Incorporating long-term spatial and temporal effects in a state space model to evaluate land management alternatives for imperiled species conservation in Alabama.

by

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Abstract

Conservation decisions are often made based on expected outcomes without full consideration of costs, likelihood of achieving targeted results, or spatial and temporal consequences of their implementation. We used structured decision making to establish management objectives and compile information for development of a decision support tool to evaluate management alternatives on ten state-owned lands in Alabama. The identified problem was to determine how to best manage state lands to enhance primary functions of properties while improving habitat for imperiled wildlife. We developed a heuristic state space model to predict consequences on wildlife species of 11 management alternatives implemented over a 100-year planning horizon. Management objectives, alternatives, and costs were elicited from land managers and included combinations of actions that affect land cover type and structure on uplands, floodplains, and wildlife openings. We used a matrix of land cover transition rates describing natural and human-induced processes to predict the cost of management, user (e.g. hunters and hikers) preferences, and wildlife responses based on likelihood of land cover change. We derived user preferences from surveys of potential users. Wildlife responses were predicted from occupancy rates estimated using field data for a suite of focal species representing each imperiled species. We estimated the utility of each alternative based on the average of the scaled outcomes for each objective on each state park and wildlife management area. The preferred alternative varied among study areas based on their intended use. For example, removing existing wildlife openings within upland pine provided greater utility for imperiled species on

wildlife management areas within the coastal plain. Our model is capable of incorporating additional objectives and trade-offs and would be useful for evaluating alternatives at landscape scales in similar regions. Additionally, we make recommendations for monitoring programs and user preference surveys that may reduce the ambiguity of management decisions.

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Chapter 1. Using occupancy analysis to select focal species as surrogates for species of concern on state managed lands in Alabama.

Abstract

Most imperiled species are rare or elusive and difficult to detect which makes it challenging to gather data to estimate their response to habitat restoration. Basing management decisions on focal species serving as surrogates of imperiled species may be a useful alternative for evaluating habitat restoration until populations rebound. Focal species have commonly been used to indicate ecosystem health or to evaluate the effects of changes in landscapes or management. However, selection of focal species is often criticized when qualitative methods are used, or when single species are selected to represent diversity at landscape scales. We present a repeatable, systematic method for selecting focal species on 13 sites in Alabama. We developed occupancy models based on literature review and expert opinion to determine relationships between use by species to land cover, vegetative structure, and landscape characteristics. We estimated relative sensitivity of each species to covariates from the log-odds of the effect of standardized site covariates on probability of occupancy. We selected focal species based on their relative sensitivity to changes in site covariates that would be affected by restoration of habitat characteristics preferred by imperiled species.

Introduction

The state of Alabama is home to the third largest number of threatened and endangered species among U.S. states and territories (www.fws.gov/endangered/species/index.html). Two hundred sixty animal species including 26 birds, 20 mammals, 40 reptiles and amphibians, 48 fishes, 28 crayfish, and 98 mussels and snails have been identified as imperiled (i.e. Priority 1 or Priority 2 species, Wildlife and Freshwater Fisheries Division: Alabama Department of

Conservation and Natural Resources 2005). In addition, only 4.2 % of the state is in public landholding of which only 0.75 % is managed by the Department of Conservation and Natural Resources (Silvano et al. 2009). This issue alone not only results in a limited area for conservation of imperiled species but can further contribute to their population loss if these lands are not managed efficiently. Resource managers are regularly required to make decisions on how to best manipulate the landscape for conservation of these imperiled species. However, there are limited data available relating species responses to forest management or landscape change. Consequently, decisions are often made without a clear understanding of how these species will respond to proposed management actions. Further, most imperiled species are difficult to monitor and detect which makes it challenging to gather data to research their response to habitat management. If focal species can be identified that are more abundant or easier to detect than imperiled species within similar habitat requirement they can be a useful alternative for monitoring the success of habitat manipulation.

Focal species are surrogate species used for guiding management (Marcot and Flather 2007). Depending upon their intended use, surrogate species (Caro and O'Doherty 1999) have been categorized as umbrella, focal (Lambeck 1997), indicator, keystone (Noss 1999), or substitute (Caro et al. 2005). In conservation biology, focal species have commonly been used to indicate ecosystem health (Carignan and Villard 2002, Niemi and McDonald 2004), prioritize areas for conservation (Margules and Pressey 2000, Hess et al. 2006) define conservation needs (Sanderson et al. 2002), or monitor effects of changes in landscapes or management (Noss 1999, Schwenk and Donovan 2011). However, utility of focal species is potentially limited when qualitative methods are used for selecting species, or when single species are selected to represent diversity at landscape scales (Lindemayer et al. 2002, Ficetola et al. 2007). In general, multiple focal species are necessary to accurately represent different landscape elements and capture the variation in habitats required by most other species (Lambeck 1997, Lindemayer et al. 2002, Lindenmayer and Fischer 2003, Roberge and Angelstam 2004, Ficetola et al. 2007). Since many species use different habitats for different requirements or life stages, focal species should be selected to represent a mosaic of habitats and habitat structure to account for the heterogeneity in resources needed to sustain populations of multiple species (Poiani et al. 2000, Sanderson et al. 2002, McCarthy 2009). However, a rigorous approach to quantify focal species use across multiple habitats or structural components of a landscape is needed. Recently, more quantitative approaches for selecting multiple focal species have been evaluated and applied. However, these approaches have focused on selecting species based on co-occurrence patterns for biodiversity representation (Wiens et al. 2008, Cushman et al. 2010), to represent different habitat guilds (e.g. land cover, microhabitat, disturbance patterns) for a single taxa of species (Watson et al. 2001, Schwenk and Donovan 2011), or isolating single threatening processes (Ficetola et al. 2007, Wenger 2008). The information needed to use these approaches are lacking for many imperiled species.

Given the difficulty that resource managers are commonly tasked with restoring and conserving habitats through some type of active management, we needed a measurable means to determine and evaluate alternative courses of action for conservation of these imperiled species. Monitoring and assessing their response to management is essential to establishing good management strategies (Nichols and Williams 2006, Sauer and Knutson 2008). However, when these species are not easily detected or data is insufficient to quantify a response to management there is no clear way to gauge effectiveness of these efforts which essentially limits good decision making (McCarthy 2009). One way to develop models for predicting the effects of management on rare species is to use quantitative models for more commonly detected species that respond to the habitat requirements of rare species. Occupancy analysis can provide a means for estimating these responses. Occupancy analysis uses presence/absence data to estimate species response to site characteristics, while accounting for biases resulting from imperfect detection (MacKenzie et al. 2006). The results therefore provide a means of obtaining less-biased estimates of species' sensitivities to important site attributes.

Our objective was to identify a suite of easily detected species that have the same associations with local and landscape site characteristics as imperiled species within Alabama. We performed field inventories and used occupancy analyses to estimate species' sensitivities to land cover, vegetative structure, and landscape characteristics for all species detected. For undetected imperiled species, we developed habitat profiles based on literature review and expert opinion to identify relationships between use and response to changes in those same site characteristics. We then employed a repeatable systematic approach to select multiple focal species from our suite of detected species that were correlated with the identified relative sensitivity to changes in site characteristics of the undetected imperiled species. We suggest that these species can then be used as focal species, comparable to Lambeck's (1997) resources or process limited focal species, to evaluate impacts of proposed management actions when imperiled species cannot be monitored.

Study Area

We conducted surveys for terrestrial and aquatic species on 13 study areas distributed across the state of Alabama (Figure 1.1). Alabama encompasses an area of approximately 52,500 square miles and spans six physiographic provinces, or ecoregions: Interior Low Plateau, Southwestern Appalachians, Ridge and Valley, Piedmont, Southeastern Plains, and Southern

Coastal Plain (Griffith et al. 2001b). Elevations range from sea level along the coastal Gulf of Mexico in the Southern Coastal Plain to 2,407 feet above mean sea level at Mount Cheaha in the Southwestern Appalachians.

Our study areas were clusters of state-owned and managed parks, wildlife management areas, and nature preserves. We selected areas greater than 1000 acres in consultation with representatives from Alabama Department of Conservation and Natural Resources (ADCNR) agency based on AL-GAP Stewardship (Silvano et al. 2007a) , imperiled species distribution data (Silvano et al. 2009) and greatest management potential to impact multiple imperiled species.

Coastal Plain Study Areas

Six of our 13 study areas were located in the Coastal Plain ecological region (Figure 1.1) and ranged in size from 51,300 acres to 3,400 acres. Generally topography within the coastal plain region is very flat and soils are typically acidic and sandy with expansive calcareous areas occurring in the central and northern reaches (Mount 1975). Land cover composition throughout is generally a mixture of managed pine forests in the uplands (> 85% of study area) and mixed pine-hardwood forests on sloped extents. Historically, these areas encompassed large regions of bottomland floodplain forests (i.e. forested wetlands) however in the early 1900s much of this was cleared for agriculture or planted in pine for timber production (Harper 1943). Currently, only remnant patches of bottomland forest remain (< 15 %) throughout these properties.

Conversely, Lauderdale-Colbert (Figure 1.1), located in the northern most reach of the coastal plain has an underlying geology of limestone and sandstone creating rolling topography with numerous rock outcroppings (Mount 1975). The resultant terrain and edaphic conditions has restricted historical land use conversion. Therefore, large areas of hardwood and mixed pine-hardwood forests (combined > 50 % of the total study area) still exist on lower slopes and coves.

The Sipsey study area spans 3,407 acres and lies entirely within the floodplain of the Sipsey River, a blackwater river system composed of sandy soil sediments (Billings and Billings 2000). This study area is primarily all bottomland forest (> 95 %). In Contrast, Gulf State in the lower coastal plain is largely xeric coastal sand with a pine dominated land cover (>87%) and expanses of beach and tidal marsh habitat.

Piedmont Study Areas

Three of our study areas were located in the piedmont ecological province, Coosa, Wind Creek, and Cheaha (Figure 1.1). The piedmont region is characterized as a transition area between the mountains and coastal plain regions of Alabama. Areas in the piedmont are generally hilly and rocky with heavy clay soils (Mount 1975). Cheaha is nested within an area locally referred to as the Blue Ridge. This is the most mountainous area within the state containing Alabama's highest point, Cheaha Mountain and is heavily forested with hardwood dominated land cover (over 75% of area). Whereas, Wind Creek and Coosa are located in the inner piedmont region at lower elevations than Cheaha having less relief and extensive rolling hills throughout (Griffith et al. 2001b). The forest cover of Wind Creek is composed primarily of pine on upland ridges and hardwoods forests on lower slopes (50 % proportional split).

The Coosa study area differs from others within the Piedmont. The property was heavily managed for timber production in the past and over 65 % of the area is in pine planation forest. The remaining areas of Coosa are dominated with hardwood (13 %) on the upper slopes and remnant patches of bottomland/riparian forest (< 1%) along riverbanks. However, over the last several years, large quantities of timber have been cleared creating large patches of disturbed areas throughout.

Ridge and Valley Study Areas

The ridge and valley region is relatively low-lying with undulating landforms of rounded-ridges and valleys (Griffith et al. 2001b). The soils of this region are generally loamy or clay with an underlining geology of limestone resulting in many caves and springs systems throughout (Mount 1975, Griffith et al. 2001b). Encompassed within this region are two study areas, Coldwater and Oak Mountain. Due to the landform and edaphic conditions these study areas are both heavily forested with over 87 % in closed canopy hardwood forest.

Southwestern Appalachian Study Areas

Two study areas are found within the Southwestern Appalachian ecological region, Guntersville and Monte Sano (Figure 1.1). Guntersville encompasses over 6000 acres surrounding Lake Guntersville, an impoundment of the Tennessee River. The area is locally referred to as part of the Tennessee Valley and is characterized by steep slopes, bluffs, and rock outcroppings of limestone. The area includes a large developed tract with a campground and golf course (< 5 % of total study area) with the remaining area dominated by hardwood forests. Where, Monte Sano is found on an isolated plateau of steeply sloped landform with high gradient streams and gorges of sandstone and limestone (Griffith et al. 2001). Due to the landform being highly dissected, over 95% of Monte Sano is closed canopy intact hardwood forest.

Methods

Species Surveys

We performed presence –absence surveys for terrestrial and aquatic species on each of the 13 study areas. For terrestrial species we surveyed a stratified random sample of each study area base on land cover type and selected sampling points for terrestrial vertebrates from a 270m grid in proportion to expected species richness (see Silvano et al. 2012, *unpublished* for a detailed description of terrestrial sampling techniques). For aquatic species, we stratified stream networks (U.S. Environmental Protection Agency and U.S. Geological Survey 1999) by stream order (U.S. Environmental Protection Agency 2005). We identified stream segments of varying length dependent on the magnitude of stream order (1st & 2nd- 100m, 3rd & 4th - 150m, ≥5th - 250m). We then randomly selected up to 10 segments in each stream order that occurred on each study area as sampling units for aquatic species surveys (see Silvano et al. 2012, *unpublished* for a detailed description of aquatic sampling techniques).

We conducted amphibian and reptile surveys using timed-area visual encounter survey methods and audio data loggers for anuran species (i.e. frogs and toads) from February to May 2008-2010. We conducted visual encounter surveys on five 25m radius subplots located at the sampling point center and at 100 m in each sub-cardinal direction (i.e. NE, SE, SW, NW) from point center. Each survey lasted 20 min. We placed automated audio data loggers (Model SM2, Firmware version 2.2.0, Acoustic Research, Inc.) at each sampling point and recorded vocalizations in stereo setting (2 audio channels) with a frequency rate of 16KHz for 1-minute at the beginning of each hour from sunset to sunrise for three consecutive days. We surveyed birds using standard point count methods (Ralph et al. 1995, Farnsworth et al. 2002). We visited each site once during the breeding season between May and June. On each visit, we conducted 3 consecutive 4-minute surveys. We conducted mammal surveys from September to December 2008-2010 using three different methods dependent on species and size. We live-trapped for both terrestrial (e.g. mice, moles, voles, shrews, etc.) and arboreal small mammals (e.g. squirrels, chipmunks, etc.) using arrays of box traps (H.B. Sherman Trap, SFA Folding Trap). A trap array composed of 20 ground set and 10 tree-mounted traps placed on 4 50m transects radiating from the sampling point. We checked traps twice each day (Jones et al. 1996), for three consecutive days. We surveyed medium-sized (e.g. skunks, rabbits, weasels, etc.) and large bodied mammals (e.g. coyotes, foxes, bobcats, etc.) using digital game cameras (RapidFire PC85 Professional, Firmware Version 1.5.1, Reconyx, Inc.) using time lapse (1 min interval) and passive infrared motion triggers (3 photos per event) for three consecutive days. Survey protocols were approved by Auburn University Animal Care and Use Committee (permit Numbers 2008-1319 and 2008-1457).

We deployed several different sampling methods for each aquatic taxa group. Fish were sampled from June to July using kick or pull seines, or backpack or boat electroshocking methods dependent upon stream conditions at each transect (e.g. mesohabitat, stream order, or water depth). Mollusks were sampled from April to September. A minimum of three 0.25 m^2 quadrats were excavated along cross-channel transects in each pool, run, and riffle mesohabitats within a sampling unit. We excavated substrates to a depth of ~10 cm or until we stopped finding live organisms, primarily *C. fluminea*. All larger substrate particles (>200 mm diameter) were examined for attached gastropods and excavated materials were passed through a 6 mm mesh sieve. To sample for crayfish, we baited metal crayfish traps with canned cat food and placed 3 traps in each mesohabitat transect within a sampling unit from February to September each year. We conducted surveys for aquatic herptiles using time-area visual encounter survey methods from May to July. Shoreline transects were examined for the presence of salamanders, by turning rocks and raking leaf litter. Accumulated and submerged piles of leaves were scooped into a dip net and the content was examined for salamanders and aquatic invertebrates. Water based transects (i.e. riffle, run, and pool meshabitats) were explored for the presence of turtles using a snorkel and mask. Large rocks were overturned to explore undersurfaces and submerged areas with a sandy bottom were raked to expose buried softshell turtles.

Occupancy Modeling

Detection probabilities and occupancy for each species surveyed were estimated using single-season models (MacKenzie et al. 2002) and encounter data pooled from all 13 study sites. For each species we generated a candidate set of models based on literature review and expert opinion. These models were used to estimate probabilities associated with different detection covariates as well as estimate relationships of use to local and landscape level site characteristics for each species. Detection covariates varied with each taxa group and were measured during species surveys, or derived from ancillary data sources (Table 1.1). We estimated landscape characteristics of both terrestrial survey sites and aquatic sampling units from multiple spatial data sources (Table 1.2) using zonal statistics in ArcGIS (v9.1, ESRI, Inc). We then measured local site characteristics at each terrestrial sampling point using standardized survey methods (Table 1.3). All covariates were standardized to allow inference regarding sensitivities to parameter changes to be made across all covariates for all species across all different taxa groups. Thus, affording selection of focal species to not be restricted to species of the same taxa group as the imperiled species if a better representative focal could be found outside of it's taxa group (e.g. best representative focal species with similar sensitivities as an imperiled bird species may be an amphibian).

We compared *a priori* models using Akaike's Information Criterion (AIC, Anderson 2008). Models were run hierarchically following Franklin et al. (2004) approach to meta-analyses. We first assessed detection models for each species from an *a priori* model set. Detection models with an AIC value < 2 were then combined with occupancy models with landscape covariate models including a null model. Models from this analysis with an AIC value < 2 were then combined with local site level covariates to determine if use could be further explained by local characteristics. In this final modeling tier we compared both combined landscape and local models and compared them to models that consisted of local site covariates only. This allowed us to determine if local site characteristics alone rather than a combination of both local and landscape would better explain variation in occupancy.

Since we wanted to assess sensitivity to site characteristics, for each species we averaged parameter estimates across all models from the final hierarchical modeling tier. For each parameter, we calculated weighted averaged estimates of β (log-odds of the effect size) and standard error across all models in the *a priori* model set using AIC weights (Anderson 2008). We felt averaging parameters was appropriate in our case, because we could improve accuracy and reduce bias by averaging. Averaging parameters estimates across multiple models allows for more robust inference to be made regarding sensitivities to change in parameters estimates rather than drawing conclusions from a single model estimate (Burnham and Anderson 2002, Anderson 2008). We then estimated relative sensitivity of the probability of occupancy for each species to covariates using the log-odds of the effect (β) of standardized site covariates..

Identifying Habitat Profiles for Imperiled Species

Imperiled (i.e. Priority1 and Priority 2) species were previously identified as part of Alabama's Comprehensive Wildlife Conservation Strategy (Wildlife and Freshwater Fisheries Division: Alabama Department of Conservation and Natural Resources 2005). In total, 260 imperiled species are known to occur within the state. However, based on species distribution data, only 47 terrestrial (Silvano et al. 2009) and 71 aquatic imperiled (Mirarchi et al. 2004a) species potentially occur on the thirteen properties we sampled. Therefore we defined important habitat characteristics for these 118 imperiled species using information and literature sources from the SEGAP Vertebrate Modeling Database (www.basic.ncsu.edu/segap/) and Mirarchi et al. (2004b) for terrestrial species and expert opinion for aquatics. We identified information regarding dominant land cover types, forest structure, and landscape characteristics (e.g. landform, streams, elevation, etc.). We then assembled a matrix that included the imperiled species and the local and landscape characteristics (Tables 1.2 and 1.3) used for modeling occupancy of species detected during surveys. With information gleaned from the vertebrate modeling database and experts we assigned a positive or negative indicator to associate imperiled species use with those covariates. A positive indicator identified that species use would increase if the parameter estimate increased. Whereas a negative indicator signified use would decrease if the parameter estimate increased. If there was no known association with a covariate we assigned a blank value. We then assigned an ordinal rank to each associated covariate. We defined the primary rank (1) as the parameter most limiting the imperiled species in distribution (in most cases this was a Land Cover parameter). When appropriate we then assigned secondary parameter rankings ordered in decreasing importance to an imperiled species habitat requirements (1=most important, 4=lowest important). In our case, we had several imperiled species with similar habitat requirements. For these scenarios we created one habitat profile representing important habitat characteristics for multiple imperiled species. This method provided a repeatable, qualitative means to develop habitat profiles for imperiled species.

Selecting Focal Species

We applied a systematic approach to selecting focal species for each of the different imperiled habitat profiles. We used the modeled-averaged parameter estimates from the occupancy results to select species based their directional relationship and sensitivity to profile parameters. We first grouped species with the same relationship to the primary parameter in a given profile. We then refined that group by selecting for the species that had a similar relationship with the secondary parameter(s) in the given profile. The refinement process was repeated for each parameter within a profile until a unique representative focal species was identified to match the habitat profile, or we determined that no species was representative of a profile. If the latter occurred we selected the detected species with the most similar relationship to parameters within the imperiled habitat profile. If multiple species were found that could be representative for a profile, we selected the species with the greatest sensitivity to parameters within the profile and were less sensitive to parameters not part of the profile.

Results

We conducted 3688 species surveys and 858 vegetation surveys on 714 terrestrial sites and 269 aquatic units across 13 properties within Alabama (Table 1.4). The number of sites surveyed varied because for some taxa multiple survey methods were required and the time required for conducting different surveys varied with each protocol. Our species surveys resulted in 32,162 detections for 451 different species of which 22 were imperiled species (See Silvano et al. 2012, *unpublished*). We developed detection and occupancy models for 277 species detected on at least 5 survey occasions (Table 1.5) and were able to generate parameter estimates for 214 species. Result tables for the detection, landscape, and combine landscape and local occupancy model assessment can be found in Silvano et al. 2012, *unpublished*.

For aquatics, 36 species had a positive relationship with stream order, indicating a preference for larger streams (Figure 1.2). With the majority of species (n=37) exhibiting a sensitivity to disturbance or urbanization within the surrounding watershed (Figure 1.3). For terrestrial species, 95 were positively associated with one or more forested land cover type.

However, the majority of species exhibited positive associations with either forested wetlands (n = 32) or hardwood (n = 32), and a few (n = 10) species were positively associated with pine. Conversely, occupancy of 30 species was not sensitive to any forested land cover but was either positively or negatively influenced by only the vegetative structure, stream density, or geology of a site. Species habitat associations did vary across taxa groups. Terrestrial herptile species commonly showed (18 of 45 species) a positive relationship with forested wetlands whereas 19 of 85 bird species were sensitive to the presence of hardwood (Figure 1.2). In contrast, 6 of 12 mammal species were negatively association with forested land cover with 8 of 10 having positive associations with local site characteristic of reproductive cover (Figure 1.2-1.3).

Twenty-two imperiled species were encountered during field surveys and although encounters for all 22 were low we were able to generate parameter estimates for 6 imperiled species: Kentucky warbler, Swainson's warbler, wood thrush, worm-eating warbler, gopher tortoise, and eastern kingsnake. We removed these 6 imperiled species from the habitat profile list since a quantitative relationship to site characteristics was determined through occupancy analyses. For the remaining 41 terrestrial and 71 aquatic imperiled species not detected during surveys we identified 26 unique habitat profiles that identified associations to measured site characteristic (Table 1.6). These profiles were described using 6 general land cover types, 5 structural, 4 landscape characteristics. Habitat profiles 1, 2, and 3 were characterized as species primarily associated with forested wetlands where 2 and 3 were further influenced by the presence of streams or reproductive cover. Profiles 4, 5, 6, and 7 represented imperiled species associated with hardwood forest and high reproductive cover. With 5 and 6 restricted to hardwood forests with underlying limestone or karst geology. Habitat profiles 8-11 represented imperiled species commonly known to use open canopy pine forests. However, species within profile 8 were known to use more xeric conditions, and were not usually associated with wetlands or hardwood environments. Habitat profile 12 represented the eastern coral snake, which will utilize any closed forested area with a dense understory. American kestrel, prairie kingsnake, Brazilian free-tailed bat, and short-eared owl are imperiled species that are commonly associated with open or disturbed areas with good ground cover and are represented by habitat profiles 13 and 14. Profiles 15-18 are imperiled species found in habitats with a high density of streams. With profile 15 preferring high reproductive cover, profile 16 known to use any forest type in close proximity to streams, profile 17 known to use only pine dominated areas around streams, and profile 18 requiring open canopy habitats with high ground cover and a dense stream network. Imperiled species restricted by caves or karst environments associated with hardwood or riverine systems were grouped under habitat profile 19. The remaining two (20-21) profiles were described as species primarily associated local structural site characteristics such as reproductive and ground cover.

Imperiled aquatic species were represented using 4 habitat profiles (22-26). In general, disturbance and urbanization negatively impact stream quality by increasing siltation and sediments loads due to excess run-off caused by deforestation. As result, this degradation of stream quality is considered the primary cause of all aquatic species imperilment. Therefore, all 4 aquatic habitat profiles represent areas associated with low urban or disturbed environments (Table 1.6). Profile 22-23, represented imperiled aquatic vertebrate species (i.e. fish) associated with large magnitudes of stream order (22) and smaller magnitudes of stream order (23). The remaining profiles represent imperiled aquatic invertebrates (i.e. mollusks and crayfish) commonly known to use only streams of smaller stream orders. Where profile 24 is associated with species endemic to the Mobile Basin, profile 25 encompasses imperiled species of Coastal drainages, and profile 26 representing imperiled crayfish.

We were able to isolate 25 focal species to represent the different habitat profiles for the imperiled species based on parameters estimates (Table 1.7). The focal species list is composed of 11 birds, 6 herptiles, 3 mammals, 2 fish, 2 mollusks and 1 crayfish. We found 8 species that were able to represent multiple habitat profiles. Consequently, we were unable to find focal species that directly meet all requirements directly for 9 habitat profiles (Table 1.6). However, for these nine profiles we found focal species that were sensitive to at least 2 parameters listed in the habitat profile (Table 1.6).

Discussion

In Alabama, managers on state lands are required to include conservation of imperiled species as part of their management and monitoring programs. We encountered some of these species, frequently enough data to estimate habitat relationships. However, many imperiled species were not detected during our survey efforts, although species with similar habitat requirements were encountered.. While focal species traditionally have been used to define conservation needs or assess biodiversity representation (Ficetola et al. 2007), our intent was to select focal species to indicate the potential response of imperiled species to habitat management. Our approach used empirical data derived from species detected within areas where imperiled species were expected to occur to select focal species were sensitive to the same site characteristics as those species. Using these methods we were able to find focal species for 76% of the targeted habitat profiles of imperiled species.

We systematically selected for focal species rather than using a quantitative approach such as cluster analysis (Wiens et al. 2008, Cushman et al. 2010, Schwenk and Donovan 2011).

Cluster analysis groups detected species based on similar covariate relationships. We identified a focal species that had the same directional response to changes in site level characteristics as the imperiled species they would represent. Although we used a qualitative method to select focal species, we based our selection on empirically derived sensitivities to site characteristics. Caro et al. (2005) explain that focal or substitute species are adequate to predict responses for other species if the relationship between the focal species and traits of interest are known and the response to changes in that trait for both the focal and representative species are also known. In our case we used model-averaged estimates of the effect of standardized site covariates on probability of occupancy for each candidate focal species to predict the response of the species of interest to habitat characteristics and potentially habitat management. Using empirically derived parameter estimates and standard errors from our occupancy analyses for each focal species allowed for us to develop quantitative models for predicting and evaluating species responses to management rather than using qualitative habitat response predictions. In addition, standard errors associated with parameter estimates can be used to incorporate the uncertainty in response of focal species in predictions of response to management. Thus, when evaluating plans for habitat restoration managers could use focal species to assess potential consequences of management actions on imperiled species that are not present or not detected during monitoring efforts.

For some imperiled species we were unable to find suitable focal species. However 54% of these species (6 of 11; Table 1.6) are highly dependent on karst landscape features of limestone and caves, habitats we did not sample. Future sampling efforts focused specifically in these geological formations may provide for better opportunities to detect these species or encounter suitable focal species reliant on this feature. For imperiled species we were unable to find suitable surrogates, a plausible alternative would be to derive quantitative response values for changes in site covariates that are based on expert knowledge to make predictions regarding their responses to management. Expert knowledge has been proven to be an effective alternative when empirical data is unavailable if elicitation approaches are rigorous allowing for biases to be controlled for and uncertainty in responses quantified (Doswald et al. 2007, Low Choy et al. 2009, Murray et al. 2009, Drew and Perera 2011). In particular expert knowledge is well suited for use in adaptive management using a Bayesian statistical framework. Expert elicited estimates can be used to predict responses of imperiled species to management, that are updated once habitat restoration and monitoring efforts are implemented (see Martin et al. 2005, Marcot 2006, Low Choy et al. 2009, Drew and Collazo 2012).

We felt our selection process yielded several focal species that are good representatives of resource limited species that would respond well to implementation of management actions. For example, we determined Indigo Bunting (INBU) as a suitable focal species for those imperiled species sensitive to open canopy or disturbed habitat with the presence of ground cover vegetation (Habitat Profile 13, Table 1.6) based on our β estimates for those covariates. Barrioz et al. (2013) and Brawn (2006) found similar correlations for INBU to increases in open habitat and ground cover as a function of habitat restoration efforts. Multiple studies have included INBU in their analyses to evaluate avian species responses to forest management and landscape change (see for example Twedt et al. 1999, Wallendorf et al. 2007, Twedt et al. 2010) further supporting our conclusions. Our approach also identified Southeastern Short-tailed Shrew (SSSH) and Six-lined Racerunner (CNESEX) as focal species for multiple habitat guilds (Table 1.6). These two species have fossorial tendencies and require loose friable soils for burrowing or existing burrows for seeking refugee (Mount 1975, Learm et al. 2007). The imperiled species they represent within those habitat guilds (i.e. 8, 11, and 13, Table 1.6) are also fossorial (Mirarchi et al. 2004b). This makes both SSSH and CNESEX unique representative focal species because they exhibit sensitivities for forest type and structure and are also associated with a limiting characteristic that is not easily measurable at landscape scales.

The process we used to select focal species is a repeatable, systematic, and rigorous approach to select multiple species based on statistically derived sensitivities to landscape characteristics. We suggest that these focal species can be used to predict and possibly evaluate impacts of proposed management actions when empirical data for imperiled species are not available. We caution that this focal species approach for imperiled species is not intended to be a substitute for implementing mandated actions for threatened or endangered species. However, we suggest that managing for and monitoring focal species response to restoration when managing landscapes as a composite of multiple functioning ecosystems is a useful way to make testable predictions regarding response by imperiled species.

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Table 1.1. Characteristics of sampling occasions used as detection covariates in occupancy analysis for each taxon of terrestrial vertebrates encountered on 13 study areas in Alabama 2008-2010. Percentages were determined using a 125m buffer around each sampling point.

Taxa	Covariate	Description
Birds		
	jdate	Julian date
	precip	Daily precipitation total (cm)[1]
	time	Start time
	wind	Wind level[2]
	sky	Sky condition[3]
	temp	Ambient temperature (°C)
Amphibian and Reptiles		
	sp_ph	Soil pH
	sp_soilmoist	Soil moisture (% Relative Saturation**)**
	sp_sky	Sky condition[3]
	sp_wind	Wind level[2]
	jdate	Julian date
	sp_precip	Daily precipitation total (cm)[1]
	sp_temp	Ambient temperature (°C)
	time	Start time
Mammals - Detection with Camera		
	precip	Hourly precipitation total (cm)[1]
	windspd	Wind level[2]
	temp	Ambient temperature (°C)
	season	field season[4]
	time	Start time
	jdate	Julian date
	sseq	Days since camera deployment
Mammals - Trapped		
	sseq	Days since trap deployment
	jdate	Julian date
	precip	Daily precipitation total (cm)[1]
	temp	Mean daily temperature (°C)[1]
	lndgrp	Property[5]
Mussel and Crayfish		
	depth_quad	Water depth in mussel quadrat (m)

Table 1.1. Characteristics of sampling occasions used as detection covariates in occupancy analysis for each taxon of terrestrial vertebrates encountered on 13 study areas in Alabama 2008-2010. Percentages were determined using a 125m buffer around each sampling point.

	depth_trap	water depth at crayfish trap location (m)
	jdate	date
	quadrat	sampling method of quadrat
	sub_mean_quad	substrate mean across quadrats
	sub_mean_trap	mean substrate size across crayfish trap locations
	velocity_quad	stream velocity in mussel quadrat (m/s)
	velocity_trap	stream velocity at crayfish trap location (m/s)
Aquatic Amphibian and Reptiles		
	dn_detmeth	sampling method of dip net
	h2otemp	water temperature (°C)
	jdate	date of survey
	precip	Daily precipitation total (cm)[1]
	ra_detmeth	sampling method of rake
	sn_detmeth	sampling method of snorkle
	time	time of survey
	ve_detmeth	sampling method of visual encounter
Fish		
	Depth	depth of transect or seine pull (m)
	Velocity	stream velocity measured (m/s)
	Vegetation	proportion of vegetation cover measured for transect
	Woody	proportion of woody debris cover measured for transect
	Substrate	estimated size of the substrate for an occasion
	Backpack	sample taken with a backpack shocker

[1] www.noaa.gov
[2] Beaufort Scale ranked on a scale from 0 to 5 (<1 to 24 mi/h index) Describe the measurement scale
[3] Sky condition categorized on a scale from 0 to 8 (0-clear or few clouds, 1-partly cloudy, 2-cloudy or overcast, 4-Fog or Smoke, 5-drizzle, 7-snow, 8-showers)
[4] Continuous variable for year in which survey was conducted (1-2008, 2-2009,3-2010)

Table 1.2. Landscape attributes of sampling sites and sources of GIS data used as characteristics of habitat use in occupancy analysis for terrestrial vertebrates encounters on 13 study areas in Alabama 2008-2010. Terrestrial percentages were determined using a 125m buffer around each sampling point. Aquatic percentages were determined using the surrounding National Hydrography Dataset Plus (NHDPlus) catchment[1] area around each sampling unit.

Covariate	Description
state_water	% fresh or salt water[2]
state_hdwd	% hardwood[2]
state_forest	% pine, hardwood, or forested wetland[2]
state_dist	% disturbed[2]
state_agopendist	% agriculture, open, or disturbed[2]
state_fowet	% forested or non-forested wetland[2]
state_beachmarsh	% beach or tidal marsh[2]
state_distdev	% disturbed or urban[2]
state_buffer_distdev	% state_distdev[2] within 100m buffer of streams[1]
edgeden	Indicator of edge where 1 is forest interior, 0 is on the edge between forest and open and -1 is opening interior[3]
streamden	Density of freshwater in surrounding landscape[4]
elevation	Elevation scaled by 1000[5]
roaddens	Density of urban in surrounding landscape[6]
slope	% in slope[7]
flat_bottom	% in flat bottom[7]
limestone	% in limestone[8]
sand	% in sand[8]
snd_sndstne	% in sand with sandstone[8]
strmorder	Stream order[9]
bufame_range	American toad range limiter[10]
desmon_range	Seal salamander range limiter[10]
eurluc_range	Cave salamander range[10]
nersip_range	Northern water snake range[10]

Table 1.2. Landscape attributes of sampling sites and sources of GIS data used as characteristics of habitat use in occupancy analysis for terrestrial vertebrates encounters on 13 study areas in Alabama 2008-2010. Terrestrial percentages were determined using a 125m buffer around each sampling point. Aquatic percentages were determined using the surrounding National Hydrography Dataset Plus (NHDPlus) catchment[1] area around each sampling unit.

pleven_range	Southern zigzag salamander range[10]
Barbour	Sites in Barbour study area[11]
Fall_Line	Sites above the Fall Line[11 12]
Gulf	Sites in Gulf State study area[11]
Guntersville	Sites in Guntersville study area[11]
Lauderdale	Sites in Lauderdale-Colbert study area[11]
Monte_Sano	Sites in Monte Sano study area[11]
Oak_Mountain	Sites in Oak Mountain study area[11]
Perdido	Sites in Perdido study area[11]
Slope	Majority slope[3] within a NHD catchment[1]
Stimpson	Sites in the Sanctuaries study area[11]
Str_Size	Stream order - 1[9]
Str_Slope	Majority slope[3] within 100m buffer of stream[1]

[1] U.S. Environmental Protection Agency and U.S. Geological Survey (1999).
[2] Kleiner et al. (2007), Esri (2011), and stand maps of management for study areas delineated by ADCNR personnel
[3] Rubino and Williams (2006a)
[4] Rubino and Williams (2006b)
[5] Gesch et al. (2002)
[6] Rubino and Williams (2006c)
[7] Terando and Rubino (2006)
[8] Dicken et al. (2005)
[9] U.S. Environmental Protection Agency (2005)
[10] Silvano et al. (2007b)
[11] Binary indicator variable where 1=sampling site occurs on study area or in region, 0=does not occur
[12] Griffith et al. (2001a)

Table 1.3. Local site attributes measured during vegetation surveys for potential use as characteristics of habitat use in occupancy analysis for terrestrial vertebrates encountered on 13 study areas in Alabama 2008-2010.

