, and Texas. A mixed mode method was utilized for data collection including in-person meetings and online survey administration (Dillman et al. 2014). These respondents represent a motivated group of volunteers, as data collection took place on-site at four meetings within the Cross-timbers ecoregion of Oklahoma and Kansas. In addition, the same survey was designed in the web-based Qualtrics platform and was distributed among additional stakeholders within the Cross-timber regions of all three states. Of note, a detailed description of Cross-timbers ecoregion as well as some potential active management activities, which included, but not limited to, prescribed burning, herbicide use thinning, and implementation of Best Management Practices (BMPs) were provided to reduce the cognitive burden of the respondents. The total number of responses for the first survey was seventy-five with twenty-six from government agencies, twenty-three landowners, eleven academics, six industry, and nine NGO/other. The stakeholders revealed their perceived priorities for the strengths, weaknesses, opportunities, and threats (SWOT) associated with active management in the Cross-timbers forests. Following the protocols used in previous research (e.g. Catron et al. (2013)), participants were asked to make several pairwise comparisons between the identified SWOT factors using a scale suggested by Saaty (1977). The scale ranges from equal importance (participant assigns a numerical value of 1) to extreme importance (participant assigns a numerical value of 9) of one element over another. Figure 2.1 provides an example of pairwise comparison from survey one for the *strengths* category. After each respondent completed the set of comparisons for each category, the results were analyzed following steps as suggested in ANP literature (Saaty 2006, Yüksel and Dagdeviren 2007, Catron et al. 2013). These steps involved utilizing an eigenvalue methodology to compute the priority weights for each stakeholder group and are further described below.

2.3 Analysis

The first step was to place the responses into an unweighted supermatrix and a priority value was calculated using the Eigenvalue method (Saaty and Vargas 2012).

The reciprocal matrix takes the form:

$$A = \begin{bmatrix} 1 & {w_1}/{w_2} & \cdots & {w_1}/{w_n} \\ {w_2}/{w_1} & 1 & \cdots & {w_2}/{w_n} \\ \vdots & \vdots & 1 & \vdots \\ {w_n}/{w_1} & {w_n}/{w_2} & \cdots & 1 \end{bmatrix} \qquad \textbf{(1)}$$

In matrix A, represented by equation (1), w is the relative weight of the pairwise comparisons.

After all results were placed in the matrix, each column was normalized so that its sum was equal to one (Saaty 1977). In order to aggregate individual decisions, the geometric mean was used to compute the normalized priority comparison matrix (Saaty and Vargas 2012). Next, following Saaty (1977), the transpose of the vector of weights w^T, represented by (2) below, was multiplied by matrix A. The vector ($\lambda_{\max} w^T$), which is the largest eigenvalue multiplied by the factor weights, was used to determine the consistency ratio for each set of decisions (Saaty 1977, Catron et al. 2013).

$$w^T = [w_1 \quad w_2 \quad \cdots \quad w_n] \qquad \textbf{(2)}$$

Where w represents the interchanged weights from matrix A (equation 1) to form the transpose vector.

In order to determine the consistency amongst participants, a consistency ratio (CR) was calculated for each set of factors (Kurttila et al. 2000, Catron et al. 2013). Of note, the CR in ANP was used to determine the validity of the model. To get the ratio, the consistency index (CI) was calculated using the formula:

$$CI = (\lambda_{max} - n)/(n - 1) \qquad \textbf{(3)}$$

Where, λ_{max} is the maximum eigenvalue and n is the size of the matrix (Yüksel and Dagdeviren 2007, Saaty and Vargas 2012). The consistency ratio was calculated by dividing the CI with the random index (RI). The RI was determined by a scale suggested by Saaty (table 2.2). In order for the model to be valid, the CR value is suggested to be less than 10% for consistent estimation (Saaty 1980, 2006).

$$CR = \left(\frac{CI}{RI(n)}\right) * 100 \qquad \textbf{(4)}$$

The four SWOT categories were then entered into a 4x1 matrix and the priority values of each category were represented as follows:

$$B = \begin{bmatrix} S \\ W \\ O \\ T \end{bmatrix} \qquad \textbf{(5)}$$

After the first round of analysis, a second round of surveys was administered to similar experts using the top priority value for each SWOT category. The total number of responses was forty-seven with sixteen government agencies, eleven landowners, four academics, four industry, and twelve NGO/other. The second survey asked respondents to make comparisons between the highest-ranking sub-factors between each category. In other words, highest-ranking strength with the highest-ranking weakness was compared for between attribute analyses. An example of this procedure is shown in figure 2.2. Since the highest-ranking sub-factors differ among stakeholders, each stakeholder category received different versions of the second questionnaire. Additionally, pairwise comparisons were again made to determine how each SWOT category may influence the other (Kurttila et al. 2000). This procedure is demonstrated in figure 2.3.

The eigenvalue method was repeated for the comparisons of each SWOT category. The comparison matrix was multiplied with the priority values from matrix B, equation (5), to form a new 4x1 matrix representing the scaling factors of each SWOT category (Kurttila et al. 2000, Saaty 2006, Catron et al. 2013).

$$C = \begin{bmatrix} S_{sf} \\ W_{sf} \\ O_{sf} \\ T_{sf} \end{bmatrix} \tag{6}$$

Finally, a global priority factor was calculated by multiplying the local priority factor calculated above with the scaling factors from equation (6).

3. RESULTS

The summary of all factors and their global priorities can be found in table 2.3. For all stakeholder categories, the CR was less than 10% which validates the ANP model and signifies consistency among individual and aggregate stakeholder responses. Overall, strengths (30%) were the most important attributes followed by opportunities (28%), threats (24%), and lastly the weaknesses (18%). Regarding the strengths category, government and academic stakeholders revealed that the presence of healthy and resilient forests (S1) is the primary strength influencing active management, with overall priority scores of 0.09 and 0.12**,** respectively. While the reduced risk of wildfire (S3) was their top priority with corresponding values of 0.09 and 0.12, landowners and industry professionals also found healthy and resilient forests (S1) to be a principal strength (values of 0.09 and 0.09). NGO and other stakeholders marked improved wildlife habitat (S2) as their top strength with an overall priority value of 0.14. In contrast, stakeholders revealed improved aesthetics (S4) to be the least important strength influencing the management of the Cross-timbers forests (table 2.3).

Stakeholders across-the-board stated that the financial burden of management (W1) and the threat of uncontrolled fire (T1) were the biggest weakness (0.07) and threat (0.09) hindering the management of the Cross-timbers forests (table 2.3). They also reported that liability and health hazards (W2) were another possible shortcoming of active management (0.06) and may further hinder management implementation. However, they marked the decreased incentives of cost-share programs (T3) and the temporary loss of aesthetics (W3) to be of little significance in management decisions.

With respect to opportunities, academics and landowners revealed that the opportunity for increased revenue (O4) was of importance when considering management of the Cross-timbers forests. However, government and industry stakeholders indicated the ability to attract investment into the region (O1) to be their first priority, with values of 0.11 and 0.11. Finally, NGO/other stakeholders stated that the potential for financial assistance from federal/state agencies (O2) might be the driving force in managing the Cross-timbers forests.

4. DISCUSSION

In general, results indicate that all stakeholders agree that the positive factors associated with active management (i.e. strengths and opportunities) are more important than the negative factors (weaknesses and threats). This suggests that many Cross-timbers stakeholders are optimistic about adopting an active management strategy and the productive dialogues that may benefit the region as a whole.

Across-the-board, respondents perceived the financial burden of management and the possible threat of uncontrolled fire to be the biggest hindrances of managing the Cross-timbers. The exclusion of fire increases fuel loads and risk for wildfire (Fernandes and Botelho 2003). Our results corroborate earlier findings that the perceived risks of uncontrolled fire, such as property damage, injuries, or liabilities, are the major obstacles in using prescribed fire as an active land management tool in the region (Elmore et al. 2009). Consistent with what McCaffrey (2006) suggested, encouraging landowners to participate in management decisions may help foster the desire to adopt an active management practice in the Cross-timbers. These practices can restore the health and resilience of the Cross-timbers forests and allow for the continued use of ecosystem services.

Furthermore, real threats coming from population dynamics and associated land use change were also widely acknowledged by stakeholders. These opinions make intuitive sense given that urbanization and climate variability will continue to alter the structure and function of the Cross-timbers (Hallgren et al. 2012). The cities of Fort

Worth, TX, Oklahoma City, OK and Tulsa, OK are all growing metropolitan areas located within the Cross-timbers. As the population continues to increase, so does the expansion of residential areas and the interaction between humans and the environment (Theobald and Romme 2007). However, this interaction also reiterates the need to manage the Cross-timbers forests for the critical ecosystem services and resources they provide to these surrounding areas (Hallgren et al. 2012).

Consistent with previous research (Wolfslehner et al. 2005, Catron et al. 2013), our results suggest that dependencies, the interconnection of factors evaluated when utilizing ANP, can make a meaningful difference in SWOT matrices. While the results from ANP and AHP were similar in terms of the relative importance placed by a stakeholder towards an attribute, differences were non-trivial for some global priorities. For example, without considering dependencies, the financial burden of management and liability and health hazards were rated as equally important weaknesses by industry stakeholders. However, the financial burden of management became the top valued weakness after taking interdependency into account.

A couple limitations of this work are worth noting. First, despite reasonable efforts, I found difficulty in recruiting diverse industry professionals during survey data collection. Professionals representing a variety of industries might result in better representation. Second, while landowners providing information were knowledgeable about the Cross-timbers forests and were heavily engaged during data collection, some landowners might not have detailed insights due to lack of practical experience with active management activities. With these caveats withstanding, this research can help developing education and outreach opportunities for both landowners and other non-traditional stakeholders.

5. CONCLUSION

The results from this study suggest that, while there are some general reservations associated with the cost of management and the perceived wildfire risks, stakeholders are generally willing to implement an active management strategy in the Cross-timbers and recognize several favorable attributes of doing so. Improving the Cross-timbers forests will rely heavily on active management and involvement from a variety of stakeholders. By utilizing the SWOT-AHP/ANP methodologies, I demonstrated which factors are important for managing the Cross-timbers forests. Future research that can reveal landowner willingness to pay (WTP) for non-commodity related Cross-timber forest benefits or their willingness to accept (WTA) the costs incurred in active management are recommended.

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LIST OF TABLES AND FIGURES

Table 2.1: Description of SWOT factors used to compare stakeholders' perceptions on active management in the Cross-timbers ecoregion.

Strengths	**Weaknesses**
S1: healthy and resilient forests **S2**: improved wildlife habitat **S3**: reduced risk of wildfire **S4**: improved aesthetics	**W1**: financial burden of management **W2**: liability and health hazards **W3**: temporary loss of aesthetics **W4**: limited market
Opportunities	**Threats**
O1: attract investment into the region **O2**: financial assistance from federal/ state agencies **O3**: seasonal job creation **O4**: increased revenue	**T1**: uncontrolled fire (loss property/liability) **T2**: population dynamics and land use change **T3**: decreased incentives of cost-share programs **T4**: lack of expertise (burning and management)

Table 2.2: Consistency index as suggested by Saaty (RI(n)) where n is the number of factors and RI is the random index.

n	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
RI(n)	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45

Table 2.3: Global priorities for each SWOT factor. The largest global priority factor for each category is in bold, and comparisons of factors not accounting for dependency are in parentheses.

