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Spatial analysis of family forest landownership in the southern United States

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ABSTRACT

Family forest landowners in the United States have diverse ownership and management objectives. Assessing and monitoring regional patterns and trends in landowner motivations and management behavior may aid in understanding the conservation and economic implications of social change. This paper presents a regional analysis of family forest landowners in the southern United States by combining a GIS-based exploratory data analysis with spatially explicit information on landowner motivations and management behavior data obtained from the U.S. Forest Service National Woodland Owners Survey (NWOS). Results reveal that spatial autocorrelation was present in motivations reflecting tangible and pecuniary benefits (e.g. timber, investment, hunting), but not in motivations reflecting intangible and non-pecuniary benefits (e.g. privacy, beauty). Statistically significant clusters of landowners with similar motivations and management behaviors (i.e., hotspots/coldspots) were identified using local indicators of spatial association and visualized in a series of maps to discuss their policy and management implications. The findings are useful in understanding regional variations as well as concentrations in landownership motivation, management activities, and will guide stakeholders in locating areas of interest for conservation planning, strategic marketing, and education and outreach.

1. Introduction

Family forest landowners, also known as non-industrial private forest (NIPF) landowners, own and manage approximately 121 million hectares of forestland across the United States (Butler, Hewes et al., 2016; Dickinson, Hewes et al., 2016). Studies conducted over the years at local (Erickson, Ryan, & Young, 2002; Salmon, Brunson, & Kuhns, 2006) as well as national scales (Butler, & Leatherberry, 2004; Butler, Hewes et al., 2016; Dickinson, Hewes et al., 2016) have consistently shown that family forest landowners are highly diverse in terms of ownership motivation and management objectives that range from intensive timber production to preservation of non-timber interests such as amenity and family legacy. Sustaining forest resources in this ownership is critical because a range of public benefits from these forests directly and indirectly benefit society. Emerging literature on human dimensions of family forest landownership suggest that motivations of landowners are changing across the nation (Sorice, Kreuter, Wilcox, & Fox, 2014) and the general public is largely concerned about the way forests are managed by private landowners (Poudyal, Moore, & Young, 2015).

Furthermore, a recent review of literature on private forest landowners revealed that landowner decision-making (e.g., harvesting) behavior still remains an under-studied subject (Silver, Leahy, Weiskittel, Noblet, & Kittredge, 2015). Previous studies (Salmon et al., 2006) have taken non-spatial approaches (e.g. multivariate analysis of socio-psychological constructs) to segment landowner population into homogenous groups. However, none of these studies have tied landowner behavior to their spatial distribution. Comparing patterns in landownership may be helpful in understanding regional dynamics of ownership patterns (Nielsen-Pincus, Ribe, & Johnson, 2015) and management, as well as informing outreach/education/extension activities. Recent studies have argued that landowner preference mapping can be a useful tool in conservation planning on the ground (Bontrager, Krester, Leong, & Connelly, 2017).

Social scientists in natural resources typically analyze landowner motivations to understand and predict why and how forests under private ownership are managed. Existing theory in landowner motivation and behavior suggests that motivations are an important part of their decision-making and drive land management practices (Sorice et al., 2014). Studies have also shown that landowner management decision-making is better predicted by cognitive variables such as motivations and opinions rather than the spatial characteristics of property (Jacobson, 2002). Consistent with the theory of cognitive hierarchy (Vaske & Donnelly, 1999), motivations are formed based on personal values and attachment to the forests. Similarly, the theory of planned behavior (Ajzen, 1991) posits that motivational or intentional factors such as why landowners value their forests or what they want to do with their forests ultimately influence their behavior.

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Studies have examined landowner motivation and management behavior based on this theoretical foundation (Finley & Kittredge, 2006; Salmon et al., 2006; Majumdar, Teeter, & Butler, 2008; Sorice et al., 2014; Metcalf, Gruver, Finley, & Luloff, 2016). While most of these studies identify common themes defining motivation and management behaviors, no regional or spatial analysis has examined landownership motivations or predicted behavioral intentions. A few exceptions exist, however. For example, Kaetzel, Majumdar, Teeter, and Butler (2012) compared landowner characteristics and intentions among six USDA Forest Inventory and Analysis regions, although it did not involve any spatial analysis. Recently, a study of landowner attitudes in the Piedmont-Blue Ridge region found that landowners in certain areas within the landscape had similar conservation attitudes (Chambers, Baldwin, Baldwin, Bridges, & Fouch, 2017). Aguilar, Cai, and Butler (2017) utilized a geo-referenced survey dataset of family forest landowners to analyze forest management behavior in relation to their geographic proximity. Their results confirmed spatial association in landowner land use choices. Bontrager et al. (2017) demonstrated how spatial mapping of landowner survey data could assist in on-the ground planning of conservation efforts across a landscape.

As stated in Aguilar, Cai, and Butler (2017), we argue that Tobler's first law of geography: "everything is related with everything else, but near things are more related than distanced things," is relevant in describing the motivation and management behavior of landowners at a regional scale. The theoretical notion to support this argument is that landowners facing similar local challenges under similar social, economic, and cultural circumstances may act in similar fashions. In some cases, landowners may behave similarly to their proximal neighbors through social interaction or from the benefit of peer networking (Mouw, 2006; Munshi, 2004; Kueper, Sagor, & Becker, 2013), whereas in other cases, landowners with similar resources may be restricted to certain management choices. Further, emerging literature on landscape analysis of landownership suggests a variety of interactions and interrelationships among landowners as well as other relevant organizations assisting them in land management (Galik & Grala, 2017). Hence, the spatial pattern in landowner motivation and behavior may be related to underlying similarities and differences in biophysical, social, and economic factors. For example, forest species type, site quality/productivity, logging feasibility, and aesthetic appeal might affect the suitability of forests for certain objectives. Likewise, a number of social and economic phenomena such as abundance of sawmills, relative supply and demand of wood products in the regional market, concentration of absentee or retiree landowners, proximity to public lands and outdoor recreation hotspots also may affect landowner options.