Covariate	Description	Survey Method
cnpy_cov	Percentage of 50 sampling points at each site with forest canopy present.	Densitometer
mid_cov	Percentage of 50 sampling points at each site with mid-story vegetation present (over 3.5 m tall but not extending into dominant canopy)	Densitometer
rep_cov	Percentage of 50 sampling points at each site with reproductive cover present (less than 3.5m tall)	Densitometer
grd_cov	Percentage of 50 sampling points at each site with green herbaceous ground cover	Densitometer
duff	Average depth of duff layer	Ruler measurement

Table 1.4. Number of sites surveyed for occupancy by each taxa group and vegetation across the 13 study areas in Alabama.

Taxa	2008	2009	2010	Totals
Terrestrial Herptiles	175	194	369	738
Birds	235	194	429	858
Mammals	119	109	228	456
Aquatic Herptiles	106	111	217	434
Fishes	106	111	217	434
Mussels	66	111	177	354
Crayfish	96	111	207	414
Species Total	903	941	1844	3688
Vegetation	235	194	429	858

Table 1.5. Number of a priori models used in hierarchical analysis of occupancy by each taxa group on 13 study areas in Alabama 2008-2010.

Taxon	*p*	*Psi* (Landscape)	*Psi* (Landscape & Local)	Total
Birds	328	672	1408	2408
Mammals	152	160	292	604
Terrestrial Herptiles	402	408	546	1356
Mussels & Snails	24	50	0	74
Crayfish	79	120	0	199
Fishes	89	450	0	539
Aquatic Herptiles	74	102	83	259
Total	1148	1962	2329	5439

Table 1.6. Imperiled species habitat profiles and number of detected species that have the same association to each habitat parameter, including the selected focal species for each profile.

							Landscape													
		Local							Forest type							Number of species				
Imperiled Species	Habitat Profile	cnpy_cov	grd_cov	mid_cov	rep_cov	duff	state_agopendist	state_distdev	state_forest	state_forwet	state_hdwd	state_pine	streamden	limestone	Str_Size	1° Parameter	2° Paremeter	3° Parameter	4° Parameter	Focal Species Code
Swallow-Tailed Kite	1									1+						32	n/a	n/a	n/a	wodu
River Frog	1									1+						32	n/a	n/a	n/a	wodu
Rafinesque's Big-eared Bat	1									1+						32	n/a	n/a	n/a	wodu
American Black Duck (winter)	2									1+			2+			32	8	n/a	n/a	rancla
Indiana Bat	2									1+	3+		2+			32	8	0	n/a	rancla
Least Bittern	2									1+			2+			32	8	n/a	n/a	rancla
Black bear	3				2+					1+			3+			32	11	1	n/a	tercar howa
Green Salamander	4				2+					3-	1+					32	7	4	n/a	woth pleven
Allegheny Woodrat	5				3+						1+			2+		32	1	0	n/a	pleven
Northern Myotis	6	2+									1+			3+		32	19	0	n/a	scta
American Woodcock	7				2+		3+				1+					33	7	0	n/a	wovo

Table 1.6. Imperiled species habitat profiles and number of detected species that have the same association to each habitat parameter, including the selected focal species for each profile.

							Landscape													
		Local							Forest type							Number of species				
Imperiled Species	Habitat Profile	cnpy_cov	grd_cov	mid_cov	rep_cov	duff	state_agopendist	state_distdev	state_forest	state_forwet	state_hdwd	state_pine	streamden	limestone	Str_Size	1° Parameter	2° Paremeter	3° Parameter	4° Parameter	Focal Species Code
Black Pine Snake	8	3-	4+							2-	2-	1+				10	3	3	1	cnesex
Florida Pine Snake	8	3-	4+							2-	2-	1+				10	3	3	1	cnesex
Southern Hognose snake	8	3-	4+							2-	2-	1+				10	3	3	1	cnesex
Northen Pine Snake	8	3-	4+							2-	2-	1+				10	3	3	1	cnesex
Southeastern Five-Lined Skink	8	3-	4+							2-	2-	1+				10	3	3	1	cnesex
Red-cockaded Woodpecker	9	3-	2+									1+				10	4	1	n/a	golpol
Eastern Indigo Snake	9	3-	2+									1+				10	4	1	n/a	golpol
Mimic Glass Lizard	9	3-	2+									1+				10	4	1	n/a	golpol
Mississippi Gopher Frog	9	3-	2+									1+				10	4	1	n/a	golpol
Gopher Frog	9	3-	2+									1+				10	4	1	n/a	golpol
Reticulated Flatwoods Salamander	9	3-	2+									1+				10	4	1	n/a	golpol

Table 1.6. Imperiled species habitat profiles and number of detected species that have the same association to each habitat parameter, including the selected focal species for each profile.

							Landscape													
		Local							Forest type							Number of species				
Imperiled Species	Habitat Profile	cnpy_cov	grd_cov	mid_cov	rep_cov	duff	state_agopendist	state_distdev	state_forest	state_forwet	state_hdwd	state_pine	streamden	limestone	Str_Size	1° Parameter	2° Paremeter	3° Parameter	4° Parameter	Focal Species Code
Eastern Diamondback Rattlesnake	10	4-	2+				3+					1+				10	4	1	1	golpol
Bachman'S Sparrow	10	4-	2+				3+					1+				10	4	1	1	golpol
Henslow''s Sparrow (winter)	11	3-	2+								4-	1+				10	4	1	1	cnesex
Southeastern Pocket Gopher	11	3-	2+								4-	1+				10	4	1	1	cnesex
Eastern Coral Snake	12	2-	3+						1+							21	5	2	n/a	sssh
American Kestrel	13	3-	2+				1+									21	13	4	n/a	inbu
Prairie Kingsnake	13	3-	2+				1+									21	13	4	n/a	inbu
Brazilian Free-tailed bat	13	3-	2+				1+									21	13	4	n/a	inbu
Short-eared Owl (winter)	14		2+		3+		1+									21	7	0	n/a	fisp
Long-tailed Weasel	15				2+								1+			23	7	n/a	n/a	tercar kewa
Coal Skink	16				3+				2+				1+			23	5	3	n/a	rsha

Table 1.6. Imperiled species habitat profiles and number of detected species that have the same association to each habitat parameter, including the selected focal species for each profile.

		Local					Landscape									Number of species				
									Forest type											
Imperiled Species	Habitat Profile	cnpy_cov	grd_cov	mid_cov	rep_cov	duff	state_agopendist	state_distdev	state_forest	state_forwet	state_hdwd	state_pine	streamden	limestone	Str_Size	1° Parameter	2° Paremeter	3° Parameter	4° Parameter	Focal Species Code
Northern Yellow Bat	17											2+	1+			23	1	n/a	n/a	eurcha
Meadow Jumping Mouse	18	2-	3+				4+						1+			23	3	1	0	puma
Tennessee Cave Salamander	19										2+		3+	1+		1	1	0	n/a	pleven
Southeastern Myotis	19										2+		3+	1+		1	1	0	n/a	pleven
Little Brown Myotis (winter)	19										2+		3+	1+		1	1	0	n/a	pleven
Gray Bat	19										2+		3+	1+		1	1	0	n/a	pleven
Eastern Spotted Skunk	20		3+		1+				2+	4-						30	5	2	1	rabbit
Northern Harrier (winter)	21	2-	1+				3+						4+			46	20	3	0	inbu
Fish Species (Large Stream)	22							1-							2+	24	16	n/a	n/a	perkat
Fish Species (Small Stream)	23							1-							2-	24	7	n/a	n/a	ptesig

Table 1.6. Imperiled species habitat profiles and number of detected species that have the same association to each habitat parameter, including the selected focal species for each profile.

							Landscape													
		Local							Forest type							Number of species				
Imperiled Species	Habitat Profile	cnpy_cov	grd_cov	mid_cov	rep_cov	duff	state_agopendist	state_distdev	state_forest	state_forwet	state_hdwd	state_pine	streamden	limestone	Str_Size	1° Parameter	2° Paremeter	3° Parameter	4° Parameter	Focal Species Code
Mollusks (Mobile Basin)	24							1-							2-	2	2	n/a	n/a	elimia
Mollusks (Coastal Basins)	25							1-							2-	2	2	n/a	n/a	unicar
Crayfish	26							1-							2-	8	5	n/a	n/a	orcchi

Table 1.7. Model averaged parameter estimates (β) and standard errors (SE) for each selected focal species. Parameter estimates listed as NA were not considered for the taxa group.

Scientific Name	*Aspidoscelis sexlineata*	*Eurycea chamberlaini*	*Gopherus polyphemus*	*Lampropeltis getula getula*	*Plethodon ventralis*	*Rana clamitans*
Common Name	Six-Lined Racerunner	Chamberlain's Dwarf Salamander	Gopher Tortoise	Eastern Kingsnake	Zigzag Salamander	Green Frog
Species Code	cnesex	eurcha	goppol	lamget	pleven	rancla
cnpy_cov	-0.163 (0.108)	-0.024 (0.078)	0.036 (0.087)	0.1 (0.141)	0 (0)	0 (0)
duff	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
grd_cov	0.005 (0.039)	0.001 (0.111)	0.14 (0.199)	0 (0)	0 (0)	-0.051 (0.111)
mid_cov	0 (0)	0 (0)	0.061 (0.103)	0 (0)	0 (0)	0 (0)
rep_cov	0 (0)	0 (0)	-0.011 (0.031)	0 (0)	0 (0)	0 (0)
state_agopendist	0 (0)	0 (0)	0.214 (0.235)	0 (0)	0 (0)	0 (0)
state_distdev	NA	NA	NA	NA	NA	NA
state_forest	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
state_forwet	0 (0)	0.088 (0.142)	0 (0)	0 (0)	0 (0)	4.376 (8.077)
state_hdwd	-3.928 (2.289)	0 (0)	0 (0)	0 (0)	0.086 (0.087)	0 (0)
state_pine	0.061 (0.472)	0.041 (0.067)	1.732 (1.745)	0 (0)	0 (0)	0 (0)
streamden	0 (0)	0.018 (0.136)	0 (0)	-0.269 (0.156)	0 (0)	1.114 (0.981)
limestone	0 (0)	0 (0)	0 (0)	0 (0)	0.725 (0.616)	0 (0)
Str_Size	NA	NA	NA	NA	NA	NA

Table 1.7. Model averaged parameter estimates (β) and standard errors (SE) for each selected focal species. Parameter estimates listed as NA were not considered for the taxa group.

Scientific Name	*Terrapene carolina carolina*	*Spizella pusilla*	*Wilsonia citrina*	*Passerina cyanea*	*Oporornis formosus*	*Buteo lineatus*
Common Name	Eastern Box Turtle	Field Sparrow	Hooded Warbler	Indigo Bunting	Kentucky Warbler	Red-Shouldered Hawk
Species Code	tercar	fisp	howa	inbu	kewa	rsha
cnpy_cov	0 (0)	0 (0)	0.587 (0.589)	-1.852 (0.156)	1.082 (0.871)	0.257 (0.428)
duff	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
grd_cov	0 (0)	4.928 (2.116)	0 (0)	1.589 (0.7)	0.114 (0.26)	-0.7 (0.436)
mid_cov	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
rep_cov	0.03 (0.108)	3.209 (2.113)	1.957 (0.861)	-0.363 (0.167)	1.742 (1.012)	0.379 (0.334)
state_agopendist	0 (0)	1.375 (1.174)	0 (0)	1.537 (0.997)	0 (0)	0 (0)
state_distdev	NA	NA	NA	NA	NA	NA
state_forest	0 (0)	0 (0)	0 (0)	0 (0)	1.376 (1.725)	0.094 (0.233)
state_forwet	0.097 (0.127)	0 (0)	1.9 (0.994)	0 (0)	0 (0)	0 (0)
state_hdwd	0 (0)	0 (0)	0 (0)	0 (0)	0.001 (0.002)	0.096 (0.181)
state_pine	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
streamden	0.334 (0.298)	0 (0)	0 (0)	0 (0)	11.588 (7.802)	6.509 (4.454)
limestone	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Str_Size	NA	NA	NA	NA	NA	NA

Table 1.7. Model averaged parameter estimates (β) and standard errors (SE) for each selected focal species. Parameter estimates listed as NA were not considered for the taxa group.

Scientific Name	*Piranga olivacea*	*Limnothlypis swainsonii*	*Helmitheros vermivorus*	*Aix sponsa*	*Hylocichla mustelina*	*Blarina carolinensis*
Common Name	Scarlet Tanager	Swainson's Warbler	Worm-Eating Warbler	Wood Duck	Wood Thrush	Southern Short-tailed Shrew
Species Code	scta	swwa	wewa	wodu	woth	sssh
cnpy_cov	1.435 (1.113)	9.551 (7.034)	1.784 (1.133)	-0.488 (0.412)	1.711 (0.964)	-0.822 (0.432)
duff	0 (0)	0.054 (0.05)	0 (0)	0 (0)	0 (0)	0.031 (0.236)
grd_cov	0 (0)	0 (0)	0 (0)	0.034 (0.247)	0 (0)	0.349 (0.648)
mid_cov	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
rep_cov	0 (0)	14.776 (8.318)	2.312 (1.163)	0 (0)	1.075 (0.735)	0 (0)
state_agopendist	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
state_distdev	N/A	N/A	N/A	N/A	N/A	N/A
state_forest	0 (0)	0.55 (2.429)	0 (0)	0 (0)	0 (0)	0.2 (0.491)
state_forwet	0 (0)	-0.077 (0.319)	0 (0)	3.602 (3.01)	0 (0)	0 (0)
state_hdwd	1.695 (1.021)	0.031 (0.117)	0.759 (0.499)	0 (0)	0.797 (0.48)	-0.586 (0.279)
state_pine	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.144 (0.244)
streamden	0 (0)	-8.096 (8.245)	0.119 (0.317)	0 (0)	0 (0)	0 (0)
limestone	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Str_Size	NA	NA	NA	NA	NA	NA

Table 1.7. Model averaged parameter estimates (β) and standard errors (SE) for each selected focal species. Parameter estimates listed as NA were not considered for the taxa group.

Scientific Name	*Microtus pinetorum*	*Sylvilagus spp.*	*Progne subis*	*Percina kathae*	*Pternotropis signipinnis*	*Elimia spp.*
Common Name	Woodland Vole	Rabbit	Purple Martin	Logperch	Flagfin Shiner	Elimia snails
Species Code	wovo	rabbit	puma	perkat	ptesig	elimia
cnpy_cov	-0.152 (0.217)	-0.226 (0.039)	-0.404 (1.282)	NA	NA	NA
duff	0.005 (0.044)	0 (0)	0 (0)	NA	NA	NA
grd_cov	0.593 (0.842)	0.164 (0.14)	0.962 (1.048)	NA	NA	NA
mid_cov	0 (0)	0 (0)	0 (0)	NA	NA	NA
rep_cov	2.052 (2.018)	0.207 (0.223)	0 (0)	NA	NA	NA
state_agopendist	0 (0)	-0.092 (0.09)	0 (0)	NA	NA	NA
state_distdev	NA	NA	NA	-3.621 (1.799)	-4.417 (1.86)	-0.992 (0.442)
state_forest	0 (0)	0.072 (0.095)	0 (0)	NA	NA	NA
state_forwet	0 (0)	-0.006 (0.029)	0 (0)	NA	NA	NA
state_hdwd	0.71 (0.83)	0 (0)	0 (0)	NA	NA	NA
state_pine	0 (0)	0 (0)	0 (0)	NA	NA	NA
streamden	0 (0)	0 (0)	1.503 (2.029)	NA	NA	NA
limestone	0 (0)	0 (0)	0 (0)	NA	NA	NA
Str_Size	NA	NA	NA	1.183 (0.825)	-1.232 (0.244)	0.051 (0.089)

Table 1.7. Model averaged parameter estimates (β) and standard errors (SE) for each selected focal species. Parameter estimates listed as NA were not considered for the taxa group.

Scientific Name	*Uniomerus carolinianus*	*Orconectes chickasawae*
Common Name	Eastern Pondhorn	Chickasaw crayfish
Species Code	unicar	orcchi
cnpy_cov	NA	NA
duff	NA	NA
grd_cov	NA	NA
mid_cov	NA	NA
rep_cov	NA	NA
state_agopendist	NA	NA
state_distdev	-0.351 (0.15)	-5.667 (2.464)
state_forest	NA	NA
state_forwet	NA	NA
state_hdwd	NA	NA
state_pine	NA	NA
streamden	NA	NA
limestone	NA	NA
Str_Size	0.018 (0.056)	-0.168 (0.038)

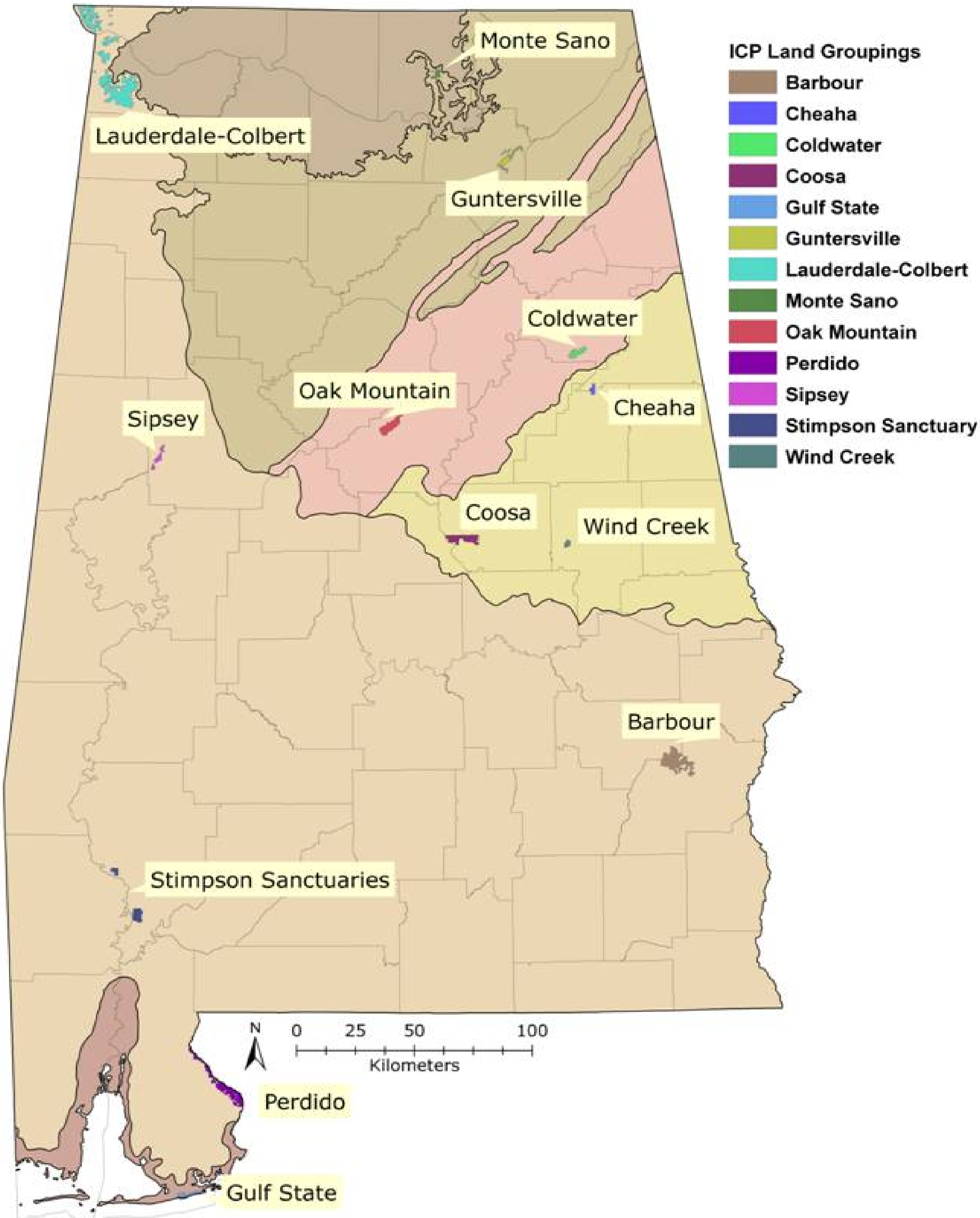


Figure 1.1. Terrestrial vertebrate surveys were conducted on 13 study areas managed by Alabama Department of Conservation and Natural resources in the lower and upper coastal plain, piedmont, ridge and valley, southwestern Appalachians, and interior low plateau during 2008-2010.

Figure 1.2. Number of species per taxonomic group with positive model averaged parameter estimates (β) for each covariate (Tables 1.2 and 1.3) used for occupancy analysis on ADCNR managed lands.

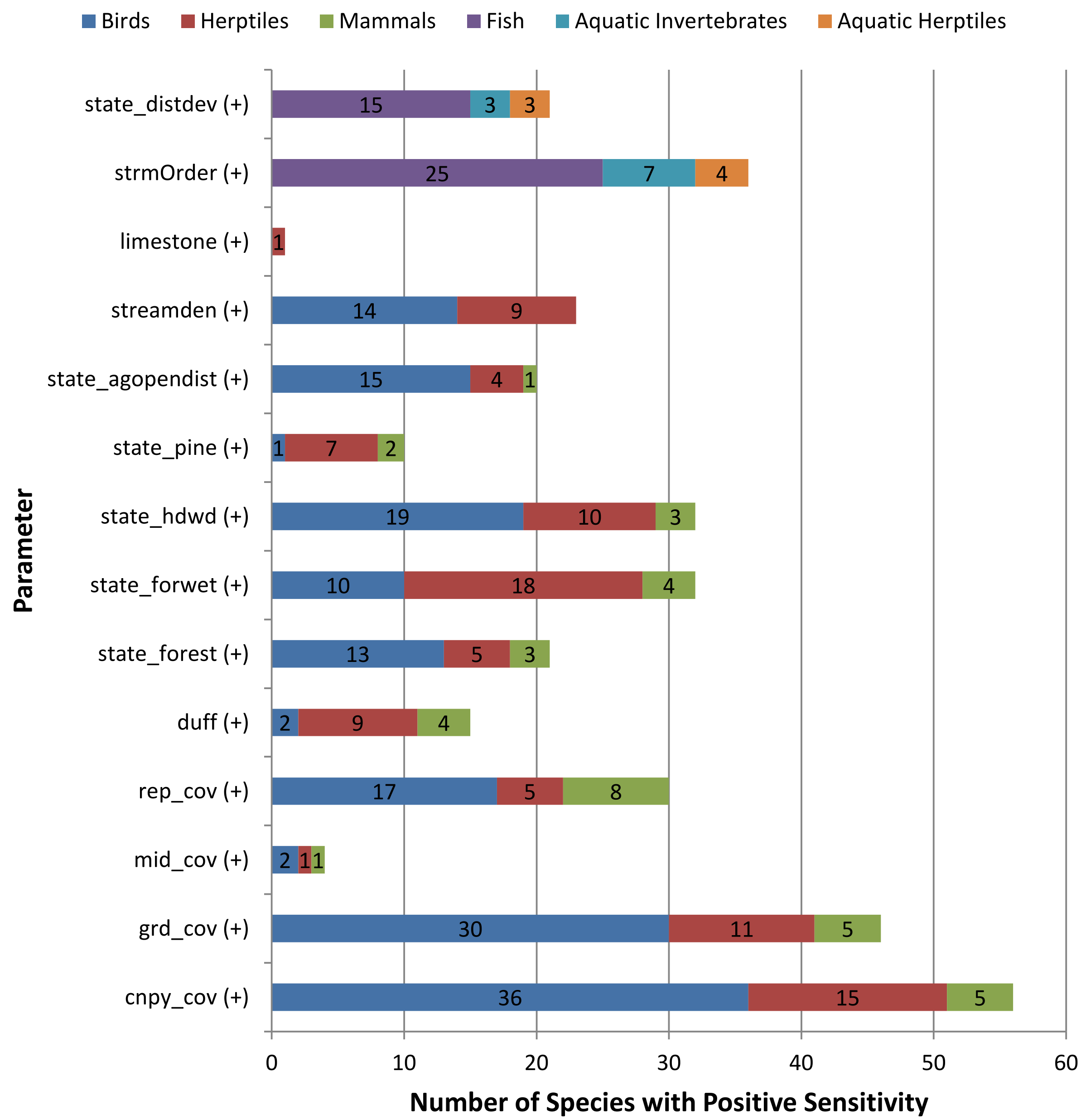
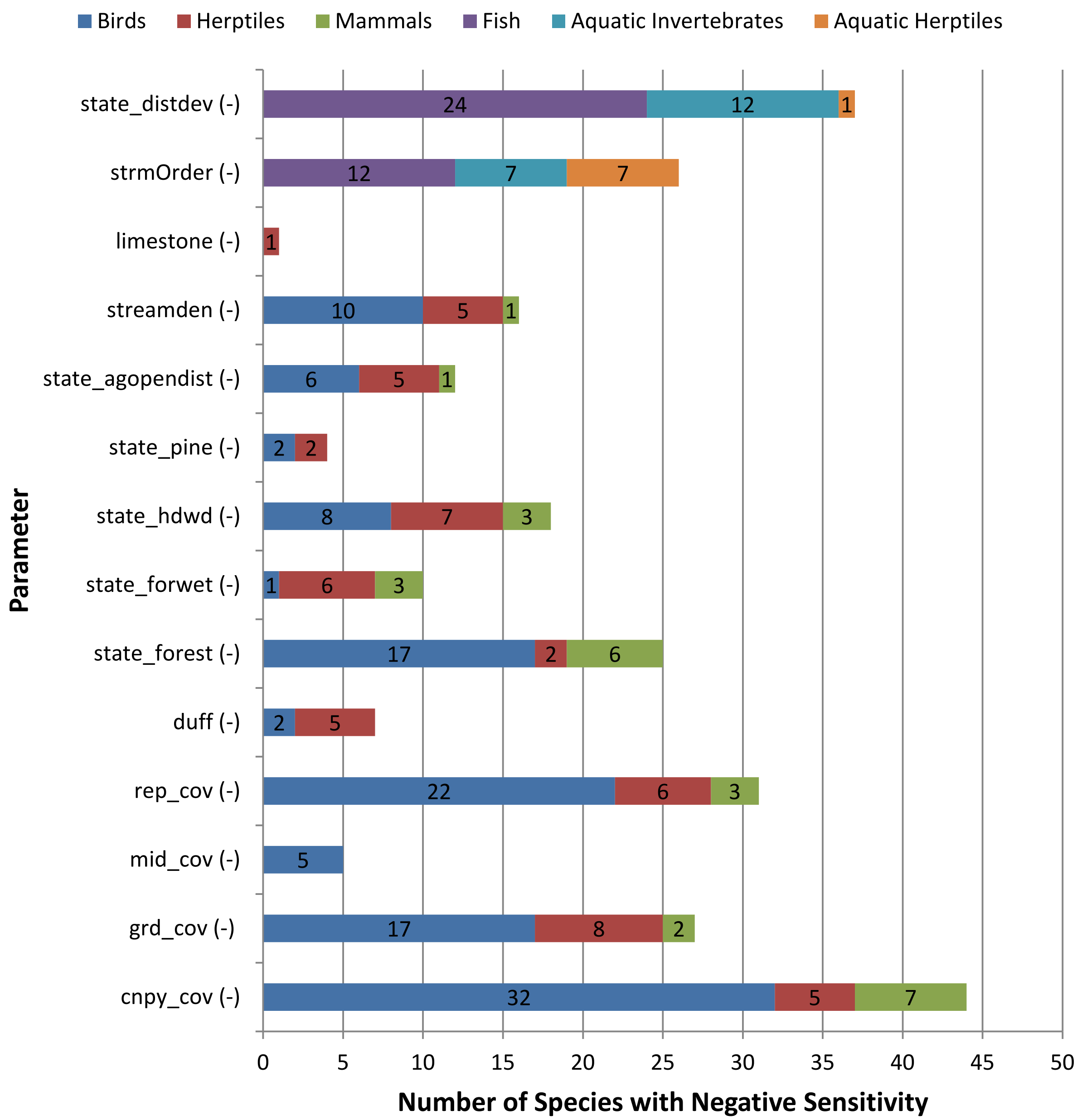


Figure 1.3. Number of species per taxonomic group with negative model averaged parameter estimates (β) for each covariate (Tables 1.2 and 1.3) used for occupancy analysis on ADCNR managed lands.



Chapter 2. Incorporating long-term spatial and temporal effects in a state space model to evaluate land management alternatives in Alabama.

Abstract

Conservation decisions are often made based on expected outcomes without full consideration of costs, likelihood of achieving targeted results, or spatial and temporal consequences of their implementation. We used structured decision making to establish management objectives and compile information for development of a decision support tool to evaluate management alternatives on ten state-owned lands in Alabama. The identified problem was to determine how to best manage state lands to enhance primary functions of properties while improving habitat for imperiled wildlife species. We developed a heuristic state space model to predict consequences on wildlife species of 11 management alternatives implemented over a 100-year planning horizon. Management objectives, alternatives, and costs were elicited from land managers and included combinations of actions that affect land cover type and structure on uplands, floodplains, and wildlife openings. We used a matrix of land cover transition rates describing natural and human-induced processes to predict the cost of management, user (e.g. hunters and hikers) preferences, and wildlife responses based on likelihood of land cover change. We derived user preferences from surveys of potential users. Wildlife responses were predicted from occupancy rates estimated from field data for a suite of focal species representing each imperiled species. We estimated the utility of each alternative based on the average of the scaled outcomes for each objective on each state park and wildlife management area. The preferred alternative varied among study areas based on their intended use. For example, removing existing wildlife openings within upland pine provided greater utility for imperiled species on wildlife management areas within the coastal plain. Our model is

capable of incorporating additional objectives and trade-offs and would be useful for evaluating alternatives at landscape scales in similar regions. Additionally, we make recommendations for monitoring programs and user preference surveys that may reduce the ambiguity of management decisions.

Problem

In 2002, federal appropriations became available under the State Wildlife Grant (SWG) program for state agencies to design and implement a more comprehensive approach to conservation of wildlife (US Fish & Wildlife Service, http://wsfrprograms.fws.gov). The program requires each state to identify species in "greatest need of conservation" and develop a Comprehensive Wildlife Conservation Strategy (CWCS) to focus efforts towards management that reduces their imperilment (Wildlife and Freshwater Fisheries Division: Alabama Department of Conservation and Natural Resources 2005). In 2005, Alabama completed their CWCS which included information on the distribution and abundance of species in "greatest conservation need" (GCN) and associated critical habitat (Wildlife and Freshwater Fisheries Division: Alabama Department of Conservation and Natural Resources 2005). This strategy also identified threats to GCN species and habitats as well as descriptions of conservation actions and implementation priorities. However, Alabama's CWCS also acknowledged that information for monitoring many species of concern was limited, their habitat requirements were poorly known, and the effectiveness of conservation actions were poorly understood.

Currently, within Alabama little guidance exists to help ADCNR resource managers manage their lands for GCN species. Subsequently little data exists relating species responses to forest management or landscape change. This is compounded by the fact that only 4.2% of the state is public land of which only 0.75% is managed by ADCNR (Silvano et al. 2009). With limited public land in the state, most ADCNR lands are mandated to provide an assortment of activities for public benefit. Typical use includes consumptive and non-consumptive recreation such as hunting, hiking, and fishing. They may also include revenue generation through timber harvest and mineral extraction. This multi-objective approach further complicates managers' ability to discern appropriate and effective conservation management actions for GCN species.

Managers are regularly required to make decisions on how to best manipulate the landscape and vegetative structure for an array of activities. These decisions are often made without a precise statement of objectives or understanding how species will respond to proposed management actions. Lack of clear objectives can lead to ineffective conservation. Without precise, explicit, measurable objectives there is no clear way to define success or gauge effectiveness of conservation which essentially limits good decision making. Additionally, lack of information regarding system dynamics can cause uncertainty regarding outcomes. In general four types of uncertainty can exist; partial controllability, structural uncertainty, partial observability, and environmental variation (Nichols et al. 1995, Williams 2001, Nichols et al. 2011). Partial controllability is uncertainty relating to the imprecision of management implemented and structural uncertainty is lack of knowledge regarding how a system responds to management (Nichols et al. 2011). Partial observability is the result of an inability to directly measure the system and environmental variation results from are imprecise or inaccurate estimates of s stochastic processes (Nichols et al. 1995, Williams 2001). All these sources of uncertainty can make outcomes highly unpredictable. With these compounding uncertainties, managers need a means to identify clear objectives and determine optimal management actions to maximize proposed target objectives, cope with system uncertainties, and allow for more informed conservation decisions (Moore and Conroy 2006).

In recent years, conservation biologists, resources managers, and ecologists have moved towards using structured decision making to frame their conservation questions and management actions. Structured decision making (SDM) is a formal process that guides decision making by subdividing a problem into components. The process relies on eight key elements to effectively make an informed decision (Gregory and Keeney 2002). These elements are an explicit statement of the problem, identification of key objectives, creation of alternatives, assessment of consequences of those actions, evaluation of trade-offs and incorporation of uncertainty, risk, and linked decisions (Hammond et al. 1999).

Here we describe using the SDM process to establish management objectives and compile information for the development of a decision support tool to evaluate management alternatives on state-owned properties within Alabama. The identified management problem was to determine how to improve landscape composition and characteristics to maintain or enhance primary functions of state lands while enhancing habitat for imperiled species (i.e. Priority 1 and Priority 2 GCN species) through uneven-aged forest management.

Ecological Context

Study areas were clusters of state-owned and managed wildlife management areas, parks, and nature preserves that span six physiographic provinces, or ecoregions: Interior Low Plateau, Southwestern Appalachians, Ridge and Valley, Piedmont, Southeastern Plains, and Southern Coastal Plain (Griffith et al. 2001a). We selected areas greater than 1000 acres in consultation with representatives from Alabama Department of Conservation and Natural Resources (ADCNR) agency based on AL-GAP Stewardship (Silvano et al. 2007a) , imperiled species distribution data (Silvano et al. 2007b) and greatest potential to impact multiple imperiled species.

Coastal Plain Study Areas

Five of our 10 study areas were located in the Coastal Plain ecological region (Figure 2.1) and ranged in size from 51,300 acres to 3,400 acres. Generally topography within the coastal plain region is very flat and soils are acidic and sandy with expansive calcareous areas occurring in the central and northern reaches (Mount 1975). Of the 5 coastal plain areas Barbour, Perdido, and Lauderdale-Colbert (i.e. Lauderdale WMA and Freedom Hills WMA, Figure 2.1) are primarily managed by ADCNR Wildlife and Freshwater Fisheries Division (WFF) as general use wildlife management areas that provide recreation opportunities to the public in the form of hunting, hiking, nature-viewing, or horseback riding. Land parcels encompassing each of these properties were predominately acquired through various land and timber agreements with private landowners. As such the land cover composition throughout is generally a mixture of intensively managed pine forests in uplands and mixed pine-hardwood forests on sloped extents where terrain inhibited the use of harvesting equipment. Historically, these areas encompassed large regions of bottomland floodplain or riparian forests however in the early 1900s much of this was cleared for agriculture or planted in pine for timber production (Harper 1943). Currently, only remnant patches of bottomland forest remain throughout these properties. Conversely, Lauderdale-Colbert located in the northern most reach of the coastal plain has an underlying geology of limestone and sandstone creating rolling topography with numerous rock outcroppings (Mount 1975). The resultant terrain and edaphic conditions has restricted timber operations in the past limiting forest conversion to plantation pine for timber production. Therefore, large areas of hardwood and mixed pine-hardwood forests still exist on lower slopes and coves.

