JOURNAL OF INTERNATIONAL ACADEMIC RESEARCH FOR MULTIDISCIPLINARY
Impact Factor 3.114, ISSN: 2320-5083, Volume 5, Issue 6, July 2017

EVALUATING THE RELATIONSHIP BETWEEN VEGETATIVE COMPOSITION AND FOREST AESTHETICS OF PRESCRIBED FIRE MANAGEMENT IN LONGLEAF PINE (*PINUS PALUSTRIS* MILL.) FORESTS

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Abstract

The majority of the coastal plain from Virginia to Texas was predominantly covered by longleaf pine (*Pinus palustris* Mill.) stands. These forests were described as 'park like' forests with a clean, aesthetic, and picturesque understory. However, European settlement dramatically degraded the longleaf pine ecosystem. Today, suppression of fires has substantially reduced the pine reproduction, increased the woody understory vegetation, and has significantly decreased the stand maintenance and regeneration of longleaf pine stands. Yet, there is a gap in understanding the relationship between the scenic beauty, forests aesthetics and how prescribed fire treatments impact the public perception of longleaf pine forests. This study aims to evaluate how different seasons and timing of prescribed fire treatments impact the scenic beauty of longleaf pine forests on the Escambia Experimental Forest near Brewton, Alabama. The main objectives of this research was to examine the forest measurements associated with each of the prescribed fire treatments in an attempt determine additional factors that may contribute to the scenic beauty of a forest scene.

Keywords; prescribed fire, forest aesthetics, longleaf pine, scenic beauty

Introduction

Most of the forested lands in the southeastern United States were dominated by longleaf pine as fire-maintained pine forests along the Gulf and Atlantic coastal plains, from eastern Texas north to southern Virginia and inland to the Piedmont to the mountain provinces of Alabama and Georgia (Schwarz 1907). Historically, two-thirds of the Southeast was once covered by longleaf pine communities at approximately 36 million ha which significantly declined to nearly 1.2 million ha land cover (Frost 1993). The longleaf pine forests were often described as “park-like” and maintained by natural and human-ignition fires every 2-4 years. Also, southern woods fires were also part of the culture and the ecosystem, nevertheless, there is a lack of understanding the positive outcomes of fire application today.

Importance of Forest Aesthetics Assessments

Forest aesthetics can be defined as the application of the management practices that improve the visual quality of the forested landscapes (Purcell et al. 2001). Forest aesthetics and landscape preference have been studied since the 1960s, and scenic beauty of the landscapes is not only scientific, but also carried out as public interest (Purcell et al. 2001). Kalidindi et al. (1996) reported that the concept of scenic beauty can be a major component of landscapes because public experience of the visual appearance of landscapes has a significant effect on scenic beauty consideration. According to Frank et al. (2013), landscape aesthetics and its effects on human well-being have gained a momentum due to increase in importance of public perceptions of scenic beauty. There are also several interests such as energy production, economic benefits, relative abundance of plant species, and scenic beauty which are balanced because of the relationship between landscape aesthetics and public preference (Blaschke 2006). However, there have been few studies documented the relationship between longleaf pine forests and forest aesthetics considering application of prescribed fire in different seasons.

The judgment of scenic beauty of landscapes is highly associated with the opinion of observers, and forests are considered to have a positive effect on the psychological and physiological health of public (Chen et al. 2015). There has been an increase in the aesthetic assessment of landscapes, and there are two methods of aesthetic assessment, objective and subjective methods (Daniel and Boster 1976). Photographic surveys are considered a subjectivist method of assessment of scenic beauty, and photographs are used to determine the landscape quality of environmental components including forest lands (Daniel and Boster 1976). Also, photographic evaluations provide economical and efficient methods of visual evaluation (Zubelzu and del Campo 2014).