	Global Priorities				
Factor	**Government**	**Landowner**	**Academic**	**Industry**	**NGO&other**
S1	**0.085**	**0.098**	**0.117**	0.083	**0.122**
	(0.098)	(0.147)	(0.160)	(0.100)	(0.166)
S2	0.043	0.059	0.080	0.065	0.086
	(0.050)	(0.087)	(0.109)	(0.079)	(0.118)
S3	0.056	0.056	0.087	**0.092**	0.063
	(0.065)	(0.083)	(0.119)	(0.110)	(0.086)
S4	0.045	0.078	0.067	0.084	0.043
	(0.051)	(0.116)	(0.091)	(0.101)	(0.058)
Sum	0.230	0.291	0.352	0.325	0.314
W1	0.050	0.042	0.029	0.025	**0.060**
	(0.053)	(0.061)	(0.019)	(0.024)	(0.056)
W2	**0.070**	**0.055**	0.037	0.064	0.056
	(0.074)	(0.079)	(0.024)	(0.062)	(0.112)
W3	0.042	0.025	0.036	0.036	0.051
	(0.044)	(0.035)	(0.023)	(0.035)	(0.103)
W4	0.035	0.032	**0.043**	**0.079**	0.047
	(0.037)	(0.046)	(0.028)	(0.076)	(0.094)
Sum	0.197	0.154	0.145	0.204	0.214
O1	0.049	**0.089**	0.054	0.052	0.082
	(0.029)	(0.075)	(0.045)	(0.054)	(0.080)
O2	**0.119**	0.086	**0.111**	**0.087**	**0.139**
	(0.071)	(0.073)	(0.092)	(0.090)	(0.137)
O3	0.062	0.059	0.085	0.069	0.042
	(0.037)	(0.050)	(0.070)	(0.072)	(0.041)
O4	0.032	0.039	0.060	0.074	0.035
	(0.019)	(0.033)	(0.050)	(0.077)	(0.034)
Sum	0.262	0.273	0.310	0.281	0.298
T1	**0.097**	0.077	0.048	0.047	**0.054**
	(0.046)	(0.032)	(0.042)	(0.030)	(0.024)
T2	0.057	0.075	0.034	0.033	0.033
	(0.027)	(0.031)	(0.030)	(0.021)	(0.015)
T3	0.075	**0.078**	**0.057**	0.041	0.041
	(0.035)	(0.032)	(0.051)	(0.026)	(0.018)
T4	0.083	0.051	0.054	**0.068**	0.047
	(0.039)	(0.021)	(0.047)	(0.043)	(0.021)
Sum	0.312	0.282	0.194	0.190	0.175

Figure 2.1: An example pairwise comparison from survey one for the *strengths* category.

Please carryout a pairwise comparison of the following set of factors that are likely to be considered a **strength** of active management in Cross-timbers. Please mark the factor that you think is more important than other. For example, compare the factor “Healthy and resilient forests” with “Improved wildlife habitat” and mark the option in the direction that accurately reflects your opinion. Please note that there is no ‘right’ or ‘wrong’ answer, we are interested in your opinion.

Factors	9	7	5	3	1	3	5	7	9	Factors
Healthy and resilient forests										Improved wildlife habitat
Healthy and resilient forests										Reduce risk of wildfire
Healthy and resilient forests										Improved aesthetics
Improved wildlife habitat										Reduced risk of wildfire
Improved wildlife habitat										Improved aesthetics
Reduced risk of wildfire										Improved aesthetics
1=Equally important; 3= Moderately more important; 5=More important; 7=Very important; 9=Extremely important										

Figure 2.2: An example pairwise comparison for the *academic* stakeholders from survey two. The respondents were asked to compare the highest-ranking sub factor in each category.

In the same survey, participants were also asked to rate the strengths, weaknesses, opportunities, and threats associated with active management in the Cross-timbers. Based on their responses the highest ranked strength, weakness, opportunity, and threat are:

Strength (S1): Healthy and resilient forests

Weakness (W1): Financial burden of management

Opportunity (O1): Increased revenue

Threat (T1): Uncontrolled fire (loss of property/liability)

Now, we are asking that you make additional comparisons for each of the highest ranked factors in Section A.

First, please compare the strength factor "S1" with the weakness factor "W1" and mark in the direction that accurately reflects your opinion. Please note there is no 'right' or 'wrong' answer, we are interested in your opinion.

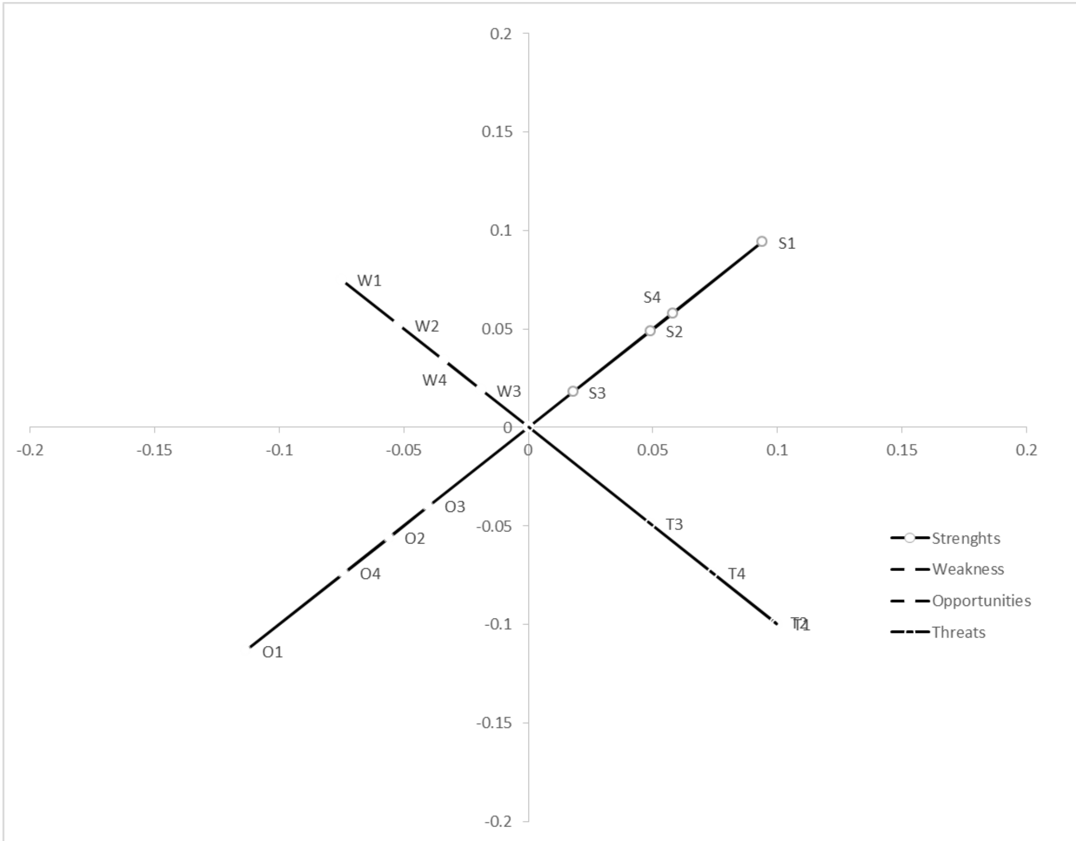
Factors	9	7	5	3	1	3	5	7	9	Factors
	←								→	
Healthy and resilient forests										Financial burden of management
Healthy and resilient forests										Increased revenue
Healthy and resilient forests										Uncontrolled fire (loss of property/liability)
Financial burden of management										Increased revenue
Financial burden of management										Uncontrolled fire (loss of property/liability)
Increased revenue										Uncontrolled fire (loss of property/liability)
1=Equally important; 3= Moderately more important; 5=More important; 7=Very important; 9=Extremely important										

Figure 2.3: Example pairwise comparison from survey two measuring dependencies among factors.

Please evaluate the dependencies among factors. For example, with respect to the weaknesses category, compare the factor “enhancing strengths” with the factor “enhancing opportunities” by asking “which of these is more important for overcoming weaknesses?” and mark in the direction that accurately reflects your opinion. Please note there is no ‘right’ or ‘wrong’ answer, we are interested in your opinion.

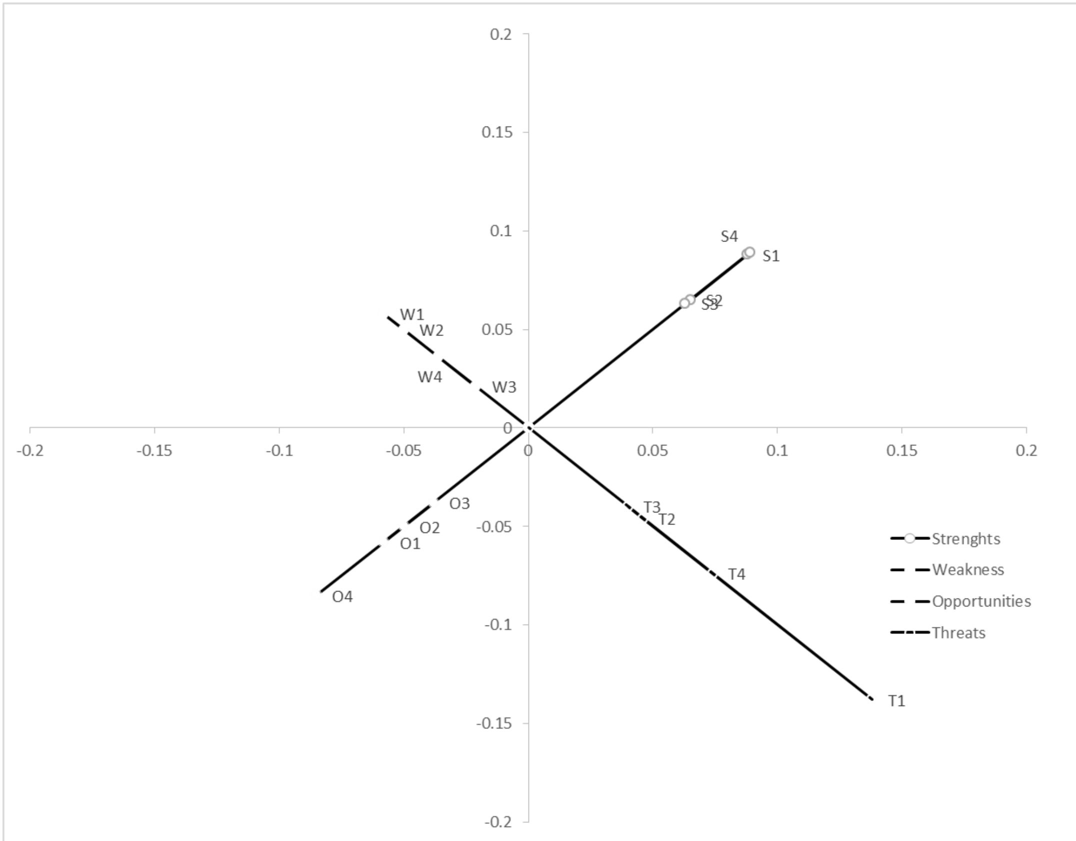
Which is more important for overcoming **weaknesses** and by how much?										
Factors	9	7	5	3	1	3	5	7	9	Factors
	←								→	
Enhancing strengths										Enhancing opportunities
Enhancing strengths										Mitigating threats
Enhancing opportunities										Mitigating threats
1=Equally important; 3= Moderately more important; 5=More important; 7=Very important; 9=Extremely important										

Figure 2.4: Graphical representation of each SWOT factor for *government* stakeholders. The factors with the highest global priority are positioned the furthest from the origin.