The Sanctuaries study area includes two tracts of land, Upper State Sanctuary and Fred T. Stimpson Sanctuary (Figure 2.1). These tracts are located in Clark County, nestled between the Tombigbee and Alabama Rivers. The topography in this region is deeply dissected and boasts the most rugged terrain within the coastal plain of Alabama (Griffith et al. 2001b). Both tracts are managed as game sanctuaries under the provision of ADCNR WFF Division. Fred T. Stimpson can be characterized as hilly terrain with deep ravines, rocky bluffs, and outcroppings of claystone, sandstone and limestone (Mount 1975, Griffith et al 2001b). The forests found throughout Fred T. Stimpson are either mixed pine-hardwood or hardwood forests on slopes and coves and managed pine forest on upland plateaus. However in the last 5 years over 15 % of the pine component was harvested in the uplands creating large amounts of disturbed habitat. In contrast, Upper State Sanctuary is located within the floodplain of the Tombigbee River and primarily composed of bottomland floodplain forests with less than 5 % of the area in upland pine forest.

Gulf State (Figure 2.1) study area encompasses Gulf State Park in Baldwin County on the coast of Alabama. Most of this area is xeric coastal sand with pine dominated land cover. The remaining area includes beaches, inundated tidal marshes, and developed areas such as a campground, picnic areas, golf course, nature center, and hiking trails. Although ADCNR Parks Division primarily manages for these developed activities the forested areas are managed towards meeting wildlife habitat needs.

Piedmont Study Areas

Two of our study areas were located in the piedmont ecological province, Coosa and Wind Creek (Figure 2.1). The piedmont region is characterized as a transition area between the mountains and coastal plain regions of Alabama. Areas in the piedmont are generally hilly and rocky with heavy clay soils (Mount 1975). Wind Creek is a state park managed by ADC NR Parks Division for public recreation. Wind Creek is located in the inner piedmont region adjacent to Lake Martin, a man-made impoundment of the Tallapoosa River. Wind Creek has extensive rolling hills throughout (Griffith et al. 2001b) and the forest cover is a mixed of both pine and hardwoods. With the upland ridges in mixed pine-hardwood, or managed pine forests and the lower slopes hardwood.

The Coosa study area differs from others within the Piedmont, in that it is managed as a wildlife management area under the direction of ADCNR WFF division. It is located along the banks of the Coosa River upstream from Lake Mitchell. The tract was acquired though a timber agreement and has been heavily managed for timber production in the past. Over half of the area is in pine plantation. The remaining areas are dominated with hardwood on the upper slopes and remnant patches of bottomland/riparian forest along riverbanks. However, over the last several years, large quantities of timber have been cleared creating large patches of disturbed areas throughout study area.

Ridge and Valley Study Areas

The ridge and valley region (Figure 2.1) is relatively low-lying with undulating landforms of rounded-ridges and valleys (Griffith et al. 2001b). The soils of this region are generally loamy or clay with an underlining geology of limestone resulting in many caves and springs systems throughout (Mount 1975, Griffith et al. 2001b). This region encompasses the Oak Mountain study area (Figure 2.1), which is located adjacent to highly urbanized areas, however due to the landform and edaphic conditions it remains heavily forested. Oak Mountain is a state park managed by ADCNR Parks Division for camping, and public day use activities such as hiking, biking, and picnicking. Although, Oak Mountain has an extensive trail system over 87 % of the areas is closed canopy hardwood forest.

Southwestern Appalachian Study Areas

Guntersville study area is found within the Southwestern Appalachian ecological region (Figure 2.1). It is a State Park that encompasses over 6000 acres surrounding Lake Guntersville, an impoundment of the Tennessee River. The area is locally referred to as part of the Tennessee Valley and is characterized by steep slopes, bluffs, and rock outcroppings of limestone. Guntersville includes a large developed tract with a campground and golf course with the remaining area dominated by hardwood forests. However, in 2011 this study area sustained heavy tornado damage that devastated 30 % of the forested area within the study area.

Objectives

The desired outcomes from implementing different management actions are objectives (Martin et al. 2009). Under each objective, performance measures are identified to gauge success or relevant impacts that actions (Gregory and Long 2009, Martin et al. 2009). Hammond et al. (1999) identify two classes of objectives. Fundamental objectives, the broadest objectives directly influenced by management alternatives and means objectives, how you attain or proceed toward a fundamental objective. Defining clear objectives is a key component to making sound managements decisions, without which it is not possible to measure performance or bound management problems (Nichols et al. 1995).

To elicit management objectives, alternatives, and compile information for the decision support tool we established two committees to engage property stakeholders and additional vested parties to elucidate management needs on a subset of state managed lands. We established a steering committee composed of divisional heads from ADCNR Wildlife &

Freshwater Fisheries, Parks, and Lands Division to frame the management problem, identify fundamental management objectives and choose appropriate properties for the project. The management and research committee also was established and included land managers from each of the ADCNR Divisions, as well as researchers in the field of ecological modeling, forestry practices, and wildlife natural history and ecology. The primary focus of this committee was to identify potential means and performance measures to achieve fundamental objectives, and to predict consequences of management actions, and related effects on GCN species. We held a series of workshops, which generally consisted of either half day meetings for the Steering Committee or 2-day sessions for the management and research Committee. All workshops were facilitated by Alabama Cooperative Fish & Wildlife Research Unit (ALCFWRU) personnel.

For this project, we engaged the steering committee and asked members to identify management mandates for properties within their division's management jurisdiction. From the assembled list, mandates with similar goals were grouped together, and fundamental objectives were defined from those groupings. In addition, probable means to achieve the stated objectives were discussed and noted. In secondary meetings, these were reviewed and refined until objectives that meet management needs for all stakeholders were agreed upon. Committee members then assigned performance measures for the different objectives through facilitated discussions. Table 2.1 outlines these performance measures as well as stated objectives of the project. With information compiled during steering committee workshops we developed an objectives hierarchy to illustrate how various means objectives influence fundamental objectives and impact the overall project goal (Figure 2.2). The objectives hierarchy also served as an influence diagram to guide development of an analytical model to evaluate management alternatives and their effects on objectives.

Alternatives

The different management options that can be implemented to achieve stated objectives and alternatives (Gregory and Keeney 2002). To develop management alternatives we held four 2-day workshops. During initial workshops land managers and foresters from each division were asked to outline their current management intent for each property they were responsible for managing. They were given maps for their respective property, and asked to outline areas where they are currently applying any habitat manipulation or management action, any previous actions, as well as planned future actions. They were instructed to list the proposed management intent for those actions and the intended management goal of the property as a whole. Management action lists from all properties were pooled together and those actions with similar management intent were grouped into portfolios of actions (Table 2.2). Information regarding management goals was also combined for all properties. In successive workshops, management actions and goals were reviewed, from which a list of potential land management alternatives were elicited through several rounds of facilitated discussions.

In general, conversion of forests to an uneven-aged system has been the common goal for forest management on state managed lands within Alabama, over the past decade. The impetus was the mandate set forth in the state's Comprehensive Wildlife Conservation Strategy (Wildlife and Freshwater Fisheries Division: Alabama Department of Conservation and Natural Resources 2005). This strategy identified that changes in vegetative structure, species composition, and fragmentation caused from forest conversion and intensive silviculture practices has resulted in the decline of many native wildlife species. In general, when forests are managed with uneven-aged methods, single trees or small groups of trees are harvested periodically within units maintaining a constant, complex structure as well as the contiguous integrity of the overall forested landscape. Preserving forest structure minimizes changes in the overall forest which promotes sustainability of vertebrate populations, and reduction in predation or nest parasitism that often increases with forest fragmentation (Thompson et al. 1995, Barber et al. 2001, Nyland 2002) . Although alternative practices such as even- or two-aged management may result in units of many age classes interspersed throughout the forest, each unit is made up of only one or two age classes (Smith 1962). When forest manipulation occurs, typically entire units or large groups of trees are removed creating open areas with hard edges that fragment the overall forested landscape (Nyland 2002). In terms of providing suitable habitat for animal species these forests tend to have lower diversity due to the monotypic forest structure and a high turnover of species due to complete removal of forest units (Thompson et al. 1995).

We identified 11 management alternatives (Table 2.3) based on management actions elicited from land managers and foresters during workshops. Each alternative defined a target landscape configuration to be managed for over a 100-yr projection period. Under each management alternative, all forested management units are converted from even-aged to an uneven-age forest structure to provide a diversity of vertical vegetation to support more wildlife species than a monotypic structure of even-aged forest stands. All management alternatives follow Alabama's Best Management Practices (BMP) guidelines for foresters (Alabama Forestry Commission 2007). In specific, the target landscape configuration under every alternative includes a forested streamside management zone (SMZ) of 35 feet from a stream bank as specified in Alabama's BMP. Within this SMZ, a residual tree cover of >50% is maintained to protect the physical and biological integrity of waters.

We defined a landscape, as the composition of management units found within a study areas bounding extent. Individual management units within a landscape were defined as an area composed predominantly of identical land cover type in which management actions can be applied to produce a single effect. Component management units within a landscape varied in size but generally ranged from .5 acres to 250 acres, the latter identified as the largest extent by which a crew of workers could apply the most intense management action within a day (i.e. forest entry).

Alternatives 1 and 2

Alternative 1 was described as a minimum management prescription based on current study area conditions circa 2011. This entails sustaining the current landscape configuration, which includes preserving the 35-foot forested SMZ along all streams, and maintaining the existing land cover types (e.g. forest, agricultural field, open green field). All forested units (e.g. young and mature even-aged pine, hardwood, and forested wetlands) would be managed to achieve an uneven-aged forested state through thinning and selective cutting. Mixed pine-hardwood units would not receive management intervention, allowing for natural succession to occur over time. The pine component in these units would eventually be overtopped and naturally die off resulting in a hardwood-dominated unit over time.

In Alternative 2, forested areas are managed as they are in Alternative 1, but wildlife openings (areas planted in agricultural crops, disked fields, or grasses) are restored to the surrounding forest type. Although beneficial to many game species, maintaining these open areas fragment the overall landscape, which may have negative repercussions for sustaining GCN species.

Alternatives 3 and 4

Under Alternative 3, we evaluate the impacts of forest management on north-facing slopes. North-facing slopes are protected from the sun, providing cooler and moister environments than south-facing slopes that receive more sunlight throughout the day. These cool moist conditions typically support hardwood dominated vegetation and provide microclimate conditions desirable to a large number of GCN species, especially amphibian and reptiles. However, due to the historic land use most north-facing slopes were cleared and planted in pine for timber production subsequently altering the vegetation and microclimate conditions. Under this alternative, wildlife openings are maintained, forested areas, except those on north-facing slopes, are managed as they are under Alternatives 1 and 2. On north-facing slopes hardwoods are planted and managed for an uneven-age or allowed to naturally progress to an uneven-age hardwood forested state. .

Alternative 4 is the compliment to Alternative 3. In Alternative 4, we evaluate the impacts of restoring 50% wildlife openings to a forested state based on their surrounding forest type.

Alternatives 5 and 6

These alternatives evaluate impacts of expanding the SMZ from 35ft to the extent of the natural floodplain for all streams and rivers. Alabama's BMPs currently recommend a 35ft forested SMZ be maintained from all stream banks to protect integrity of waters. This SMZ area is considerably smaller than historical floodplain and riparian areas that were once prevalent throughout much of the coastal plain and piedmont regions (Richardson 2000). In general these natural floodplain and riparian areas were once vast areas of moist hardwood dominated forest communities that provided natural water filtration and supported diverse assemblages of wildlife species (Burke and Gibbons 1995). However, these swampy forests have been lost due to development, or drained and converted to agricultural fields or planted in pine for timber production (Wildlife and Freshwater Fisheries Division: Alabama Department of Conservation and Natural Resources 2005). With these alternatives all units within the natural floodplain of water/streams would be converted to (planted) or managed for uneven-aged hardwood forested wetland, and the remaining forested areas are managed as they are under Alternatives 1 and 2. The extent of the natural floodplain was delineated from topographic relief and would be variable for different streams and rivers within the landscape. Similar to the pairs of alternatives described above, Under Alternative 5, all wildlife openings are maintained in their current state and under Alternative 6, they are converted back to the surrounding forest type.

Alternatives 7 and 8

Under these alternatives, north-facing slopes are managed as they are under Alternatives 3 and 4, floodplains are managed as in Alternatives 5 & 6, and the remaining forested areas are managed as they are under Alternatives 1 and 2. Under Alternative 7 wildlife openings are maintained and in Alternative 8 they are converted to the surrounding forest type.

Alternatives 9 and 10

Historically most of Alabama was dominated by fire maintained pine ecosystems. Under these alternatives we simulated the effects of managing and converting forests to uneven-aged pine throughout the entire landscape, except where forested wetlands currently exist and within the 35 ft SMZ. Under Alternative 9 wildlife openings are maintained and in Alternative 10 they are converted to pine.

Alternative 11

Under this alternative, we simulated the effect of no forest manipulation except prescribed fire within pine units. All other forested units would not receive management intervention, allowing for natural succession to occur over time. The intent was to emulate regional conditions prior to European settlement.

Consequences

Methods

We used a state space transition model to predict the consequences of each management alternative on each management unit for each study area. We defined management units as patches of land that could be managed for a single land cover type (state). We projected land cover change for 100-years based on models for each management alternative. We predicted vegetative structure within each state based on field observations and simulation. We estimated the probability of use of each state based on physical characteristics, probability of land cover type, and the expected vegetative structure. For each alternative, we estimated wildlife value based on the average probability of use of a management unit by each of the focal species over the 100-yr projection. We estimated user preference value for each unit under each alternative based on the probable land cover state using probabilities of preference values summed over the 100-yr projection. We estimated the relative cost of management of each unit based on expert elicitation and the probability of perturbation and maintenance of states under each alternative summed over the 100-yr projection. We calculated wildlife, user preference, and cost value of each alternative on each study area, and then determined the value of each alternative for each study area to ADCNR biologists and managers based on objective weights.

Attributes of Management Units

We developed a geographic information system for each study area that included management units and important attributes that would affect their management under each alternative using data from a variety of sources. We defined management units as patches that could be managed independently of other units for homogeneous land cover. Management units varied in size but generally ranged from .5 acres to 250 acres. We mapped management units by using roads and streams, which typically act as physical partitions for implementing management actions. We further subdivided these areas based on image interpretation and from maps provided by area managers delineating historical and planned management activities. We then used seamless high-resolution color imagery (Esri 2011) to add visible boundaries between forested and non-forested areas (Appendix 1 Property maps of initial states). We manually digitized stream floodplains based on topographic data (U.S. Geological Survey (USGS) 2009) and added streamside management zones (SMZ) by estimating 35 foot buffer along streams from hydrographic data (U.S. Environmental Protection Agency and U.S. Geological Survey 1999).

The important attributes of each management unit included: current land cover type (ca. 2011), whether it was managed as a wildlife opening, if and when it was scheduled for timber harvest, and whether it fell on a north-facing slope, in an SMZ, or stream floodplain (Table 2.4). We determined the initial land cover type based on the majority type within the management unit using Gap Analysis Project (GAP) Land Use and Land Cover data (Kleiner et al. 2007) in conjunction with high-resolution color imagery (Esri 2011). We used GAP data to classify management units as pine, mixed pine/hardwood, upland hardwood, forested wetlands, or developed. We then used high-resolution imagery to reclassify management units that were recently disturbed (clear-cut) or open fields. Since we could not discern from imagery if open areas were grassy or planted in agricultural crops, we used data provided by land managers and foresters to further classify wildlife openings. For pine and hardwood management units we further refined the land cover type into classes that represented typical timber stages: seedling/sapling (< 4" dbh), poles/small trees (4"-12" dbh) or mature trees (>12"dbh) using maps outlining areas of current habitat management, previous harvest records, and current high-resolution imagery.

For the land cover types observed in the field, we calculated the mean and SE of vegetative characteristics (canopy, mid-story, reproductive, and ground cover) based on field observations (Silvano et al. 2012). For states that did not exist on any of our study areas (two-aged pine and hardwood, uneven-aged pine, hardwood, and forested wetlands) we estimated canopy and mid-story using Forest Vegetation Simulator (Version 2.0, US Forest Service; Tacconelli, personal communications). We estimated the relationship between canopy cover and mid-story to reproductive and ground cover using a Bayesian belief network (Grand, unpublished).

State-space Model

State-space models (state and transition models) capture ecosystem dynamics by integrating knowledge about how vegetation responds to environmental conditions or management (Bashari et al. 2009, Rumpff et al. 2011). In its simplest graphical form, states represent vegetation or landscape variables and connecting lines, transitions from one state to another as a function of specified attributes (Figure 2.3). The transitions represent natural and human-induced processes that affect the state of each management unit.

Target end states for our model represented the ultimate outcomes, while initial and intermediary states represented either current land cover conditions, natural stages of habitat succession, or the recent effects of management. We used a 100-yr period to allow for the slow rate of development for uneven-aged forest types. For each transition we assigned a temporal rate of change based on the likelihood land cover would change from one state to another in a given year as a function of management or natural succession or catastrophic events (e.g. wildfires, tornadoes) (Appendix 2). Pine and hardwood rates were based on standard rotation age classes for timber production and were developed based on expert knowledge of our study areas. We estimated mean length of time (*l*) each unit would remain in a particular state (*i*) using:

$$l_i = \frac{-1}{\ln(r_{ijk})}$$

where r_{ij} is the probability a unit remained in state *i* under alternative *k* when $i = j$, or transitioned to state (*j*) when $i \neq j$.

We then cast a 25 x 25 element matrix (R_k) composed of the r_{ijk} for each possible state transition for each of the k management alternatives. For each management unit we constructed an initial state vector (S_1) consisting of zeros and a single 1 to indicate the initial (known) state of the management unit.

We multiplied the transition matrix (R_k) by state vector (S_t) to estimate the probability that a management unit was in each of the *j* states one year later (t+1),

$$\mathbf{S}_{t+1} = \mathbf{RS}_t .$$

We repeated this process to estimate the probable states of each management unit each year through t+100. Thus, our model is both temporally and spatially explicit.

We simulated alternatives by either modifying the state vector for the management unit or the transition matrix. For immediate action, such as timber harvest, we simply modified the state vector to simulate a transition from forested to early successional habitat. For changes in forest management, such as thinning, we modified the transition rates. The result was a corresponding matrix of the probability that each management unit was in each state at each time for each alternative.

Wildlife

Most GCN species are rare or elusive and difficult to monitor precipitating challenges for to gathering data to estimate and predict their response to habitat management actions.

Management based on focal species that are indicators of habitat requirements of imperiled species may be a useful alternative for monitoring the success of habitat manipulation until populations rebound. We applied a systematic approach to selecting focal species for each of the different GCN species (Chapter 1)

We estimated the probability of use (ψ_{ijt}) for each management unit by each of the focal species each year based on the weighted averages of ψ for each species and state (Table 2.5) where weights consisted of the probability a management unit was in a state at time t:

$$\psi_{ijt} = \sum_{k=1}^{K} s_{ikt} \frac{\exp(\mathbf{X}_{ik}\beta_j)}{1+\exp(\mathbf{X}_{ik}\beta_j)}$$

where X_{ik} is a matrix of characteristics of management unit i and the vegetative characteristics of state k, β_j is a vector of the estimated effect of each characteristic on ψ for species j, and s_{ikt} is the probability that management unit i is in stake k (Table 2.5). We then averaged probability of use (ψ_{ijt}) across all management units in a landscape to estimate the percent area occupied (PAO) for each focal species each year.

Appropriate Use/ User Preferences

ADCNR lands are managed for multiple objectives to provide an assortment of activities for the benefit of the public including outdoor recreation in the form of hunting, hiking, camping, as well as conservation of natural resources and maintaining ecosystem function. Although these lands have a designated intended use they still must take into account GCN species conservation and all other mandated objectives. In addition, most Alabama State lands are clusters of land parcels purchased in tandem by the different divisions of ADCNR (i.e. Wildlife Freshwater Fisheries Division, Parks Division, and State Lands Division) resulting in stakeholders and mandates that vary on a single property further complicating the management decision making process. To evaluate appropriate use on state lands we estimated preference values for landscapes characteristics that are preferred by intended to users of the property for recreation.

We estimated user preferences from surveys of potential users by Grill (2010). Grill conducted mail surveys of urban residents and those subscribing to *Outdoor Alabama*. They asked a sample of individuals to respond to questions regarding the importance of natural landscape characteristics to an ideal setting for their favorite outdoor recreation activity. Based on their responses, we divided responses into 4 recreational user groups representing preferences of hunters, non-hunters, nature-viewers, and those engaged in more developed activities, such as camping or family gathering. This allowed us to estimate preferences of the intended users for land cover characteristics of each study area. For example, on wildlife management area study sites, we estimated preferences for hunters and non-hunters, and on state park study sites we estimated preferences for nature viewers and groups more interested in developed areas.

On the survey, respondents were asked to assign each landscape characteristic a qualitative score on a 5-point Likert scale from not at all important to very important. We assigned each score a value from 1-5. We use the proportion of each response by each user group to each landscape characteristic as the conditional probability of the score for that characteristic, given the user group. We focused analysis on a subset of responses concentrated on natural landscape characteristics that were directly representative of land cover types in our state-space model (Table 2.4).

To evaluate consequences of the different management alternatives on user preferences we calculated the preference value for each user group for each management unit at each time under each alternative based on the probability that the unit would be in a given state. We use the weighted sum across all management units, using the area of each unit as the weight, to generate a preference value for each alternative for each different user group each year. However, since most properties have multiple use designations we combine preference values for multiple user groups by averaging across them.

Cost

We estimated the relative cost of management of each unit under each alternative by summing the relative cost of transition and maintenance of states over the 100-yr projection. We use expert opinion of ADCNR managers to estimate annual maintenance cost for each state and transition. Managers were asked to identify the most expensive and least expensive management activities and place every other management activity on a relative scale between these costs (Table 2.2). We annualized relative costs by dividing the relative cost by the frequency of the actions. We calculated the expected costs as the weighted sum of the relative annual cost of management for each management unit at each time period.

Objective Value

We calculated value for each objective under each management alternative to evaluate consequences or impacts of management on each objective. We estimated the value (V_{ik}) for an objective (i) under each alternative (k) using:

$$V_{ik} = \sum_{t=0}^{T} O_{ikt}$$

where O_{ikt} is the sum of the response (i.e. wildlife occupancy, user preference, and cost) in each time step (t) for objective i over the 100-year period planning horizon (T) under alterative k. Since ADCNR currently has a management prescription in place (i.e. Alternative 9) we evaluated whether implementing a different management prescription would give ADCNR more benefit or a greater chance of achieving their stated objectives over the current management prescription. We estimated a marginal difference value (M_{ik}) for each objective (i) under each alternative (k) using:

$$M_{ik} = \frac{V_{ik} - V_{i9}}{V_{i9}}$$

to evaluate the percent difference in objective value (V_{ik}) for objective i under alternative k from the objective value for their current management prescription (V_{i9}) for objective i under Alternative 9.

Tradeoffs (decisions)

We calculated utility values for each alternative to allow a comparison of management alternatives based on expected consequences of wildlife , user preferences, and costs, which are otherwise incomparable We determined utility value of each alternative for each study area as the sum of the marginal difference values for wildlife, user preference, and cost objectives.

We also calculated a weighted utility values for each alternative based on weights that reflect the relative importance of each objective to ADCNR biologists and managers (Wilson et al. 2011). We elicited these weights by asking the management and research committee members to rank each objective in order of relative importance. We then converted each members responses to a weight by multiplying the elicited ordinal value for each objective by the "rank-ordered centroid" (ROC) weight (Barron and Barret 1996, Goodwin and Wright 2004) We used the weighted sum of the objective values to identify the alternative that is expected to provide the greatest value to ADCNR given the objectives for the agency and each study area.

Results

We determined the initial landscape composition for each study area, which established baseline conditions to project landscape change over time under each management alternative (Figure 2.4). Overall, initial conditions across all 10 study areas were composed primarily

(>85%) of young (i.e. seedling/saplings and poles/ small trees <12dbh) or mature even-aged forests (trees >12dbh). In general, each study area had less than 5% in a disturbed state, with the exception of Guntersville State Park where >30% of the area was disturbed due to tornado damage in 2011. Less than 5% of each study area was wildlife openings (agriculture, or open green fields), excluding Oak Mountain, Gulf State, and Wind Creek, where no wildlife openings exist. As a whole, state park study areas contained larger developed areas (upwards of 11%) whereas all others were less than 1% developed. However, none of the study areas initially contained uneven-aged forests, the target forested system under all management alternatives.

The initial forest type (state) varied across the study areas. However, study areas could be classed into three distinct groups, those with forest communities dominated by 1) pine forest, 2) both pine and hardwood forest and, 3) hardwood forest (Figure 2.4). Half of the study areas (5 of 10) had an even-aged pine composition greater than 60%, a mature even-aged hardwood component <20% and <10% even-aged forested wetlands. Of these 5 study areas, the pine forests on Coosa, Perdido, and Barbour were predominately young even-aged pine (>65%) whereas, Gulf State Park and the Sanctuaries were predominately mature even-aged pine forests (>75%). Lauderdale, Freedom Hills, and Wind Creek's initial forest type were a mix of 50% even-aged pine and 50% mature even-aged hardwood with <5% mature even-aged forested wetlands. Both Lauderdale and Freedom Hills had a pine component dominated by young even-aged pine forest with <1.5% in mature pine forest whereas Wind Creek's pine component was all mature even-aged pine. The remaining study areas of Oak Mountain and Guntersville State Parks had an initial forest community dominated by mature even-aged hardwood and less than 5% mature even-age pine.

For each alternative the desired outcome under each management alternative differed by landscape composition and configuration (Appendix 1) at the end of the 100-yr projection period. With alternative 1, we expect all study areas to be maintained with identical proportion of land cover types as in the initial (current) condition except all forested land cover types (pine, hardwood, and forested wetlands) are managed for an uneven-aged structure. Alternative 2 differs only by small increases in forested areas that result from the reforestation of wildlife openings (i.e. agriculture or open green fields). Under alternative 3, all forested land cover types are converted to uneven-aged forest and wildlife openings are maintained. However, management units on north-facing slopes convert to uneven-aged hardwood resulting in a general increase in hardwood forest ranging from 0.1% (Sanctuaries) to 10% (Coosa) and corresponding decreases in pine or mixed forest. Alternative 4 is identical to alternative 3, but wildlife openings are reforested as in alternative 2, resulting in small increases in forest types. With alternative 5, the overall percentage of forested wetlands increases on all study areas due to the conversion of management units within the natural floodplains of all streams to uneven-aged forested wetland. This increased the percentage of floodplain forest from 5% on Guntersville to 41% on Perdido. In contrast, the percentage of pine in the landscape decreased across nine study areas (Barbour, Perdido, Coosa, Sanctuaries, Freedom Hills, Lauderdale, Wind Creek, Oak Mountain) under this alternative. Alternative 6 differs from alternative 5 only in that wildlife openings are reforested. In comparison, under alternatives 7 and 8 achieved nearly identical results to alternative 5 and 6 however the percentage of hardwood also increases due to conversion from either mixed or pine to hardwood on north-facing slopes. Because hardwood forest dominates north-facing slopes on Guntersville, the composition of the landscape is unchanged. Under alternative 9 and 10 the percentage of pine increases on all study areas ranging from .5% on Perdido to 91% on Guntersville because only SMZs are not managed for uneven-aged pine. With alternative 11 the desired landscape composition on all properties was identical to alternative 8. The targeted landscape composition and configuration are identical for both alternatives, but the means for attaining them differed.

Pine dominated, pine and hardwood dominated, and hardwood dominated study areas responded similarly to management alternatives (Figure 2.4), unless the topography was vastly different from others within that group. Study areas initially dominated by even-aged hardwood (Oak Mountain and Guntersville State Park) yield landscapes dominated by uneven-aged hardwood under all alternatives except 9 and 10. In comparison, study areas initially dominated by even-aged pine (Barbour, Coosa, Perdido, The Sanctuaries, and Gulf State) result in landscapes dominated by uneven-aged pine with most alternatives (7 of 11). However, under alternatives 5 through 8 the resultant landscape composition varies depending on topographic relief of the study area. For example, Perdido is largely bottomland floodplain so under these alternatives the resultant landscape is primarily uneven-aged forested wetland rather than an upland forest type (i.e. hardwood or pine). The study areas initially an equal mix of even-age pine and even-aged hardwood (Freedom Hills, Lauderdale, and Wind Creek) result in landscapes with nearly equal portions of uneven-aged pine and uneven-aged hardwood under alternatives 1 through 4. Whereas, alternatives 5 through 8 and 11 produced a landscape proportional spilt across uneven-aged pine, hardwood, and forested wetlands. The percentage in each forested type varied among these four study areas depending on terrain. For example, Lauderdale has a larger pine and hardwood component because terrain of the area is deeply dissected resulting in steeply sloped areas with large flat ridge tops, which support upland forest types rather than bottomland.

The average probability of attaining a targeted end state in year 100 under each alternative varied with each land cover state (Figure 2.5). Under each alternative, the average probability targeted areas reaching uneven-aged hardwood by year 100 is <51% across all study areas. This is most due to the slow growth rate of hardwood tree species in general. Whereas the average probability targeted areas reach uneven-aged pine is >79% by year 100. Agriculture and open fields are retained in alternatives 1, 3, 5, 7, and 9, thus we estimate >95% probability that they will remain as such on most study areas. However, >25% of openings occur within areas where timber will be harvested and replanted on Coosa, Perdido, and Lauderdale, and we assumed the openings would also be planted eliminating them as a landscape feature. This reduces the likelihood that those openings will exist by year 100.

Alternative 11 resulted in the lowest probabilities of reaching the targeted landscape composition for all study areas (<20% n=2, <30% n=5, <50% n=3) (Figure 2.5). This is due to the length of time needed to reach an uneven-aged state with natural succession and no forest manipulation other than prescribed fires. Whereas, the probability the targeted landscape composition was achieved is most likely (>90%) with alternatives 9 and 10, because all forested areas are converted to uneven-aged pine through intense forest manipulation. Alternatives 5 and 6, then 7 and 8 were next most likely to attain their targeted composition on all study areas except Perdido. On Perdido >75% of the land area is natural floodplain that has been planted in even-aged pine. Under these alternatives, management units in those areas are converted from pine to forested wetlands as such tree species in this forest community are generally slower growing species reducing probability of reaching the end state by year 100. In comparison, study areas initially dominated by hardwood (i.e. Guntersville and Oak Mountain) also had a lower probability of reaching the targeted landscape composition for all alternatives except 9 and 10, under which managers convert most hardwoods to pine.

The probability that landscape features, openings, SMZ, north-facing slopes, and floodplains, reached the targeted state by year 100 also varied among alternatives (Figure 2.6). SMZs were most likely (>90%) to reach the targeted state, uneven-age forested wetland across alternatives 1-9. Since SMZs existed as even-aged forested wetlands on all properties except Perdido and Barbour, an uneven-aged state was easily attainable over 100-yr period. However, with alternative 11, the likelihood of SMZs reaching uneven-aged is <25% for all alternatives because without forest management the natural process is slow. The average probability that floodplains reached the targeted state of uneven-aged forested wetlands is more likely (>85%) under alternatives 5 – 8. These management alternatives specifically target maximizing topographic floodplains through enhancement or conversion of all forested and non-forested management units within this area to uneven-aged forested wetlands. Similarly the likelihood areas of wildlife openings attain their targeted end state is higher under management alternatives 1, 3, 5, 7, and 9 which retain areas of wildlife openings that existed in the initial landscape of a study area. In contrast, areas of a landscape on north-facing slopes are less likely to reach their targeted end-state of uneven-aged hardwood under alternatives 3 and 4 because of the growth rate of hardwood trees. Since ecological conditions on north-facing slopes naturally support hardwood, under these two alternatives hardwood naturally encroaches and progresses to uneven-aged hardwood via natural processes. Similar to alternative 11, the rate of this natural progression is inherently slower than anthropogenic forest manipulation, thus the likelihood the targeted end state is reached during 100-yr projection period is lower than other alternatives.

Focal Species Response

Initially, the mean percent area occupied (PAO) by focal species is <21% on all study areas (Figures 2.7-2.16). The initial low estimated PAO for focal species is expected because initial conditions across all study areas are either young pine or a mix of even-aged pine or hardwood, which typically does not support the complex forest structure most focal species require. However, the initial PAO for individual focal species did range in value from 57% (Eastern Box Turtle (*Terrapene carolina carolina;* TERCAR), Perdido) to <1% (Zigzag Salamander (*Plethodon ventralis;* PLENVEN), Guntersville) across all study areas and species. Generally, the species with a higher initial PAO (>50%, n=3) are those that utilize either disturbed habitat or benefit from high reproductive cover associated with young forests (e.g., Indigo Bunting (*Passerina cyanea;* INBU) and TERCAR). In addition, the initial PAO range varied with study area for each species dependent on a species habitat preference and the initial landscape conditions. However, this range for a given species was generally small (>1%). For example, Scarlet Tanagers (*Piranga olivacea;* SCTA) initial PAO is highest (>20%) on study areas initially dominated by hardwood (i.e. Guntersville and Oak Mountain) because this species is primarily associated with mature hardwood forest. This pattern is identical for PLENVEN, another hardwood obligate species.

The expected mean PAO of focal species when the targeted landscape condition is reached is 49% across all study areas under all alternatives (Figure 2.7-2.16). The associated range is small (~ 10%), with overall PAO values ranging from 44% to 55%. Alternatives 5-8 consistently support (8 of 10 study areas) the greatest overall PAO (>50%) at target landscape conditions. This is due to the fact that these alternatives maximize floodplains within a landscape and many of our focal species (10 of 20) are associated primarily with forested wetlands. Expected POA across focal species ranged from 27% to 72% across study areas, and varied with alternative. For an individual species the range of expected PAO across alternatives is between 10% and 38%. The expected POA for any given species was highest with alternatives that increased the availability and condition of its preferred habitats in the target landscape. For example, pine obligate focal species (e.g., Six-Lined Racerunner (*Aspidoscelis sexlineata;* CNESEX) and Gopher Tortoise (*Gopherus polyphemus*; GOLPOL)) are expect to attain the highest expected POA with alternatives 9 and 10 across all study areas, since under these alternatives all upland forest types are converted to uneven-aged pine.

Overall expected PAO of focal species in year 100 across all study areas is between 24% and 51% (Figures 2.7-2.16). For most study areas (9 of 10), predicted mean PAO for species is 5% or less than the expected PAO under each alternative, except for alternative 11. Predicted mean PAO for this alternative is on average 18% lower than the targeted PAO, most likely because target landscape conditions are not yet attained in year 100 under this alternative. However, the average increase in overall PAO from initial to predicted (i.e. year 100) is 25% with every alternative across all study areas. Mean predicted PAO in year 100 for individual focal species is 45% and ranged between 9% and 64% across study areas and alternatives. In general, predicted PAO for individual species (17 of 20) increased from initial PAO with all alternatives, except for INBU, Green Frog (*Rana clamitans* (RANCLA), and TERCAR. The decrease in PAO for these species is expected due to habitat preferences towards specific vegetative structural conditions that are reduced in an uneven-aged forest. For example, INBU and TERCAR prefer dense reproductive cover, which is higher in young and even-aged forests and generally decreases as the forest canopy closes with an uneven-aged forest. RANCLA prefers dense ground cover within forested wetlands, which is also lower in an uneven-aged forested state.