In the assessment process of forest aesthetics, Scenic Beauty Estimation (SBE) model was first applied by Daniel and Boster (1976) who involved the observers' perception rankings on scenic beauty of vistas. SBE is defined as a psychophysical method which tests subjects scoring the visual quality of photographs of forest stands that have been measured on-site by forest management techniques (Edwards et al. 2012). Moreover, the scenic beauty values of landscapes can be derived from different landscape scenes by participation of various observers and results of visual preference surveys can be analyzed using the RMRATE rating data software (Daniel and Boster 1976). The SBE method is considered as accurately depicting observers' perceptions of changes in a landscape and how they impact the scenic beauty (Ray 1994).

Factors That Influence the Scenic Beauty Estimation

Scenic beauty of a landscape is mainly affected by characteristics of the scene such as color, size of the plants, and ground cover (Daniel and Boster 1976). In fact, less plant cover and increased visual depth in an image is considered as high scenic beauty, where thin trees with high density of foliage understory and small diameter stems are defined as low scenic beauty landscapes (Kalidindi et al. 1996). People prefer mostly mature forest stands with clear visibility and understory, and a green field layer, in contrast, direct traces of tree cutting and logging residues have negative effect on scenic beauty preference of public (Silvennoinen et al. 2002; Ribe 2009; Tyrvainen 2016).

Several studies reported basal area and tree density can influence the preference of scenic beauty. For instance, Arthur (1977) applied a physical feature model to ponderosa pine stands with variable tree density, and concluded that higher densities of ponderosa pine tree in stand had a positive impact on scenic beauty preference. Also, Vodak et al. (1985) claimed that there was a positive and significant relationship between SBE and basal area of forest stands. Another study by Rudis et al. (1988) found that there was a positive relationship between pine stand density and scenic value of the landscape in east Texas. Hoffman and Palmer (1996) additionally asserted that forest measurements and silvicultural methods have a significant impact on understanding the fundamental concepts of forest aesthetics and scenic beauty.

Regenerating forested stand using the shelter wood or seed tree methods are generally thought more picturesque than open regeneration landscapes (Silvennoinen et al. 2002; Ribe 2009; Tyrvainen 2016). Ribe (2009) additionally claimed that SBE can also impact cognitive judgments of timber harvests' preference, and the frequency of harvests along with economic benefits. More importantly, there is a lack of understanding if there is an optimal tree density which influences the scenic quality approval of a landscape by public (Schroeder and Green 1985).

Prescribed fire management is one of the most effective methods to naturally regenerate forests. In fact, according to Kauffman (2004), it is estimated that ten times more landscape was burned in the history than today. More importantly, prescribed burning has more positive impact on naturally regenerating forest stands than grazing, timber harvest, thinning, and biomass utilization (Kauffman 2004). Thus, determination of the effects of fire on naturally regenerating forest stands can be associated with SBE and public preference of prescribed fire management.

Longleaf Pine and Prescribed Fire Management

Longleaf pine (*Pinus palustris* Mill.) forests are one of the most important ecosystems dependant on naturally regeneration methods such as prescribed fire management in the southeastern United States, (Frost 1993; Kush et al. 2000). At present, due to inadequate regeneration, the cover of longleaf pine forests dramatically declined to less than 1.2 million hectares (Alavalapati et al. 2002). Moreover, lightning strikes in the southeastern United States led to frequent fire occurrence in the region which resulted with the dominance of longleaf pine forests (Croker 1987). In addition, native Americans set fire to control their landscape in the southern Coastal Plain (Croker 1987). Longleaf pines are also more resistant to fire, diseases, and insects than any other southern pines, and succession to hardwoods, new plantation applications, and suppression of natural fire regimes have caused significant reduction in longleaf pine forest stands (Croker and Boyer 1975; Brockway et al. 2006). There has been also an increase in the restoration of the longleaf pine forests because they are considered species at high risk in the United States (Brockway and Outcalt 2000; Frost 2006). More importantly, in the absence of frequent fire, hardwood trees and woody shrubs occupy the ground cover of longleaf pine forests (Barlow et al. 2010).