The above-mentioned issues warrant new research on spatial pattern and processes driving the dynamics of ownership and management. This paper combines spatial modeling techniques with spatially explicit U.S. Forest Service National Woodland Owners Survey (NWOS) data to explore spatial patterns of landownership dynamics. Mapping patterns allows evaluating similarities and differences in NWOS variables as well as locating where and why certain types of ownership and management activities are concentrated. While some existing studies (e.g. Majumdar et al., 2008; Nielson-Pincus, Ribe, & Johnson, 2015) analyzed typology of motivations, and others (e.g. Aquillar, Cai, & Butler, 2017) confirmed the spatial dependence in association between motivations and behavioral intentions, no regional study explored the geographical patterns in ownership motivations and management behavior. Results from this study will provide a regional perspective for understanding the dynamics of family forest landownership in the United States. The specific objectives of this study are to:

- test the extent of spatial autocorrelation in specific NWOS variables measuring landowner motivations, and management behavior, and
- conduct exploratory spatial data analysis of spatially autocorrected NWOS variables to identify and map spatial clusters.

We hypothesize that landowner motivations for forest ownership and management behavior in the study area are spatially autocorrelated, and distinguishable clusters of landowners with similar motivations and behavior in certain areas exist.

2. Methodology

2.1. Study area

The study area includes 13 southern states: Alabama, Arkansas, Georgia, Florida, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Virginia, Tennessee and the eastern parts of Oklahoma and Texas. Western parts of Texas and Oklahoma were excluded from this analysis because of differences in forest coverage. This region was chosen because it contains more than half of U.S. forests and approximately 155 million acres of forest belonging to family forest landowners (Butler, Hewes et al., 2016; Dickinson, Hewes et al., 2016). Over the years, landowners in the region have witnessed changing social and economic circumstances because landscapes in the region are subject to competing land use interests such as timber, urban development, and recreation. Recent NWOS data show that the average size of private forest landownerships in the region is 25% larger than the national average, but the average tenure is slightly shorter than its national counterpart (Butler, Hewes et al., 2016; Dickinson, Hewes et al., 2016). The region is traditionally regarded as the "timber basket" of the nation, but recently it has experienced land use change due to migration and urban sprawl around several metropolitan areas. As a result, landownership in the region is gradually changing (Sorice et al., 2014), becoming less stable (Wear & Greis, 2012) and more diverse (Butler & Wear, 2013). As a result, government and non-government institutions in the region are facing increasing challenges in designing and administering public programs such as education and outreach, and in forging cross-boundary cooperation for resource management.

2.2. Data

Data used in this analysis were obtained from the most recent version of the NWOS from 2011 to 2013 (Butler, Hewes et al., 2016; Dickinson, Hewes et al., 2016). A total of 2893 survey responses from our study area were extracted and analyzed. The NWOS offers rich and reliable information on ownership motivations and management behavior of family forest landowners including families, individuals, trusts, estates, family partnership and other unincorporated groups. Studies have previously utilized the NWOS data to answer many questions regarding private forest landownership (e.g. Kaetzel et al., 2012; Majumdar et al., 2008; Song, Aguilar, & Butler, 2014; Aquillar, Cai, & Butler, 2017).

NWOS data are specific to individual landownerships and provide information on ownership motivations and management objectives, as well as recent management activities such as harvesting, planting, controlled burning, and participation in cost-share programs. Variables analyzed in this study are defined and presented in Table 1. The importance placed on motivations for owning forestland was measured on a five-point Likert scale (1-not important, 5-very important) and engagement in management activities over the past five-year period was coded as a dichotomous variable (1 – yes, 0 – otherwise). Similarly, their participation in various programs including green certification, federal and state sponsored cost-share programs, and tax-relief programs were also coded as a dichotomous variable.

2.3. Spatial analysis technique

Spatial analysis in this study involved three stages. First, spatial autocorrelation for each of the motivation and behavioral variables presented in Table 1 were checked. An exploratory spatial data analysis was carried out on variables with confirmed spatial autocorrelation (from stage 1) in the second stage, to identify and classify the significance and type (high-high, low-low, etc.) of spatial association at the individual observation level. Finally, significant parameters (at the 5% level) were filtered to visualize spatial clusters of similar observations using ArcGIS 10. It should be noted that 5% level of significance was chosen as decision criteria mainly because

Table 1
Description and spatial autocorrelation of NWOS variables.