Objective Value of Alternatives

Wildlife value (Mean PAO) for all alternatives increased over time for all study areas (Figure 2.17). We expect the greatest increase in wildlife value over the 100-yr projection period from Alternatives 9 and 10, with value approaching an asymptote around year 60. With these two alternatives, all upland forests are converted to uneven-aged pine within the landscape. Tree species within pine forests typically grow at a faster rate than hardwood, thus the climax uneven-age state is more likely to be attained sooner than hardwood forests, which are more common in the other alternatives. This provides higher value to wildlife for a longer time period since the complex forest structure of an uneven-age forest required by focal species is available earlier in the projection period. In contrast, alternative 11 incurred the lowest value of wildlife for all study areas, because in that alternative forests transition from even-aged to uneven-aged via natural processes rather than by management intervention.

Similarly, user value, the relative expected mean user preference among user groups, also increased asymptotically over time reaching a near maximum after approximately 80 years (Figure 2.18). Alternatives 9 and 10 sustained the greatest increase in value for user preference among alternatives. This is expected, since all user groups had a higher preference for uneven-aged forests (Appendix 3).

Value of cost (1 - expected relative management costs) is initially low for the first 20 years of the projection period across alternatives with value varying with study area (Figure 2.19). However, after 20 years value of cost sharply increases and stabilizes at a higher value with all alternatives across study areas. This is likely due to the high initial relative cost of planting and managing even-aged forests to an uneven-aged state (Table 2.2). Since we used 1-cost to calculate value, high relative cost has a low utility value whereas low relative cost has a high utility value. Alternative 11 sustained the highest value over the 100-yr projection period because under this alternative no forest manipulation occurs except prescribed fires. Inherently, naturally progressing to an uneven-aged state or using prescribed fire is relatively inexpensive compared to other management actions hence the value of cost is much higher with this alternative.

Comparing Objectives Across Alternatives

Marginal wildlife value for each alternative relative to alternative 9 initially increases and then declines becoming negative, that is, less than alternative 9 (Figure 2.20). For each of the other alternatives, except 10, wildlife value increased in the short term (<15 years) decreased to less than the value of alternative 9 and then increased slowly for the remainder of the 100-yr projection period. However, marginal wildlife value for alternative 10 is continually positive over the entire 100-yr projection period for 9 of 10 study areas. This alternative is identical to reference conditions, except all wildlife openings in the landscape are reforested. Similarly, the marginal gain in value for user preference is initially positive then declines to negative in year 25 except in alternative 10 (Figure 2.21). On every study area, alternative 10 is the best management alternative for wildlife and user preference.

The marginal difference in value of cost over time is variable in the short term (<25 years) across all alternatives (Figure 2.22). These short term differences, change in value from positive to negative among alternatives and is dependent on initial study area conditions. For example, study areas subjected to extensive timber harvests and forest manipulation (i.e. Perdido, Barbour, Lauderdale, Freedom Hills and Coosa) tend to have larger fluctuations in cost value short term. However, value of cost does stabilize over time with all alternatives. Marginal difference of cost is continually positive and incurs the highest marginal difference with alternative 11 across all properties.

Tradeoffs

Wildlife utility value, marginal wildlife value summed over time, was greatest for Alternatives 9 and 10 (Table 2.6). The wildlife utility value of alternative 9 is zero for all alternatives because it is the reference to which all other alternatives are compared against. On most study areas, alternative 10 attains the highest utility value. The only difference between 9 and 10 being that wildlife openings are reforested under alternative 10. Negative values for many alternatives on most of the study areas are indicative that they were less valuable over the 100-yr period than Alternative 9, even though PAO increased for the majority of wildlife species over the 100-yr period (Figures 2.7-2.16). Outside of alternatives 9 and 10, alternatives 5 through 8 had the next best utility value for wildlife across study areas. This is predominately due to the fact that 10 of 20 focal species are associated with forested wetlands and these alternatives increase the availability of this habitat type. Alternative 11 consistently has the lowest utility value for wildlife across all study areas as expected because under this alternative we are least likely to attain target conditions by year 100 giving it a very low utility value for the wildlife objective. Alternatives that revert wildlife openings (i.e. 2, 4, 6, 8, and 10) to a forested state had a better utility value for wildlife than the comparable alternative that retained openings (i.e. 1, 3, 5, 7, and 9).

Utility value for the user preference objective is negative for all alternatives except 9 and 10 for the same reasons that many wildlife utility values are negative (Table 2.6). However, in contrast to the wildlife objective values, alternatives 5 through 8 are the lowest in utility value for users on all study areas. This is due to the low preference of all user groups (i.e. hunters, non-hunters, nature-viewers, and developed activity) for forested wetlands (Appendix 3). Also, in direct contrast to the wildlife objective value on study areas where wildlife openings exist (i.e. Barbour, Coosa, Perdido, Sanctuaries, Freedom Hills, and Lauderdale), alternatives that retain openings consistently had a higher utility value for user preference than the complimentary alternatives where they are reforested. The aforementioned study areas are designated wildlife management areas and the primary user group (i.e. hunters) had a higher preference for agriculture (Appendix 3) yielding a higher utility value for user preference in alternatives with wildlife openings in the landscape.

Utility value of the cost objective was highest for alternative 11 on all study areas (Table 2.6). In general, alternatives 9 and 10 had the lowest utility value for this objective for all study areas except those initially dominated by pine because they were the most costly (i.e. Barbour, Coosa, Perdido, Sanctuaries, and Gulf State). With alternative 9 and 10, all forested states are converted to uneven-aged pine and relative cost associated with converting a forest type is high, therefore value of cost is low for these alternatives. The lowest total utility value of cost for study areas initial dominated by pine is alternatives 5 and 6 with similar rationale. Under these alternatives all forested types are transitioned to uneven-aged forested wetland (i.e. alternative 5 and 6) and relative cost for converting forest type is high yielding a lower value of cost overall. However, total utility value of cost is higher with alternatives that convert wildlife openings to a forested state (i.e. 2, 4, 6, 8, and 10) in comparison to the complimentary alternative that retain wildlife openings (i.e. 1, 3, 5, 7, and 9). In general, it is more costly to retain wildlife openings because there is an annualized cost of mowing, seeding, or plowing to maintain the management unit in that state. Whereas, converting wildlife openings to forested is initially expensive but long-term cost of management to uneven-aged forest is relatively low.

Weighting utility values for each objective equally, the total utility for alternatives exhibited nearly identical pattern as utility value of the cost objective in terms of which alternates attained best value across all study areas (Table 2.6). Alternative 11 attained the highest total utility value, then 10 and 9, respectively. Consequently, it is expected that the total utility value for an alternative would mimic the cost objective since utility value of cost has a high positive value in comparison to both negative values for the wildlife and user preference objectives. Therefore, when summed across all three objectives, value of cost inherently drives the overall decision value.

Normalized objective rankings elicited from individual steering committee members are highest for the wildlife objective (value = .45), user preference objective (.40), then cost objective (.15), respectively. Total utility value weighted with objective ranks yielded changes in total utility value from the equally weighted values for each alternative across all study areas (Table 2.7). In general, alternative 11 changed from the best to worst valued alternative across nearly all study areas (n=9) because weighting objectives by steering committee members essentially limited effects of the cost objective in comparison to other objectives.

Discussion

The decision analysis presented here suggests that restoring forest types naturally supported by specific topographic features and maintaining wildlife openings within a landscape is the best management approach to equally maximize value for each target objective set forth by ADCNR (i.e. alternative 11). This approach also reveals that best management means to attain this targeted landscape on each study area is without forest manipulation except prescribe fire in pine forest types, allowing all other forested types to naturally progress to an uneven-aged state.

Our modeling process highlighted that initial land cover conditions and topography of a study area were key factors that influence whether a management alternative would be achieved within the 100-yr projection period on a given study area. In general, slower development of hardwood forests and forested wetlands versus pine forests resulted in a much lower probability of reaching an uneven-aged hardwood or forested wetland state. Thus, the probability of successfully achieving a target landscape with a management alternative specifically aimed at restoring hardwood on north-facing slopes or flood plain forest would consistently be low across all study areas. However, our results did not conform to this pattern. If the study area was within the coastal plain and initially dominated by pine it had a higher success rate under these alternatives (i.e. 3 and 4) than study areas initially dominated by mature hardwoods outside the coastal plain. Broadly speaking the coastal plain region is relatively flat with little terrain or sloped areas, therefore less area of slope to convert from pine to hardwood so more likely to attain the target landscape overall. Whereas, study areas outside of the coastal plain are predominantly sloped terrain supporting more area for hardwood management so less likely to achieve the targeted end state across the entire landscape within 100-yr projection period.

In addition, initial impacts of timber harvest regimes on a study area influenced success of a management alternative. Initial conditions across most coastal plain study areas are dominated by young or mature planted even-aged pine or even-aged hardwood. Although timber revenue is not an ADCNR agency objective, land managers are mandated to maximize the value of timber where appropriate and cannot remove timber until merchantable. Therefore on some study areas management actions cannot be implemented immediately in certain management units, reducing the likelihood the unit would reach the targeted uneven-aged state by year 100.

This modeling approach also revealed that probability of state is the main driver of value for objectives. Consequently, for wildlife value we have fewer focal species (2 of 20) dependent on pine forest types yet management alternatives (i.e. 9 and 10) that generate a pine dominated landscape consistently yield higher total wildlife utility value. In most cases, uneven-aged pine has a high probability of being in that state at year 100 than uneven-aged hardwood or forested wetland; therefore, we attain maximum value for pine focal species with less uncertainty than with species dependent on other forested types. This is identical situation with user preference objective. The value for user preference is identical for both uneven-aged pine and uneven-aged hardwood states however, management alternatives that produced pine dominated landscape have a higher utility value. This is primarily a function of uneven-aged pine having a higher probability of being in that state at year 100.

In the decision modeling process, we compared each alternative against alternative 9, which we believe represents ADCNRs current management prescription across all study areas. We felt that to make informed decisions land managers would need to know whether altering their current management prescription would result in any greater benefit to wildlife and users at a lower cost. Choosing a different alternative as the reference condition would only have affected marginal values; thus, the decision would have been unaffected.

Our decision analysis highlighted how weighting objectives can influence the relative value of the alternatives when comparisons are made across multiple objectives. In our case, the management problem identified was to determine the best alternative for managing state lands based on primary functions of the property and enhancing habitat for rare and declining species (i.e. GCN species). We hypothesized that the preferred alternative would be one that was best for wildlife and user preference. However, when objective utility values were equally weighted, cost was the most influential, because among alternatives there was relatively little difference in value for user preference or wildlife in comparison to the range of cost values. Nonetheless, this decision may not accurately reflect the best outcome for our stated problem. Re-evaluating the decision and weighting objectives so wildlife and user preference have a greater influence on the decision outcome accurately represent the values of the stakeholders in this problem.

Currently limited information regarding vegetation dynamics is available in literature. As such, we derived vegetation transition rates from expert knowledge. Although, expert opinion is not without criticisms we feel that transition rates used in our model were sufficient to emulate systems dynamics and conduct a robust analysis.

State space dynamics for focal species are based on differences in vegetative structure for each state. Nevertheless, we assumed that the target forest structure was identical for all uneven-aged forest types. Although the target structure was elicited from experts on the steering committee, our target basal area (BA) for pine (70 ft^2/ac for trees >12 diameter breast height) is higher than what is general perceived as representative of pre-European pine forests. Shaw and Long (2007) suggest a minimum basal area range of 20 ft^2/ac to 40 ft^2/ac for trees >14 diameter breast height (DBH) and trees < 14 DBH respectively for good quality open pine habitat. Therefore, conditions for pine obligate focal species may be poorly represented with our model.

Additionally, focal species whose occupancy is driven by specific landscape features that are not manipulated as part of an alternative result in little differentiation in value for that species across alternatives. For, example Green Frog (RANCLA) and Eastern Box Turtle (TERCAR) occupancy is sensitive to stream density within a management unit so occupancy is nearly identical across alternatives because this physical attribute does not vary temporally or among alternatives. Future analyses should consider selecting focal species whose occupancy is sensitive to attributes that are more affected by alternatives. Furthermore, our model currently weights each focal species equally which may not accurately represent community dynamics or stakeholder objectives. For example, if 90% of species are pine obligates we could weight focal species correspondingly for better community level representation on a study area. Likewise, if conservation of some species or habitats is of greater importance than others focal species weights could be applied accordingly.

Lastly, we incorporated existing recreation survey data for user preference in the decision model. As such repeated values were used for multiple end states in our state space leading to little differentiation in preference value across alternatives. Future human dimensions studies or recreation surveys that directly address questions relating to satisfaction in response to specific management actions, landscape conditions, or focal user groups would prove useful for this type of decision analysis. Additionally, we incorporated data on relative cost for management actions elicited from steering committee members. Although the cost function within our model responds as expected with alternatives, a budget in terms of dollars or man hours would more accurately reflect impacts of valuing the cost of management actions on an annual basis.

Incorporating uncertainty in system dynamics has been increasingly emphasized as an important factor that can influence impacts of decisions outcomes (Gregory and Keeney 2002, Nichols et al. 2011, Runge et al. 2011, Moore and Runge 2012). Common sources identified as contributing to uncertainty in conservation include environmental variability, imprecision in sampling, ability to implement management actions, and relationship between management actions and species responses (Williams 2001, Peterson et al. 2007). Uncertainties and known information about effects of management, future environmental, or habitat conditions on species or ecosystems can be incorporated into decision models to assess the likelihood of success of management actions (Nichols et al. 1995, Peterson et al. 2007).

More recently studies have begun to incorporate system uncertainty in their decision analysis. Bashari et al. (2009) used a state transition model within a Bayes net to directly incorporate uncertainty in rangeland dynamics to evaluate if management intervention was required. They modeled the likelihood a current grass community would transition to a native grass or non-native grass state given different grazing pressures. However, this study did not directly incorporate impacts of management actions. Model output predicted only the most likely transition in the absence of management without decision outcomes. In comparison, Rumpff et al. (2011) successfully used a similar approach directly incorporating management actions influence on the probability of achieving a native woodland state at restoration sites. Although probability of management success was incorporated this study focused only on dynamics of single system and did not project long-term system changes over time. In contrast, Moore and Conroy (2006) included environmental stochasticity in their forest dynamic model to determine optimal management strategies that maximize sustainable woodpecker habitat long term. Where the probability of a future old-growth pine state was reduced by the probability of a stochastic event thus reducing the likelihood a particular forest would provide optimal long-term woodpecker habitat under different harvest regimes. While parameter uncertainty was considered in their management decisions the model was not spatially explicit. In our case, we applied a similar approach to the above studies using a state based transition model to explicitly incorporate varying sources of uncertainty in a dynamic landscape model. However, in contrast we evaluated impacts of management alternatives on stated objectives across a landscape in a spatial and temporal framework to account partial controllability in management and stochastic processes. We used transition probabilities based on variable growth rates of tree species and stochastic events to measure the probability of a land cover state for each management unit. To estimate the likelihood of attaining the desired landscape composition and spatial configuration under each management alternative we projected impacts of management on the landscape over 100-years. Calculating the cumulative effects of management allowed us to determine the likelihood we would achieve the desired conditions to meet our stated objectives given the alternative.

Considering multiple species and multiple habitats in conservation planning as well as uncertainty of state is critical to making sound ecological decisions in today's dynamic landscapes. Since different species use unique habitat types or multiple habitats for different requirements a mosaic of habitats are needed to account for numerous resources needed for species to persist in a landscape (Poiani et al. 2000, McCarthy 2009). Furthermore, a landscape will change over time with management and restoration efforts and as such species use will also change as more or less habitat becomes available throughout the landscape. Consequently, including multiple species and habitats in analyses to inform conservation decisions allows us to better evaluate trade-offs between species use of different habitat components within a landscape over time.

Studies in the past that incorporate needs of multiple species or taxa group in a decision analyses framework are generally aimed at prioritizing lands for conservation of biodiversity (Margules and Pressey 2000), reserve site selections for species persistence (Nicholson et al. 2006, Nicholson and Possingham 2007), or assessing the conservation status of species and habitats (GAP Analyses) and not designed to evaluate effects of management alternatives or account for dynamic landscapes. However, studies that do account for changes in landscape or evaluate impacts of management are generally focused on a single system type. For example, Blomquist et al. (2010) assessed impacts of management strategies for riparian forests on habitat suitability for multiple taxa groups as the forest structure changed over time with management intervention. However, this study focused on dynamics of a single forest type and used habitat suitability index (HSI) model for species response. Although HSI models are commonly employed they are a deterministic index for habitat quality and do not take into account uncertainty in species occupancy. The approach we present to evaluate impacts of management alternatives to meet our wildlife objective is unique in that our objective includes all state listed GCN species which span multiple taxa groups each of which has unique habitat requirements. We estimated the rate of use for each land cover state for representative species (Chapter 1) using occupancy analysis. We then predicted percent area occupied (PAO) for each species based on the probability of each land cover state and its proportionate area represented within the landscape. Our state space model projected changes in the landscape composition over time each under management alternative which allowed us to determine PAO for each species in every time step based on the probability of states within a landscape. This provided a means to evaluate both short-term and long-term tradeoffs between species response to management alternatives.

We considered multiple objectives in our decision analysis, GCN species abundance, recreation user preference, and cost of management implementation. Although, previous studies have included multiples objectives these have been primarily centered on aquatic systems (Peterson et al. 2007, Conroy et al. 2008, Irwin et al. 2011), evaluate response of a single species (Gregory and Long 2009) or taxa group (Moore et al. 2005) to multiple objectives, or use deterministic modeling approaches that do not take into account uncertainty (Marzluff et al.

2002, Shifley et al. 2008, Price et al. 2012, Shang et al. 2012). To our knowledge, no studies exist that considers wildlife species, user preference, and uncertainty in landscape dynamics in a spatial and temporal framework to evaluate land management alternatives.

We included multiple objectives because public lands have multiple resources and numerous stakeholders. Managing agencies of these lands are commonly challenged with managing landscapes for multiple objectives while being good stewards of the land both fiscally and from a conservation perspective. We used the structure decision making (SDM) process which allowed us to establish a mechanism to perform a robust multi-criteria decision analysis. SDM provided a stepwise process to evaluate impacts of management alternatives on multiple objectives and assess the likelihood of success of implementation. The method we present will hopefully serve as a guide to land managers a means to inform decision when dealing with complex management issues.

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Table 2.1. Fundamental and mean objectives, performance measures, and desired outcomes for ADNCR lands.

Objective (Fundamental)	Subobjective (Means)	Performance Measure	Desired Outcome
Conservation of GCN Species (Maximize benefit to GCN)	Enhance habitat for GCN Species	Percentage area occupied by GCN and focal species each year	Use by GCN and focal species is stable or increasing.
Appropriate Use of Property (Maximize Appropriate Use)	Enhance habitat and landscape characteristics preferred by recreational user groups	Satisfaction of appropriate user groups each year	Satisfaction of appropriate user groups is high
Responsible use of management funds	Choose effective low-cost management	Annual cost of management	Achieve above objectives for lowest possible cost

Table 2.2. Portfolios of management actions used in developing management alternatives and associated relative management costs for ADCNR lands. Relative cost rank ranged from least expensive (value = 1) to most expensive (value = 20).

Portfolio	Actions	Relative Cost
Upland Forest Management	Conversion to longleaf, shortleaf or hardwood as appropriate (clearcut)	1
	Natural regeneration of pine (seed tree or shelterwood)	2
	Mechanical Site Prep	20
	Fire Site Prep	5
	Chemical Site Prep	8
	Plant longleaf or shortleaf on appropriate sites	7
	Light thinning and maintain existing forest type	4
	B-level thin (moderate thinning) and maintain existing forest type	5
	Heavy thin to hardwood savannah (create savannah)	4
	Selection cut (uneven-aged management oak)	5
	Selection cut (uneven-aged management pine)	5
	Chemical control of mid-story/understory vegetation	6
	Mechanical control of mid-story/understory vegetation	15
	Maintain north facing slopes in mixed pine hardwoods	1
	Status quo	1
Floodplain Forest Management	Thinning in Streamside Management Zone (SMZ) or floodplain	5
	Restore/plant hardwood in Ag/open	16
	Restore/plant hardwood trees in SMZs or floodplain	20
	Status quo	1
Wildlife Openings Management	Establish native warm season grasses in existing openings	20
	Maintain without cultivated plantings (early successional habitat)	3
	Status quo (planted crops)	

Table 2.2. Portfolios of management actions used in developing management alternatives and associated relative management costs for ADCNR lands. Relative cost rank ranged from least expensive (value = 1) to most expensive (value = 20).

	Remove openings (reforest)	6
		1

Table 2.3. Management alternatives simulated for evaluation on ADCNR-managed study areas.

Alternative		
No.	Name	Management prescription
1	SQ, Lv Opening	All forest types managed for uneven-age distribution. Mixed pine hardwood succeeds to upland hardwood. Openings retained in either agriculture crops or native warm-season grasses.
2	SQ, Revert Opening	Same as alternative 1, but openings are reforested to adjacent forest type.
3	Nslope, LvOpening	Hardwood and forested wetlands managed for uneven-age distribution. Mixed pine- hardwood stands are thinned and managed to uneven-aged hardwood. Pine forests on north-facing slopes are converted to uneven-aged hardwoods. Openings retained in either agriculture crops or native warm-season grasses.
4	NSlope, Revert Opening	Same as alternative 3, but openings are reforested to adjacent forest type.
5	MaxT, LvOpening	All forest types managed for uneven-age distribution. Pine and upland hardwoods in floodplains are managed for flood plain forest types. Openings retained in either agriculture crops or native warm-season grasses.
6	MaxT, Revert Opening	Same as alternative 5, but openings are reforested to adjacent forest type.
7	NSLope, MaxT, Lv Openings	All forest types managed for uneven-age distribution. Pine forests on north-facing slopes are converted to uneven-aged hardwoods. Pine and upland hardwoods in floodplains are managed for flood plain forest types. Openings retained in either agriculture crops or native warm-season grasses.
8	NSLope, MaxT, Revert Openings	Same as alternative 7, but openings are reforested to adjacent forest type.
9	Management Intent, LvOpening	All forest types except existing floodplain forests are converted or managed for uneven-aged pine. Openings retained in either agriculture crops or native warm-season grasses.
10	Management Intent, Revert Opening	Same as alternative 9, but but openings are reforested to adjacent forest type.
11	No intensive management	Prescribed fire is used to manage forest type and structure. Wildlife openings are allowed to succeed to surrounding forest type.

Table 2.4. Land cover types (states) used in state and transition (state space) model for ADCNR managed lands.

		User evaluated land cover characteristics					
Land cover type (state)	Description	Agriculture	Disturbed	Forested Wetlands	Mixed	Even-aged Forest	Uneven-aged Forest
Ag (pine)	Wildlife openings planted in agricultural crops.	1	0	0	0	0	0
Open (pine)	Wildlife openings planted or maintained in native warm season grasses or non-native cool season grasses and forbs.	0	0	0	0	0	0
Disturbed (to Pine)	Recent clear cuts surrounded by pine forest	0	1	0	0	0	0
EA Forested Wetland	Unmanaged, even-aged flood plain forest	0	0	1	0	0	0
Seedling/Sapling pine	Recently established single-aged pine stands (<4" dbh)	0	0	0	0	1	0
Poles/Small trees pine	Young, single-aged pine stands (4-12" dbh)	0	0	0	0	1	0
Trees >12dbh pine	Mature, single-aged, upland pine stands (>12dbh)	0	0	0	0	1	0
Two age pine	Thinned, single aged, mature pine stands with 2 dominant	0	0	0	0	1	0

Table 2.4. Land cover types (states) used in state and transition (state space) model for ADCNR managed lands.							
		User evaluated land cover characteristics					
Land cover type (state)	Description	Agriculture	Disturbed	Forested Wetlands	Mixed	Even-aged Forest	Uneven-aged Forest
	age classes.						
Uneven-aged pine	Pine-dominated stands managed for a mixture of ≥ 3 size and age classes.	0	0	0	0	0	1
Ag (hardwood)	Wildlife openings planted in agricultural crops.	1	0	0	0	0	0
Open (hardwood)	Wildlife openings planted or maintained in native warm season grasses or non-native cool season grasses and forbs.	0	0	0	0	0	0
Disturbed (hardwood)	Recent clear cuts surrounded by hardwood forest	0	1	0	0	0	0
Uneven-aged forested wetland	Flood plain forest managed for a mixture of ≥ 3 size and age classes.	0	0	1	0	0	0
Mixed Pine/Hardwood	Even-aged mixed pine/hardwood forest	0	0	0	1	0	0

Table 2.4. Land cover types (states) used in state and transition (state space) model for ADCNR managed lands.

		User evaluated land cover characteristics					
Land cover type (state)	Description	Agriculture	Disturbed	Forested Wetlands	Mixed	Even-aged Forest	Uneven-aged Forest
Seedling/Sapling hardwood	Recently established single-aged hardwood stands (<4" dbh)	0	0	0	0	1	0
Poles/Small trees hardwood	Young, single-aged hardwood stands (4-12" dbh)	0	0	0	0	1	0
Trees >12dbh hardwood	Mature, single-aged, upland hardwood stands (>12dbh)	0	0	0	0	1	0
Two age hardwood	Thinned, single aged, mature hardwood stands with 2 dominant age classes.	0	0	0	0	1	0
Uneven-aged hardwood	Hardwood-dominated stands managed for a mixture of $\geq$ 3 size and age classes.	0	0	0	0	0	1
Tidal Marsh	Brackish tidal marsh	0	0	0	0	0	0
Water	Freshwater ponds and lakes.	0	0	0	0	0	0
Developed	Roadsides, campgrounds, golf courses, lawns, buildings, etc.	0	1	0	0	0	0

Table 2.5. Focal species used to evaluate wildlife value on ADCNR managed lands

Code	Scientific Name	Common Name
FISP	*Spizella pusilla*	Field Sparrow
HOWA	*Wilsonia citrina*	Hooded Warbler
INBU	*Passerina cyanea*	Indigo Bunting
KEWA	*Oporornis formosus*	Kentucky Warbler
RSHA	*Buteo lineatus*	Red-Shouldered Hawk
SCTA	*Piranga olivacea*	Scarlet Tanager
SWWA	*Limnothlypis swainsonii*	Swainson's Warbler
WEWA	*Helmitheros vermivorus*	Worm-Eating Warbler
WODU	*Aix sponsa*	Wood Duck
WOTH	*Hylocichla mustelina*	Wood Thrush
CNESEX	*Aspidoscelis sexlineata*	Six-Lined Racerunner
EURCHA	*Eurycea chamberlaini*	Chamberlain's Dwarf Salamander
GOPPOL	*Gopherus polyphemus*	Gopher Tortoise
LAMGET	*Lampropeltis getula getula*	Eastern Kingsnake
PLEVEN	Plethodon ventralis	Zigzag Salamander
RANCLA	Rana clamitans	Green Frog
TERCAR	Terrapene carolina carolina	Eastern Box Turtle
RABBIT	*Sylvilagus species*	Rabbit
SSSH	*Blarina carolinensis*	Southern Short-tailed Shrew
WOVO	*Microtus pinetorum*	Woodland Vole

Table 2.6. Unweighted utility values for 100-year projections for user preference, wildlife, cost, and total for each management alternative for each study area in Alabama.

Study Area Objective	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 8	Alt. 9	Alt. 10	Alt. 11
Barbour											
Users	-0.035	-0.034	-0.034	-0.033	-0.080	-0.079	-0.079	-0.078	0.000	0.002	-0.033
Wildlife	-0.163	-0.160	-0.181	-0.178	-0.067	-0.060	-0.081	-0.075	0.000	0.004	-0.428
Cost	0.027	0.034	0.031	0.039	-0.472	-0.465	-0.468	-0.461	0.000	0.007	0.940
Total	-0.172	-0.160	-0.184	-0.172	-0.619	-0.604	-0.629	-0.614	0.000	0.013	0.480
Coosa											
Users	-0.023	-0.022	-0.023	-0.023	-0.062	-0.062	-0.064	-0.064	0.000	0.000	-0.067
Wildlife	-0.045	-0.044	-0.078	-0.077	0.038	0.039	0.016	0.017	0.000	0.001	-0.412
Cost	0.044	0.045	0.051	0.051	-0.544	-0.544	-0.542	-0.541	0.000	0.000	0.915
Total	-0.023	-0.021	-0.050	-0.049	-0.568	-0.567	-0.590	-0.589	0.000	0.001	0.437
Freedom Hills											
Users	-0.052	-0.050	-0.054	-0.052	-0.084	-0.082	-0.086	-0.084	0.000	0.003	-0.097
Wildlife	-0.139	-0.134	-0.161	-0.156	0.016	0.022	-0.003	0.003	0.000	0.007	-0.472
Cost	0.355	0.364	0.357	0.366	0.210	0.219	0.211	0.220	0.000	0.009	0.967
Total	0.163	0.180	0.142	0.159	0.141	0.159	0.122	0.139	0.000	0.019	0.398
Gulf State											
Users	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	0.000	0.000	-0.035
Wildlife	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.309

Table 2.6. Unweighted utility values for 100-year projections for user preference, wildlife, cost, and total for each management alternative for each study area in Alabama.

Study Area						Management alternative						
	Objective	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 8	Alt. 9	Alt. 10	Alt. 11
	Cost	-0.041	-0.041	-0.041	-0.041	-0.041	-0.041	-0.041	-0.041	0.000	0.000	0.764
	Total	-0.044	-0.044	-0.044	-0.044	-0.044	-0.044	-0.044	-0.044	0.000	0.000	0.420
Guntersville												
	Users	-0.070	-0.070	-0.070	-0.070	-0.077	-0.077	-0.077	-0.077	0.000	0.005	-0.079
	Wildlife	-0.234	-0.234	-0.234	-0.234	-0.216	-0.216	-0.216	-0.216	0.000	-0.003	-0.491
	Cost	0.438	0.438	0.438	0.438	0.438	0.438	0.438	0.438	0.000	0.013	0.948
	Total	0.133	0.133	0.133	0.133	0.145	0.145	0.145	0.145	0.000	0.015	0.378
Lauderdale												
	Users	-0.036	-0.034	-0.036	-0.034	-0.074	-0.072	-0.074	-0.072	0.000	0.002	-0.053
	Wildlife	-0.143	-0.140	-0.159	-0.156	-0.082	-0.078	-0.095	-0.091	0.000	0.005	-0.457
	Cost	0.333	0.339	0.336	0.342	0.103	0.109	0.105	0.111	0.000	0.006	0.955
	Total	0.154	0.165	0.141	0.152	-0.053	-0.042	-0.064	-0.053	0.000	0.013	0.445
Oak Mountain												
	Users	-0.063	-0.063	-0.063	-0.063	-0.099	-0.099	-0.099	-0.099	0.000	0.000	-0.083
	Wildlife	-0.243	-0.243	-0.244	-0.244	-0.155	-0.155	-0.156	-0.156	0.000	0.001	-0.484
	Cost	0.683	0.683	0.683	0.683	0.677	0.677	0.677	0.677	0.000	0.000	0.934
	Total	0.377	0.377	0.376	0.376	0.423	0.423	0.423	0.423	0.000	0.001	0.366
Perdido												

Table 2.6. Unweighted utility values for 100-year projections for user preference, wildlife, cost, and total for each management alternative for each study area in Alabama.

Study Area	Management alternative										
Objective	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 8	Alt. 9	Alt. 10	Alt. 11
Users	-0.063	-0.063	-0.063	-0.063	-0.099	-0.099	-0.099	-0.099	0.000	0.000	-0.083
Wildlife	-0.243	-0.243	-0.244	-0.244	-0.155	-0.155	-0.156	-0.156	0.000	0.001	-0.484
Cost	0.683	0.683	0.683	0.683	0.677	0.677	0.677	0.677	0.000	0.000	0.934
Total	0.377	0.377	0.376	0.376	0.423	0.423	0.423	0.423	0.000	0.001	0.366
Sanctuaries											
Users	-0.020	-0.014	-0.020	-0.014	-0.034	-0.028	-0.034	-0.028	0.000	0.007	-0.052
Wildlife	-0.045	-0.031	-0.047	-0.033	-0.021	0.000	-0.022	-0.001	0.000	0.016	-0.376
Cost	0.077	0.104	0.077	0.104	-0.121	-0.093	-0.120	-0.093	0.000	0.027	0.920
Total	0.011	0.059	0.010	0.058	-0.176	-0.121	-0.176	-0.122	0.000	0.050	0.492
Wind Creek											
Users	-0.049	-0.049	-0.049	-0.049	-0.094	-0.094	-0.094	-0.094	0.000	0.000	-0.083
Wildlife	-0.142	-0.142	-0.157	-0.157	0.019	0.019	0.010	0.010	0.000	0.000	-0.411
Cost	0.309	0.309	0.313	0.313	-0.072	-0.072	-0.070	-0.070	0.000	0.000	0.865
Total	0.118	0.118	0.107	0.107	-0.148	-0.148	-0.154	-0.154	0.000	0.001	0.371

Table 2.7. Weighted utility values for 100-year projections for user preference, wildlife, cost, and total for each management alternative for each study area in Alabama. Elicited objective weights were: wildlife – 0.45, users – 0.40, and cost – 0.15.

Study Area		Management alternative										
	Objective	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 8	Alt. 9	Alt. 10	Alt. 11
Barbour												
	Users	-0.014	-0.014	-0.014	-0.013	-0.032	-0.032	-0.032	-0.031	0.000	0.001	-0.013
	Wildlife	-0.074	-0.072	-0.082	-0.080	-0.030	-0.027	-0.037	-0.034	0.000	0.002	-0.193
	Cost	0.004	0.005	0.005	0.006	-0.069	-0.068	-0.069	-0.068	0.000	0.001	0.138
	Total	-0.084	-0.081	-0.091	-0.088	-0.132	-0.127	-0.137	-0.133	0.000	0.004	-0.068
Coosa												
	Users	-0.009	-0.009	-0.009	-0.009	-0.025	-0.025	-0.026	-0.026	0.000	0.000	-0.027
	Wildlife	-0.020	-0.020	-0.035	-0.035	0.017	0.018	0.007	0.007	0.000	0.000	-0.186
	Cost	0.007	0.007	0.007	0.008	-0.080	-0.080	-0.079	-0.079	0.000	0.000	0.134
	Total	-0.023	-0.022	-0.037	-0.037	-0.088	-0.087	-0.098	-0.098	0.000	0.001	-0.078
Freedom Hills												
	Users	-0.021	-0.020	-0.022	-0.021	-0.034	-0.033	-0.035	-0.034	0.000	0.001	-0.039
	Wildlife	-0.063	-0.060	-0.073	-0.070	0.007	0.010	-0.001	0.001	0.000	0.003	-0.213
	Cost	0.052	0.053	0.052	0.054	0.031	0.032	0.031	0.032	0.000	0.001	0.142
	Total	-0.032	-0.027	-0.042	-0.037	0.004	0.009	-0.005	0.000	0.000	0.006	-0.110
Gulf State												
	Users	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	0.000	0.000	-0.014
	Wildlife	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.140

Table 2.7. Weighted utility values for 100-year projections for user preference, wildlife, cost, and total for each management alternative for each study area in Alabama. Elicited objective weights were: wildlife – 0.45, users – 0.40, and cost – 0.15.

Study Area	Objective	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 8	Alt. 9	Alt. 10	Alt. 11
	Cost	-0.006	-0.006	-0.006	-0.006	-0.006	-0.006	-0.006	-0.006	0.000	0.000	0.112
	Total	-0.007	-0.007	-0.007	-0.007	-0.007	-0.007	-0.007	-0.007	0.000	0.000	-0.041
Guntersville												
	Users	-0.028	-0.028	-0.028	-0.028	-0.031	-0.031	-0.031	-0.031	0.000	0.002	-0.032
	Wildlife	-0.106	-0.106	-0.106	-0.106	-0.097	-0.097	-0.097	-0.097	0.000	-0.001	-0.222
	Cost	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.064	0.000	0.002	0.139
	Total	-0.070	-0.070	-0.070	-0.070	-0.064	-0.064	-0.064	-0.064	0.000	0.003	-0.114
Lauderdale												
	Users	-0.015	-0.014	-0.014	-0.014	-0.030	-0.029	-0.030	-0.029	0.000	0.001	-0.021
	Wildlife	-0.064	-0.063	-0.072	-0.070	-0.037	-0.035	-0.043	-0.041	0.000	0.002	-0.206
	Cost	0.049	0.050	0.049	0.050	0.015	0.016	0.015	0.016	0.000	0.001	0.140
	Total	-0.030	-0.027	-0.037	-0.034	-0.052	-0.048	-0.057	-0.054	0.000	0.004	-0.087
Oak Mountain												
	Users	-0.025	-0.025	-0.025	-0.025	-0.040	-0.040	-0.040	-0.040	0.000	0.000	-0.034
	Wildlife	-0.110	-0.110	-0.110	-0.110	-0.070	-0.070	-0.070	-0.070	0.000	0.000	-0.218
	Cost	0.100	0.100	0.100	0.100	0.099	0.099	0.099	0.099	0.000	0.000	0.137
	Total	-0.035	-0.035	-0.035	-0.035	-0.010	-0.010	-0.011	-0.011	0.000	0.000	-0.115
Perdido												

Table 2.7. Weighted utility values for 100-year projections for user preference, wildlife, cost, and total for each management alternative for each study area in Alabama. Elicited objective weights were: wildlife – 0.45, users – 0.40, and cost – 0.15.