The purpose of this study was to expand upon the work of public perceptions through the examination of the relationship between the scenic beauty estimation of prescribed fire management and vegetative composition of longleaf pine stands. There have been many other studies (Kauffman 2004; Loomis et al. 2001; Ostergen et al. 2008) which focused on public perceptions of ecological restoration, specifically fire management in the north, west, and southeastern U.S. Also, more information is needed about the influence of prescribed fire management on longleaf pine forests including various treatment seasons, its relationship with scenic beauty preference of public and vegetative cover of longleaf pine forests. Therefore, this study was used to examine the photographs assessed by the survey participants to see if there is a trend related to the impact of different Fire Return Intervals (FRI) of prescribed fire on scenic beauty and vegetative composition of longleaf pine stands, and to determine the correlation between aesthetics and fire treatments through a visual assessment survey. We compared the influence of prescribed fire on the vegetative composition of longleaf pine stands in relation to visual quality assessment. Photographs used during the surveys were taken from: a) two-year FRI, b) three-year FRI, c) five-year FRI, and d) no-burn treatment of Spring and Winter seasons.

METHODS

Photographic inventory

The survey photographs used in this study were taken at the Escambia Experimental Forest (EEF) in Escambia County, Alabama in 2015. The EEF was established in 1947 on 1,214 hectare area to research the longleaf pine ecology (Adams et al. 2003). This study site was initiated in 1984 on the EEF to examine the impact of winter and spring burns on longleaf pine stands. Plots used in this current study were 0.1 acre in size with approximately 40 crop trees thinned for fairly uniform spacing at project initiation (Boyer 1990). There are three treatment blocks in close proximity to each other. Prescribed fires were initiated on the plots in the winter and spring 1985 and the areas have been burned on 2-, 3-, and 5-year intervals since that time. Winter fires were performed in January/February while spring fires were usually in April/May. Flank or strip head fires were used to minimize crown scorch and were often set following soaking rains, fine fuel moisture of 7-10%, relative humidity 35-55%, and steady winds. The study also has no-burn check plots.

The photographs of the study area were taken at the corner of each treatment plot by focusing on the foreground and middle-ground forest scenes. A tripod-mounted digital SLR camera was used to take the photographs by setting up the camera over the plot corners at the average viewer's height (1.7m) (Figure 1).

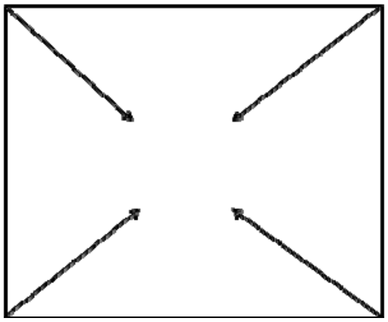

Figure 1. The illustration of photograph-taking method at each plot in study area. Each photograph was taken from the corner of each plot by looking into the center of the plot.

The photographs of each composition were taken by turning the camera approximately 30 degrees to derive a successful representation of the view in-situ. Per each corner of the plots, there were at least 10 photographs taken by adjusting the elevation angle using lines in the viewfinder (close to 1/3 down from the top of the frame). To reduce the occurrence of noise in the photographs, an ISO of 800 or lower degree was used (Craft 2015). The sampling method of photographs was derived from Daniel and Schroeder (1979). Time, date, plot number, corner number, and other associated information were recorded to be used in selection of the survey photographs.

Perceptual Preferences of Respondents

The photographs derived from different FRIs of longleaf pine forest were analyzed by the School of Forestry and Wildlife Sciences and Department of Art faculty members at Auburn University to select slides for the best quality images, exposure, the trueness of their colors, and general clarity. Each photograph was then selected based on the best representation of the study area and distracting elements such as tree numbers were eliminated to minimize bias. Then eight photographs representing the most accurate visualization or each treatment were chosen based on treatment type: Spring 2 years, Spring 3 years, Spring 5 years, Winter 2 years, Winter 3 years, Winter 5 years and no burn.

A by-slide method of analysis (Daniel and Boster 1976; Clay and Daniel 2000) was used to examine the perceptual differences of each photograph, and the photographs were presented to a total of 115 students (n=115) from a cross-section of disciplines: Forestry (19 students), Biology (11 students), Fine Arts (19 students), Economics (8 students), and "Others" (58 students) at Auburn University, Auburn, Alabama, USA. The "Others" discipline consists of students from various backgrounds and does not include Forestry, Biology, Fine Arts, and Economics disciplines.