Variable	Description	Type of Association (Significance[#])
Motivations of owning forestland		
Beauty/Scenery	To enjoy beauty or scenery	+ (0.34)
Nature	To protect nature or biological diversity	+ (0.30)
Water	To protect water resources	− (0.30)
Wildlife Habitat*	To protect or improve wildlife habitat	+ (< 0.01)
Investment*	For land investment	+ (0.05)
Home	Is part of my home site/primary residence	+ (0.10)
Cabin*	Is part of my cabin or vacation home site	+ (< 0.01)
Farm or Ranch*	Is part of my farm or ranch	+ (< 0.01)
Privacy	For privacy	+ (0.06)
Family	To raise my family	− (0.27)
Children or Heirs*	To pass land on to my children or other heirs	+ (< 0.01)
Firewood*	For firewood	+ (< 0.01)
Timber*	For timber products, such as logs or pulpwood	+ (< 0.01)
Nontimber*	For nontimber forest products, such as pine straw or berries	+ (< 0.01)
Hunting*	For hunting	+ (< 0.01)
Recreation	For recreation, other than hunting	+ (0.07)
Management behavior		
Cut for Sale*	Cut and/or remove trees for sale	+ (< 0.01)
Cut for Personal Use*	Cut and/or removed tees for own use	+ (< 0.01)
Collect Nontimber	Collected nontimber forest products	− (0.44)
Control Burning*	Controlled burn/prescribed fire	+ (< 0.01)
Eliminate Invasive*	Eliminated or reduced invasive plants	+ (< 0.01)
Improve Health	Eliminated or reduced unwanted insects or diseases	+ (0.15)
Improve Wildlife Habitat*	Improved wildlife habitat	+ (< 0.01)
Take Advice*	Have talked with or received advice from anyone about forest management in the past 5 years	+ (< 0.01)
Participate on Certification*	Have forestland currently certified	+ (< 0.01)
Participate on Cost-share Program*	Have a cost-share program to help establish or manage forestland	+ (< 0.01)
Enroll in Easement Program	Have development rights sold or voluntary given away	− (0.17)
Participate on Tax Credit Program*	Have foreland currently enrolled in state or local government program that deter, reduce or eliminate property tax for wooded land	+ (< 0.01)

* Indicates the Global Moran's I on the variable was statistically significant at the 5% or better level, confirming that the observed variation across the region is not random.
[#] Type of spatial association could be positive or negative. Numbers in parenthesis represent the p values associated with Z-scores.

it is a standard practice among researchers to use this threshold for hypothesis testing. However, results, especially the location and extent of spatial clusters, could be sensitive to the threshold chosen.

2.3.1. Spatial autocorrelation

The First of Law of Geography described above is the very principle often employed in analyzing spatial autocorrelation in a phenomenon of interest (e.g., level of importance placed on timber production by landowners). The Global Moran's *I* index, which is analogous to the product moment correlation coefficient (Moran, 1948), is the most commonly used tool to evaluate the spatial autocorrelation of similar and dissimilar values of a variable observed across space (Eq. (1)).

$$I = \frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{i,j}} \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}(\gamma_i - \bar{\gamma})(\gamma_j - \bar{\gamma})}{\sum_{i=1}^{n}(\gamma_i - \bar{\gamma})^2} \quad \text{where} \tag{1}$$

n = sample size,
$W_{ij} = \begin{Bmatrix} 1 \textit{ if the sites } i, j \textit{ are neighbors} \\ 0 \textit{ otherwise} \end{Bmatrix}$ = row-standardized spatial weight matrix showing the connectivity between sites i and j,
$\sum_{i=1}^{n}\sum_{j=1}^{n} W_{i,j}$ is the sum of the number of sampling locations per distance class,
γ_i = value of the variable of interest (e.g., landowners' importance on timber production) for the *i*th landowner.

Depending on the type of correlation (positive or negative), Global Moran's *I* value for a study area can be negative (i.e., dispersed or dissimilar values) or positive (i.e., clustering of similar values). Moran's *I* estimated with Eq. (1) is considered a global indicator of spatial association because, while it simply indicates the variable is spatially auto-correlated, it cannot reveal the local level variation in autocorrelation. Global Moran's *I* for each variable in Table 1 were estimated in GeoDa™ 1.10. Statistically significant ($p \le 0.05$) Z-scores associated with the *I* value for a given variable rejects the null hypothesis of spatial randomness (i.e., the observed pattern is random). This in turn, implies that the results provide support for alternative hypothesis of spatial non-randomness (i.e. the observed pattern is not just random). Hence, if the statistics were statistically significant, suggesting the variable is spatially auto-correlated, a follow up exploratory spatial data analysis was conducted to estimate local Moran's *I*, or the local indicator of spatial association.

2.3.2. Exploratory spatial data analysis

Identifying and locating clusters of landownership with similar motivations and management behavior required estimating Moran's *I* values at a level finer than the study area. Since the NWOS dataset includes individual landownership locations, Anselin's Univariate LISA (Local Indicator of Spatial Association) statistic was employed to calculate observation-specific values of this index (Anselin, 1995) using the equation below.

$$I_i = z_i \sum_j w_{ij} z_j, \quad \text{where} \tag{2}$$

Z_i and Z_j are standardized scores of attribute values for landownership i and j neighbor(s), which according to W_{ij} (weight matrix), are neighbors. The analysis presented in this study used distance-based matrix, where $w_{ij} = 1$ if landowners i and j are within a threshold distance, 0 otherwise. Admittedly, selecting a threshold distance to define a neighborhood is challenging and often subject to debate. A cut-off distance was chosen such that it ensured at least one neighbor to each observation in the dataset. A separate weight matrix file was created and used for each variable analyzed because of the difference in observations due to item non-response. There are other ways to define neighborhood (e.g., contiguity-based, k-nearest neighborhood) in spatial autocorrelation analysis. Contiguity-based weight matrix is not suitable for our point-based data; however, sensitivity of spatial autocorrelation was tested by using k-nearest neighbor weight matrix on select variables. At different values of k (i.e. 1,2,3), the Z-score associated with Moran's I was still significant. Since picking any value of k would be rather arbitrary, the analysis relied on distance-based matrix.