Study Area		Management alternative										
	Objective	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7	Alt. 8	Alt. 9	Alt. 10	Alt. 11
	Users	-0.006	-0.006	-0.006	-0.006	-0.006	-0.006	-0.006	-0.006	0.000	0.000	-0.025
	Wildlife	-0.010	-0.010	-0.010	-0.010	-0.010	-0.010	-0.010	-0.010	0.000	0.000	-0.176
	Cost	-0.007	-0.007	-0.007	-0.007	-0.007	-0.007	-0.007	-0.007	0.000	0.000	0.136
	Total	-0.022	-0.022	-0.022	-0.022	-0.022	-0.022	-0.022	-0.022	0.000	0.001	-0.064
Sanctuaries												
	Users	-0.008	-0.006	-0.008	-0.006	-0.014	-0.011	-0.014	-0.011	0.000	0.003	-0.021
	Wildlife	-0.020	-0.014	-0.021	-0.015	-0.010	0.000	-0.010	0.000	0.000	0.007	-0.170
	Cost	0.011	0.015	0.011	0.015	-0.018	-0.014	-0.018	-0.014	0.000	0.004	0.135
	Total	-0.017	-0.004	-0.018	-0.005	-0.041	-0.025	-0.041	-0.025	0.000	0.014	-0.056
Wind Creek												
	Users	-0.020	-0.020	-0.020	-0.020	-0.038	-0.038	-0.038	-0.038	0.000	0.000	-0.033
	Wildlife	-0.064	-0.064	-0.071	-0.071	0.008	0.008	0.004	0.004	0.000	0.000	-0.186
	Cost	0.045	0.045	0.046	0.046	-0.011	-0.011	-0.010	-0.010	0.000	0.000	0.127
	Total	-0.038	-0.038	-0.044	-0.044	-0.040	-0.040	-0.044	-0.044	0.000	0.000	-0.092

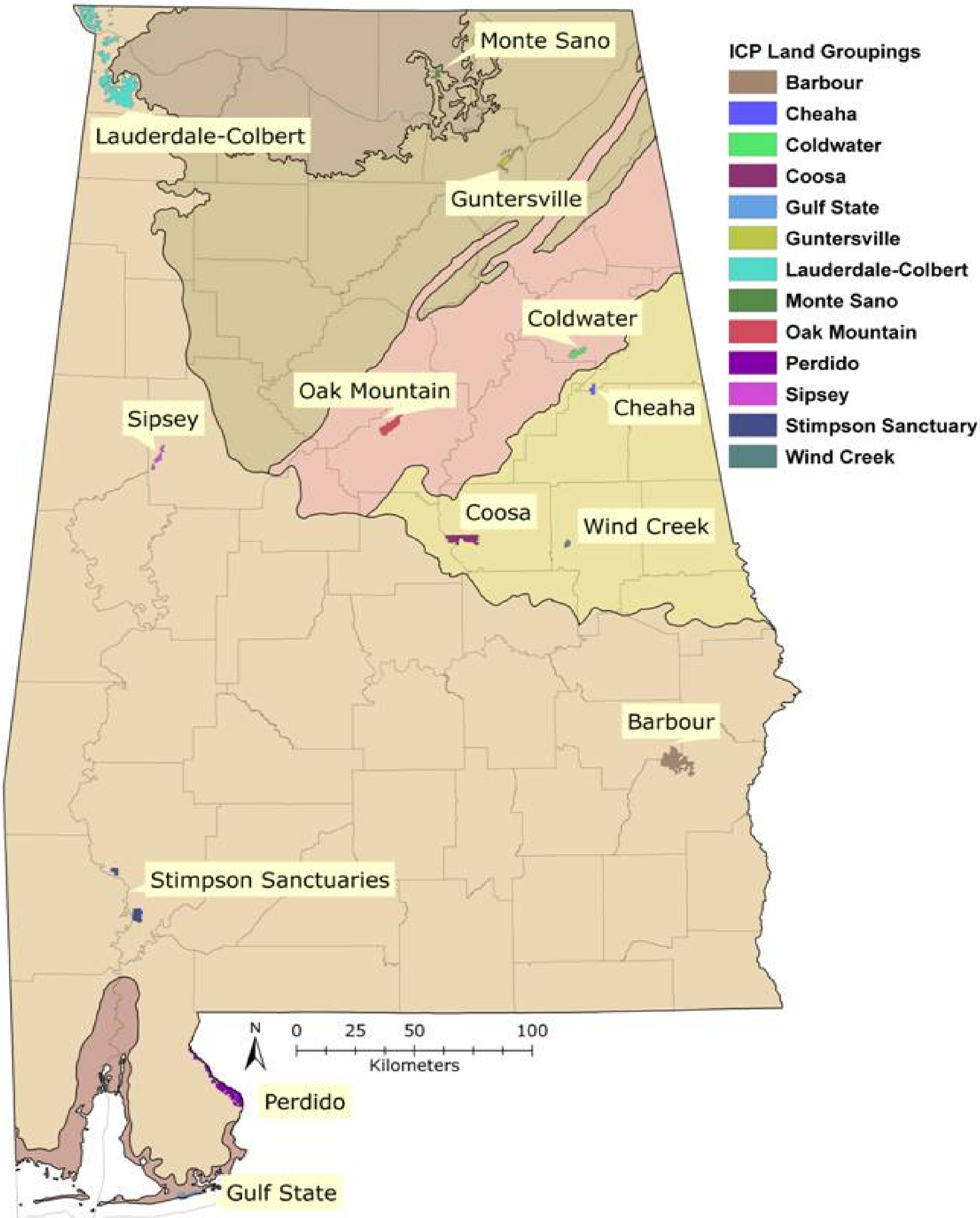


Figure 2.1. Study areas managed by Alabama Department of Conservation and Natural resources in the lower and upper coastal plain, piedmont, ridge and valley, southwestern Appalachians, and interior low plateau.

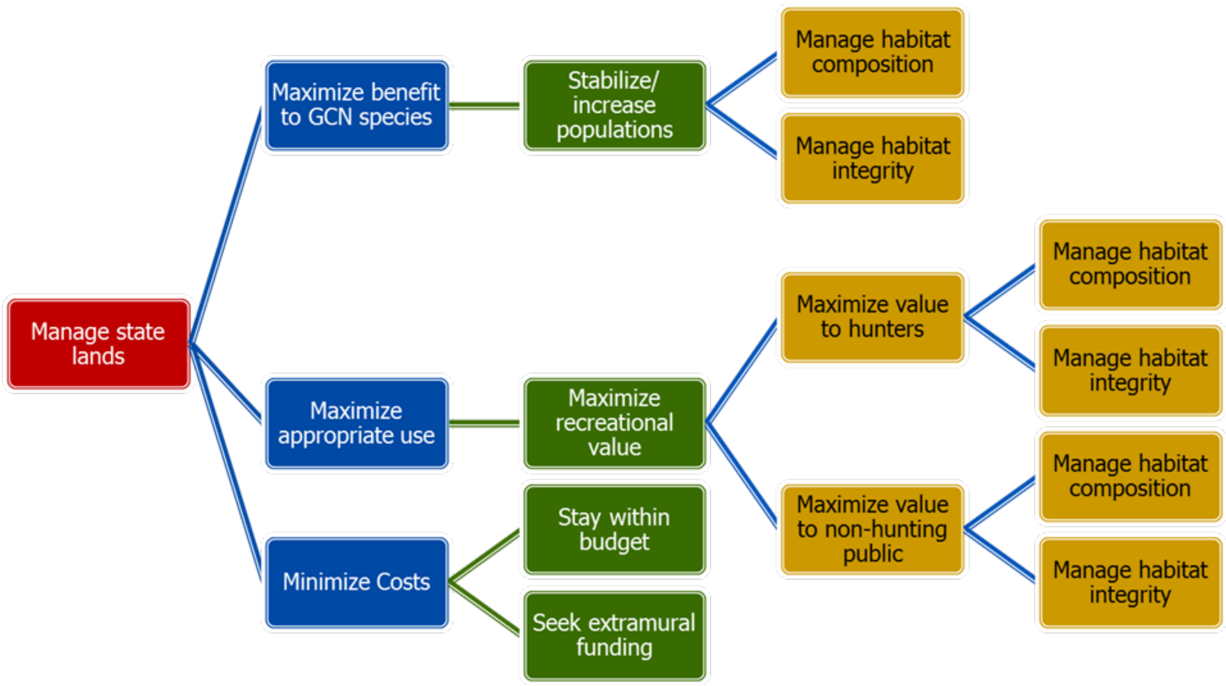


Figure 2.2. Objectives Hierarchy

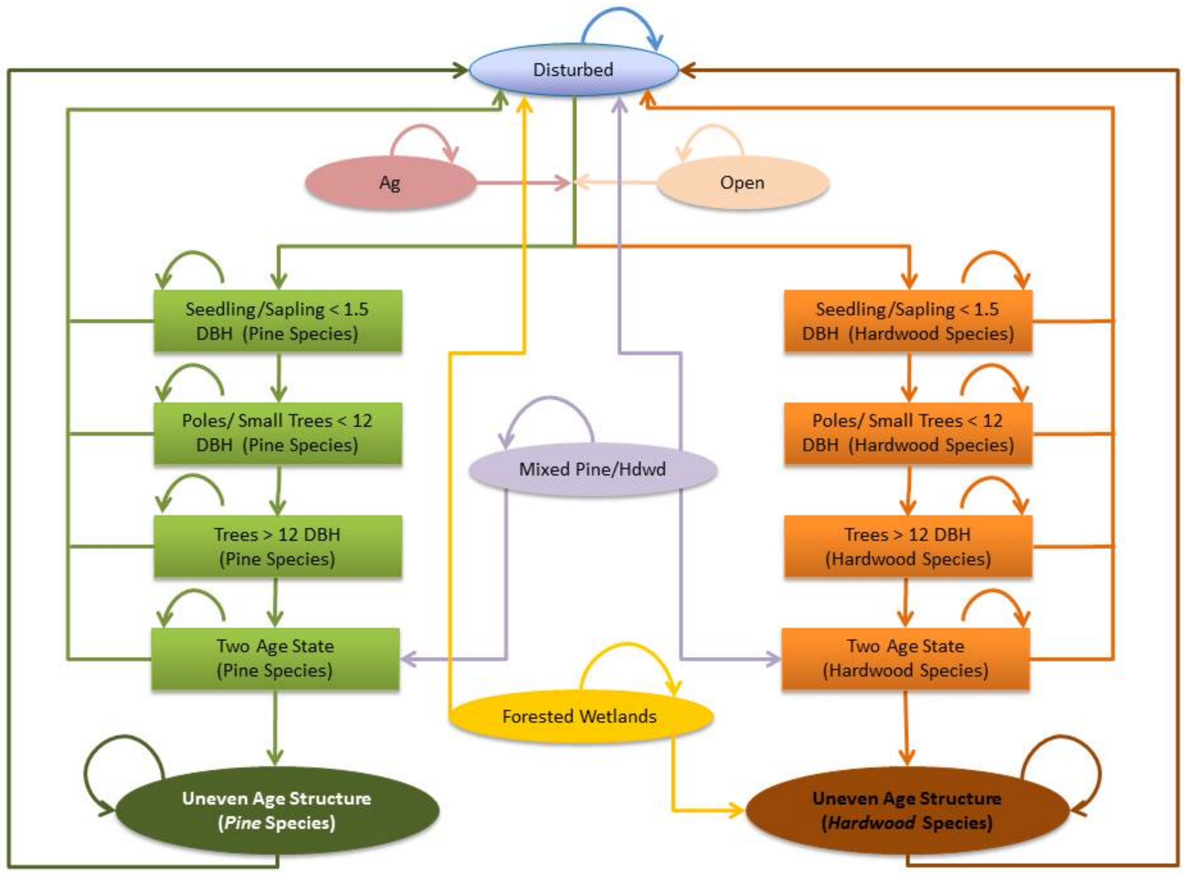


Figure 2.3. State-space model denoting projected landscape dynamics across each property

Figure 2.4. Initial (2011) and targeted (2100) landscape composition under 11 management alternatives for 10 study areas in Alabama.

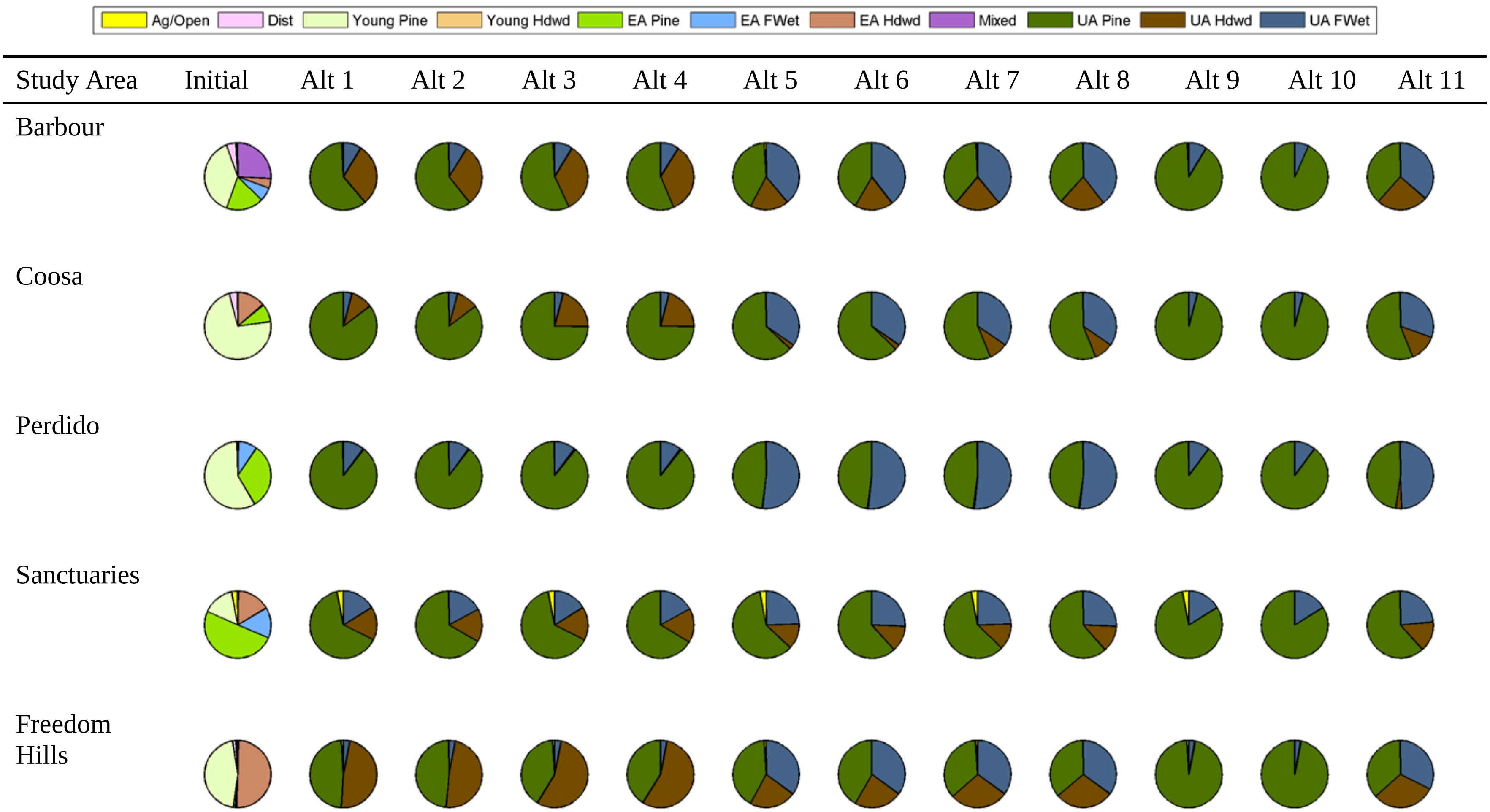


Figure 2.4. Initial (2011) and targeted (2100) landscape composition under 11 management alternatives for 10 study areas in Alabama.

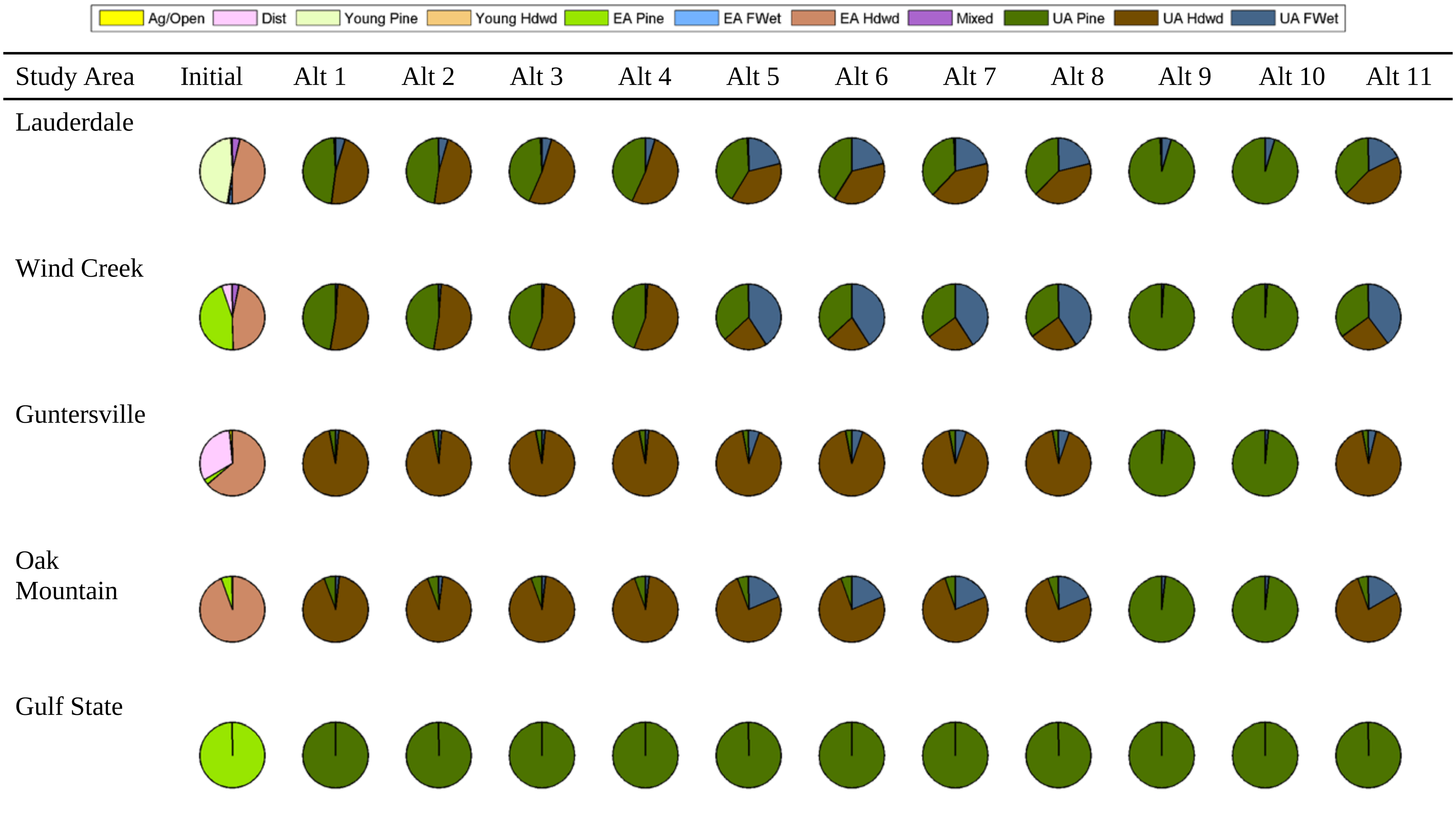


Figure 2.5. Probability of state by alternative

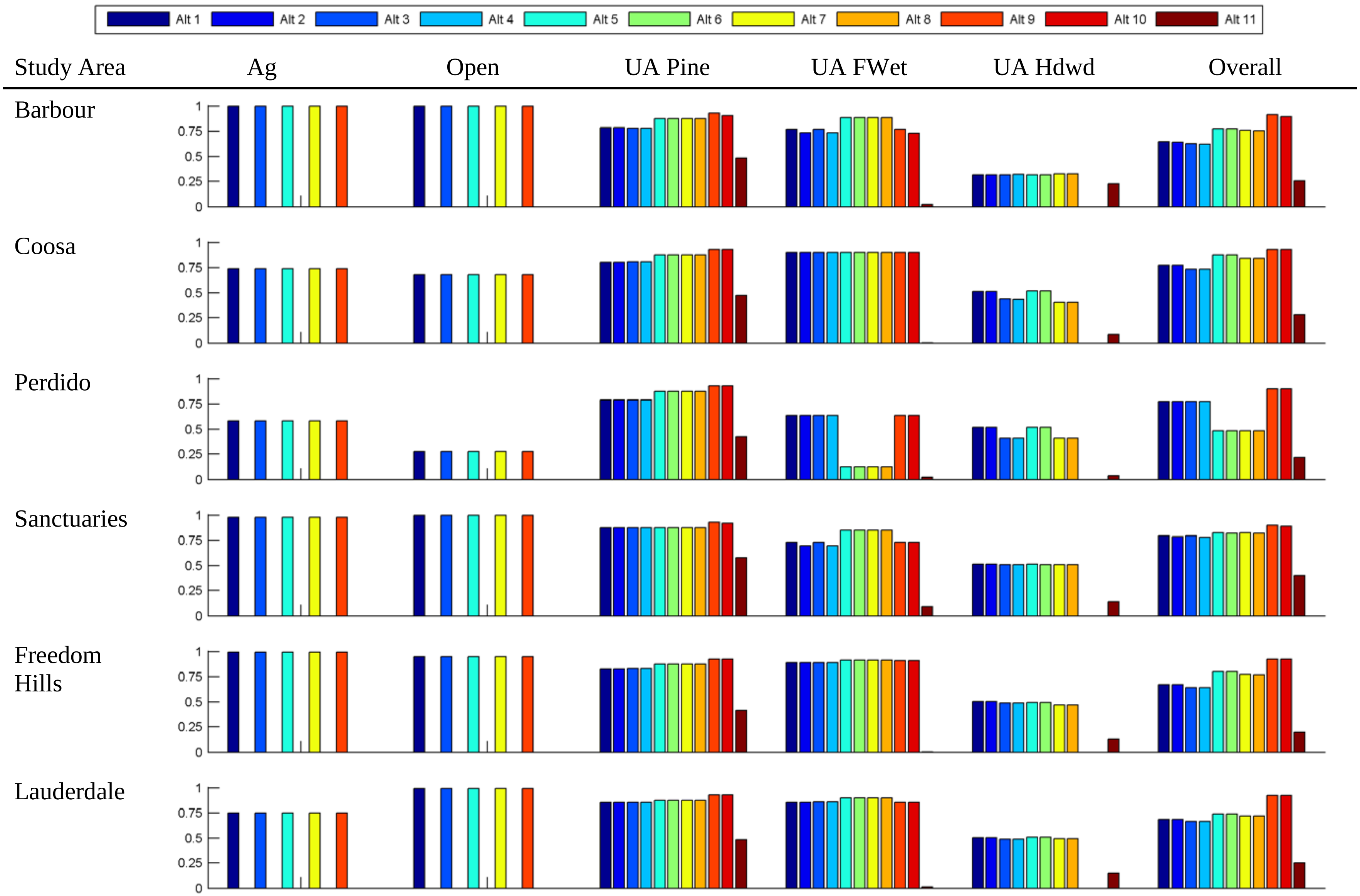


Figure 2.5. Probability of state by alternative

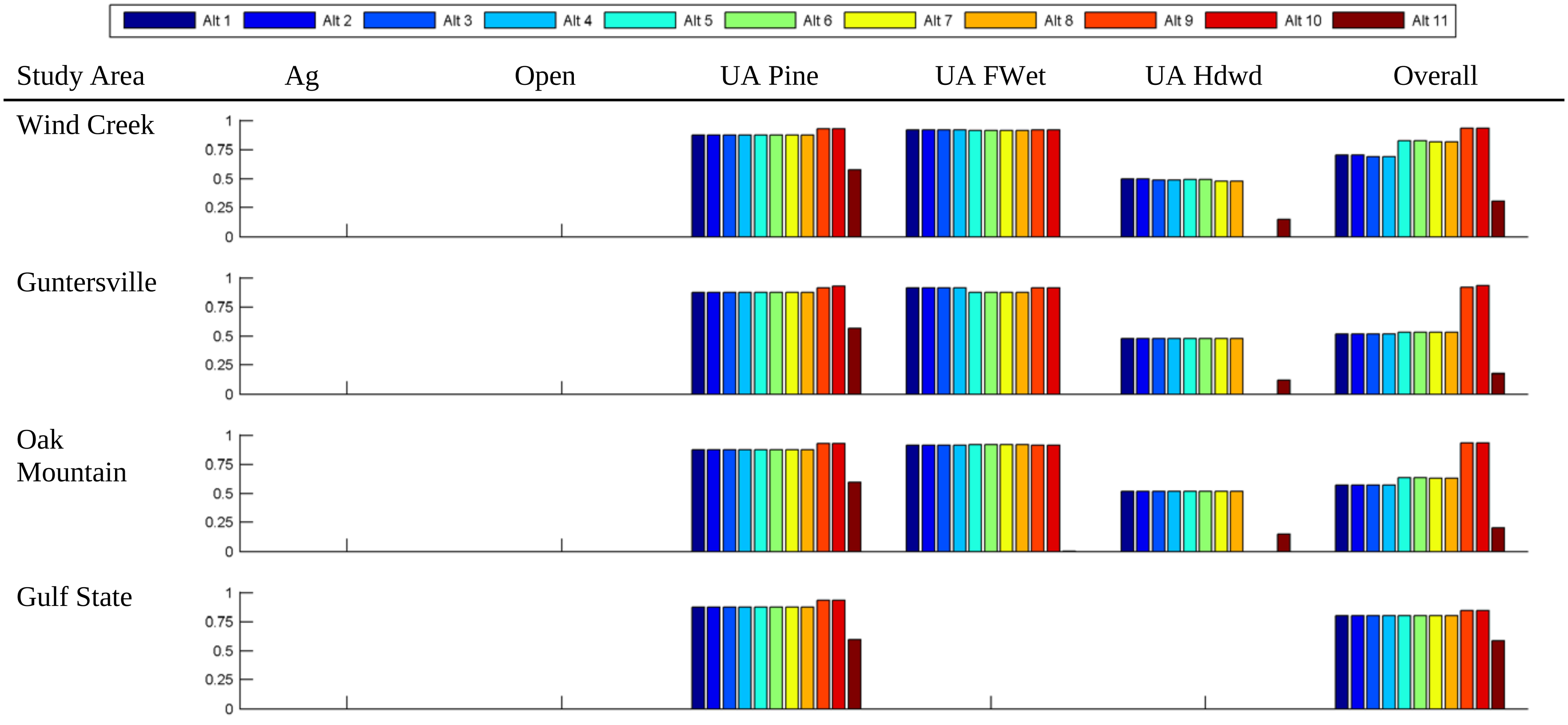


Figure 2.6. Probability of each landscape features reaching target state by alternative.

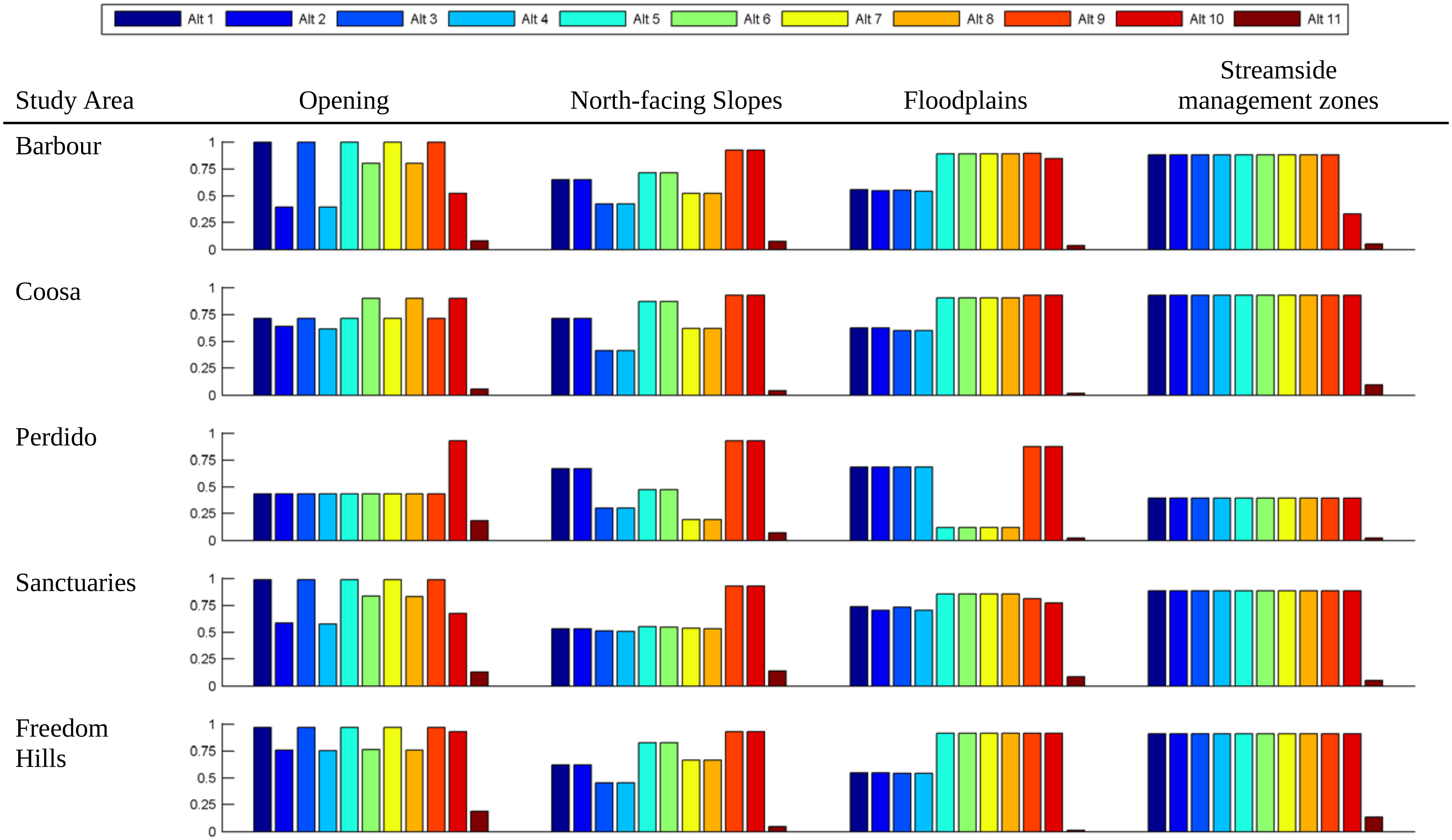
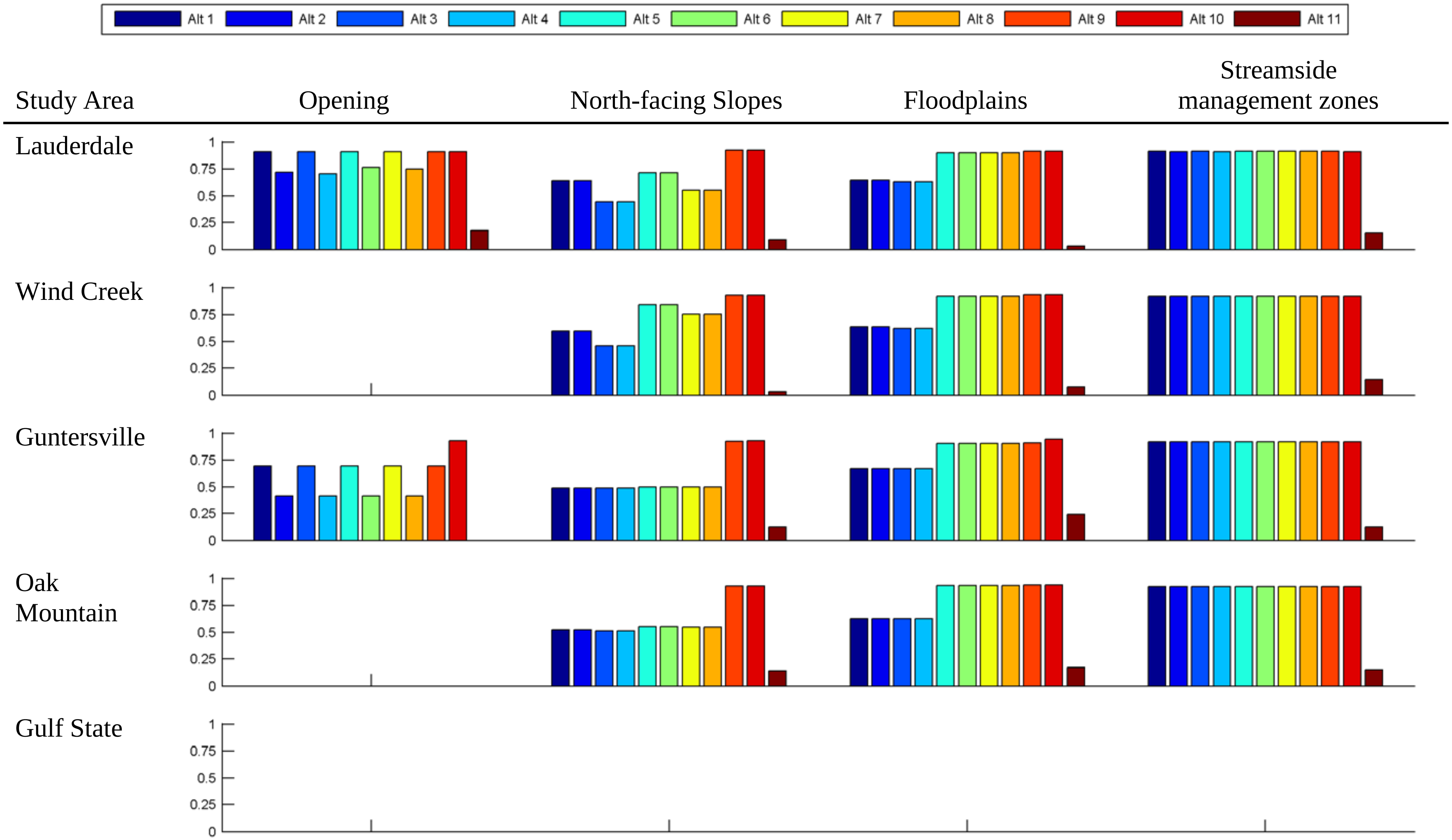


Figure 2.6. Probability of each landscape features reaching target state by alternative.