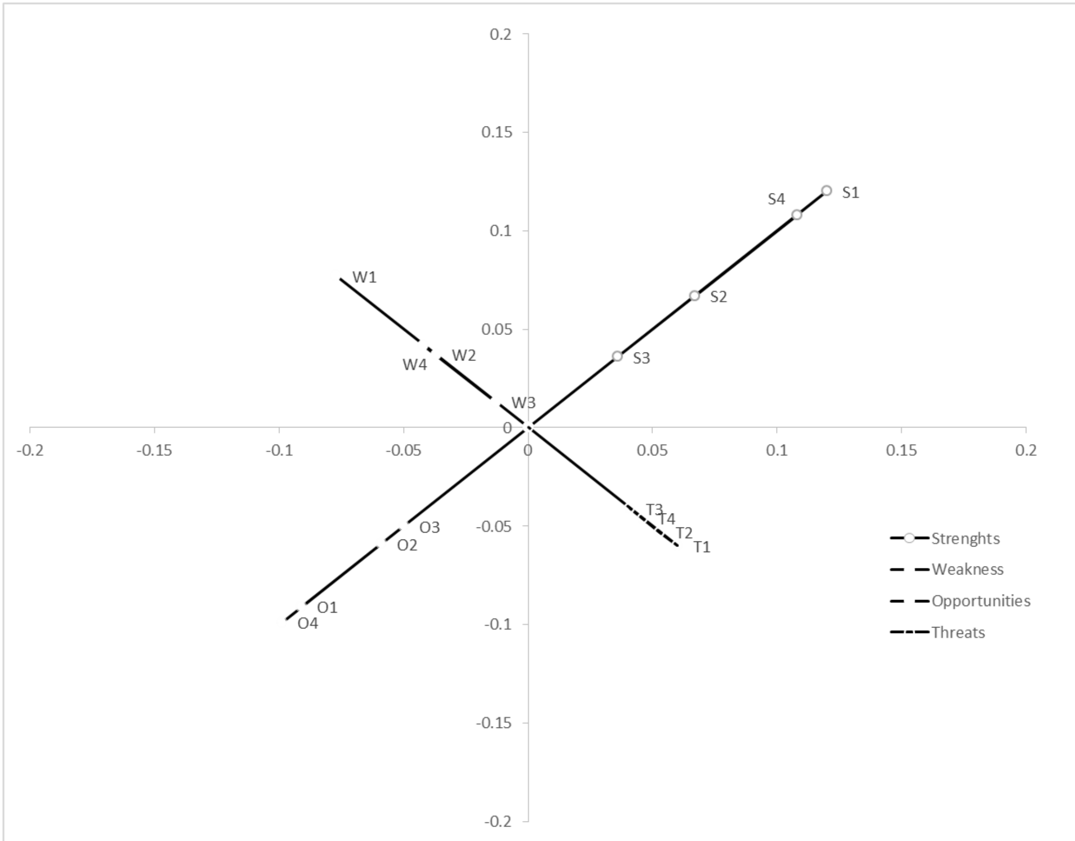
S1: healthy and resilient forests; **S2**: improved wildlife habitat; **S3**: reduced risk of wildfire; **S4**: improved aesthetics; **W1**: financial burden of management; **W2**: liability and health hazards; **W3**: temporary loss of aesthetics; **W4**: limited market; **O1**: attract investment into the region; **O2**: financial assistance from federal/ state agencies; **O3**: seasonal job creation; **O4**: increased revenue; **T1**: uncontrolled fire (loss property/liability); **T2**: population dynamics and land use change; **T3**: decreased incentives of cost-share programs; **T4**: lack of expertise (burning and management)

Figure 2.5: Graphical representation of each SWOT factor for *landowners*. The factors with the highest global priority are positioned the furthest from the origin.



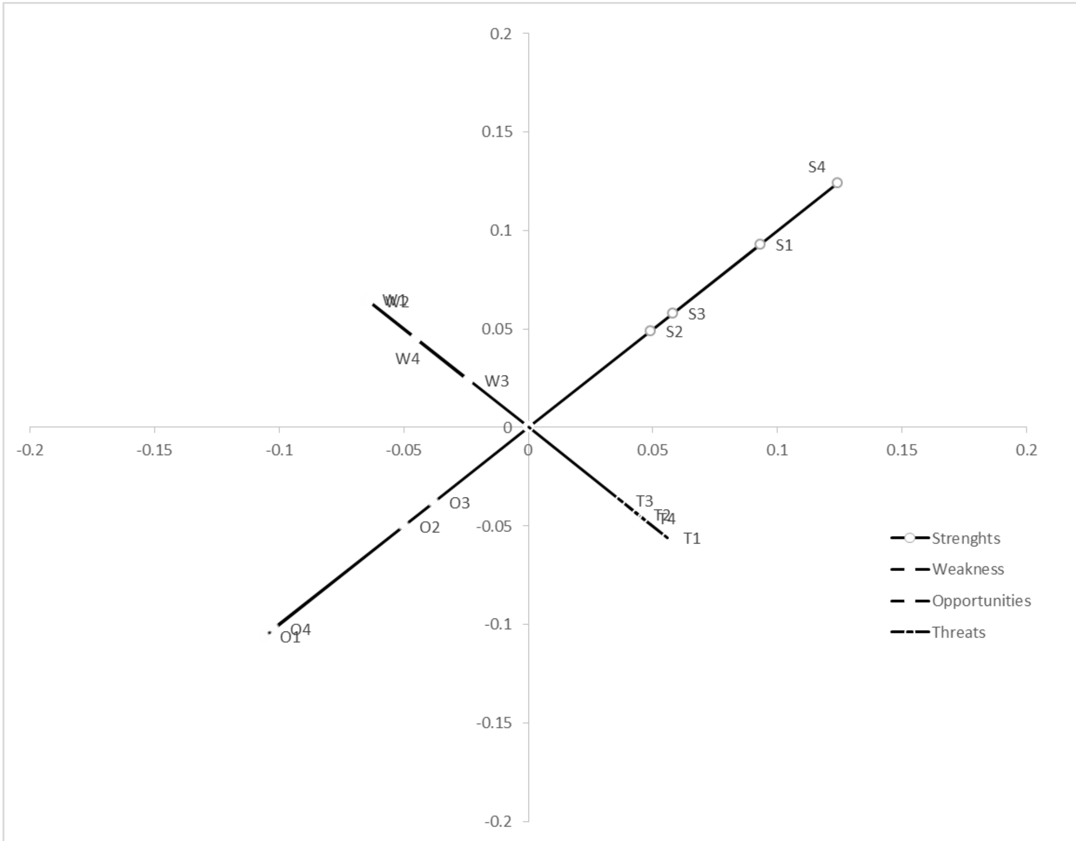
S1: healthy and resilient forests; **S2**: improved wildlife habitat; **S3**: reduced risk of wildfire; **S4**: improved aesthetics; **W1**: financial burden of management; **W2**: liability and health hazards; **W3**: temporary loss of aesthetics; **W4**: limited market; **O1**: attract investment into the region; **O2**: financial assistance from federal/ state agencies; **O3**: seasonal job creation; **O4**: increased revenue; **T1**: uncontrolled fire (loss property/liability); **T2**: population dynamics and land use change; **T3**: decreased incentives of cost-share programs; **T4**: lack of expertise (burning and management)

Figure 2.6: Graphical representation of each SWOT factor for *academic stakeholders*. The factors with the highest global priority are positioned the furthest from the origin.



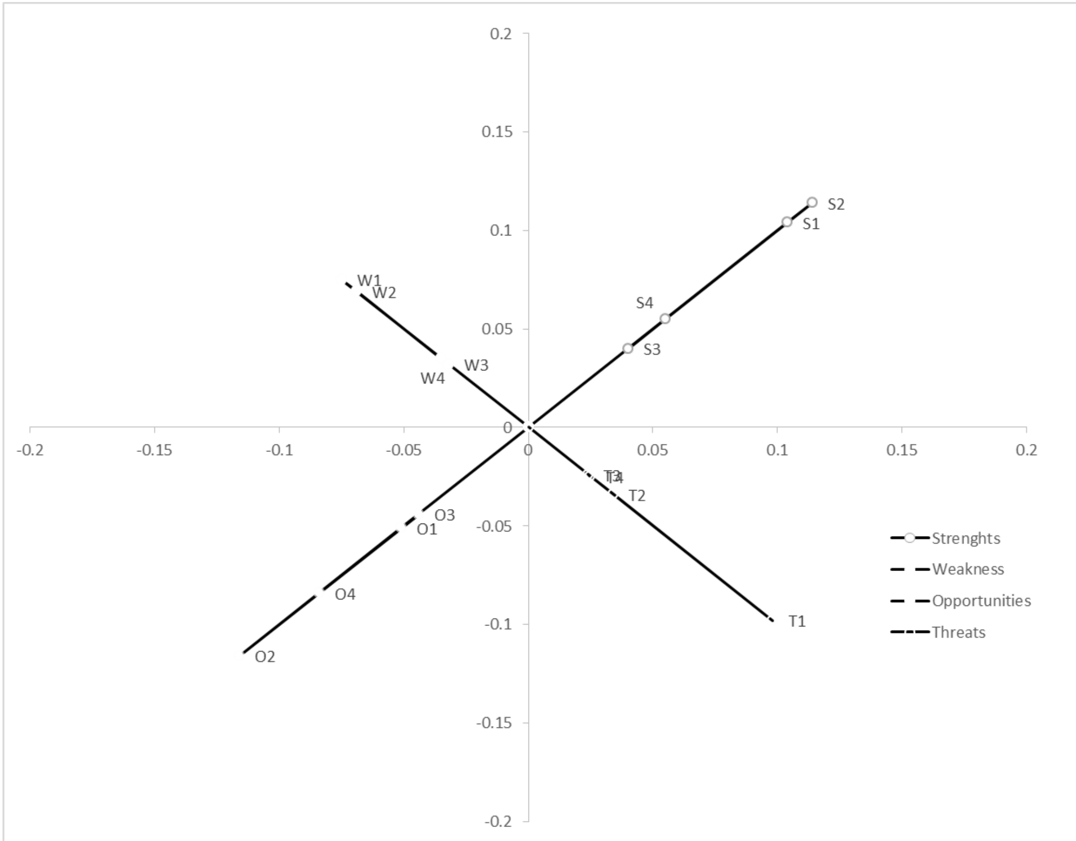
S1: healthy and resilient forests; **S2**: improved wildlife habitat; **S3**: reduced risk of wildfire; **S4**: improved aesthetics; **W1**: financial burden of management; **W2**: liability and health hazards; **W3**: temporary loss of aesthetics; **W4**: limited market; **O1**:attract investment into the region; **O2**: financial assistance from federal/ state agencies; **O3**: seasonal job creation; **O4**: increased revenue; **T1**: uncontrolled fire (loss property/liability); **T2**: population dynamics and land use change; **T3**: decreased incentives of cost-share programs; **T4**: lack of expertise (burning and management)

Figure 2.7: Graphical representation of each SWOT factor for *industry stakeholders.* The factors with the highest global priority are positioned the furthest from the origin.



S1: healthy and resilient forests; **S2**: improved wildlife habitat; **S3**: reduced risk of wildfire; **S4**: improved aesthetics; **W1**: financial burden of management; **W2**: liability and health hazards; **W3**: temporary loss of aesthetics; **W4**: limited market; **O1**: attract investment into the region; **O2**: financial assistance from federal/ state agencies; **O3**: seasonal job creation; **O4**: increased revenue; **T1**: uncontrolled fire (loss property/liability); **T2**: population dynamics and land use change; **T3**: decreased incentives of cost-share programs; **T4**: lack of expertise (burning and management)

Figure 2.8: Graphical representation of each SWOT factor for *NGO/other stakeholders*. The factors with the highest global priority are positioned the furthest from the origin.