Univariate LISA (Eq. (2)) examined the spatial association between a landowner and his/her neighbors in terms of one phenomenon (or variable of interest). For example, a univariate LISA analysis of the importance on timber production explores how the importance placed on timber production by the *i*th landowner is associated with the interest of its neighbors (j) on this item. The LISA statistics were calculated in GeoDa™ 1.10 and were imported in ArcGIS 10 to map the clusters showing various types of association. Clusters of particular interest in univariate analysis are "hotspot" and "coldspot" clusters. Hotspots mean the cluster of High-High values, i.e., landowners reporting a high value on a variable are located close to landowners that place higher importance on timber. Coldspots, on the other hand, mean the cluster of landowners with Low-Low values, i.e., landowners reporting a low value on a variable (say importance placed on timber production) surrounded by landowners that place a low importance on it. The "high" and "low" levels of a given variable are defined relative to the mean for the study region. The other two types of associations (High-Low and Low-High) are called spatial outliers but are not presented in our analysis. Only observations with LISA scores significant at $p \leq 0.05$ or better were included to show statistically significant clusters. Pseudo-p values were generated for LISA statistics utilizing 999 permutation criteria available in GeoDa™ 1.10.

To preserve the anonymity and privacy of property location, the cluster maps were shown using county boundaries. Displaying clusters based on county boundaries as opposed to census tracts had several advantages. First, privacy could not be totally preserved in some rural areas that have large properties and few large census tracks. Second, counties serve as the administrative unit for several outreach and extension programs and therefore, characterizing clusters relative to county boundaries was deemed more informative and useful than census units. Third, data on other social and economic indicators are available at the county level and could be overlaid with cluster maps at the county level to facilitate further analysis of results.

3. Results

3.1. Spatial autocorrelation results

Results from the spatial autocorrelation tests are also presented in Table 1. The final column shows the sign of the Moran's I (+/−) along with the p value of the Z-score associated with Moran's I for each variable. Of the 16 variables characterizing ownership motivation, 9 were found to have significant and positive Moran's I values, confirming the presence of spatial autocorrelation. Those included: *to product or improve wildlife habitat*, *for land investment*, *is part of my cabin or vacation home site*, *is part of my farm or ranch*, *to pass land on to my children or other heirs*, *for firewood*, *for timber products*, *for nontimber forest products*, *and for hunting.* Moran's I was statistically not significant for the remaining motivation variables: *to enjoy beauty or scenery*, *to protect nature or biodiversity*, *to protect water resources*, *is part of my home site/primary residence*, *for privacy*, *to raise my family and for recreation other than hunting.*

In terms of management behavior, 9 of 12 variables were found to have Moran's I values whose Z-score was statically significant, rejecting the null hypothesis in each case that the observed pattern across the study area is just random. The only variables with statistically non-significant Moran's I included *collected nontimber forest products*, *eliminated or reduced unwanted insects or diseases* in the past five years period, and *participation in voluntary conservation easement program.*

3.2. Spatial clusters analysis results

Results from the LISA analysis mapped in Figs. 1 and 2 are motivation variables and management choice variables, respectively. Individual maps of larger size are also available from the authors upon request. The areas shown in red (i.e. hotspots) indicate areas where landowners with high (relative to the regional average) interest in a particular motivation item are located near landowners with high (relative the regional average) interest in the same item. On the other hand, the dark blue clusters (i.e. coldspots) depict areas where landowners with low interest in a particular motivation item are located near landowners with low interest in the same item. Since these clusters are based on statistically significant variables, the clusters are not observed just by random chance. The areas that appear in white in the region do not have statistically significant spatial autocorrelation, meaning that the spatial association for a given motivation in those areas is not different from random.

3.2.1. Spatial clusters of motivation variables

Wildlife habitat: Fig. 1a–i show the hotspots and coldspots for respective variables. In Fig. 1a, hotspots of motivations for protecting or improving wildlife habitat can be seen in many places including central and northern Florida, southern Alabama, southwestern Georgia, the coastal plain of South Carolina, Blue Ridge region of Tennessee-North Carolina, Interior Plateau region of Kentucky and Tennessee, Mississippi Alluvial Plains, and the Blackland Prairies of Texas. Landowners in these clusters reported relatively higher motivation for wildlife habitat protection compared to all other landowners in the region. Coldspots of wildlife habitat protection motivation can be seen in contrast in difference places. Landowners in these coldspots reported lower motivation for wildlife protection than those in the rest of the region. It should be noted that the northern half of Alabama contained more clusters of landowners with lower motivation.

Investment: Fig. 1b depicts clusters of motivation for land investment. Hotspots of larger size are located in northern Louisiana, western half of Arkansas, eastern half of Mississippi, west Tennessee, and various parts of Alabama. Smaller sized hotspots were also observed in the Carolinas and Virginia but those states along with Kentucky, Georgia, Florida showed more clusters of coldspots than hotspots. The eastern halves of Texas, Oklahoma, and Tennessee also had more coldspots than hotspots.

Cabin: Interesting clusters of motivations for managing forests as part of cabin or vacation home sites were found in a few places only (Fig. 1c), with three major hotspots in eastern Oklahoma, central Arkansas and northern Florida. Locations of these hotspots are not surprising especially considering their proximity to three major national forests –(i.e. Ouachita and Ozark National Forests in Oklahoma-Arkansas and Apalachicola National Forest in Florida). Two additional hotspots were observed around other national forests including one in east Texas near Davy Crocket National Forest and one in southern Alabama east of De Soto National Forest. Coldspots of this motivation item did not make visible pattern other than one in northwestern Louisiana and another one in western Tennessee.

Farm or Ranch: Fig. 1d shows clusters of motivations for managing forests as part of a farm or ranch. With the exception of three relatively smaller hotspots in central Florida, southern Mississippi and east Texas, most of the hotspots were on the northern half of the study area. Those include eastern Oklahoma, northwestern Arkansas, western Kentucky, northeastern Tennessee, and the Coastal Plain areas of Virginia and North Carolina. Very few coldspots were observed in central Alabama and Mississippi.