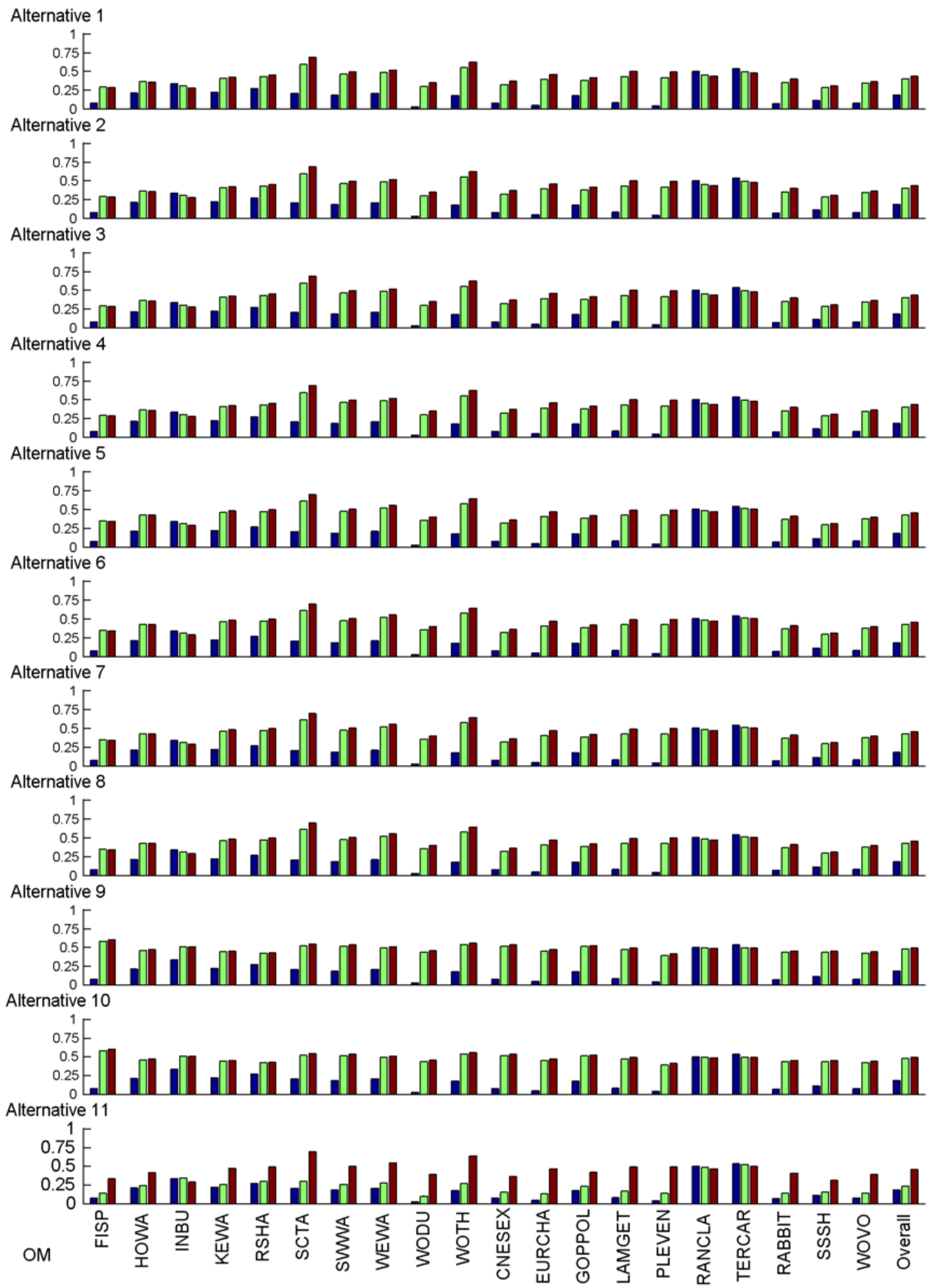


Figure 2.7. Expected percent area occupied by each species under each alternative at Oak Mountain State Park, Alabama in 2012 (blue), 2112 (green), and when target habitat conditions are reached (red). See text for description of management alternatives and species acronyms.

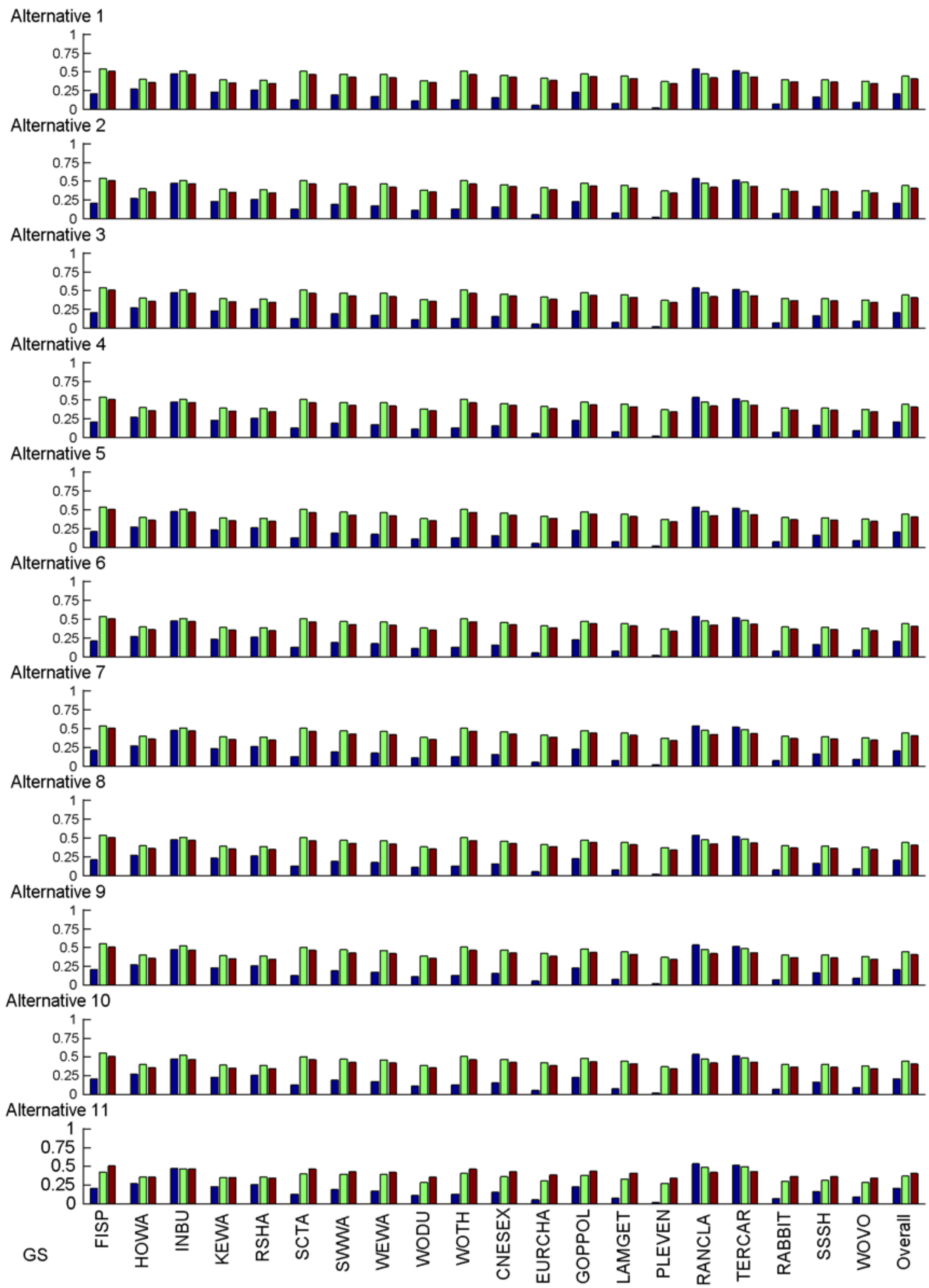


Figure 2.8. Expected percent area occupied by each species under each alternative at Gulf State Park, Alabama in 2012 (blue), 2112 (green), and when target habitat conditions are reached (red). See text for description of management alternatives and species acronyms.

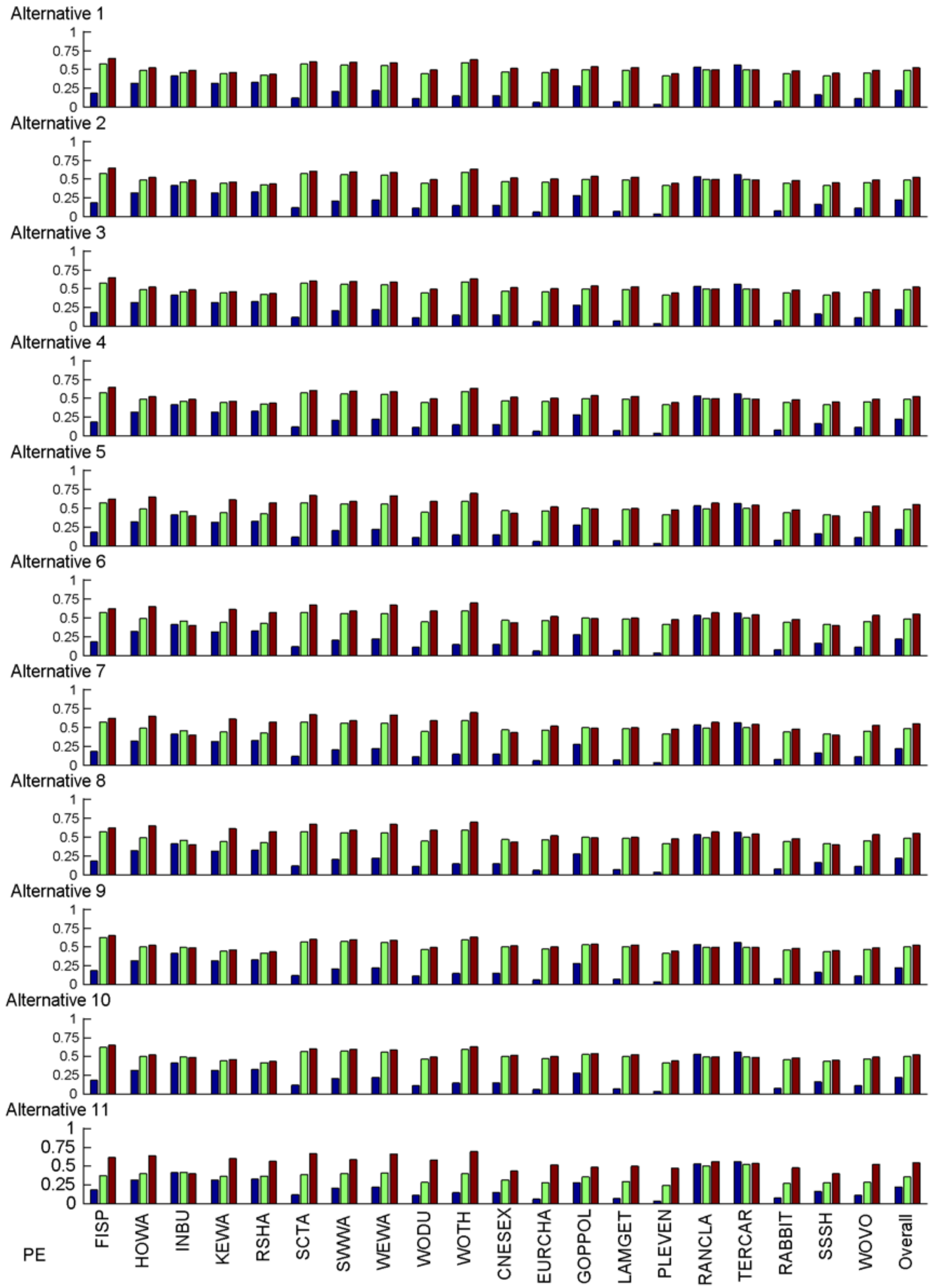


Figure 2.9. Expected percent area occupied by each species under each alternative at Perdido WMA, Alabama in 2012 (blue), 2112 (green), and when target habitat conditions are reached (red). See text for description of management alternatives and species acronyms.

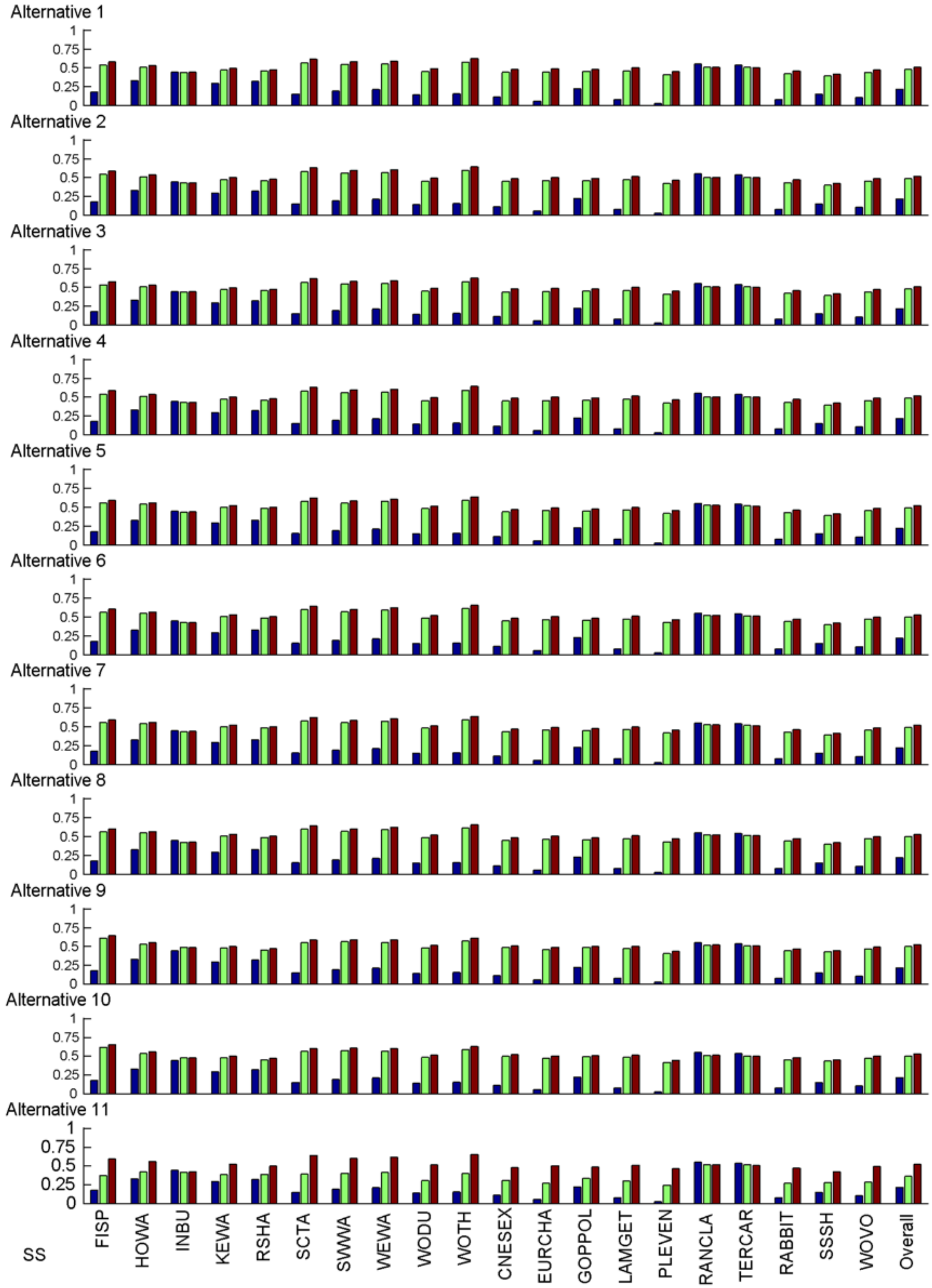


Figure 2.10. Expected percent area occupied by each species under each alternative at the Sanctuaries, Alabama in 2012 (blue), 2112 (green), and when target habitat conditions are reached (red). See text for description of management alternatives and species acronyms.

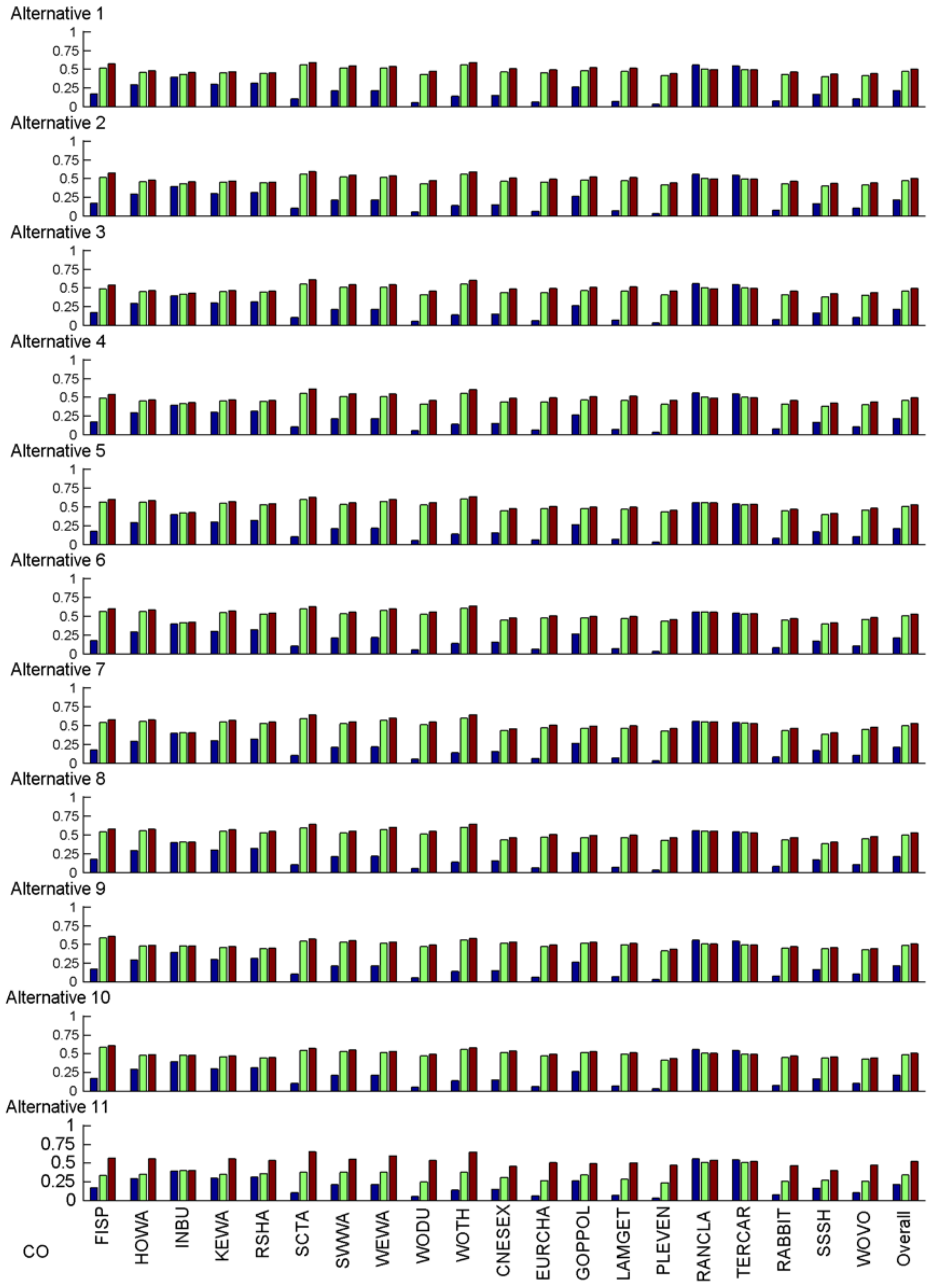


Figure 2.11. Expected percent area occupied by each species under each alternative at Coosa WMA, Alabama in 2012 (blue), 2112 (green), and when target habitat conditions are reached (red). See text for description of management alternatives and species acronyms.

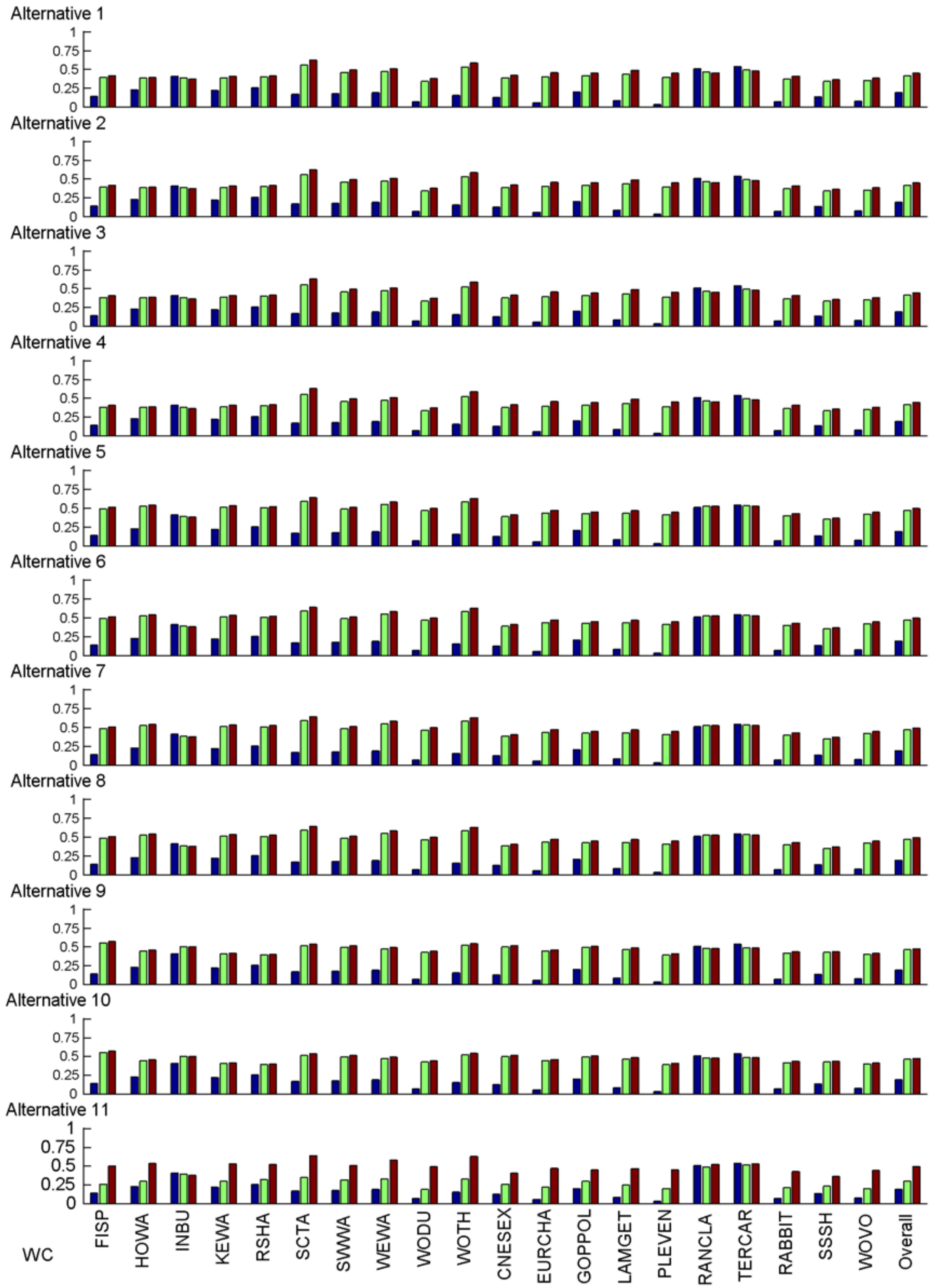


Figure 2.12. Expected percent area occupied by each species under each alternative at Wind Creek State Park, Alabama in 2012 (blue), 2112 (green), and when target habitat conditions are reached (red). See text for description of management alternatives and species acronyms.

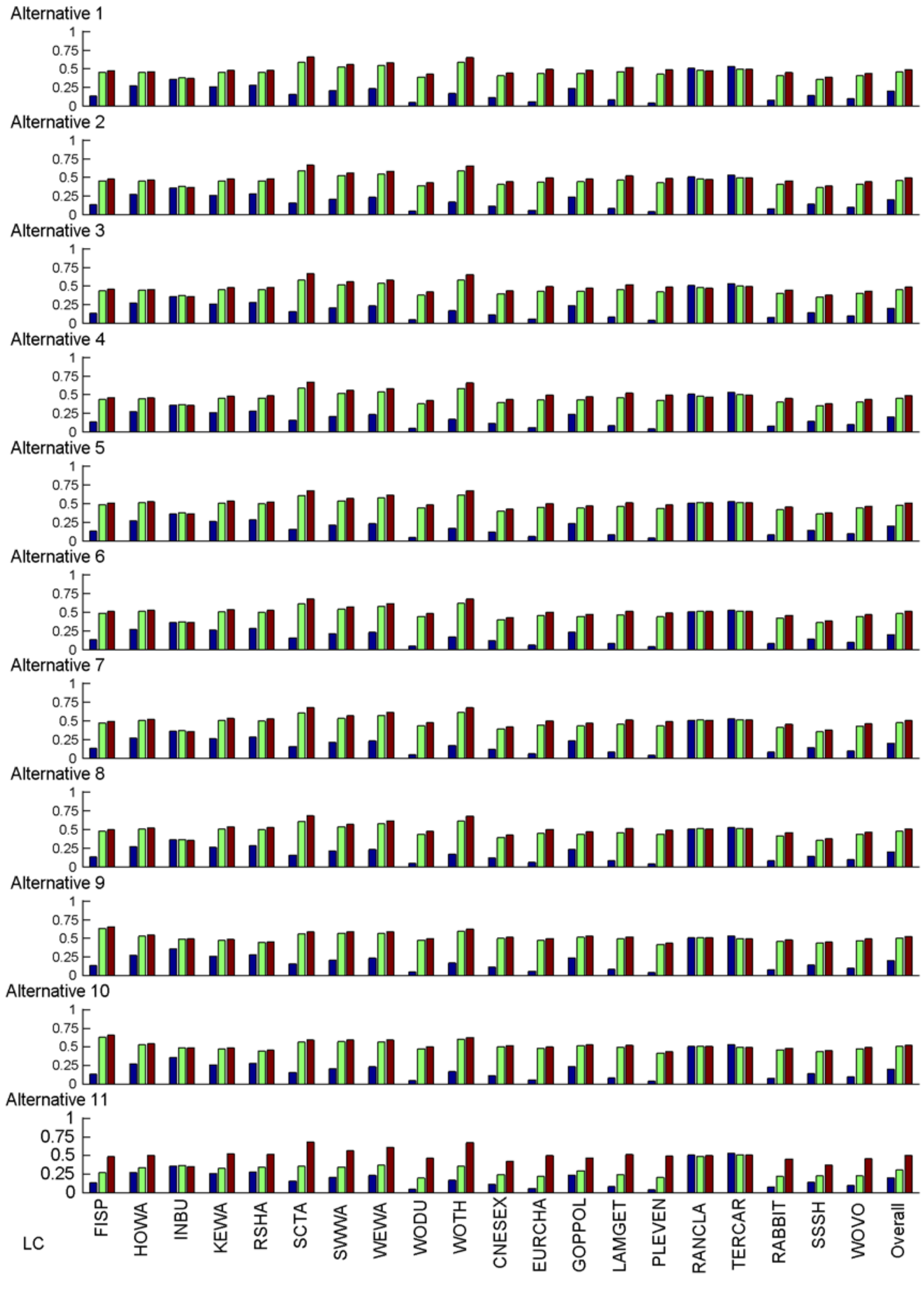


Figure 2.13. Expected percent area occupied by each species under each alternative at Lauderdale WMA, Alabama in 2012 (blue), 2112 (green), and when target habitat conditions are reached (red). See text for description of management alternatives and species acronyms.

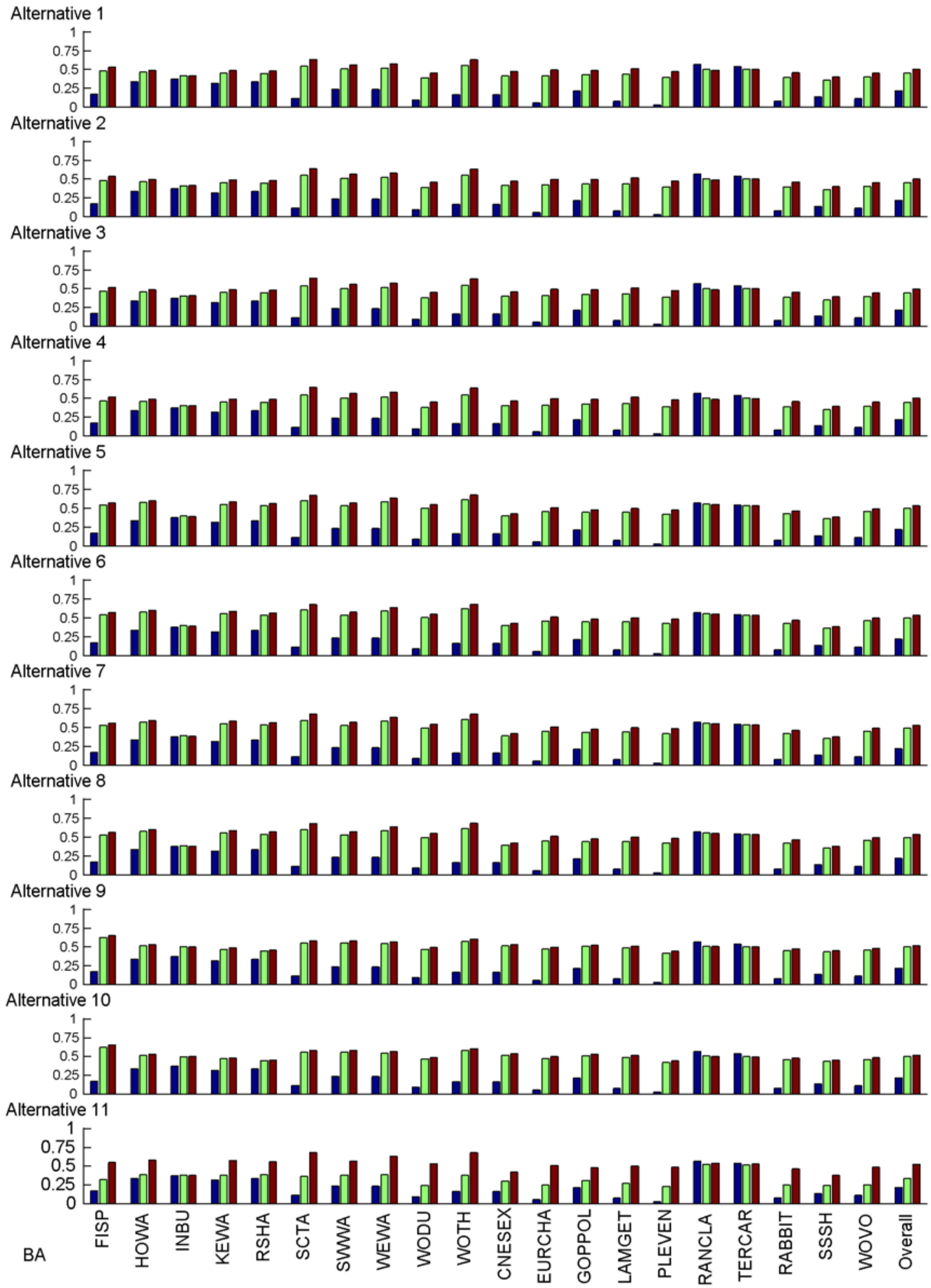


Figure 2.14. Expected percent area occupied by each species under each alternative at Barbour WMA, Alabama in 2012 (blue), 2112 (green), and when target habitat conditions are reached (red). See text for description of management alternatives and species acronyms.

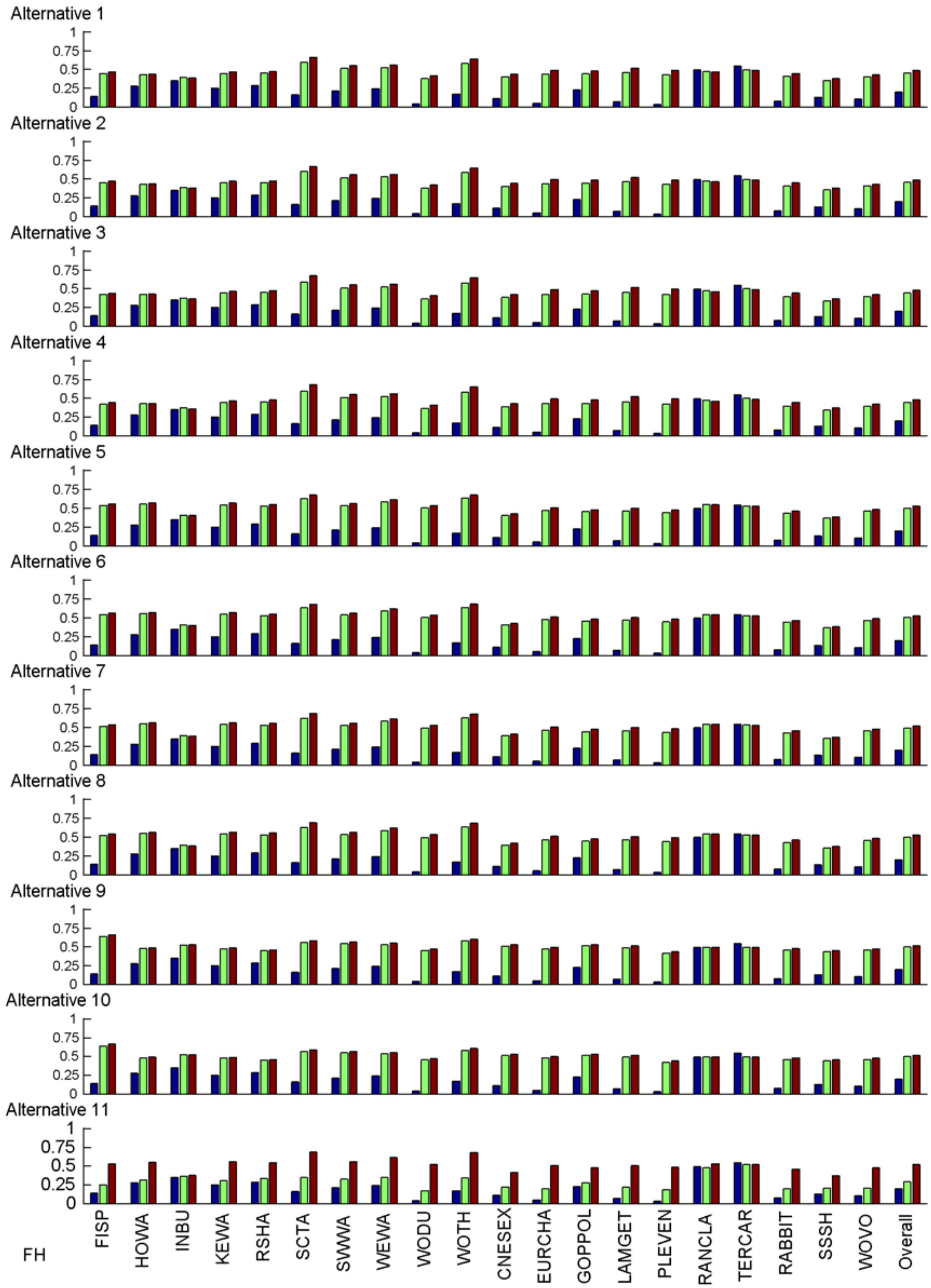


Figure 2.15. Expected percent area occupied by each species under each alternative at Freedom Hills WMA, Alabama in 2012 (blue), 2112 (green), and when target habitat conditions are reached (red). See text for description of management alternatives and species acronyms.