S1: healthy and resilient forests; **S2**: improved wildlife habitat; **S3**: reduced risk of wildfire; **S4**: improved aesthetics; **W1**: financial burden of management; **W2**: liability and health hazards; **W3**: temporary loss of aesthetics; **W4**: limited market; **O1**: attract investment into the region; **O2**: financial assistance from federal/ state agencies; **O3**: seasonal job creation; **O4**: increased revenue; **T1**: uncontrolled fire (loss property/liability); **T2**: population dynamics and land use change; **T3**: decreased incentives of cost-share programs; **T4**: lack of expertise (burning and management)

CHAPTER III

STAKEHOLDER PERCEPTIONS ON MARKET OPPORTUNITIES UTILIZING THE FOREST RESOURCES OF THE CROSS-TIMBERS ECOREGION: A SWOT-ANP ANALYSIS

ABSTRACT

The Cross-timbers forests of Oklahoma, Texas, and Kansas possess a wide variety of natural resources. However, the region faces a situation where there is no traditional forestry market for the resources in the region, as commercial timber is not viable owing to slow growth and poor quality trees. In addition, poor quality soils, frequent drought, and a steep rocky terrain in places have further limited productivity and access to many of these forest resources in the Cross-timbers. Despite the lack of traditional forest markets, the Cross-timbers possess a variety of non-commodity benefits and specialty commodities that can be marketed in the region. Carbon sequestration, bioenergy, and hunting/recreation provide emerging market opportunities within the Cross-timbers. This study utilized a strengths, weaknesses, opportunities, and threats (SWOT)-Analytic Network Process (ANP) framework to determine how a variety of stakeholders viewed the available resources of the Cross-timbers and their marketable opportunities. The requisite data were collected through a mixed-mode method, which involved online survey administration and focus group meetings. Our results suggest that the availability of a variety of natural resources and the restoration of ecosystem services could be the driving forces in developing a non-traditional market within the Cross-timbers. However, stakeholders also revealed that uncertain markets, lack of enthusiasm from manufacturers, and low-quality resources might be what currently hinder the market potential of the Cross-timbers.

Keywords: SWOT-ANP, stakeholders, market

1. INTRODUCTION

The Cross-timbers ecoregion represents the broad ecotone between the eastern deciduous forest and the tallgrass prairie (Johnson and Risser 1975), which extends over nearly 4.8 million ha from slightly north of Denton, Texas up into southeastern Kansas (Küchler 1965, Therrell and Stahle 1998). Fire exclusion in much of the Cross-timbers region, beginning in the early 1900's (Hoagland et al. 1999), has caused an increase in forest density, particularly through the encroachment of eastern redcedar (*Juniperus virginiana*) and mesic hardwoods (DeSantis and Hallgren 2011, Hoff et al. 2018b). These structural changes increase the risk of wildfire (Stambaugh et al. 2014, Hoff et al. 2018a) and predispose these forests to damage from drought. While management using prescribed fire, thinning, and herbicides can help restore the open structure and species composition of the Cross-timbers forest resources, these activities come at a cost to landowners (Drake and Todd 2002). These costs not only require monetary inputs but investments in labor and capital resources as well (Mayer and Tikka 2006). Without the assurance of a meaningful financial return, landowners may not be able to justify these costs and as a result not invest in forest management practices (Gold et al. 2005).

The Cross-timbers forests are dominated by relatively short stature and poor quality (~15 m tall) post oak (*Quercus stellata*) and blackjack oak (*Q. marilandica*), which suffer from insufficient valuation as there are no traditional forestry markets for these slower growing and relatively small diameter species. In addition, poor quality soils, frequent drought, and a steep rocky terrain in places have further limited productivity and access to many of these forest resources in the Cross-timbers region (Hallgren et al. 2012). While traditional forest commodity resources are not currently available in the Cross-timbers, non-commodity benefits and specialty commodities, such as the utilization of carbon sequestration through the trading of carbon credits, are available but yet to be explored on a commercial scale in the region (Kumar 2005). Nevertheless, there is growing support for the uses and marketing of these non-traditional and specialty commodities to encourage economic activity and market-driven forest management (Gold et al. 2004, Dawson 2010). Market-driven forest management encourages active management practices while offering landowners a meaningful financial return for investing in these efforts (Ebeling and Yasué 2009). Therefore, sustainable management of the Cross-timbers could hinge on the exploration and development of market opportunities in the region.

Establishing a sustainable market for the resources of the Cross-timbers will not only provide financial opportunities to landowners, but also support related industries and provide investment opportunities within the region (Gold et al. 2004). Further, with the variety of resources available to market, some of these materials are virtually free to harvest (eastern redcedar), as many landowners are willing to pay harvesters to remove these trees from the land (Craige et al. 2016). However, inadequate quantification of resources available, population pressures, land use changes, and the low quality of many of the Cross-timbers resources may hinder market establishment (Hoagland et al. 1999, Gold et al. 2004, Hallgren et al. 2012).

Several opportunities present themselves with market development in the Cross-timbers. Forage for cattle, improved wildlife habitat, increased biodiversity, reduced risk of wildfire, and support to related industries all provide opportunities to the stewards of the Cross-timbers following market establishment (Engle et al. 2006, Craige et al. 2016, Hoff et al. 2018b). However, policy and market uncertainty, seemingly higher transportation costs, and lack of enthusiasm from manufacturers may present drawbacks to market development (Gold et al. 2004, Craige et al. 2016). Thus far, limited research has been conducted to identify the social acceptance, as well as the economic potential of these markets (Ramli et al. 2017). Most fundamentally, I am unaware of the current perceptions of landowners and other stakeholders regarding the aforementioned opportunities and drawbacks of establishing such markets in the Cross-timbers. Consequently, I adopted the strengths, weaknesses, opportunities, and threats (SWOT)-Analytic Network Process (ANP) approach to fill the knowledge gap on these issues with the goal to better understand the perceptions of these stakeholders and provide a framework for market establishment in the region.

2. MARKET OPPORTUNITIES IN THE CROSS-TIMBERS

Marketable resources available within the Cross-timbers include the utilization of eastern redcedar (Drake and Todd 2002, Ramli et al. 2017), biomass production, carbon sequestration and carbon trading, and hunting/recreation (Dillard et al. 2006, Hallgren et al. 2012). Eastern redcedar is recognized for its scent, color, decay resistance, ease of maintenance, and insect repellent characteristics, which provides opportunities for a multitude of its uses (Craige et al. 2016). In addition to conventional lumber, it can be used for horse and dog bedding, mulch, oil, and furniture (Gold et al. 2005, Maggard et al. 2012a). Furthermore, eastern redcedar has been valued as a cheaper and more widely available compared to other wood sources in the Cross-timbers (Ramli et al. 2017). Despite its potential, sustainable feedstock supply for a large industry could be a challenge for the marketability of eastern redcedar since its encroachment is seen as a negative influence on the landscape (Gold et al. 2005, Craige et al. 2016, Ramli et al. 2017). Rather, the utilization of eastern redcedar as a marketable commodity will help slow the ongoing encroachment and mitigate the negative ecological consequences such as reduced biodiversity (van Els et al. 2010), reduced wildlife habitat, increased risk of wildfire (Hoff et al. 2018b), and decreased stream flow (Qiao et al. 2017).

Carbon sequestration and the use of biomass for energy are some additional examples of potential markets within the Cross-timbers (Montagnini and Nair 2004). Carbon sequestration in the form of carbon credits provides an opportunity to utilize this ecosystem service as a tradable commodity (Corbera and Brown 2010). Additionally, wood-based bioenergy production (i.e., pellets) can serve as another feasible market resource for the Cross-timbers (Drake and Todd 2002). The two dominant tree species, post oak and blackjack oak, may be particularly useful for bioenergy production. While these species are relatively slow growing and often of poor stem quality in the Cross-timbers (Stransky 1990), better sites can exceed 3.7 dry tons per ha of stem production per year (Johnson and Risser 1974). Wood-based bioenergy can utilize these lower quality inputs while offering landowners some financial return to harvest these resources, thus helping incentivize them to retain forested land (Dale et al. 2017) or improve forest health and structure through thinning.

Amongst other market opportunities, ecosystem services such as hunting and recreation and cattle grazing can also generate economic opportunities and are seen as important to the Cross-timbers ecoregion (Dillard et al. 2006). Management to improve habitat for lease-hunting or cattle leases are market opportunities that may increase landowner’s income and encourage better management of forest resources (Dillard et al.

2006). However, their success largely depends on marketing, the presence of wildlife and habitat, and land management practices (Porter et al. 2006). Apart from these ecosystem services, specialty non-timber forest products (NTFP) such as crafts, floral decorative, medicinal, edible and culinary products can serve as an additional management goal where timber harvesting is not economically feasible (Gold et al. 2004, Aguilar et al. 2014).

3. METHODOLOGY

3.1 SWOT-ANP

Perception analysis can play an integral role in successful market establishment as it can reveal stakeholders commitment to market entry and sustainability (Buurma and Boselie 2000). A widely adopted perception analysis approach is the strengths, weaknesses, opportunities, and threats (SWOT) methodology (Yüksel and Dagdeviren 2007). SWOT is a systematic decision-making approach to qualify the factors of a particular environment (Kurttila et al. 2000). As a structural model, SWOT is limited by its qualitative rankings, which makes it difficult to assess each factors' influence in strategic decision making (Shrestha et al. 2004). To determine the quantitative magnitude of each SWOT attribute, the Analytic Hierarchy Process (AHP) or Analytical Network Process (ANP) should supplement (Saaty 2006, Yüksel and Dagdeviren 2007).

The SWOT-AHP procedure quantifies attributes under the assumption of a hierarchical structure (Saaty 2005, Catron et al. 2013). While AHP removes the typical limitations of using SWOT alone, it is based on the assumption that all attributes are independent (Yüksel and Dagdeviren 2007). Given the nexus of the strengths, weaknesses, opportunities, and threats, especially in regards to the market opportunities of the Cross-timbers, such a stringent assumption can be problematic. The utilization of ANP allows for a feedback type structure that enables elements to be connected with one another (Saaty and Vargas 2012, Shahabi et al. 2014). For example, ANP evaluates the ability to utilize the strengths of a particular scenario to mitigate the associated threats with that scenario, and vise-versa (Yüksel and Dagdeviren 2007). Since the market potential of the Cross-timbers involves many interrelated attributes, SWOT-ANP was the methodology adopted for this study.

3.2 DATA COLLECTION AND ANALYSIS

The following procedures were used to evaluate the SWOT of market opportunities within the Cross-timbers. The SWOT-ANP methodology has successfully been used to evaluate other natural resource markets such as bioenergy production (Catron et al. 2013), the rare earth industry (Zhao et al. 2016), and the development of the mining industry (Ostrega et al. 2011). Based on the success of these studies, similar steps were utilized in data analysis to determine the perceptions of stakeholders on market establishment in the Cross-timbers.

Step 1: *Factor determination*: A focus group was assembled including four experts familiar with the available resources and scope of the Cross-timbers ecoregion. The focus group involved a moderator who led the discussion to determine a detailed list of SWOT factors. These factors were then subjected to further feedback and discussion by four additional experts to narrow down the four factors in each SWOT category. The list of SWOT factors for each category is reported in table 3.1.

Step 2: *Survey administration*: From the four factors determined for each SWOT category, a survey was developed and administered utilizing a mixed mode methodology, which included both in-person administration and an online version of the survey through the Qualtrics platform (Dillman et al. 2014). The target stakeholders were those landowners, industry professionals, academics, federal/state agency professionals, and employees of Non-Governmental Organizations (NGOs) who were familiar with the region and resources of the Cross-timbers and were located throughout the Cross-timbers of Texas, Oklahoma, and Kansas. The total number of responses for this survey was seventy-five. Respondent's distribution involved twenty-six stakeholders from government agencies, twenty-three from landowners, eleven from academics, six from industry, and nine from NGO/other.