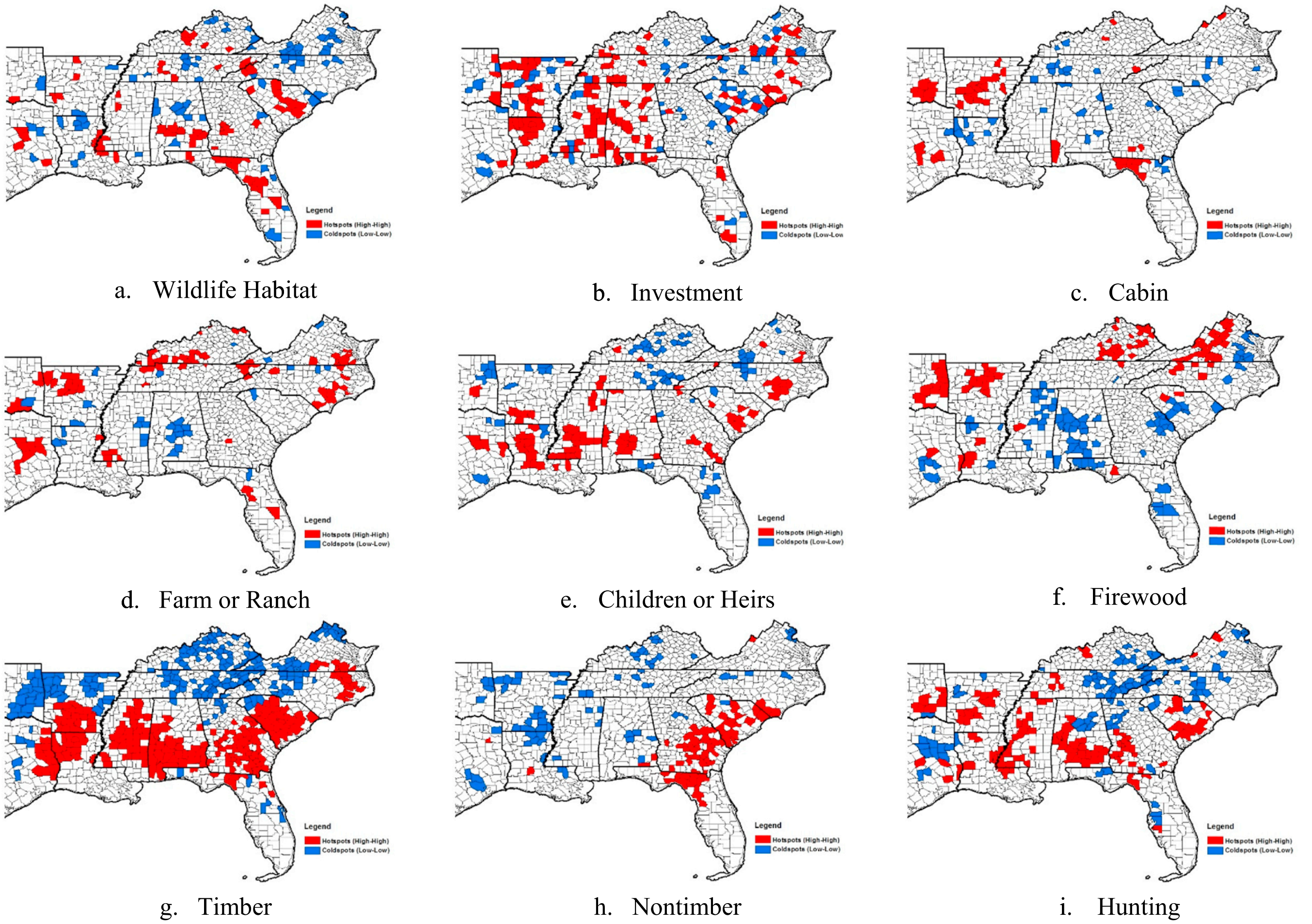

Fig. 1. Significant clusters (hotspots and coldspots) of NWOS variables related to landowners' motivation for forest ownership.

Children or Heirs: A number of motivation hotspots for passing land on to their children or other heirs were observed along the Southeastern Plain, particularly east-central Texas, central Louisiana, southern Arkansas, southern Mississippi, southwestern Alabama, southeastern Georgia, and the eastern half of the Carolinas (Fig. 1e). Distribution of hotspots of this motivation item corresponded generally with the so called "Black Belt" region (Wimberley, Morris, & Woolley, 2001). Our analysis of nationwide NWOS data for this variable showed significantly higher level of motivations among African-Americans (4.43) than other demographics (4.06). Why this motivation is more prevalent among landowners of this particular demographic segment may be a question for further investigation.

Firewood: Hotspots of managing forests for firewood were observed mostly in the northern end of the region (Fig. 1f), with three largest clusters in eastern Oklahoma-central Arkansas, eastern Kentucky and the Appalachian Mountains of Virginia and North Carolina. Not surprisingly, the southern half of the region with a relatively warmer climate were observed to have several coldspots in terms of managing for firewood.