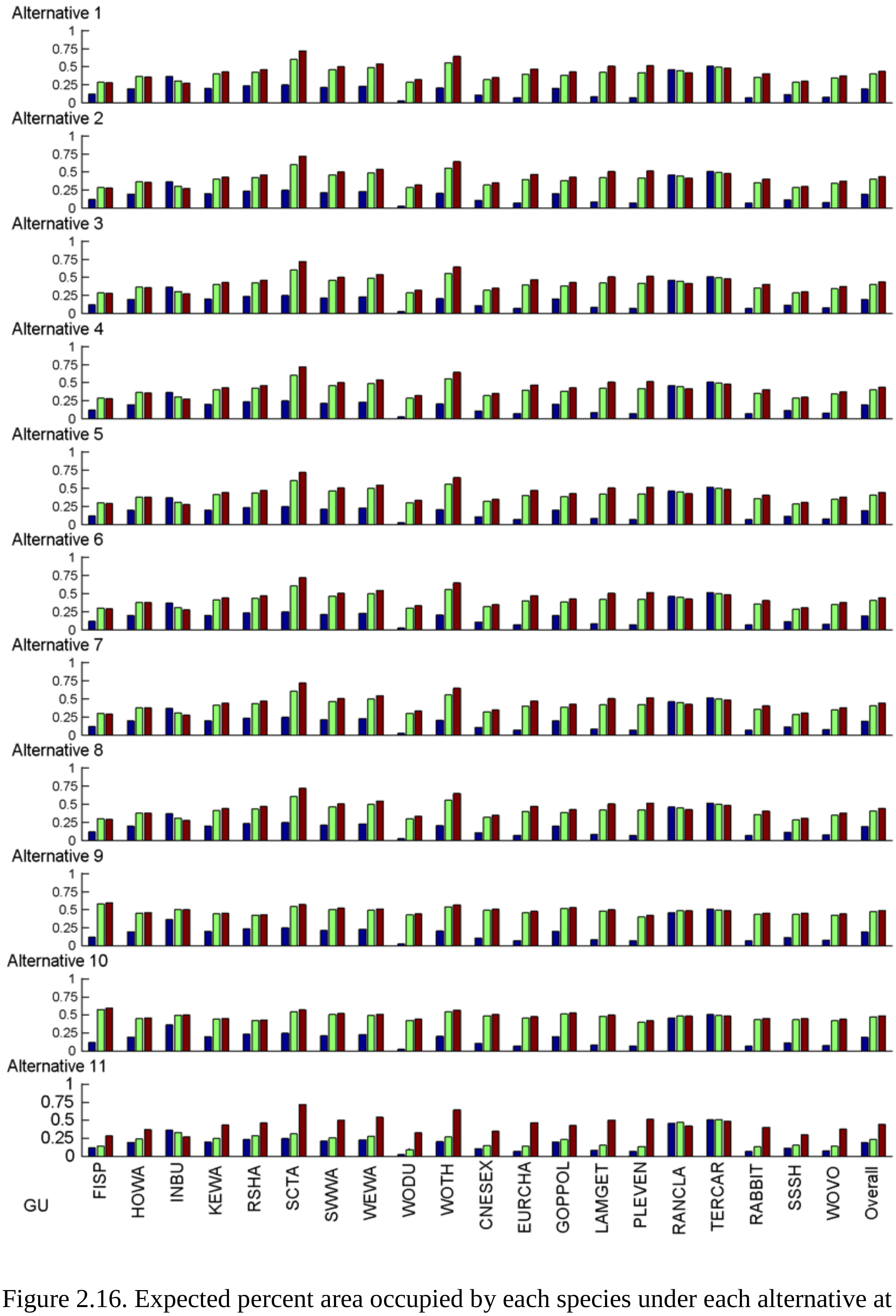


Figure 2.16. Expected percent area occupied by each species under each alternative at Guntersville State Park, Alabama in 2012 (blue), 2112 (green), and when target habitat conditions are reached (red). See text for description of management alternatives and species acronyms.

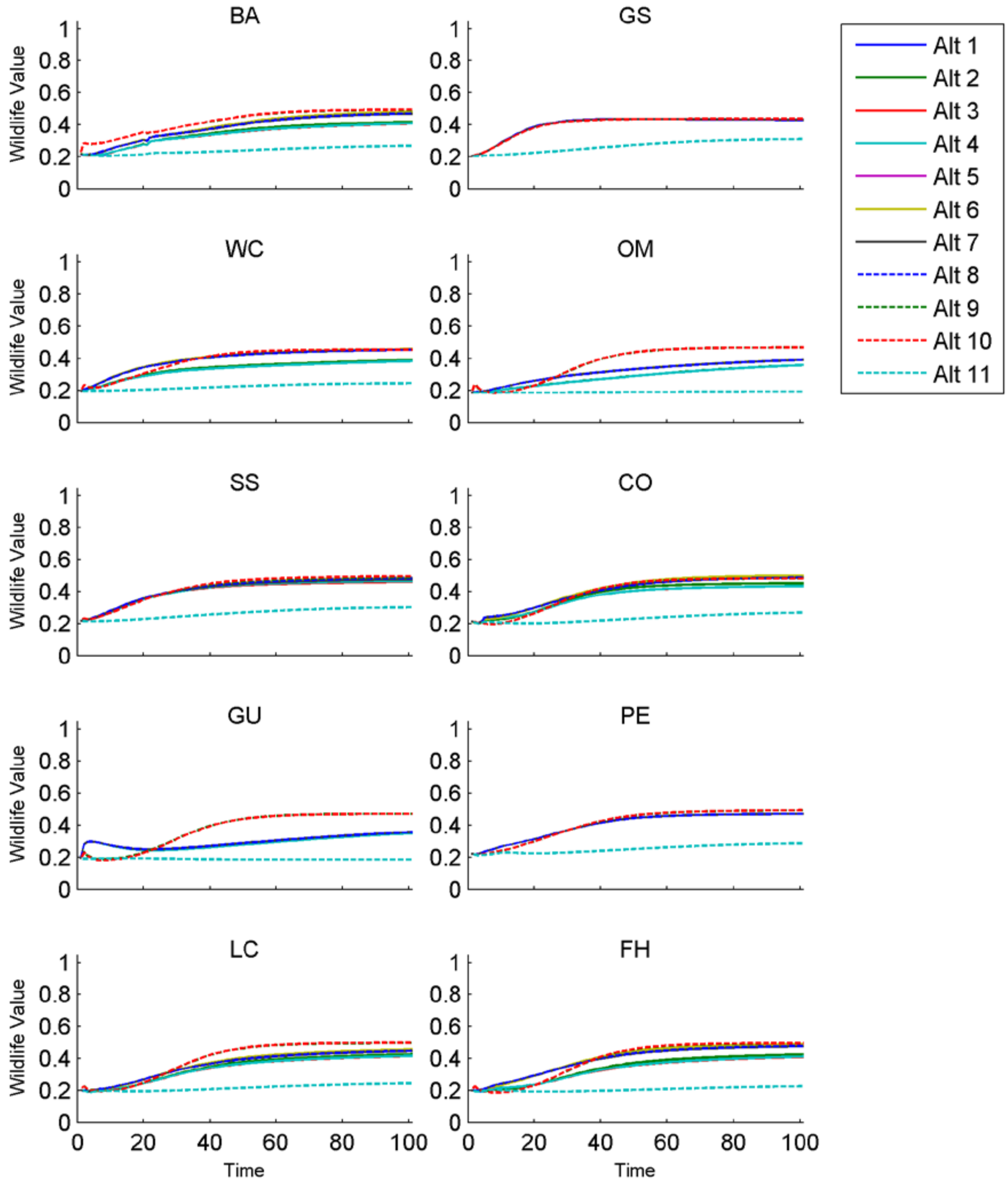


Figure 2.17. Wildlife value, the mean expected percent area occupied for focal species, over the next 100-years for each of the 11 management alternatives on each of the study areas (BA—Barbour, GS—Gulf State, WC—Wind Creek, OM—Oak Mountain, SS—Sanctuaries, CO—Coosa, GU—Guntersville, PE—Perdido, LC—Lauderdale, FH—Freedom Hills) in Alabama.

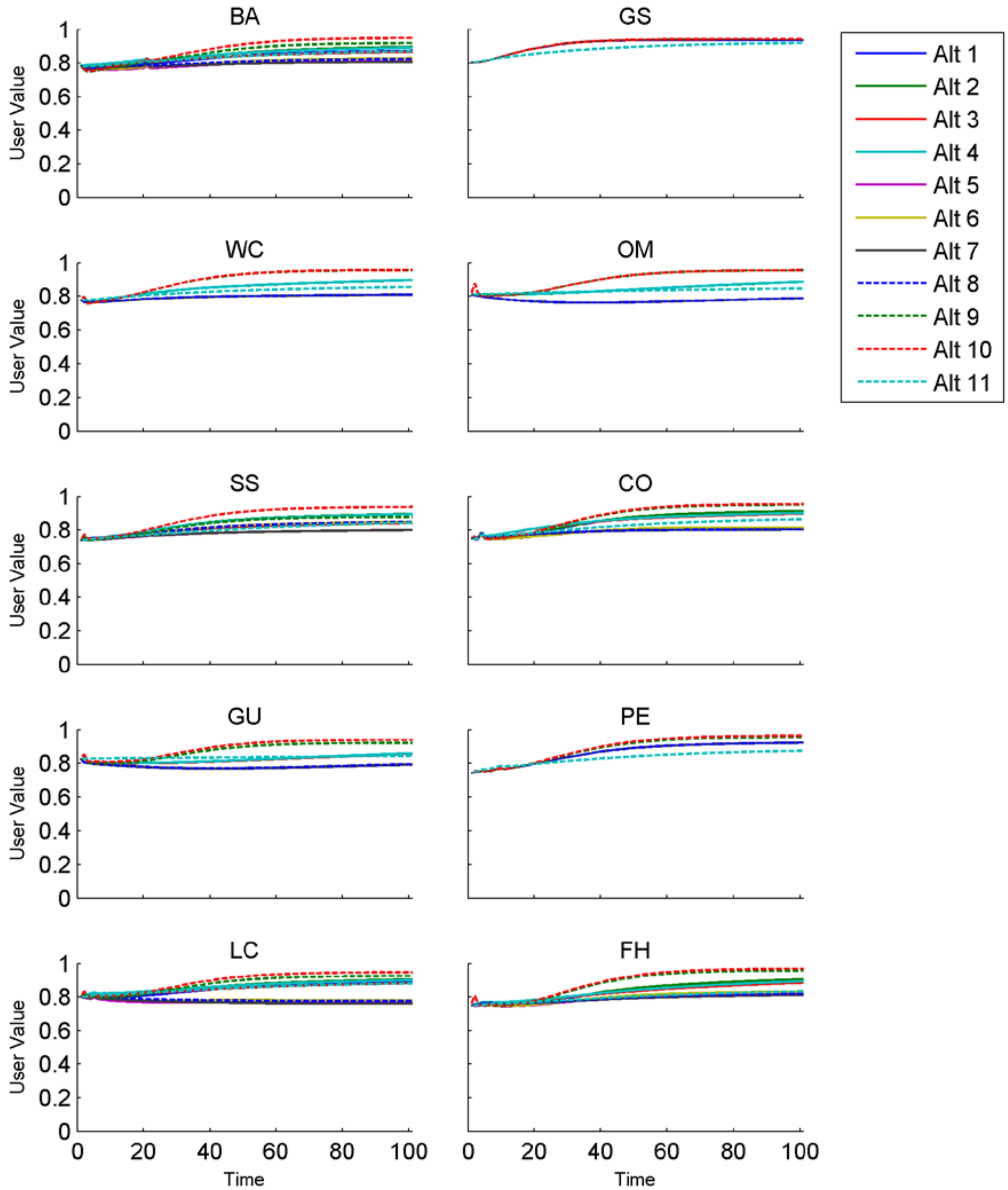


Figure 2.18. User value, the mean expected preference among user groups, over the next 100-years for each of the 11 management alternatives on each study area (BA—Barbour, GS—Gulf State, WC—Wind Creek, OM—Oak Mountain, SS—Sanctuaries, CO—Coosa, GU—Guntersville, PE—Perdido, LC—Lauderdale, FH—Freedom Hills) over the 100 year projection period) in Alabama.

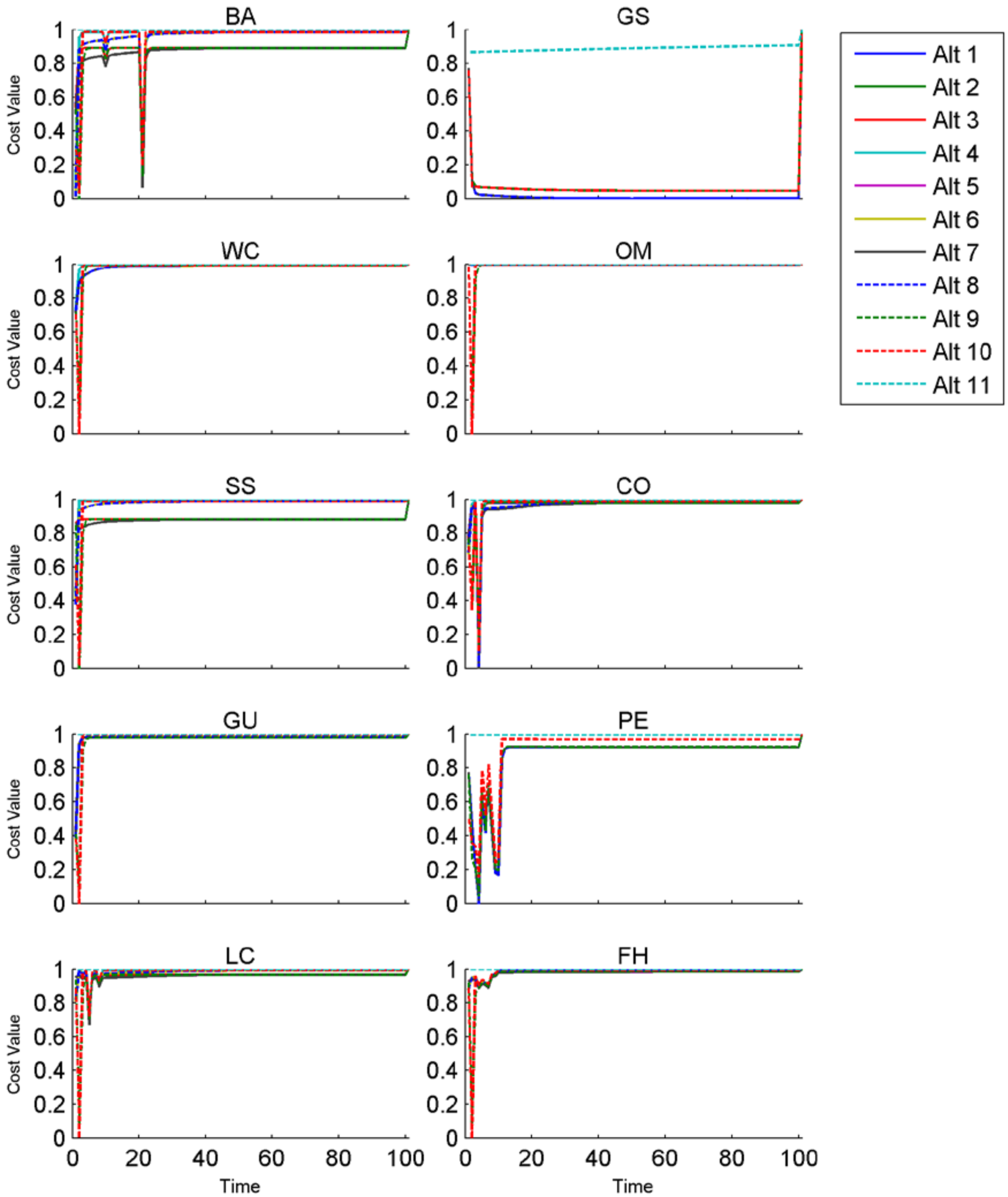


Figure 2.19. Cost value (1 - expected relative management costs) over the next 100-years for each of the 11 management alternatives on each study area (BA—Barbour, GS—Gulf State, WC—Wind Creek, OM—Oak Mountain, SS—Sanctuaries, CO—Coosa, GU—Guntersville, PE—Perdido, LC—Lauderdale, FH—Freedom Hills) in Alabama.

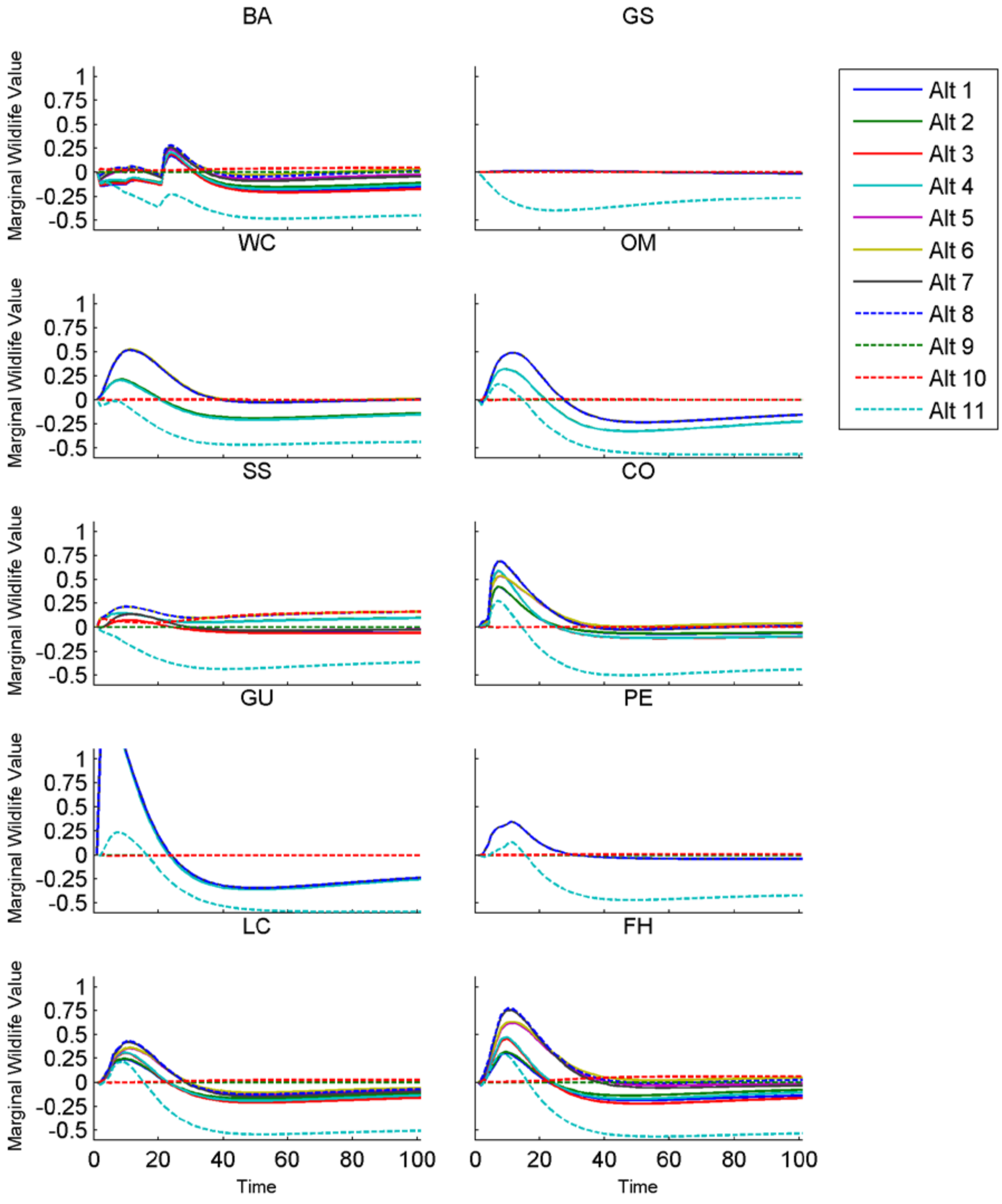


Figure 2.20. Marginal wildlife value for each alternative relative to alternative 9 over the 100-year projection period for each study area (BA—Barbour, GS—Gulf State, WC—Wind Creek, OM—Oak Mountain, SS—Sanctuaries, CO—Coosa, GU—Guntersville, PE—Perdido, LC—Lauderdale, FH—Freedom Hills) in Alabama.

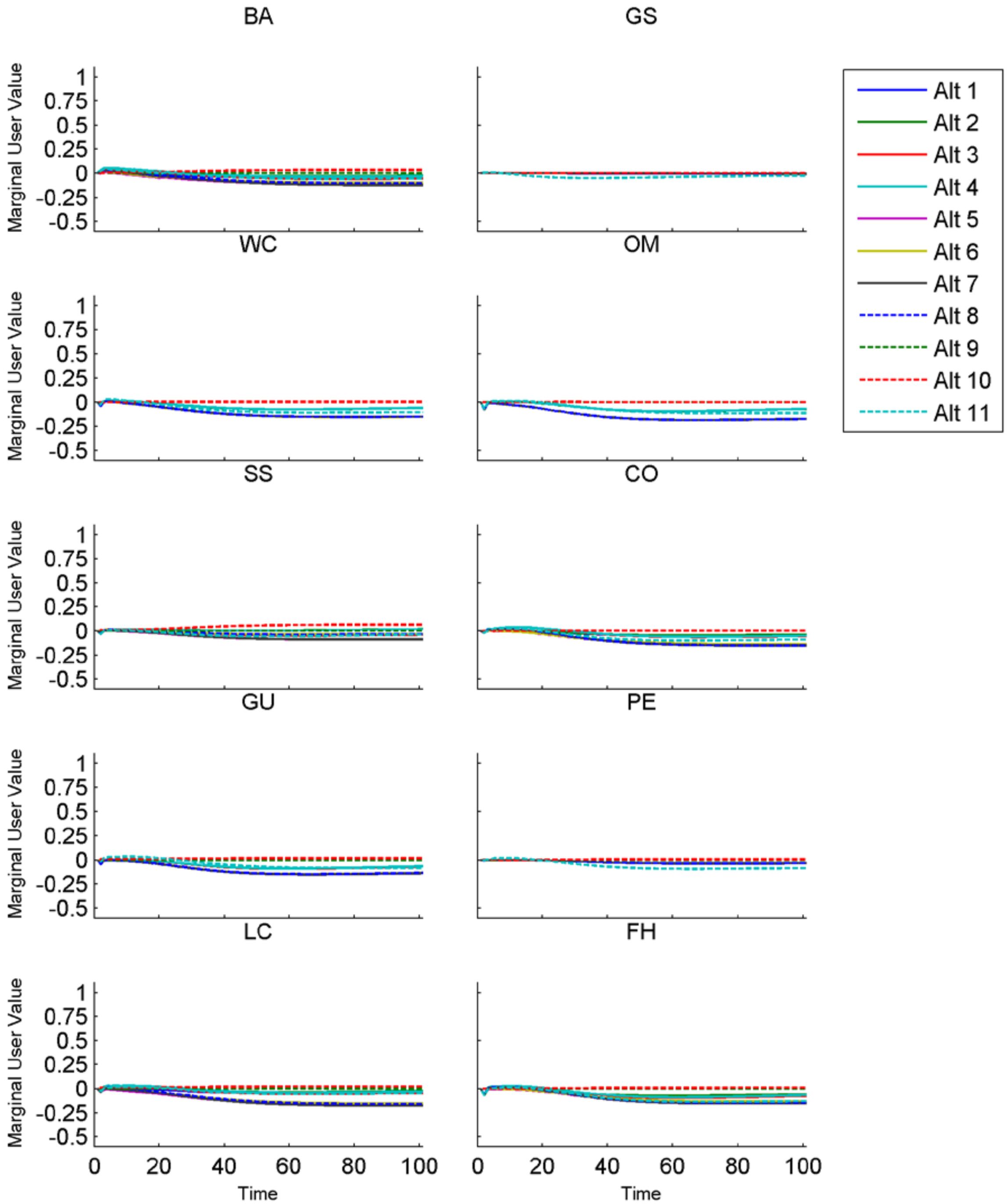


Figure 2.21. Marginal user value for each alternative relative to alternative 9 over the 100-year projection period for each study area (BA—Barbour, GS—Gulf State, WC—Wind Creek, OM—Oak Mountain, SS—Sanctuaries, CO—Coosa, GU—Guntersville, PE—Perdido, LC—Lauderdale, FH—Freedom Hills) in Alabama.

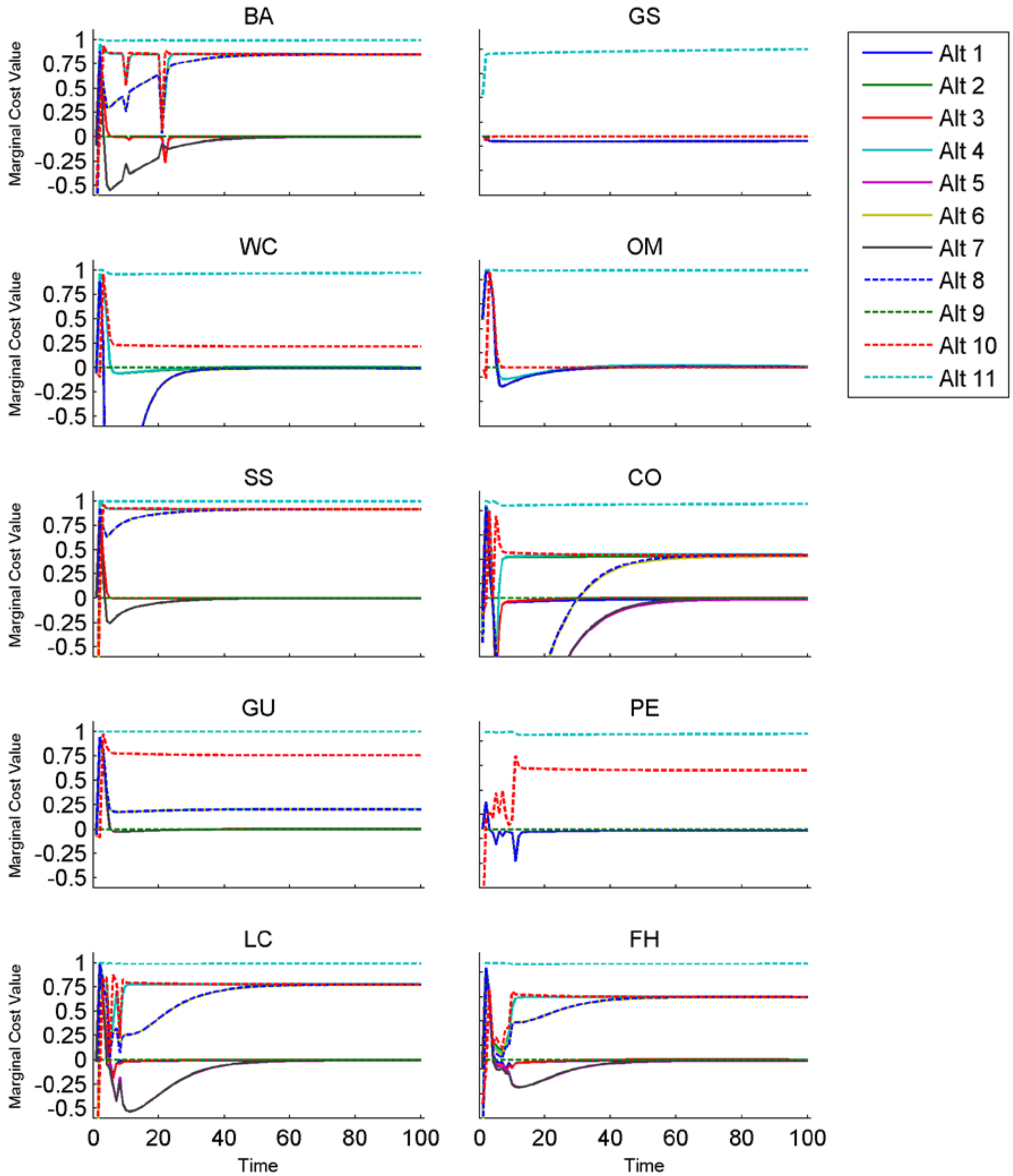
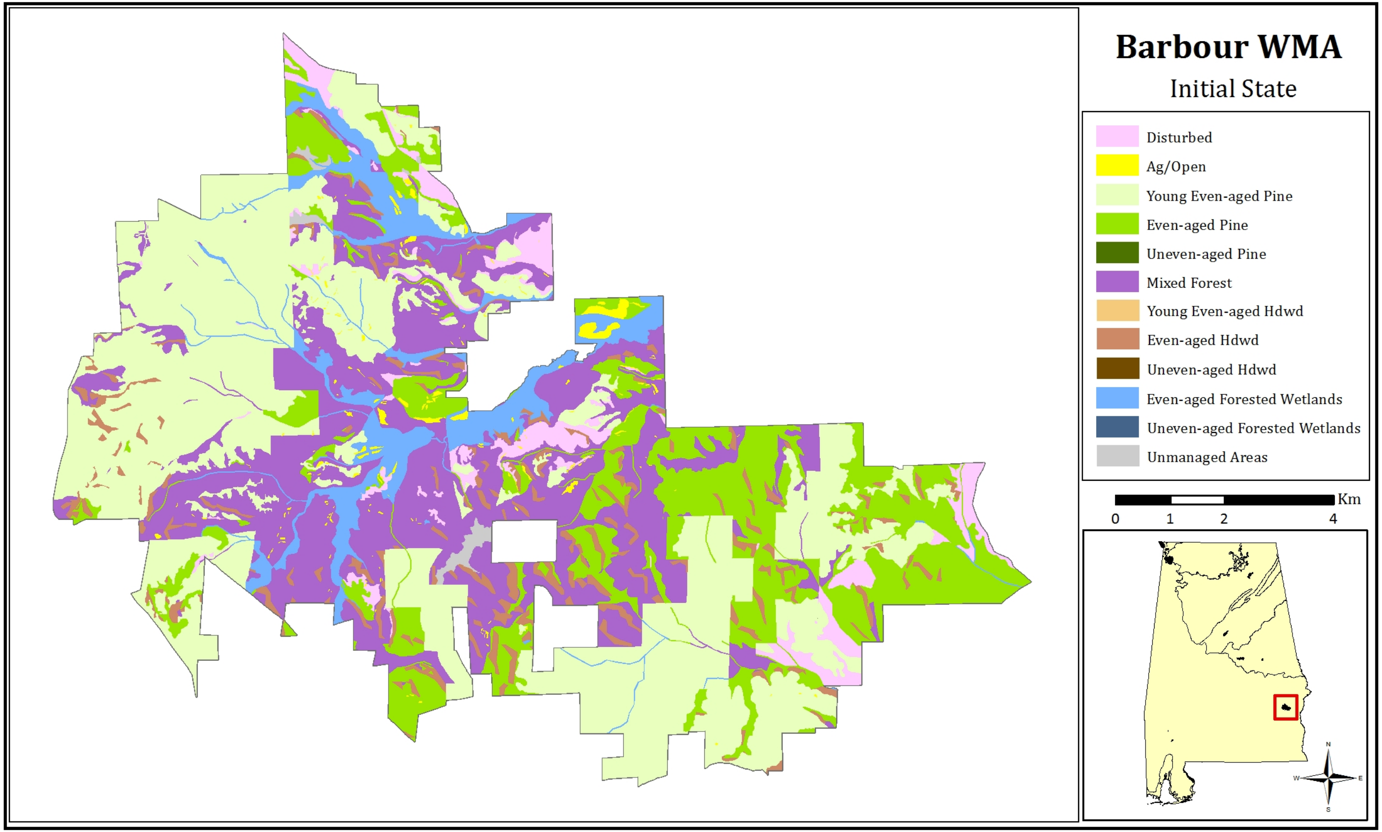


Figure 2.22. Marginal cost value for each alternative relative to alternative 9 over the 100-year projection for each study area (BA—Barbour, GS—Gulf State, WC—Wind Creek, OM—Oak Mountain, SS—Sanctuaries, CO—Coosa, GU—Guntersville, PE—Perdido, LC—Lauderdale, FH—Freedom Hills) in Alabama.

Appendix 1. Initial landscape conditions circa 2011 and targeted landscape composition and configuration at year 100 for each alternative for each study area.