Step 3: *Pairwise comparisons and priority value calculation*: Participants were asked to make a series of pairwise comparisons between the four SWOT factors using a scale developed by Saaty (1977). The scale ranges from one, signifying equal importance, to nine, signifying the extreme importance of one element over another. Additionally, respondents were provided a detailed description of the Cross-timbers and were asked to reveal their knowledge regarding the ecoregion and its resources. After the full set of comparisons was completed by each respondent, the results were analyzed following the SWOT-ANP procedures as suggested by previous literature (Saaty 1977, Yüksel and Dagdeviren 2007, Catron et al. 2013).

First, the responses were placed into pairwise comparison matrix (Eq. 1) (Saaty 1977). The geometric mean, which aggregated responses, was used to compute a reciprocal matrix for each factor and stakeholder group (Saaty and Vargas 2012). Next, following the eigenvalue method, each column was normalized to sum to unity (Saaty 2004).

The supermatrix is represented as follows:

$$Aw = \begin{bmatrix} 1 & {fw_1}/{fw_2} & \cdots & {fw_1}/{fw_n} \\ {fw_2}/{fw_1} & 1 & \cdots & {fw_2}/{fw_n} \\ \vdots & \vdots & 1 & \vdots \\ {fw_n}/{fw_1} & {fw_n}/{fw_2} & \cdots & 1 \end{bmatrix} \quad \textbf{(1)}$$

In matrix *Aw*, Eq. 1 *w* is the relative factor weight of each pairwise comparison. The transpose of the vector of weights fw^T, Eq. 2, was multiplied by matrix *Aw* to obtain the maximum eigenvalue, λ_{max} (Saaty 1977). The vector ($\lambda_{\max} fw^T$) was later used to determine the consistency of aggregated decisions (Saaty 2006, Catron et al. 2013).

$$fw^T = [fw_1 \quad fw_2 \quad \cdots \quad fw_n] \quad \textbf{(2)}$$

Step 4: *Consistency calculations*: To determine the validity of the model, a consistency ratio (CR) was calculated for each set of factors (Saaty 1977, Kurttila et al. 2000). The first step in determining the ratio was to calculate the consistency index (CI) using the formula:

$$CI = (\lambda_{max} - n)/(n - 1) \quad \textbf{(3)}$$

Where $\lambda_{\max}$ is the maximum eigenvalue and n is the size of the matrix. The CR, Eq. 4, was calculated by dividing the CI over a random index (RI). The RI is determined based on the average random consistency of different relative matrix orders (Saaty 1977).

$$CR = \left(\frac{CI}{RI(n)}\right) * 100 \quad \textbf{(4)}$$

In order for the model to be consistent, the CR value is recommended to be less than 10% (Saaty 1977, 2006). When the CR is this small, the calculated eigenvalue is considered the correct solution (Saaty 1977). Of note, a CR greater than zero signifies the cognative growth of the respondent in decision making, which is important in making consistent choices (Saaty 2004). The priority values calculated for each SWOT category were then placed into a 4x1 matrix as follows:

$$B = \begin{bmatrix} S \\ W \\ O \\ T \end{bmatrix} \quad \textbf{(5)}$$

Step 5: *Second survey administration*: Following the first round of analysis, the calculated priority values were used to develop and conduct a second round of surveys. These surveys were administered to similar stakeholders who were knowledgeable on the Cross-timbers region and the available forest resources. Forty-three respondents participated in the second data collection with 15 government agencies, 11 landowners, four academics, four industries, and nine NGO/other. Respondents of this survey were asked to compare the highest-ranking factors calculated in each category, done in similar fashion to the first survey described in step 3. Since the highest-ranking SWOT factors differed amongst each group of stakeholders, separate versions of the second survey were administered to each stakeholder group. Additionally, to determine interdependence, participants were asked to evaluate how each SWOT category may influence the other. An example of the second survey is provided in figure 3.2.

Step 6: *Calculating interdependencies:* The eigenvalue method utilized above was repeated for the second survey responses. Following the evaluation of the second pairwise comparison matrix, the derived values and the priority values from matrix B were multiplied by each other to calculate the scaling factors of each SWOT category (Eq. 6) (Saaty 2006, Catron et al. 2013).

$$C = \begin{bmatrix} S_{sc} \\ W_{sc} \\ O_{sc} \\ T_{sc} \end{bmatrix} \tag{6}$$

Step 7: *Global priorities*: Finally, the global priority factors were calculated by multiplying the priority values by the scaling factors accounting for dependency in Eq.6. These global priorities showed the final values from each stakeholder group on each SWOT factor.

4. RESULTS

Overall, Cross-timbers stakeholders perceived the positive factors (i.e., strengths and opportunities) (58.7%) to be more meaningful than the negative factors (i.e., weaknesses and threats) (41.3%) (table 3.1). The CRs for each SWOT factor perceived by each stakeholder group were all below 10%, signifying the consistency of the aggregated responses and validity of the model. Of note, the results in the table are reported in decimal format (i.e. 0.312 for government stakeholders ranking of the threats category) but results can also be viewed as percentages.

Government: Government stakeholders marked the threats category as most important (31.2%) followed by opportunities (26.2%), strengths (23%), and weaknesses

(19.7%) (table 3.1). Specifically, they reported that the availability of a variety of natural resources (S1) to be the greatest strength (priority value of 0.09) associated with the market potential of the Cross-timbers (table 3.1, figure 3.3). Additionally, they found the opportunity for the restoration of ecosystem services (O2) to be of higher importance (priority value of 0.12). However, the combination of uncertain markets (T1) and future land use change (W2) was seen as potential risks of this effort (priority values of 0.1 and 0.07, respectively).

Landowners: Landowners revealed that the strengths category was the most important in market development (29.1%) followed by threats (28.2%), opportunities (27.3%), and weaknesses (15.4%). In particular, they acknowledged that the availability of a variety of natural resources was the most important strength (S1) (priority value of 0.1) (table 3.1, figure 3.4). Further, they revealed that the opportunity of forage for cattle (O1) was of the highest importance (priority value of 0.09). However, landowners indicated that the lack of enthusiasm from manufactures (T3) might negatively influence the market potential of the Cross-timbers (priority value of 0.08). In consistency with government stakeholders, landowners also saw future land use change (W2) as a primary weakness (priority value of 0.06).

Academic: Academic stakeholders found the strengths category to be the most crucial in market development (35.2%) followed by opportunities (31.0%), threats (19.4%), and weaknesses (14.5%). To this end, academic stakeholders revealed that the availability of a variety of natural resources (S1) could be a principal factor in establishing a market in the Cross-timbers (priority value of 0.12) (table 3.1, figure 3.5). Additionally, they felt that the restoration of ecosystem services (O2) was an important opportunity (priority value of 0.11). However, academic stakeholders reported that the greatest weakness hindering market development was the inadequate assessment of resources (W4) (priority value of 0.04). Lastly, they revealed the threat associated with the lack of enthusiasm from manufacturers (T3) might be further holding back the establishment of a sustainable market (priority value of 0.06).

Industry: Industry stakeholders reported strengths category to be imperative for market establishment (32.5%), with opportunities (28.1%), weaknesses (20.4%), and threats (19.0%) in follow. In effect, industry stakeholders revealed that the possibility of investment and employment (S3) may be a driving force in market establishment in the region (priority value of 0.09) (table 3.1, figure 3.6). Furthermore, they remarked that the restoration of ecosystem services (O2) could further drive market establishment (priority value of 0.09). Nevertheless, they noted that the inadequate assessment of Cross-timbers resources (W4) and the possible transportation costs associated with harvesting (T4) to be limiting factors in establishing a market in the Cross-timbers (priority values of 0.08 and 0.07, respectively).

*NGO & Other***:** The NGO & other stakeholders ranked strengths as the most important factor (31.4%) followed by opportunities (29.8%), weaknesses (21.4%), and threats (17.5%). Specifically, NGO & other stakeholders noted that the availability of a variety of natural resources (S1) could be a positive attributor to market establishment (priority value of 0.12) (table 3.1, figure 3.7). These stakeholders also remarked that the restoration of Cross-timbers ecosystem services (O2) may be a driving force in market potential (priority value of 0.14). In their responses, growing population pressures (W1) and the uncertainty of markets (T1) were recognized as obstacles to these efforts (priority values of 0.06 and 0.05, respectively).

5. DISCUSSION

The results from this study suggest that there was a consensus among stakeholders, that the availability of natural resources is a primary strength of the Cross-timbers forests for a developing market. Like any industrial production process, the availability of raw materials is fundamentally important to attracting a new industry and lack thereof can cause markets to suffer (Fuss and McFadden 2014). Further, growing and emerging markets allow for the development of new perspectives and strategies for resource utilization (Sheth 2011), which could be beneficial to an area such as the Cross-timbers. The availability of labor, harvest equipment, market knowledge, and financial resources in conjunction with these perspectives and strategies are all paramount to both market establishment and success (Gold et al. 2004). In addition, stakeholders are optimistic about the investment and employment opportunities that come with market establishment. The Cross-timbers are predominantly located in the southcentral U.S., and are adjacent to areas where traditional forest markets have long supported a variety of economies through both employment and earnings (Dahal et al. 2015). While the Cross-timbers primarily support non-traditional markets, the employment and investment opportunities generated from markets can also contribute to the forest industry in the southeast.

There are several cost-share programs that Cross-timbers landowners may partake in to help reduce the costs of management practices and help improve the quality of trees available for marketable resources. For example, the Natural Resource Conservation

Service (NRCS) has an Environmental Quality Incentives Program (EQIP) that aims to provide financial resources to landowners for management practices that can improve agricultural operations, including forestry, while conserving natural resources (Stubbs 2010). Several EQIP initiatives may pertain to Cross-timbers landowners such as the air quality initiative or the national water quality initiative, which can be achieved through forest stand improvement practices. Additionally, NRCS also has a Wildlife Habitat Incentive Program (WHIP) as part of EQIP, which can help fund projects that develop, improve, or manage wildlife habitat on private lands (Stubbs 2017). Further, the Oklahoma Department of Wildlife Conservation employs a similar WHIP-style program. An example of management for wildlife habitat in the Cross-timbers is prescribed burning to manage habitat for northern bobwhites (*Colinus virginianus*) (Carter et al. 2002). In addition, by improving habitats of huntable species, these management practices can also improve the financial return from hunting programs on private lands.

It is important to note that developing a market in a region comes with some challenges. The real threats of population pressures and land use change can dramatically alter the availability of marketable resources in the Cross-timbers. In addition, poor road networks and lack of accessibility to forest resources with harvesting equipment can result in higher cut and haul costs, which can deter the efficiency of markets (Ramli et al. 2017). Many of the road networks in the Cross-timbers are arranged in a grid-like pattern, which can make access to some sites more difficult and can contribute to erosion by not following natural contours (Gumus et al. 2008, Turton et al. 2009). Furthermore, the Cross-timbers landscape and resources will continue to change in absence of the appropriate mix of prescribed fire and other site preparation activities, affecting both quality and availability of inputs (Burton et al. 2010, Hoff et al. 2018b). Finally, the uncertainty associated with markets and the risks involved in market entry may hinder stakeholders from engaging in market establishment in the Cross-timbers. However, these obstacles to market development can be overcome by further market research and outreach efforts (Gold et al. 2004).