Timber: Since timber is the primary product of forest landuse, comparatively larger hotspots of motivation for timber production is prevalent throughout the region (Fig. 1g). Hotspots covering at least half of the size of each state were observed in the southern half of the study area. Differences in motivation between states is clearly visible. For example, most landowners in South Carolina and Mississippi have higher motivation for timber production than the landowners in the rest of the region. However, coldspots covering almost entire states in the northern belt of the region indicates that landowners in Kentucky, Tennessee, and Oklahoma have lower motivation for timber production than those in the rest of the states in the region. Some notable differences within the state are also observed. For example, the southern half of Arkansas has clusters of landowners with higher than the regional average of motivation for timber production but the northern half has landowners with lower than regional average of motivation for the same. Similar patterns of motivations regarding timber production were observed between eastern and western portions of North Carolina, South Carolina, and Texas, and northern as well as southern end portions of Georgia and Virginia. In each of these states, the areas containing high-motivation clusters or hotspots correspond to regions of more productive timberland such as the Atlantic Coastal Plain, which in turn may have incentivized landowners to manage forestland for timber purposes.

Nontimber: Hotspots of motivation for managing forest for nontimber forest products were observed in the Atlantic Coastal Plain region of the Carolinas, southern Georgia and northern Florida (Fig. 1h). This indicates that landowners in these clusters have a higher motivation than those in the rest of the region for NTFP production. One explanation for this contrasting pattern is that the hotspots shown in this map coincide with areas of high production of pine straw, Christmas trees, and berries.

Hunting: Fig. 1i shows significant clusters of landowners with various motivations for managing forests for hunting. Large hotspots are observed in southern Alabama, southwestern Georgia, eastern Oklahoma, central Arkansas, the western half of Mississippi and eastern South Carolina. A few additional hotspots of smaller size were also observed in west Tennessee, northern Florida and northwestern

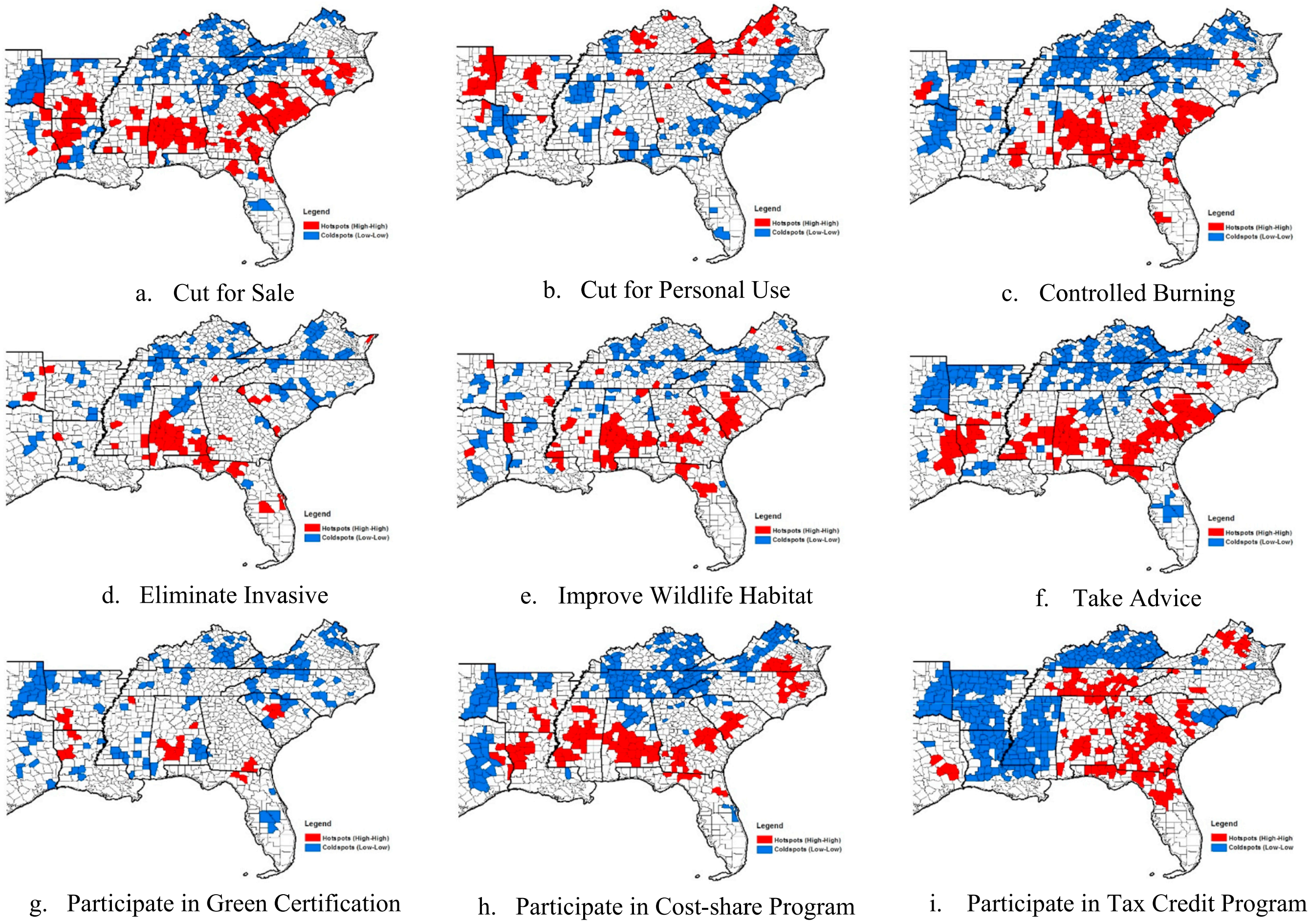

Fig. 2. Significant clusters (hotspots and coldspots) of NWOS variables related to landowners' forest management behavior.