Each survey group was tested individually using same set of photographs. Images were projected on a screen for 6 seconds with an automatic transition to allow for rating between transitions of photographs. Respondents were asked to rate each image on a scale of 1-10 based the perception of the images scenic beauty where a 1 indicated very low scenic beauty rating and a 10 represents very high scenic beauty rating (Daniel and Boster 1976; Clay and Daniel 2000).

Basal Area (BA) and Vegetative Composition Assessment

Basal area is defined as the cross-sectional area of a tree at breast height and it is calculated as follows:

$$BA = 0.005454 \times DBH^2$$

Where BA is the basal area (sqft), the number 0.005454 is called the foresters constant, and DBH is diameter at breast height of a single tree.

Also, to calculate number of trees per each photograph, we visually evaluated the survey photographs by counting the number of pine trees on each survey photograph of the fire treatments. Then, we observed the understory vegetation to evaluate the SBE rating differences between survey photographs of each fire treatment used in the survey.

Data Analysis

SBE analysis is a psychophysical method which tests subjects scoring the visual quality of photographs of forest stands that have been measured on-site by forest management techniques (Edwards et al. 2012). For the SBE analysis, each survey group was tested individually using the same set of photographs. Results of visual preference surveys were analyzed using the RMRATE rating data software (Daniel and Boster 1976; Brown and Daniel 1990; Ray 1994).

In SBE method, each stimulus was ranked based on condition of interest, then each category was converted to a Z score (as a reference to standard normal distribution). In order to eliminate biases of SBE analysis, the baseline-adjusted Z-Score procedure was applied on the survey data. In this analysis, the procedure computes standard scores as:

$$SBE_i = (MZ_i - BMMZ)100$$

Where SBE_i is SBE of stimulus i, MZ_i is the mean Z of stimulus i, and BMMZ is the mean Zs of the baseline stimuli. For each survey group, each 4th stimulus was used as a baseline during the SBE calculation process. Then, stimuli were calculated based on these baseline categories for each survey group (Daniel and Boster 1976; Ray 1994).

F test was used to examine if there was any statistical differences among seasons of prescribed fire and SBE scores of photographs taken from seven different FRI groups. For this purpose, SBE score was used as the dependent variable, and seasons were independent variables. To find where exactly the differences came from, Duncan/Waller test was applied. Duncan's multiple range test is generally used to estimate the relationship between two or more variables (Cruz 2013). In this study, Duncan's test was used to examine the potential relationship between the survey participants' SBE ratings for seven different FRIs in the study area.

RESULTS

Based on the basal area calculations, the highest basal area was found at 157.13 sqft/ac for Spring 5 years FRI group, whereas the lowest basal area was 120.56 sqft/ac for no burn treatment group. Also, for Spring 2 years and Spring 3 years treatments, basal areas were found at 124.9 sqft/ac and 138.61 sqft/ac, respectively. For Winter -2, -3, and -5 years treatment groups, basal areas were found at 141.95 sqf/ac, 130.14 sqft/ac, and 142.09 sqft/ac, respectively. For both Spring and Winter season FRI groups, there was not any relationship observed between SBE score of FRI groups and basal area calculations (Figure 2; Table 1).