Study results have several management implications. First, stakeholders are most aware of the strengths and opportunities that come with market establishment. Investment and employment opportunities, the restoration of ecosystem services, and reduced fuel loads will not only benefit landowners but also the general public within and surrounding the Cross-timbers. For example, air and water quality improvements through forest management benefit larger populations of the Cross-timbers and are not specific to landowners (Ciccarese et al. 2012). Additionally, wildfire is a major risk to human structures and health as well as one of the major causes of soil erosion in the Cross-timbers. Reducing fuel loads will decrease the risk of catastrophic wildfire and prevents streams and reservoirs from excessive sediment loads which can reduce water quality (Smith et al. 2011). Further, lower tree density and removal of eastern redcedar will increase water flow to streams and available water supply (Zou et al. 2010). In regards to surrounding economies, income generated from employment opportunities can then be used to purchase goods and services in neighboring markets (Murphy et al. 1989). Also of note, with the major cities of Dallas, Fort Worth, Tulsa, and Oklahoma City located in or within the proximity of Cross-timbers, there is plentiful access to production inputs such as equipment and labor.

Stakeholders representing academic institutions are concerned with the inadequate assessment of forest resources in the Cross-timbers. Fortunately, the Forest Inventory and Analysis (FIA) program has begun to assess the resources in the Cross-timbers region of Texas and Oklahoma (Dooley 2017). Until recently, FIA did not cover a significant percentage of forestland within the Cross-timbers (Dooley 2017). However, as data continues to be collected, the quantification of the available, marketable, and merchantable volumes of Cross-timber forest resources will be available within the coming years. Since the inventory of raw materials and development of product standards is necessary for market development (Gold et al. 2004), information from FIA and remote sensing data will likely help attract investment in the region.

While eastern redcedar encroachment has long-term ecological, economic and social ramifications in the region, it also brings several non-traditional market opportunities (Corbera and Brown 2010). Research is continuing to be done on the uses of eastern redcedar, and recent studies on non-traditional market opportunities have shown success in utilizing eastern redcedar for both particleboard manufacturing and to produce mulch (Hiziroglu et al. 2002, Cai et al. 2004, Maggard et al. 2012b). Since eastern redcedar is currently estimated to have about 10.22 million short tons of aboveground biomass in Oklahoma alone, utilizing it as an emerging market resource for the Cross-timbers may help reduce its current ecological and social stigmas (Dooley 2017).

More research is needed on the ability of Cross-timbers resources to sequester carbon (Corbera and Brown 2010). Further, outreach efforts to educate landowners on carbon credit exchange and other market opportunities are needed. Currently, the carbon markets in Oklahoma and Texas are predominantly utilized by the fast-growing pine plantations located in the eastern parts of the states (Lambert and Cooper 2014). However, since the Cross-timbers are not typically harvested, they may serve as a significant carbon sink, and retention of these forested lands can be encouraged through carbon credits (Corbera and Brown 2010). Moreover, employing carbon credits as a landowner incentive will encourage management practices to expand the ability of the Cross-timbers to sequester more carbon and increase the health and sustainability of these forests in the long-run (Masera et al. 2003).

Demand for forest-based biomass is expected to increase within the coming decades, and the Cross-timbers may be an excellent resource for this use with a proper market strategy and cost analysis. Of note, resources for biomass harvesting in Oklahoma and Texas are widely available. In central Texas alone, FIA data and a regional study show that nearly 1.6 million dry tons of woody biomass is available to harvest (Xu et al. 2008). Further, utilizing the Cross-timbers forests for pellet production can be more competitive in terms of pricing raw materials, as there is an abundance of available trees that do not follow the typical pricing structure of traditional timber resources (Xu et al. 2008).

Our study has some limitations. For example, since traditional market opportunities are largely absent in Cross-timbers, it is possible that some stakeholders might not have meaningful knowledge on rewards and risks coming from dedicated investments. Similarly, I had trouble recruiting diverse professionals representing various industries. Further, since the Cross-timbers possess not only forested areas but grassland and savannas as well, some stakeholders might not have been fully aware of the market potential of Cross-timbers forest resources. Withstanding these caveats, this research can serve as a foundational framework for the establishment of a market in the Cross-timbers region and future research objectives.

6. CONCLUSION

This study concluded that the stewards and stakeholders of the Cross-timbers are generally optimistic about market establishment. With a wide variety of available resources, market proximity, and the ability to restore ecosystem services, the Cross-timbers forests could be envisioned as a viable commodity for an emerging natural resource market. Placing emphasis on developing a market strategy that makes the best use of the available resources and directly benefits the landowners is a key driver in motivating market entry. Finally, restructuring policies and developing landowner incentives may also encourage further market involvement and management of Cross-timbers forest resources.

While there are some threats and potential caveats associated with the market establishment, these risks can be minimized through outreach and further research on the development and uses of Cross-timbers resources. By utilizing the SWOT-ANP methodology, it was revealed how stakeholders perceive the uses and management of the forest resources in the Cross-timbers. Nonetheless, to further quantify these perceptions, future research on the economic valuation of Cross-timbers ecosystem services and policy development are recommended.

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TABLES AND FIGURES

Table 3.1: Description and global priorities for each SWOT factor in regards to stakeholders perceptions of market opportunities in the Cross-timbers.

Global Priorities					
Factor	**Government**	**Landowner**	**Academic**	**Industry**	**NGO&other**
S1: availability of a variety of natural resources	**0.085**[1] (0.098)	**0.098** (0.147)	**0.117** (0.160)	0.083 (0.100)	**0.122** (0.166)
S2: market proximity	0.043 (0.050)	0.059 (0.087)	0.080 (0.109)	0.065 (0.079)	0.086 (0.118)
S3: investment and employment opportunities	0.056 (0.065)	0.056 (0.083)	0.087 (0.119)	**0.092** (0.110)	0.063 (0.086)
S4: currently raw materials are virtually free	0.045 (0.051)	0.078 (0.116)	0.067 (0.091)	0.084 (0.101)	0.043 (0.058)
Sum	**0.230**	**0.291**	**0.352**	**0.325**	**0.314**
W1: population pressures	0.050 (0.053)	0.042 (0.061)	0.029 (0.019)	0.025 (0.024)	**0.060** (0.056)
W2: future land use change	**0.070** (0.074)	**0.055** (0.079)	0.037 (0.024)	0.064 (0.062)	0.056 (0.112)
W3: low quality resources	0.042 (0.044)	0.025 (0.035)	0.036 (0.023)	0.036 (0.035)	0.051 (0.103)
W4: inadequate resource assessment	0.035 (0.037)	0.032 (0.046)	**0.043** (0.028)	**0.079** (0.076)	0.047 (0.094)
Sum	**0.197**	**0.154**	**0.145**	**0.204**	**0.214**
O1: forage for cattle	0.049 (0.029)	**0.089** (0.075)	0.054 (0.045)	0.052 (0.054)	0.082 (0.080)
O2: restoration of ecosystem services	**0.119** (0.071)	0.086 (0.073)	**0.111** (0.092)	**0.087** (0.090)	**0.139** (0.137)
O3: reduced fuel loads	0.062 (0.037)	0.059 (0.050)	0.085 (0.070)	0.069 (0.072)	0.042 (0.041)
O4: support to related industries	0.032 (0.019)	0.039 (0.033)	0.060 (0.050)	0.074 (0.077)	0.035 (0.034)
Sum	**0.262**	**0.273**	**0.310**	**0.281**	**0.298**
T1: uncertain markets	**0.097** (0.046)	0.077 (0.032)	0.048 (0.042)	0.047 (0.030)	**0.054** (0.024)
T2: uncertain policies	0.057 (0.027)	0.075 (0.031)	0.034 (0.030)	0.033 (0.021)	0.033 (0.015)
T3: lack of enthusiasm from manufacturers	0.075 (0.035)	**0.078** (0.032)	**0.057** (0.051)	0.041 (0.026)	0.041 (0.018)
T4: transportation costs	0.083 (0.039)	0.051 (0.021)	0.054 (0.047)	**0.068** (0.043)	0.047 (0.021)
Sum	**0.312**	**0.282**	**0.194**	**0.190**	**0.175**

[1] The largest global priority for each SWOT factor is in bold, and results for factors that do not account for dependency are in parentheses.

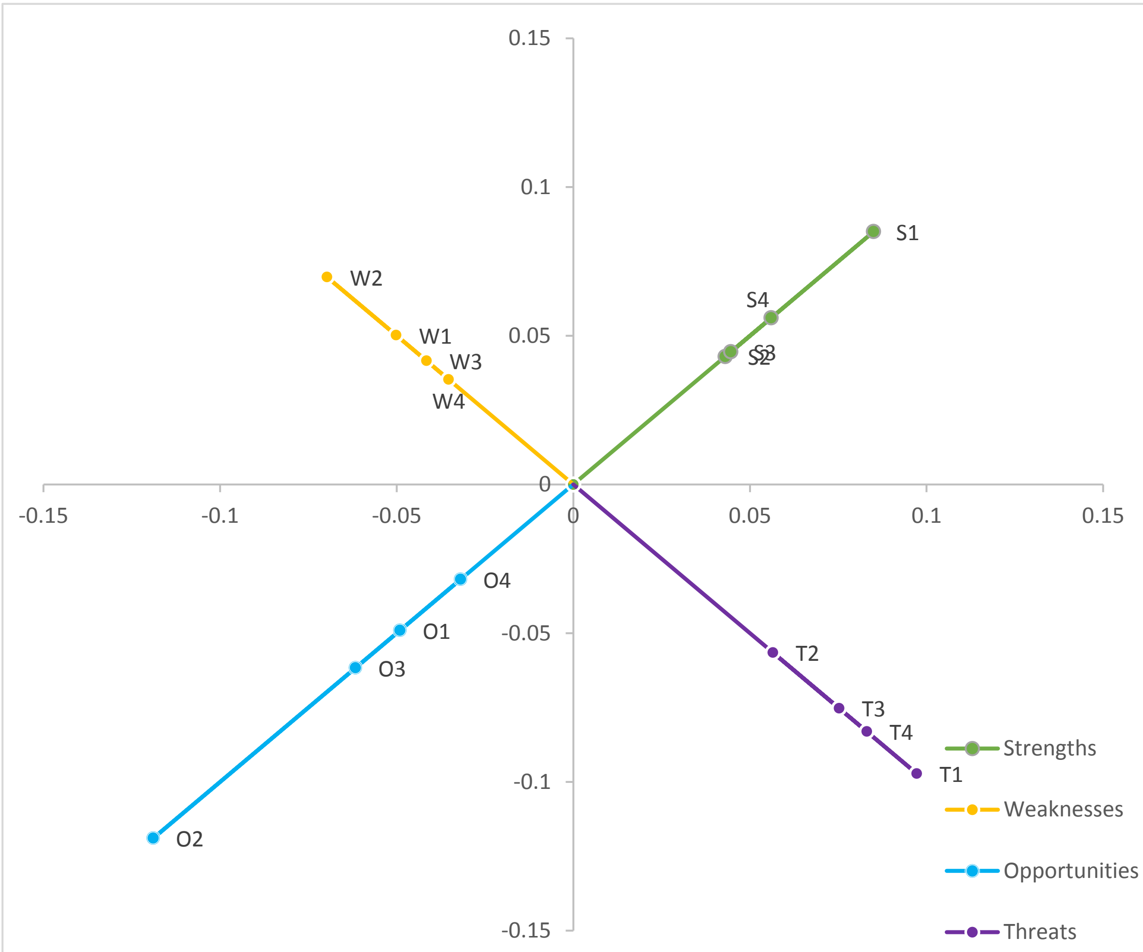
Figure 3.1. Example pairwise comparison from survey one for the *strengths* category.