Kentucky. Landowners in these clusters have higher motivation than those in the rest of the region for hunting. Coldspots are observed in northern belt states of the region including North Carolina, Tennessee, Virginia, and Kentucky. Overall, hotspots correspond generally with the habitat of white-tailed deer, quail in the Southeastern Plains and duck and waterfowl hunting regions around the Mississippi Flyway. Interesting patterns with market implications are evident in some states, especially if these hotspots and coldspots were to be considered as potential market clusters. For example, large metro areas such as Atlanta, Nashville, and Dallas may have bigger hunter populations but the immediate surroundings of these cities contain coldspots whereas distant areas have hotspots, indicating a geographical mismatch for lease hunting marketing.

3.2.2. Spatial pattern of management behavior variables

Cut for Sale: Hotspots of landowners reporting to have "cut trees for sale" over the past five years are mostly in the southern belt of the region spanning from the Atlantic Coast of North Carolina to northern Louisiana and southern Arkansas (Fig. 2a). The coldspots of cut trees for sale on the other hand are mostly in the northern half of the region spanning the Appalachian Mountains in Virginia and Tennessee to eastern Oklahoma (Fig. 2a).

Cut for Personal Use: Spatial clusters of landowners reporting to have "cut trees for personal use" showed the opposite pattern (Fig. 2b), as these hotspots are in the northern belt of the region covering northern Virginia, Kentucky, as well as the Arkansas-Oklahoma border and coldspots cover mostly the southern half of the region. These two maps depict the regional contrast in the way landowners are managing forest for two different purposes.

Controlled Burning: Hotspots of landowners reporting to have "controlled burn/prescribed fire" over the past five years were identified in the coastal plain region spanning from South Carolina to south Georgia, south Alabama, and northern Florida (Fig. 2c). There were a few additional hotspots of controlled burning in southern Mississippi and eastern Oklahoma as well. Most of the northern half of the region showed significant coldspot clusters of controlled burning, suggesting that landowners in those states were significantly less likely than their southern counterparts to have implemented controlled burning.

Eliminate Invasive Species: Southern Alabama and northern Florida had some remarkable hotspots of landowners reporting to have "eliminated or reduced invasive plants," whereas the northern parts of Alabama, Mississippi, and various parts of other states including Kentucky, Tennessee, the Carolinas, and Virginia had landowners reporting to have not done so (Fig. 2d).

Improve Wildlife Habitat: Hotspots of "improved wildlife habitat" over the past five years were spotted in the southern parts of South Carolina and Alabama as well as the northern part of Florida (Fig. 2e). A few hotspots of "improve wildlife habitat" albeit smaller in size, were observed in northwestern Louisiana and western Mississippi. Relative to landowners in the rest of study area, the landowners on these clusters reported to have "improved wildlife habitat." Many coldspots were observed in the northern half of the study region including Kentucky, Virginia, Northern Carolina, and Tennessee, suggesting that landowners in those areas are less likely than their counterparts in the region to have improved wildlife habitat on their land.

Take Advice: Landowners reporting to have received advice/information about forest management in the past five years were significantly clustered in the Southern part of the region (Fig. 2f). Regionwide distribution of hotspots and coldspots associated with “take advice” show that landowners in the Southern Plain were more likely to have received advice than those in the rest of the region.

Participate in Green Certification: Hotspots showing clusters of landowners reported to have their forests “green certified” were limited in smaller pockets of southcentral Carolina, the Tall Timber region of southern Georgia and northern Florida, southcentral Alabama, southwestern Arkansas and west-central Louisiana (Fig. 2g). This map shows relatively higher popularity of certification programs in limited areas.

Participate in Cost-share Program: Fig. 2h shows the spatial pattern of landowners participating in a cost-share program and the pattern is extremely similar to hotspots of landowners reporting to have received management advice (Fig. 2f). Participation in cost-share programs was relatively more popular among landowners in the southern part of the region than among their northern counterparts except for a hotspot cluster along the Virginia-North Carolina borderline.

Participate in Tax Credit Program: Hotspots of landowners enrolling in tax credit programs for forestland use showed a different pattern (Fig. 2i). With a notable exception of a coldspot associated with this variable north of Charleston, six states in the Southeastern corner of the region showed a number of hotspots, indicating landowners in them are more likely to have enrolled their forest under some tax credit program. Several states including Kentucky, Mississippi, Arkansas, Louisiana, and Oklahoma had nothing but coldspots of participation in tax credit programs. This may be explained by the fact that unlike federal cost-share programs, many of these tax-based incentives are administered by state or local level government, and some states currently lack programs of this type.

4. Conclusion and discussion

This study presents a relatively novel application of a spatial modeling technique into spatially explicit data on landowner motivation and management behavior. While previous studies have utilized GIS based techniques in value mapping or identifying typologies of landownership motivations, our study is the first to visually map clusters of landowners with similar motivations and management behavior. In light of a growing emphasis on place-based, cross-boundary approaches to engage landowners in sustaining forest landscapes (Creighton, Baumgartner, & Blatner, 2002), this research is important and timely in guiding new research and outreach/extension efforts.

The findings have several important implications in understanding the dynamics of land ownership, and are important to conservation planners and resource managers in the Southeastern United States in several ways. First, our study confirms spatial autocorrelation in landowner motivation, implying that landowners in certain areas possess similar motivations for forest management. While most of the areas are not statistically correlated, certain areas exhibit systematic patterns and reveal clusters of motivation. Spatial theories suggest that there may be some spatial process at work within those significant clusters. Spatial clustering of motivation was prevalent regarding tangible and pecuniary benefits (e.g. timber, investment, hunting, firewood), but not for non-pecuniary benefits (e.g. privacy, beauty). This is generally in agreement with Hall, Farnum, Slider, & Ludlow (2009), who argued that many of the intangible or nonmaterial human values may not have spatial dimension.