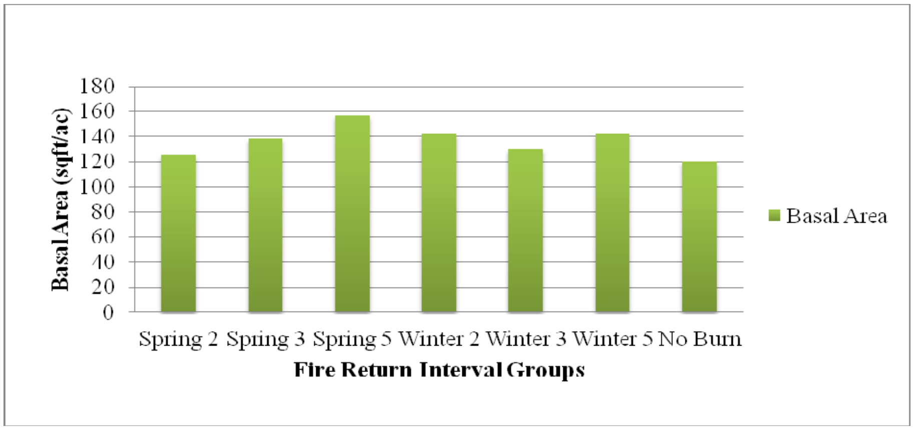

Figure 2. Basal area of the study area with relevant 7 fire return interval groups

Table 1. The relationship between mean basal area and SBE scores for each FRI treatment group (FRI: Fire Return Interval; SBE: Scenic Beauty Estimation).

FRI Groups*	Mean Basal Area (sqft/ac)	Mean SBE Scores
Spring 2 years	124.9	94.95
Spring 3 years	138.61	67.07
Spring 5 years	157.13	2.53
Winter 2 years	141.95	64.79
Winter 3 years	130.14	25.66
Winter 5 years	142.09	33.19
No Burn	120.56	-120.55

*Spring 2 years: Prescribed fire every 2 years in Spring, Spring 3 years: Prescribed fire every 3 years in Spring, Spring 5 years: Prescribed fire every 5 years in Spring, Winter 2 years:

Prescribed fire every 2 years in Winter, Winter 3 years: Prescribed fire every 3 years in Winter, Winter 5 years: Prescribed fire every 5 years in Winter, No Burn: Absence of fire).

Considering the Duncan's tests, the results of the study were statistically significant at the level of 0.01 alpha value. Also, SBE ratings of all FRI groups were statistically significant than each other (Table 2). Both Duncan and Waller tests scores based on SBE means showed that no burn treatment group was statistically significant and different than other FRI groups (Table 2). To derive why no burn treatment was different than other FRIs, we reevaluated the survey photographs of each FRI groups.

Table 2. Duncan's multiple range test results between basal areas of study area and mean SBE scores of FRI survey photographs of longleaf pine stands evaluated by students at Auburn University, Auburn, Alabama in 2016 (FRI: Fire Return Interval, SBE: Scenic Beauty Estimation).

Waller Grouping	**Mean SBE Scores**	**N**	**FRI**
A	94.95	2	Spring2
A	67.07	2	Spring3
A	64.79	3	Winter2
A	33.19	3	Winter5
A	25.66	3	Winter3
A	2.53	3	Spring5
B	-120.55	2	No Burn
		F Value	**Pr > F**
		4.79	0.019

As a result of manually counting the number of pine trees on photographs, there was also a positive relationship found between SBE scores and number of pine trees counted on the survey photographs of each treatment group. For instance, Figure 3 was rated at 56.9 mean SBE score whereas individuals ranked Figure 4 at 147.11 mean SBE score, though both photographs were taken from Spring 2 years treatment plots. Also, in Figure 4, number of pine trees was 67, whereas it was 46 in Figure 3, and Figure 4 has lower understory cover than Figure 3.

Figure 3. Survey photograph taken from prescribed fire management applied every 2 years in Spring season on study area ranked at 56.9 mean SBE score by participants.

Figure 4. Survey photograph taken from prescribed fire management applied every 2 years in Spring season on study area ranked at 147.11 mean SBE score by participants.

Moreover, Figure 5 was ranked at 89.4 mean SBE score, while Figure 6 received 147.39 mean SBE rating by survey participants, yet both photographs were taken at Winter 3 years fire treatment plot. In Figure 6, the number of pine trees counted was 60, whereas it was 35 in Figure 5, and understory level is lower in Figure 6 than observed in Figure 5. Therefore, based on individuals' responses, we found that understory height level negatively affected the mean SBE scores, and the number of pine trees counted on photographs positively affected the mean SBE ratings for each treatment group.