Factors	9	7	5	3	1	3	5	7	9	Factors
Availability of a variety of natural resources										Market proximity
Availability of a variety of natural resources										Investment and employment opportunities
Availability of a variety of natural resources										Currently raw materials are virtually free (ex. eastern redcedar)
Market proximity										Investment and employment opportunities
Market proximity										Currently raw materials are virtually free (ex. eastern redcedar)
Investment and employment opportunities										Currently raw materials are virtually free (ex. eastern redcedar)
1=Equally important; 3= Moderately more important; 5=More important; 7=Very important; 9=Extremely important										

Figure 3.2. Example pairwise comparison from survey two.

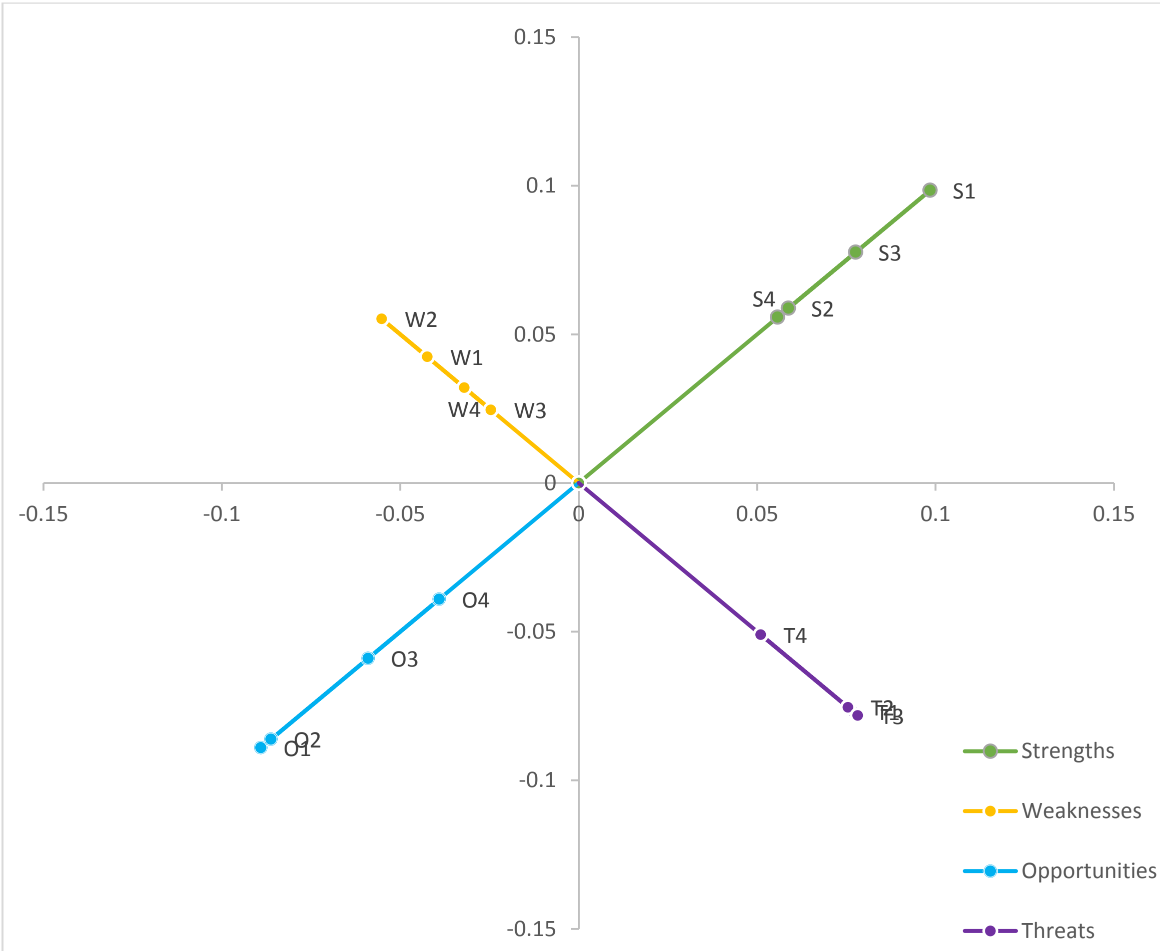
Which is more important for realizing **strengths** and by how much?										
Factors	9	7	5	3	1	3	5	7	9	Factors
Mitigating weaknesses										Enhancing opportunities
Mitigating weaknesses										Mitigating threats
Enhancing opportunities										Mitigating threats
1=Equally important; 3= Moderately more important; 5=More important; 7=Very important; 9=Extremely important										

Figure 3.3: Perception map representing importance of each SWOT factor for *government* stakeholders. The higher the global priority, the further the factor is positioned from the origin.



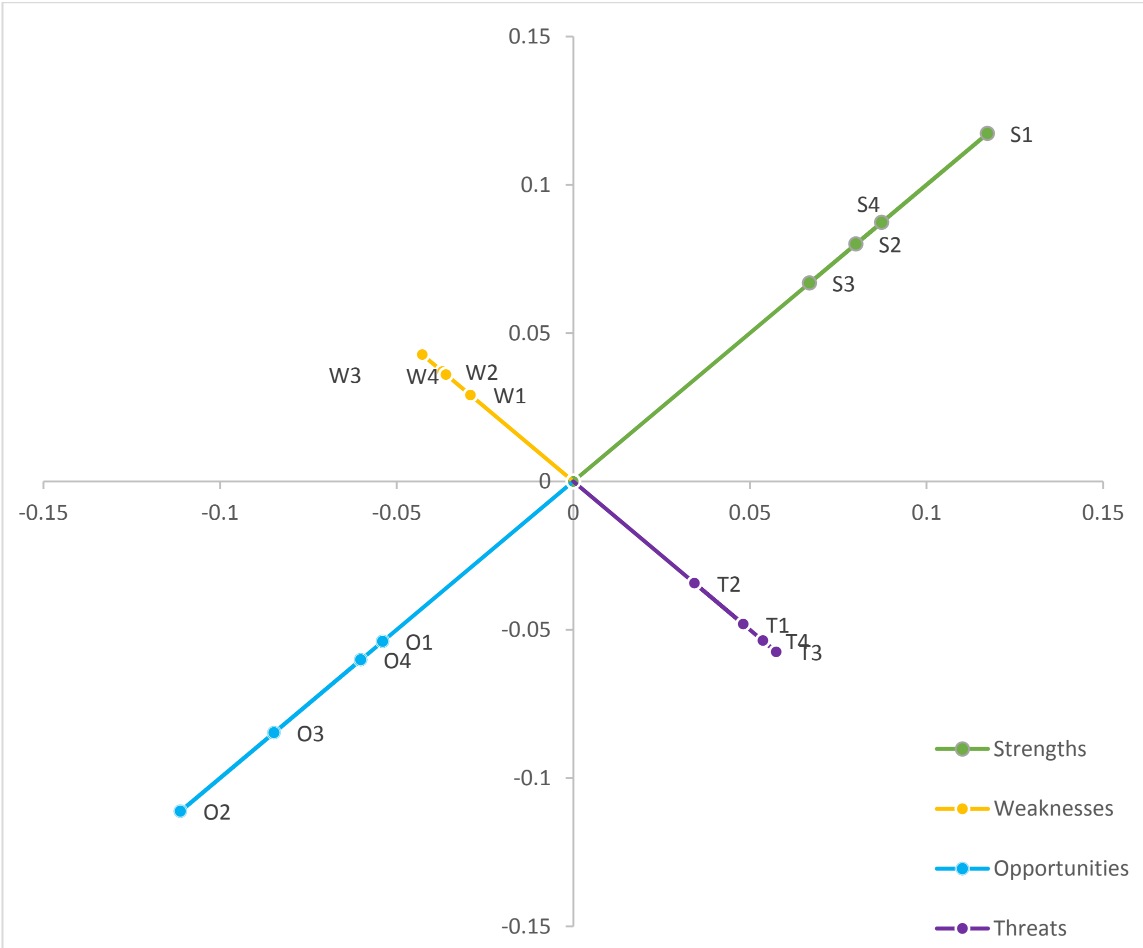
S1: availability of a variety of natural resources **S2**: market proximity; **S3**: investment and employment opportunities; **S4**: currently raw materials are virtually free (ex. eastern redcedar); **W1**: population pressures; **W2**: future land use change; **W3**: low quality resources; **W4**: inadequate resource assessment; **O1**: forage for cattle; **O2**: restoration of ecosystem services; **O3**: reduced fuel loads; **O4**: support to related industries; **T1**: uncertain markets; **T2**: uncertain policies; **T3**: lack of enthusiasm from manufacturers; **T4**: transportation costs

Figure 3.4: Perception map representing importance of each SWOT factor for *landowners*. The higher the global priority, the further the factor is positioned from the origin



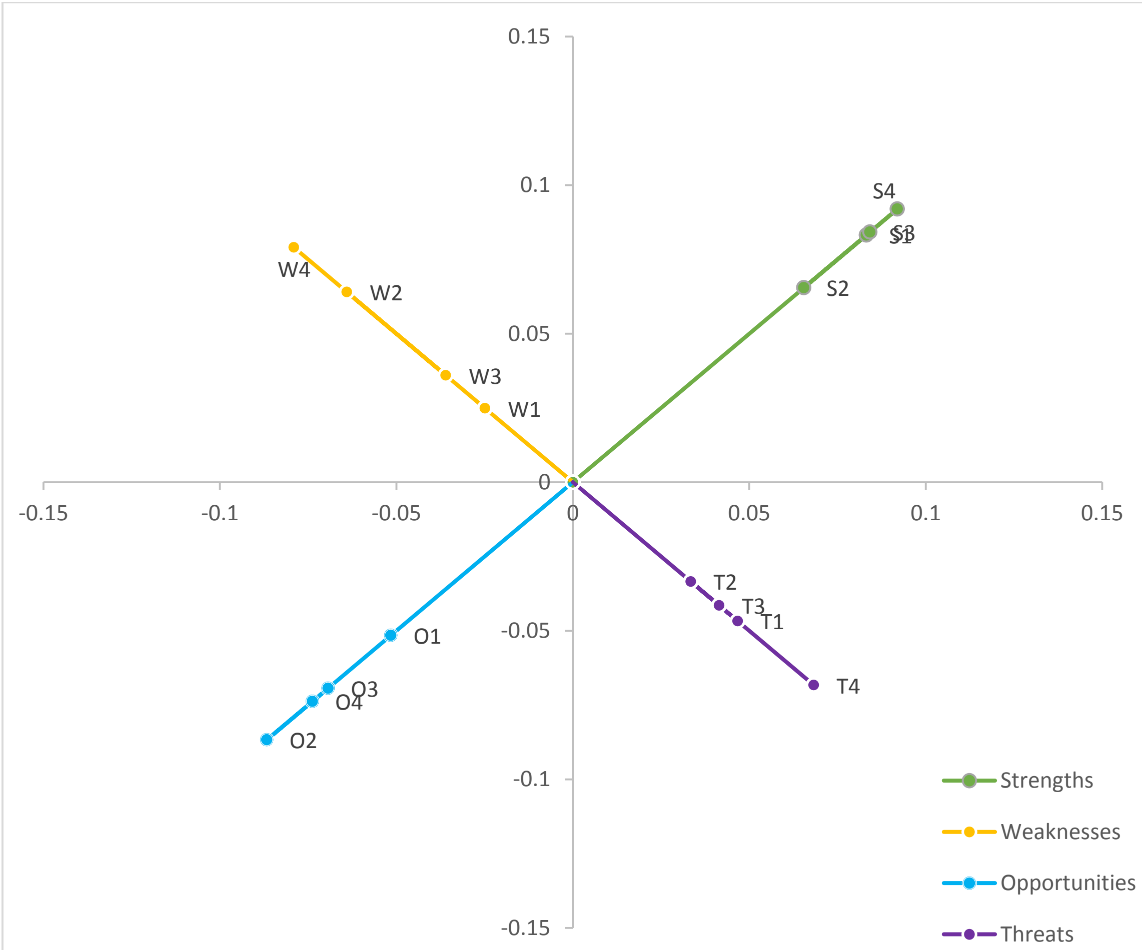
S1: availability of a variety of natural resources **S2**: market proximity; **S3**: investment and employment opportunities; **S4**: currently raw materials are virtually free (ex. eastern redcedar); **W1**: population pressures; **W2**: future land use change; **W3**: low quality resources; **W4**: inadequate resource assessment; **O1**: forage for cattle; **O2**: restoration of ecosystem services; **O3**: reduced fuel loads; **O4**: support to related industries; **T1**: uncertain markets; **T2**: uncertain policies; **T3**: lack of enthusiasm from manufacturers; **T4**: transportation costs

Figure 3.5: Perception map representing importance of each SWOT factor for *academic* stakeholders. The higher the global priority, the further the factor is positioned from the origin.