Second, maps showing clusters of various types (hotspots and coldspots) reveal important regional perspectives in understanding which areas present opportunities and challenges for conservation efforts, business opportunities, and other activities. For example, institutions such as vendors and buyers interested in locating a potential market for timber and non-timber products may also benefit from knowing where potential suppliers are clustered. Forestry and other natural resource agencies in individual states may be able to see interstate differences in many aspects of private lands stewardship and management activities. Notable differences were observed between several states in terms of landowner engagement in cost-share programs, for example, which is likely attributable to the discrepancy in the availability of such programs. Similarly, conservation agencies interested in promoting landowner participation in wildlife habitat conservation may benefit from comparing how areas of ecological importance relate/intersect with the general preferences of landowners across the landscape (Jacobson, 2002). Such information may allow them to identify areas of highest need for education and outreach (areas with concentrations of landowners with low interest).

Third, autocorrelation in variables reflecting management behavior, such as tree harvesting or enrolling in conservation programs, suggests a potential social homophily in landownership and forest management (Mouw, 2006; Aguilar, Cai, & Butler, 2017). If this is true and landowner motivations/intentions depend partly on proximal neighbors, this could have implications in fostering extension and education through peer-based learning and landowner networking. Literature on qualitative inquiry of landowner decision making have documented that landowners place higher levels of trust on their close peers than others such as scientists, government personnel (Grotta, Creighton, Schnepf, & Kantor, 2013)

Fourth, hotspots of landowner interest, which essentially show where landowners of similar management objective are located, seemed to be spread over multiple counties and even states. This warrants cross-jurisdiction collaboration among agencies in addressing the needs and challenges of landowners. Observed clusters across the landscape may have important ramifications in making public policies with landscape-level objectives (Aguilar, Cai, & Butler, 2017). For example, if the economic forecast shows a decline in market opportunities for certain forest products, planners can see where vulnerable populations exist in the region, and strategically target mitigation resources to help those areas. Agencies interested in assessing and monitoring resource use patterns and trends will benefit from maps that highlight the regional distribution of landowners, relative to motivation and behaviors. For example, the Resources Planning Act 1974 requires that the USDA Forest Service periodically assess forest resource conditions for the U.S., including our study area (i.e. Region 8) (USDA Forest Service, 2012). Similar to several existing RPA efforts on monitoring forest coverage, timber harvesting, landscape patterns, and other factors, clusters showing hotspots as well as coldspots from our analysis could provide a baseline to compare how these patterns shift in the future. Geographical location and extent (i.e., size) of these clusters in the future may be analyzed relative to changes in policy (e.g., environmental regulations) and market scenarios (e.g., demand for ecosystem services, timber prices). Forest landowners in the region have previously seen impacts of emerging markets and shifting regulations. For example, the region witnessed an increase in timber production following a decline in the harvesting of old growth forests in the Pacific Northwest under the Endangered Species Act (Sedjo, Goetzl, & Moffat, 1998). More recently, the region has been affected by emerging bio-energy markets in Europe. If the wood pellet industry in the region were to further grow, it may be reasonable to expect clusters of landowners willing to supply raw material around wood pellet mills. Similarly, future demand for carbon sequestration, be it through government regulations or markets forces, will provide additional opportunities for income generation and subsequent changes in management practices.

Fifth, observed existence of hotspots and coldspots next to each other in some areas could mean there are value differences among landowners, which may lead to regional land use conflicts in future. For example, hotspots of timber production motivation could be examined relative to proposed conservation actions for compatibility or social acceptability of public policies. Several maps of landowner behavior show regional disparity in landowner engagement in socially desirable behavior (e.g. controlled burning) and others put regional perspectives on inter-state differences in participation in assistance programs (e.g. cost share, tax) and popularity of market-based incentives (e.g. certification).

Finally, individual layers of hotspots from our analysis could be overlaid with other layers of interest to further evaluate landowner motivation and behavior in a broader sense. For example, combining hotspots of motivation maps based on some common themes (pecuniary, non-pecuniary) may help create value typology maps. In addition, combining individual layers of hotspots of management behavior may help answer such questions as where more or less active landowners are located and intersecting hotspots of behavior variables (e.g., cost share) with motivations (e.g., timber) may reveal why the popularity of some programs are limited to certain pockets. Combining multiple layers from our analysis provides further insights on where more or less active landowners are located. For example, a band of counties in southwest Alabama are relatively more likely to take advice from forestry professionals and are also relatively more engaged in implementing management activities such as controlling burning, improving wildlife habitat, and eliminating invasive species.

A few caveats of this study should be noted. First, although the analysis was conducted at the individual landowner level, the boundaries of the clusters are shown along the county lines, for a number of reasons (i.e., limitations, benefits) explained earlier in the methods. Therefore, the actual boundaries of the clusters may be slightly different than shown in the figures. Second, clusters of high and low association were depicted relative to the regional average as opposed to state average, which could have been more informative for stakeholders in each state. Nevertheless, since this parameter is set at the average of the entire study area, the methods presented in this paper could be easily replicated with a subset of the data to locate clusters at the state or even sub-state level. Third, the spatial analysis utilized location of forestland rather than the location of residence. However, it is possible that some absentee landowners may also have their motivation and management choices influenced by others who are not necessarily their neighboring landowners. Future research could focus on spatial variation in bivariate relationships, including examining how the relationship between motivation and behavior vary across the region, and whether ownership size in different places relates to motivation or behavior differently. Although the study focused on the Southern U.S., it is likely that similar patterns exist in other parts of the U.S. and the world where similar socio-economic conditions exist. This assumption needs to be verified and can be accomplished by applying the methods presented in this paper to other regions using NWOS or other spatially explicit data sets.

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