Figure 5. Survey photograph taken from prescribed fire management applied every 3 years in Winter season on study area rated at 89.4 mean SBE score by individuals.

Figure 6. Survey photograph taken from prescribed fire management applied every 3 years in Winter season on study area rated at 147.39 mean SBE score by individuals.

DISCUSSION

The purpose of this study was to examine the relationship between the scenic beauty estimation of prescribed fire management and vegetative composition of longleaf pine stands. We examined the photographs assessed by the survey participants to see if there was a trend related to the impact of different FRIs of prescribed fire on scenic beauty and vegetative composition of longleaf pine stands through a visual assessment survey. The results of this study showed that survey photographs derived from frequent fire return interval groups had the highest SBE scores which also indicates participants preferred frequently burned plots in contrast to no burn plots. Moreover, the influence of prescribed fire on the vegetative cover of longleaf pine stands showed that pine tree density and lower understory cover had a positive impact on the perception of forest aesthetics. Then, we found density of understory cover had a negative impact on the SBE scores of participants for all FRI groups. Therefore, we can assume that observers perceived photographs with higher number of pine trees and lower density understory cover more aesthetically pleasant.

Considering the seasons of prescribed fire and SBE relationship, the lowest SBE scores were derived from no burn treatment groups, in contrast, photographs of the most frequent fire treatment seasons had the highest SBE scores. Moreover, basal area calculations were found similar among the FRI groups while the mean SBE scores were significantly different than each other. This may suggest that frequency and season of fire impacted the SBE scores more than basal area due to open understory, clear vision, and increase in number of pine trees counted in more frequently-burned longleaf pine stands. Also, as tree density decreases, people prefer large diameter trees, and thinner pine forests are generally perceived aesthetic when tree density is high (Mao et al. 2015). Considering all assessed survey photographs, understory height > 1.4 m (which is also adjusted camera height) obstructed the appearance of pine trees which may also have reduced the SBE scores of these photographs. As a result, more frequently burned plots, small diameter and dense longleaf pine stands with lower understory vegetation might be another factor that increased the SBE scores even though the basal area was lower for those plots of FRI groups.

CONCLUSION

In the absence of fire, hardwoods and shrubs invade longleaf pine forests, and understanding public perception of prescribed fire can help land managers and policy makers by increasing the awareness of importance of prescribed fire management. The outcomes can also increase the awareness of benefits of improvement in scenic beauty perception, thus, the role of forest aesthetics on demonstrating the scenic beauty of longleaf pine ecosystems. This research has highlighted that understanding the process of frequent prescribed fire management has a prominent effect on public perception of forest aesthetics from different FRI groups applied for longleaf pine forests and SBE relationship. Also, importance of vegetative cover on aesthetical perception of different FRI groups associated with longleaf pine forests can help increasing the awareness of forest management activities and their positive outcomes for sustainability.

Furthermore, scenic beauty of a landscape is mainly affected by characteristics of the scene such as color, size of the plants, and ground cover. In fact, less plant cover and increased visual depth in an image is considered as high scenic beauty, where small trees with high density of foliage understory and small diameter stems are defined as low scenic beauty landscapes (Kalidindi et al. 1996).

In addition to characteristics of the scene, forest aesthetics have a significant relationship with forest management practices such as prescribed fire, and perception of various tree growth forms in terms of tree density measurement can facilitate understanding the post-fire landscape views and how they encompass with the process of frequent fire establishment. More importantly, frequent post-fire conditions of longleaf pine understory can enhance the visual quality of these ecosystems which may also increase the aesthetic perception of public. This research has shown that public perception of post-fire conditions on natural landscapes can be weighted differently by observers depending on how they determine understory density, tree measurements such as tree density, and correlate them with the post-fire views of FRI groups in longleaf pine stands. Further public surveys can be also conducted with public landowners and forest managers to demonstrate the importance of forest management practices such as prescribed fire management on basal area and tree density perception of land owners and policy makers. To evaluate the forest aesthetics of landscapes, visual evaluation methods such as pixel calculation of photographs can be also applied using ICY and LIDAR software programs for the future studies.

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