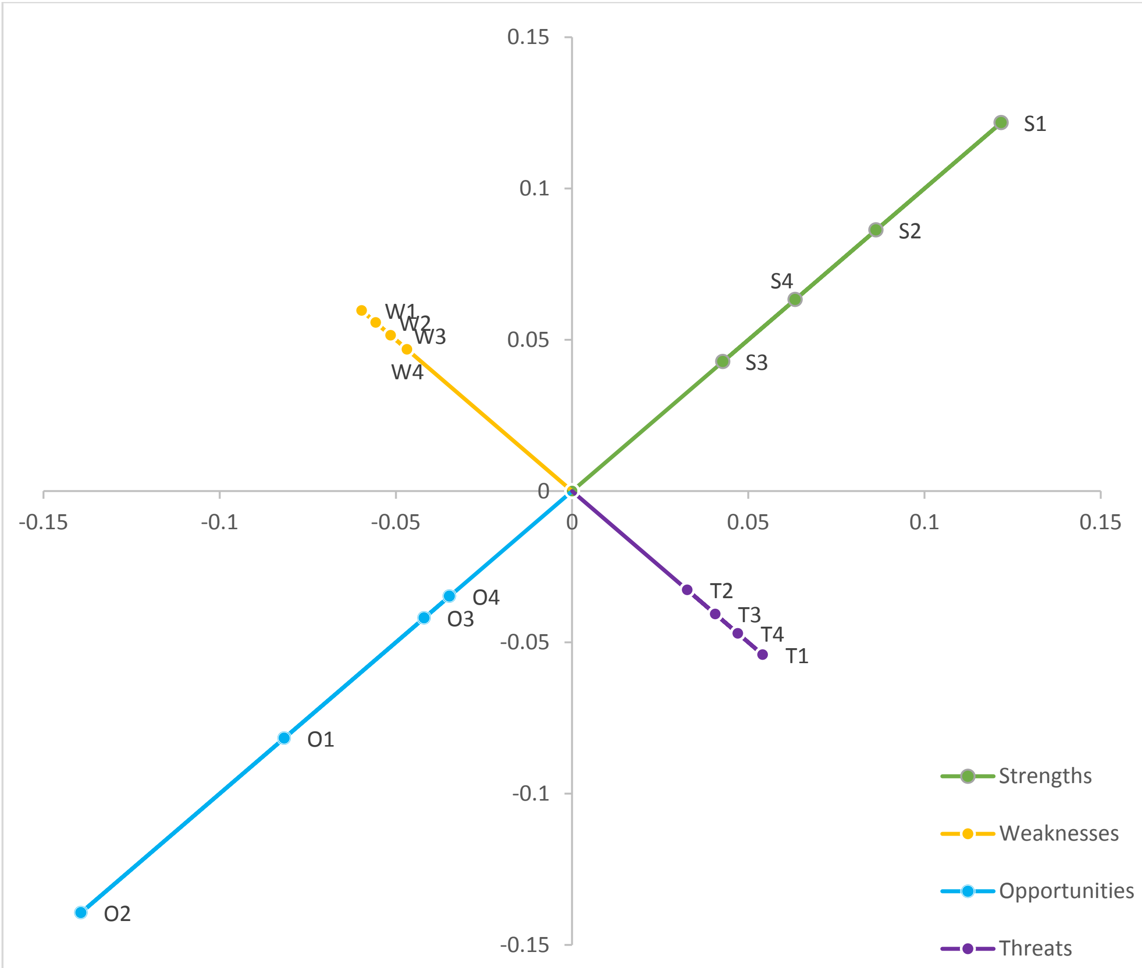
S1: availability of a variety of natural resources **S2**: market proximity; **S3**: investment and employment opportunities; **S4**: currently raw materials are virtually free (ex. eastern redcedar); **W1**: population pressures; **W2**: future land use change; **W3**: low quality resources; **W4**: inadequate resource assessment; **O1**: forage for cattle; **O2**: restoration of ecosystem services; **O3**: reduced fuel loads; **O4**: support to related industries; **T1**: uncertain markets; **T2**: uncertain policies; **T3**: lack of enthusiasm from manufacturers; **T4**: transportation costs

Figure 3.6: Perception map representing importance of each SWOT factor for *industry* stakeholders. The higher the global priority, the further the factor is positioned from the origin.



S1: availability of a variety of natural resources **S2**: market proximity; **S3**: investment and employment opportunities; **S4**: currently raw materials are virtually free (ex. eastern redcedar); **W1**: population pressures; **W2**: future land use change; **W3**: low quality resources; **W4**: inadequate resource assessment; **O1**: forage for cattle; **O2**: restoration of ecosystem services; **O3**: reduced fuel loads; **O4**: support to related industries; **T1**: uncertain markets; **T2**: uncertain policies; **T3**: lack of enthusiasm from manufacturers; **T4**: transportation costs

Figure 3.7: Perception map representing importance of each SWOT factor for *NGO & other* stakeholders. The higher the global priority, the further the factor is positioned from the origin.



S1: availability of a variety of natural resources **S2**: market proximity; **S3**: investment and employment opportunities; **S4**: currently raw materials are virtually free (ex. eastern redcedar); **W1**: population pressures; **W2**: future land use change; **W3**: low quality resources; **W4**: inadequate resource assessment; **O1**: forage for cattle; **O2**: restoration of ecosystem services; **O3**: reduced fuel loads; **O4**: support to related industries; **T1**: uncertain markets; **T2**: uncertain policies; **T3**: lack of enthusiasm from manufacturers; **T4**: transportation costs

CHAPTER IV

CONCLUSIONS

The results of this research reveal that the stakeholders and stewards of the Cross-timbers are generally optimistic about both active management and the marketable opportunities of the forest resources in the region. To this end, the stakeholders revealed that the many strengths and opportunities were more important than the overall perceived weaknesses and threats. While the weaknesses and threats cannot be ignored in managing and marketing these resources, they can be overcome with proper planning and mitigation. Utilizing the marketable forest resources in the region may provide additional income and encourage landowners to retain and manage the forested land within the Cross-timbers.

As revealed in chapter II, active management cannot only strengthen the overall health and resilience of these forests but may provide opportunities for increased investment in the region and potential revenue. Further, active management will enhance ecosystem services such as reduced wildfire risk, enhanced wildlife habitat, and improved aesthetics, which are of significant importance to Cross-timbers stakeholders. While stakeholders revealed that the financial burden of management and the potential threat of uncontrolled fire may hinder these efforts, these obstacles may be alleviated through outreach efforts and getting landowners connected with experienced fire personnel.

The results from chapter III disclosed that the wide variety of available forest resources and market proximity make the Cross-timbers a viable commodity for an emerging natural resource market. Further, market establishment can create opportunities for the restoration of ecosystem services, the reduction of fuel loads, forage for cattle, and can even bring support to related industries. While some stakeholders were concerned with the lower quality of the Cross-timbers resources, lack of enthusiasm from manufacturers, and changing land uses, these hindrances can be minimized by active management and developing a market strategy that makes the best use of the available resources.

Finally, restructuring policies and developing landowner incentives may also foster a sense and desire for stakeholders to become more involved in the management of Cross-timbers forest resources. By utilizing the SWOT-ANP methodology, I was able to understand how stakeholders perceive the uses and management of Cross-timbers resources. Nonetheless, to further quantify these perceptions, future research on the economic valuation of Cross-timbers ecosystem services and policy development, including research on landowner willingness to pay (WTP) for non-commodity related Cross-timber forest benefits or their willingness to accept (WTA) the costs incurred in active management, are recommended.

APPENDICES

APPENDIX A: IRB APPROVAL SHEET

Oklahoma State University Institutional Review Board

Date:	Wednesday, May 03, 2017
IRB Application No	AG1721
Proposal Title:	Stakeholders Perceptions on Active Management in the Cross-timbers
Reviewed and Processed as:	Exempt

Status Recommended by Reviewer(s): Approved Protocol Expires: 5/2/2020

Principal Investigator(s):

Morgan Starr	Omkar Joshi
Stillwater, OK 74078	Stillwater, OK 74078

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

☐ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1.Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval. Protocol modifications requiring approval may include changes to the title, PI advisor, funding status or sponsor, subject population composition or size, recruitment, inclusion/exclusion criteria, research site, research procedures and consent/assent process or forms
2.Submit a request for continuation if the study extends beyond the approval period. This continuation must receive IRB review and approval before the research can continue.
3.Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of the research; and
4.Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Dawnett Watkins 219 Scott Hall (phone: 405-744-5700, dawnett.watkins@okstate.edu).

Sincerely,

Hugh Crethar, Chair
Institutional Review Board

APPENDIX B: IRB APPROVAL FOR MODIFICATION INCLUDING SECOND SURVEY

Oklahoma State University Institutional Review Board

Date:	Tuesday, July 25, 2017	**Protocol Expires:**	**5/2/2020**
IRB Application No:	AG1721		
Proposal Title:	Stakeholders Perceptions on Active Management in the Cross-timbers		
Reviewed and Processed as:	Exempt **Modification**		

Status Recommended by Reviewer(s) **Approved**

Principal Investigator(s):

Morgan Starr	Omkar Joshi
Stillwater, OK 74078	Stillwater, OK 74078

The requested modification to this IRB protocol has been approved. Please note that the original expiration date of the protocol has not changed. The IRB office MUST be notified in writing when a project is complete. All approved projects are subject to monitoring by the IRB.

☐ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

The reviewer(s) had these comments:

addition of survey 2

Signature :

Hugh Crethar, Chair, Institutional Review Board

Tuesday, July 25, 2017
Date

VITA

Morgan Starr

Candidate for the Degree of

Master of Science

Thesis: STAKEHOLDER PERCEPTIONS ON THE BETTER MANAGEMENT OF CROSS-TIMBERS FOREST RESOURCES

Major Field: Natural Resource Ecology and Management

Biographical:

Education: Completed the requirements for the Master of Science in Natural Resource Ecology and Management at Oklahoma State University, Stillwater, Oklahoma in July, 2018. Received a Bachelor of Science in Economics and Forestry at Texas A&M University, College of Liberal Arts, College Station, Texas in August, 2016.

Experience: Student worker at Texas Forest Service, 2014-2016; Internship at Plum Creek, 2015; Graduate Research Assistant at Oklahoma State University, 2016-2018

Professional Memberships: Society of American Foresters, Xi Sigma Pi