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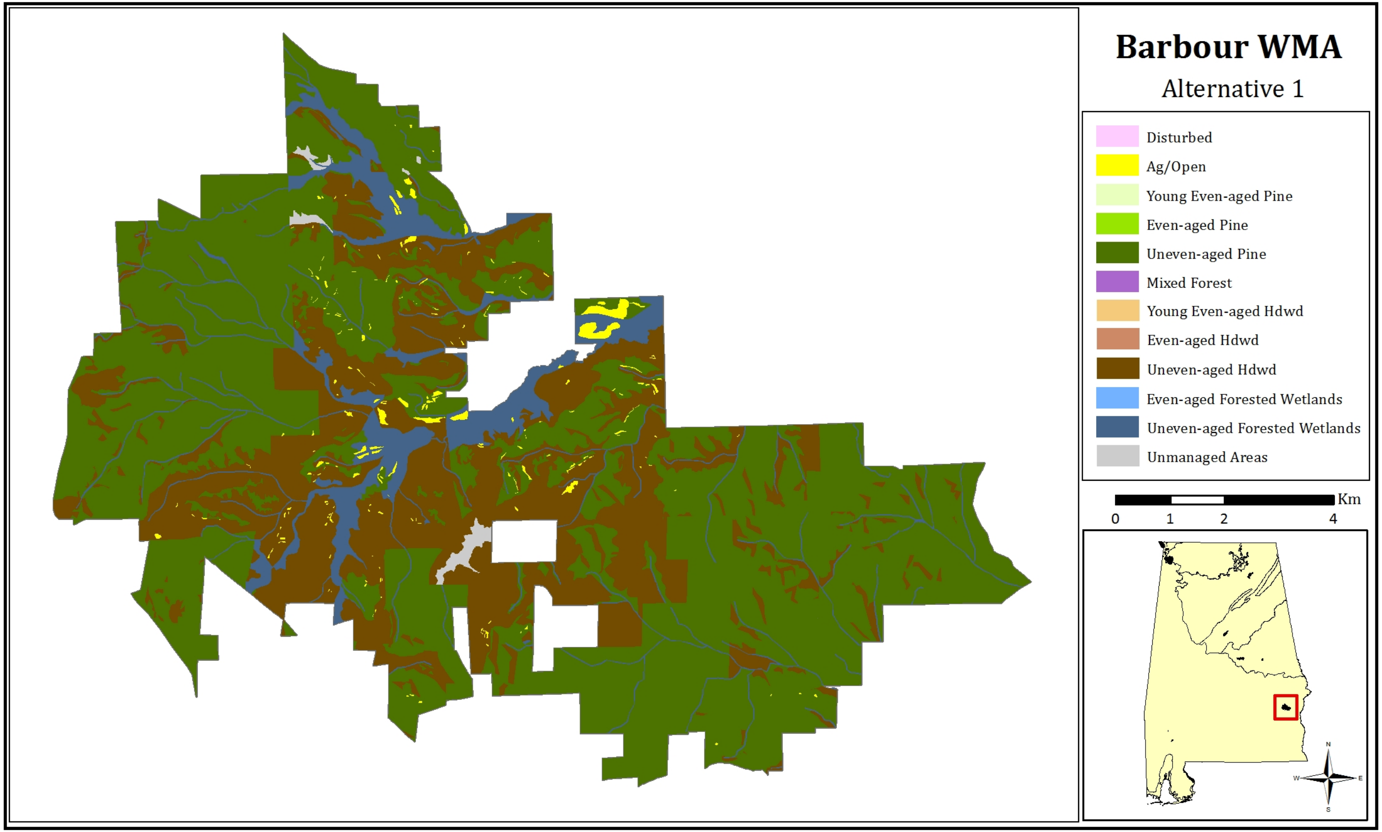

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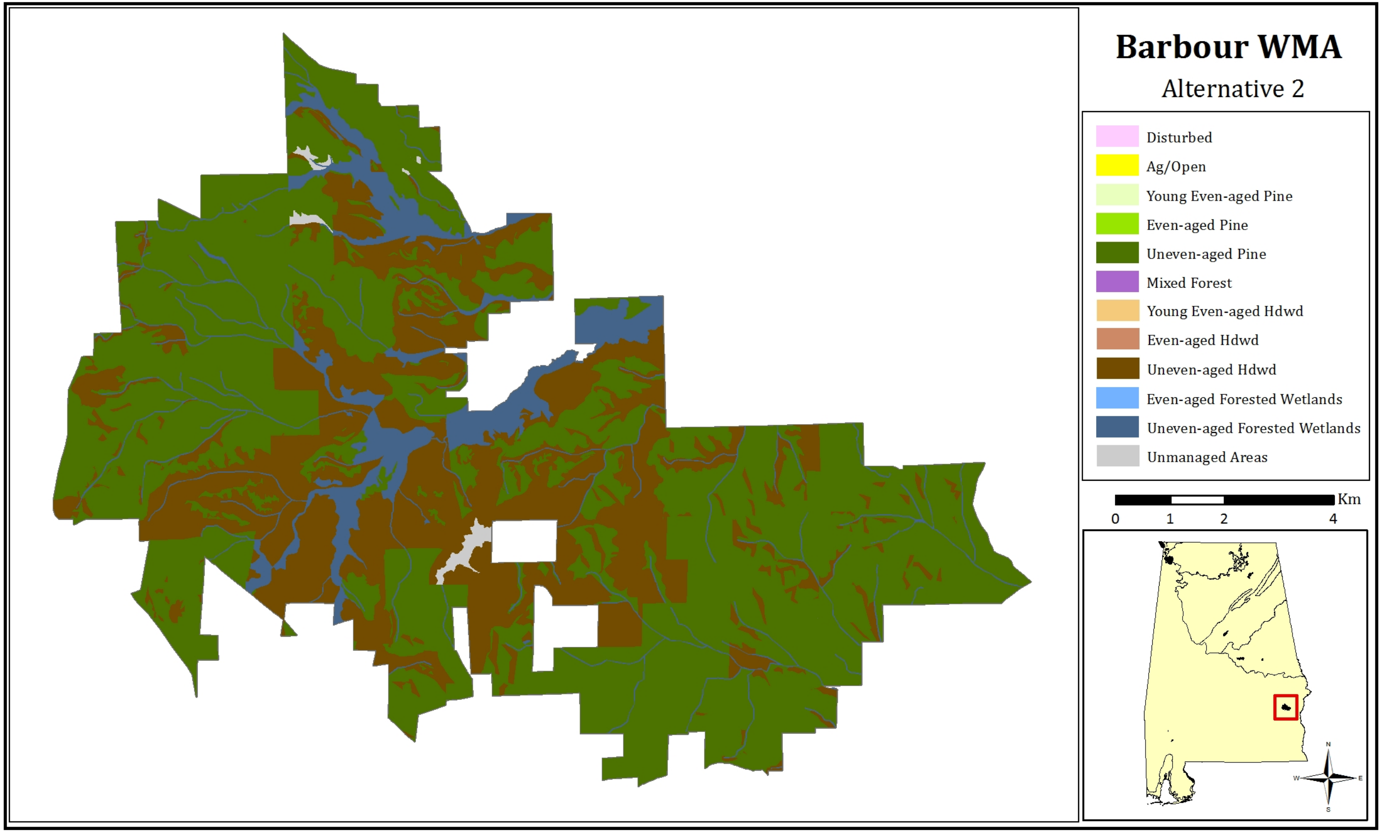

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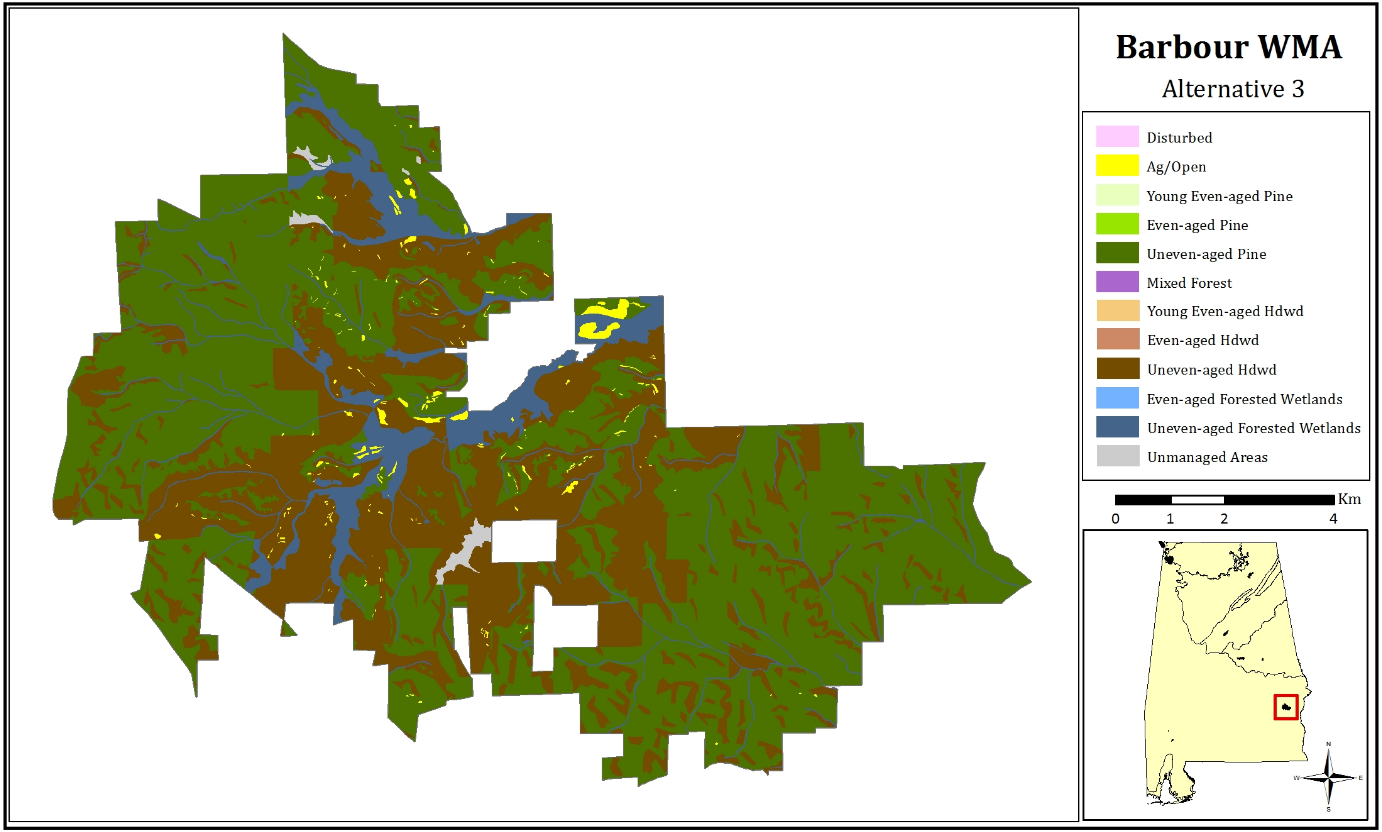

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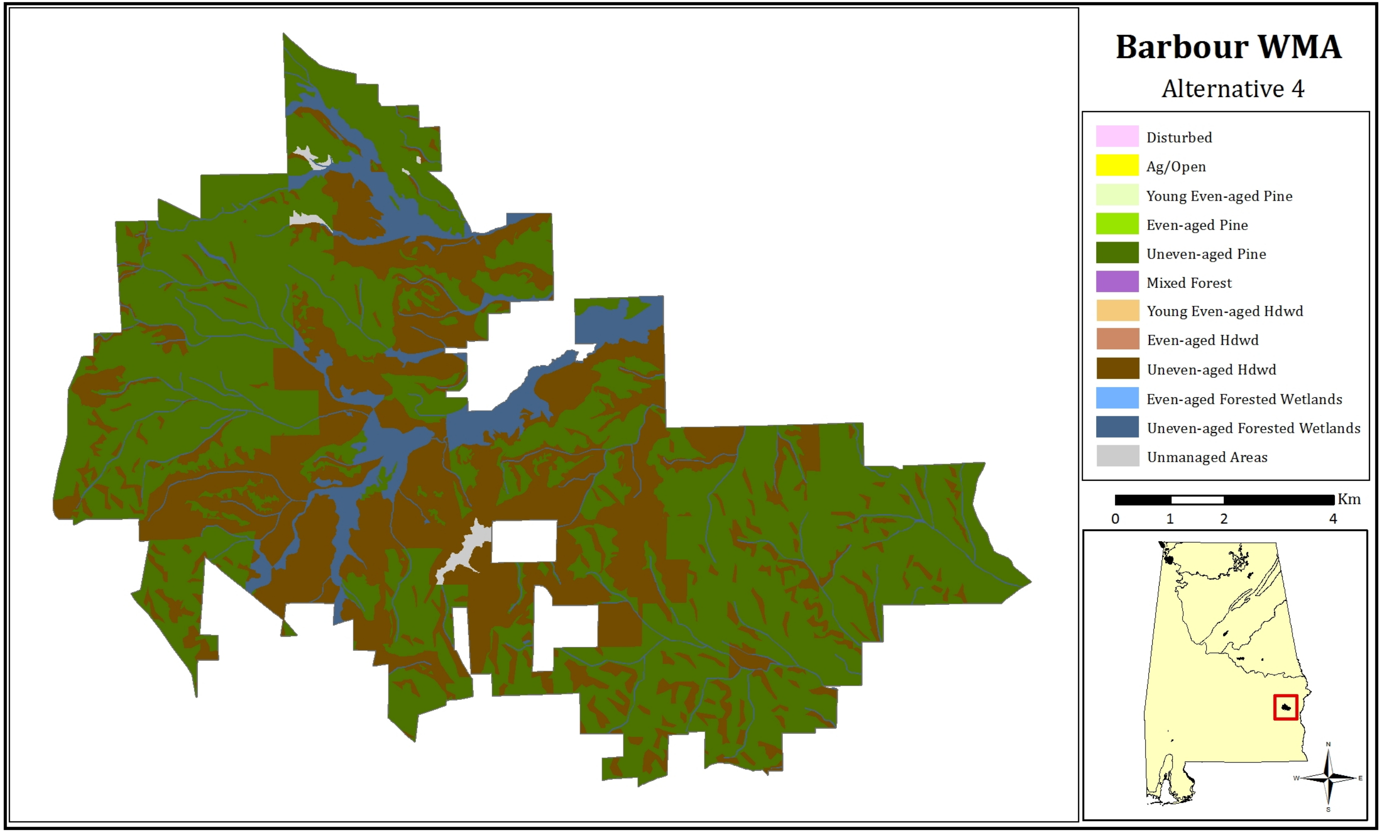

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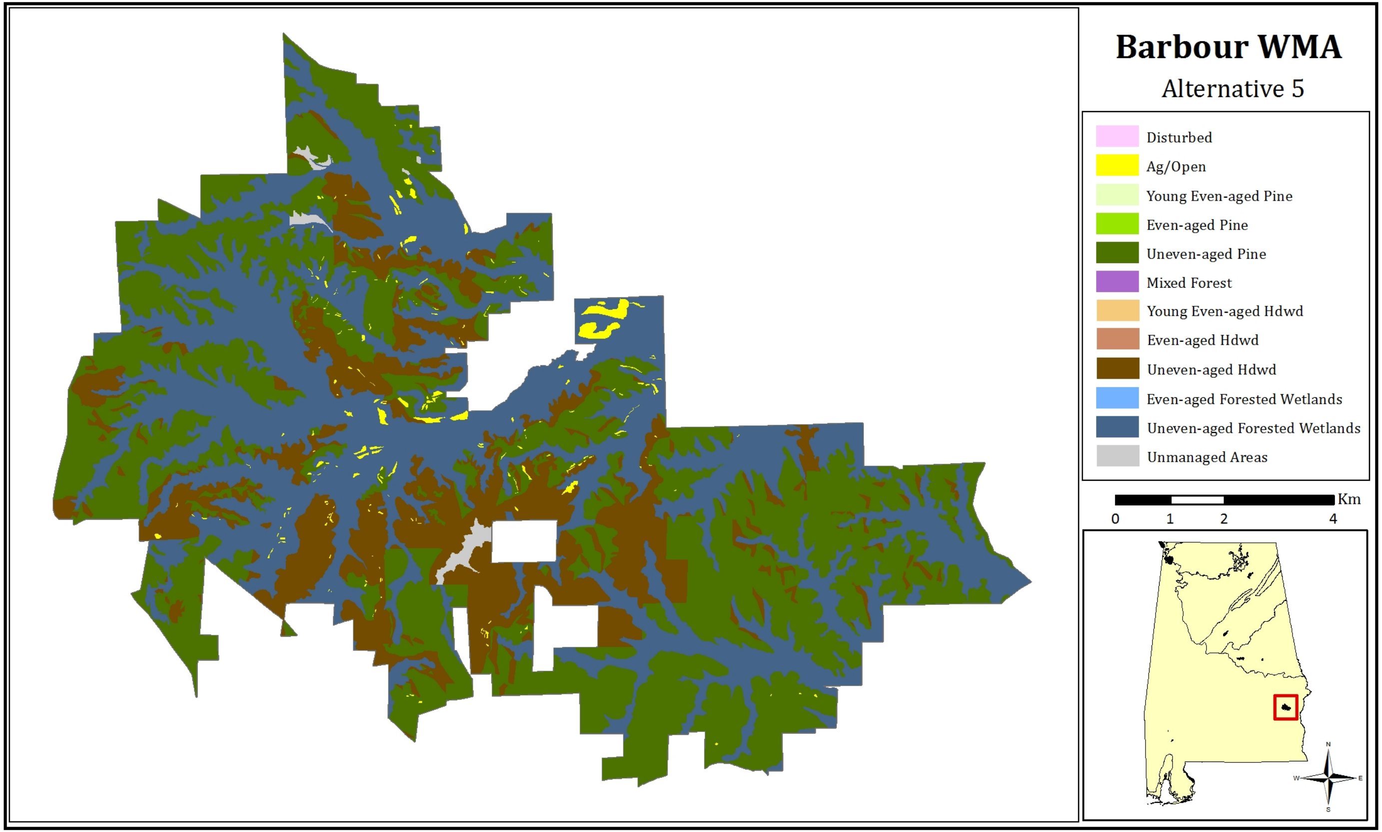

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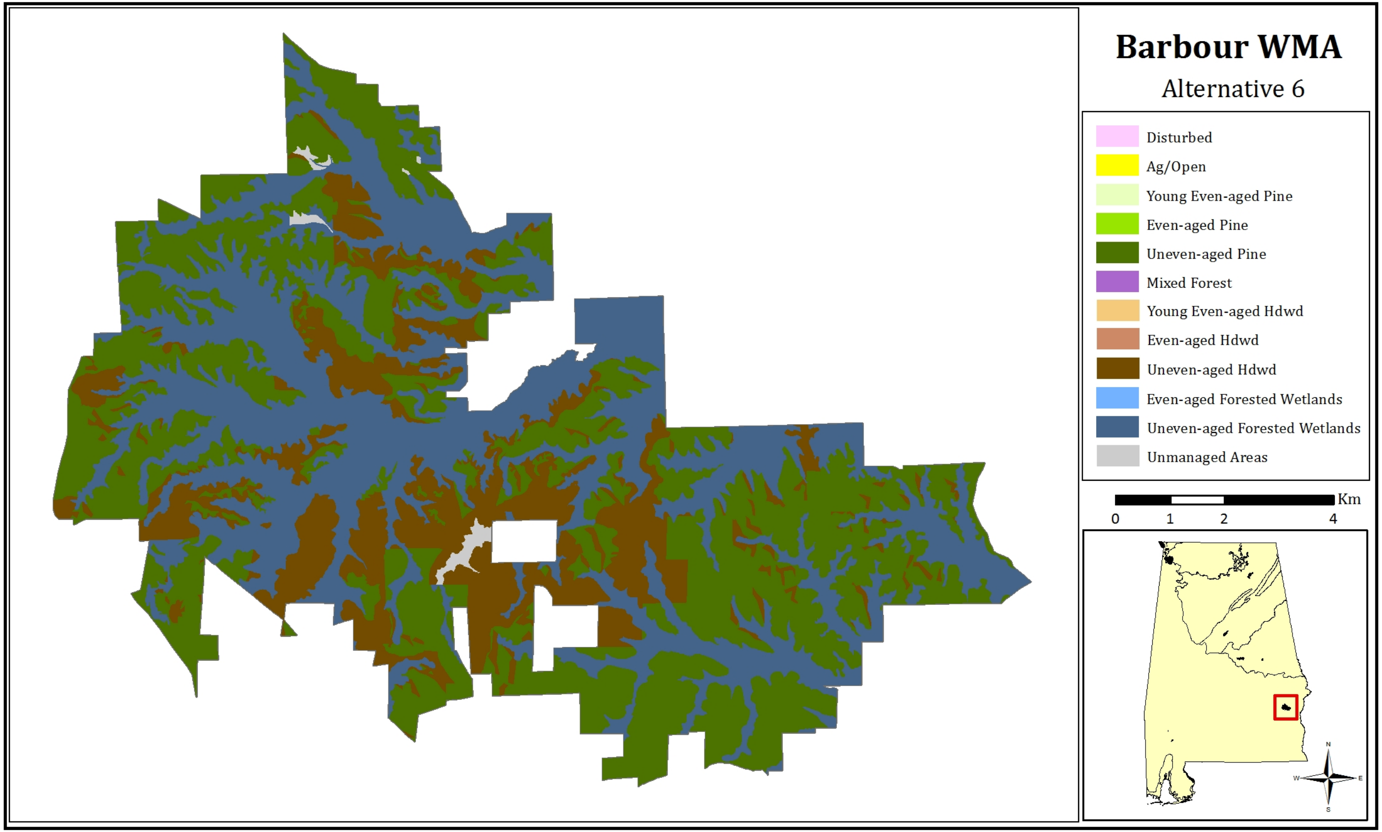

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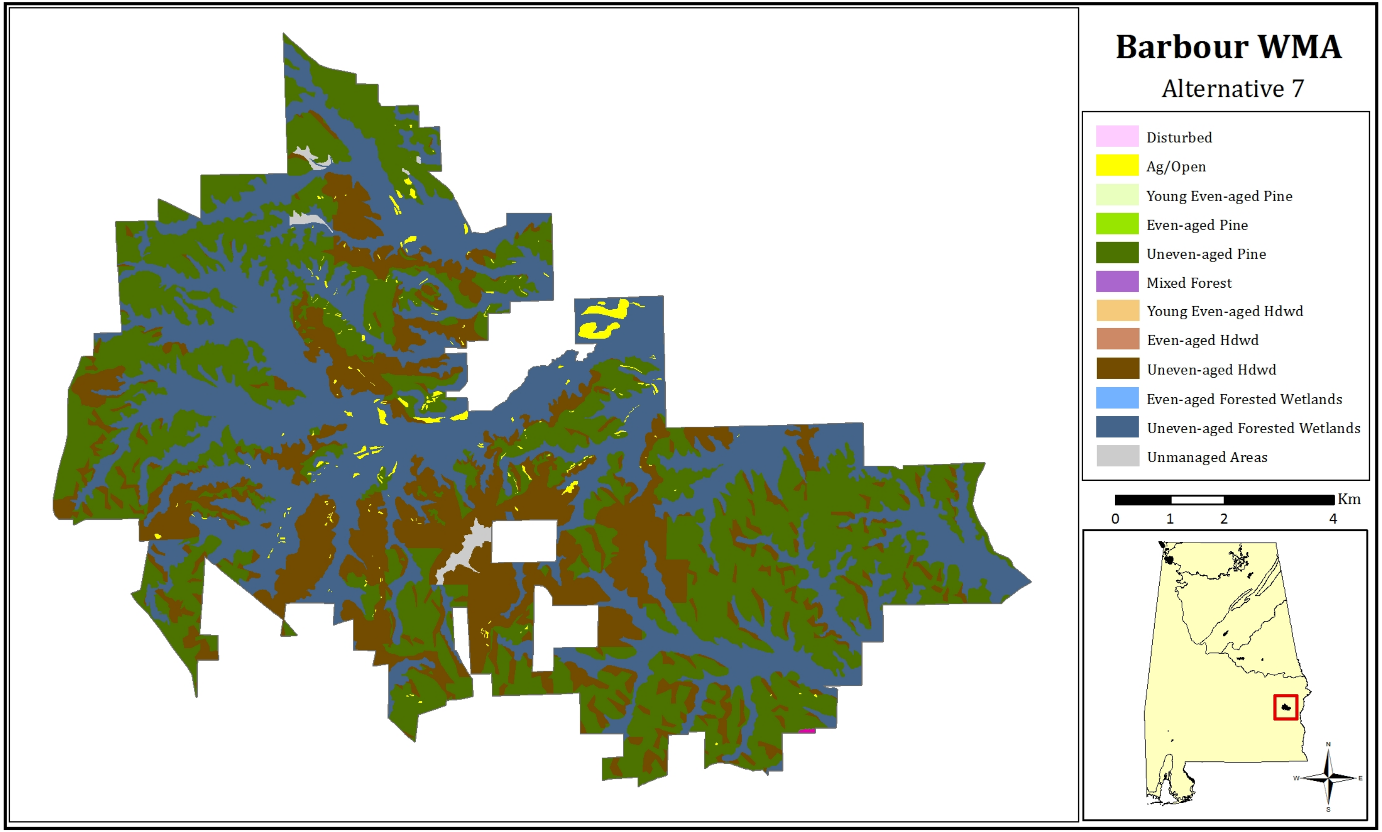

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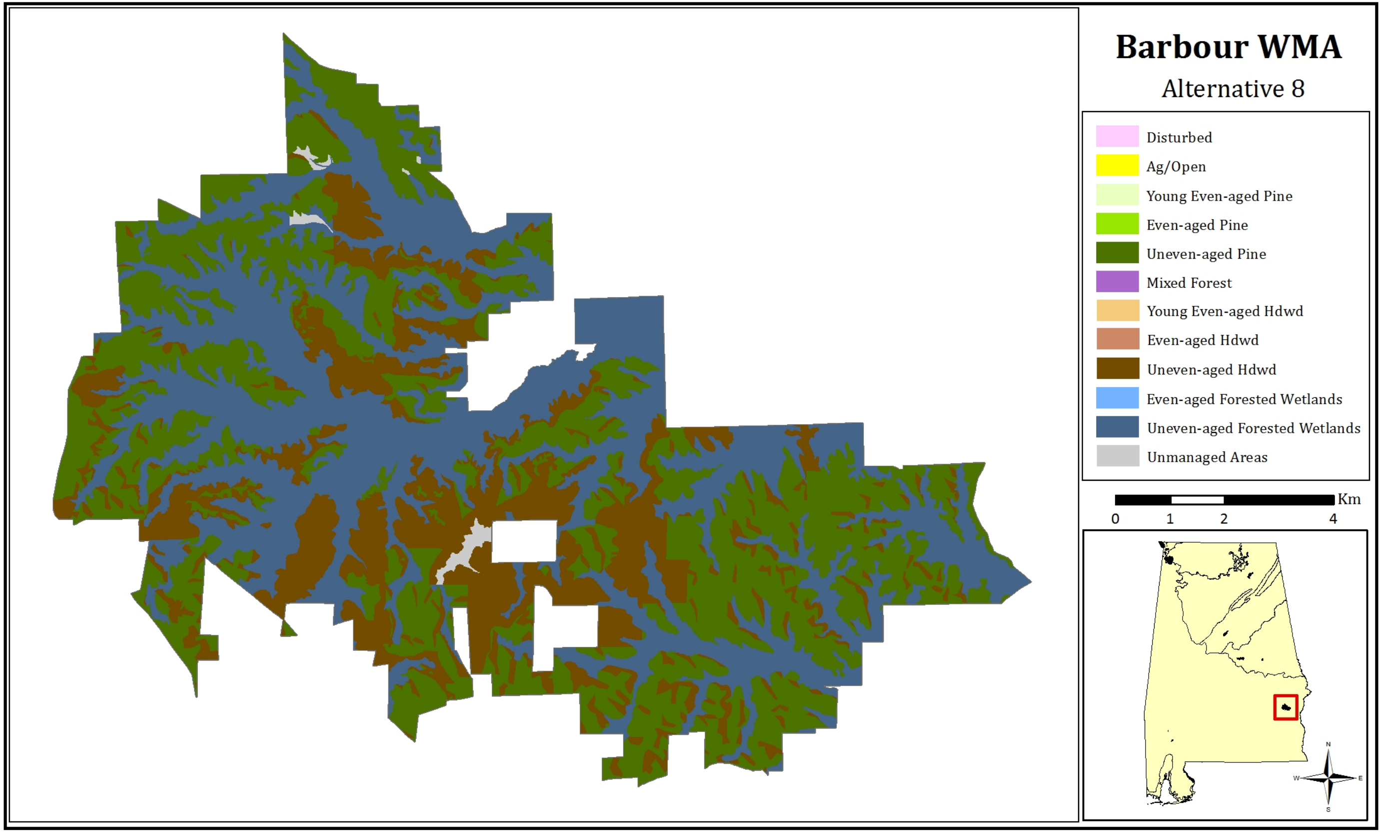

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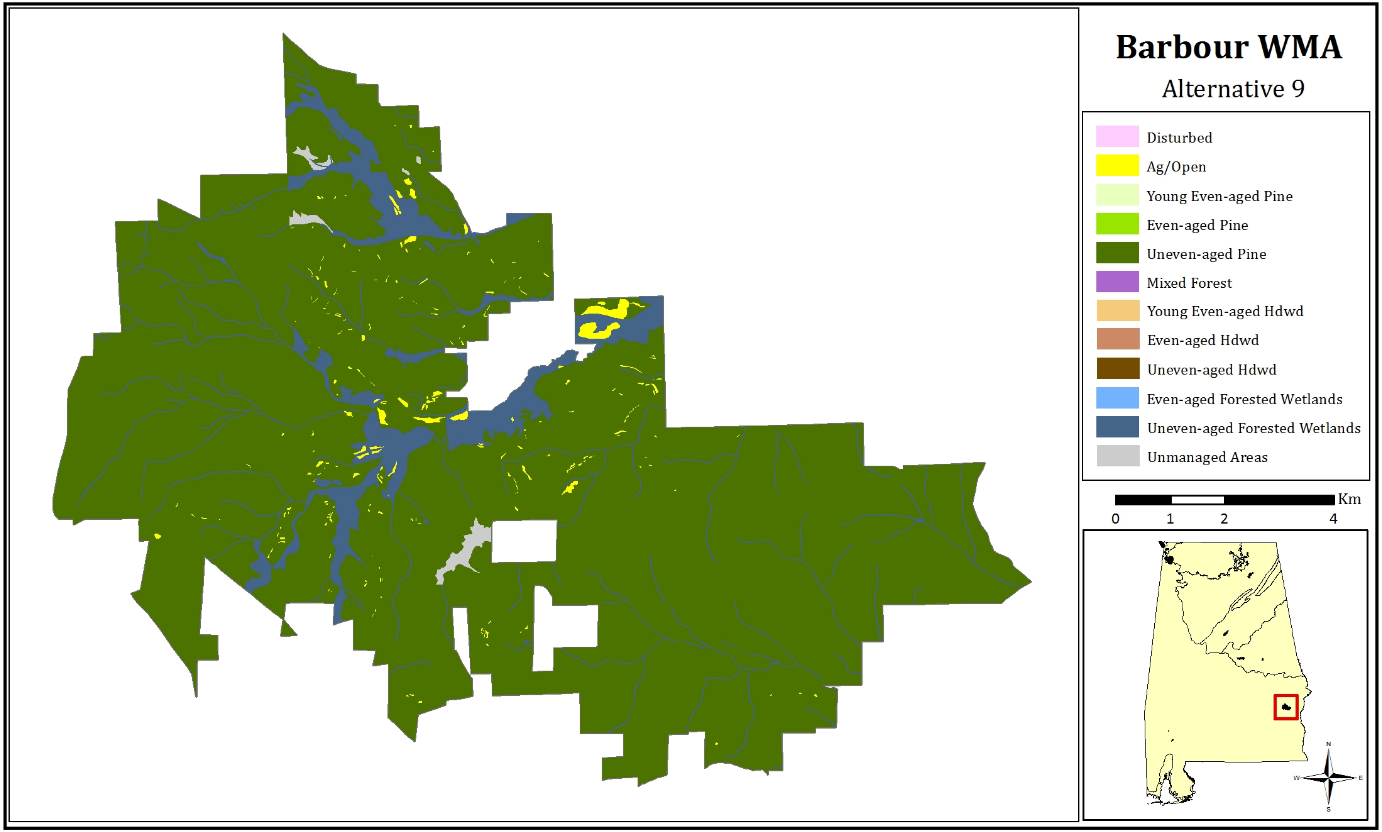

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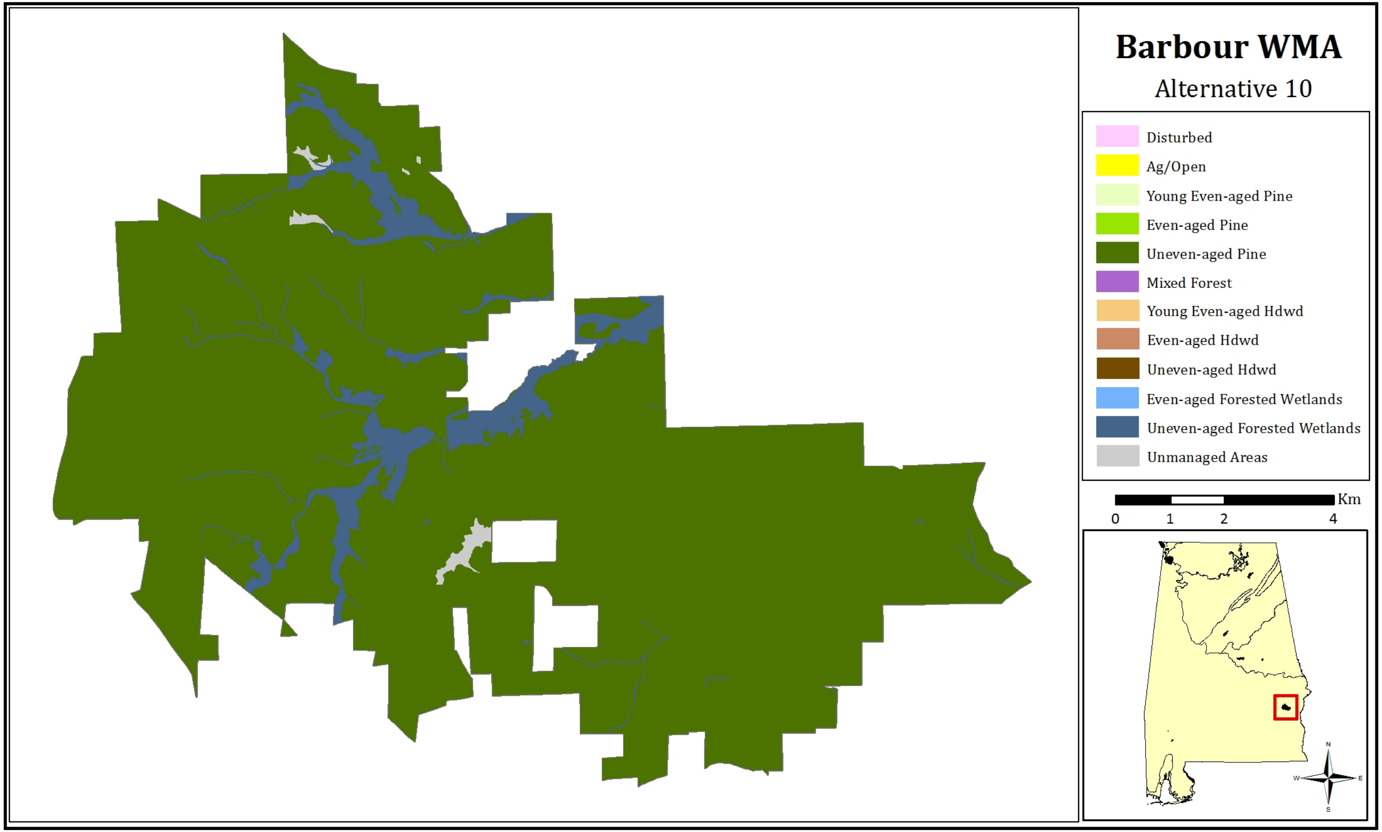

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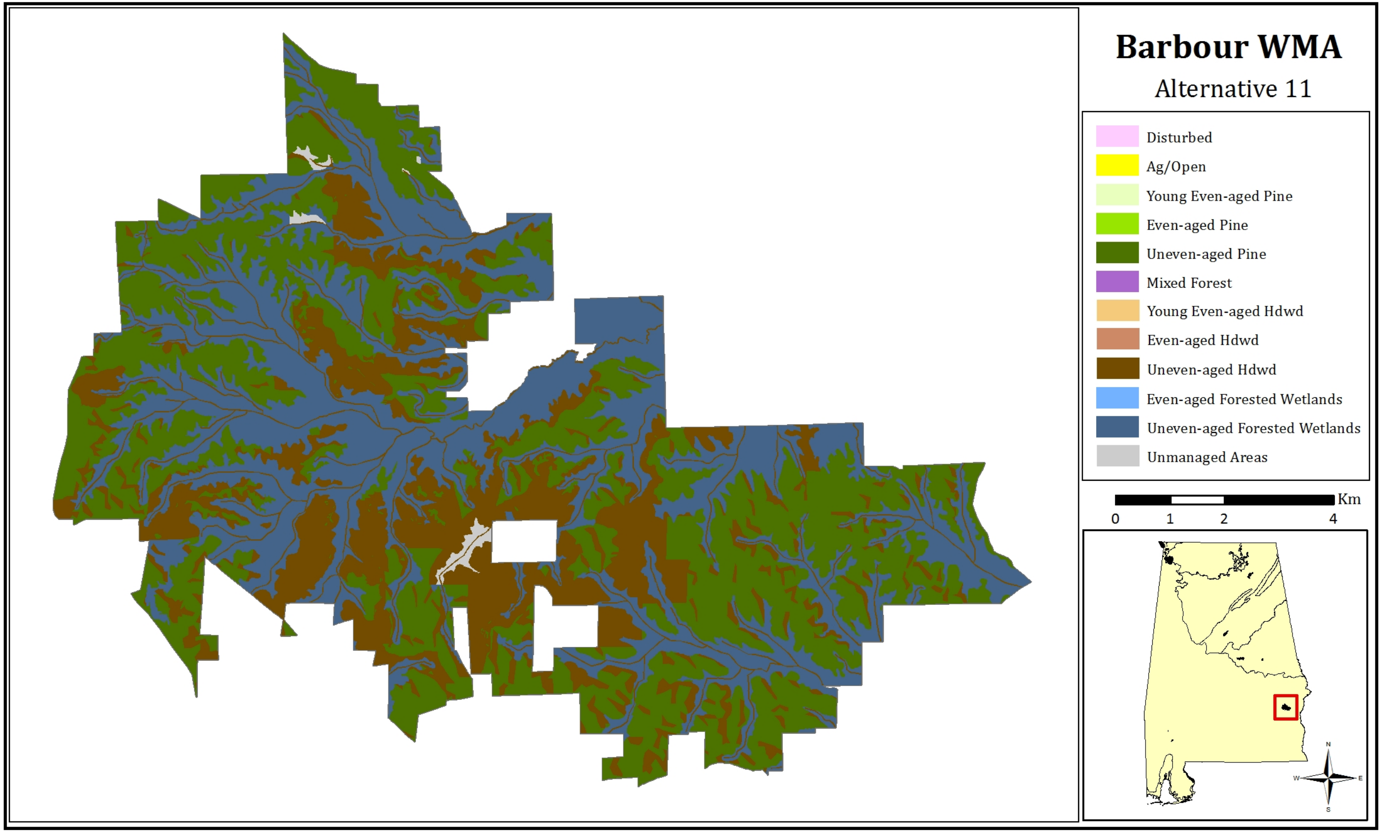

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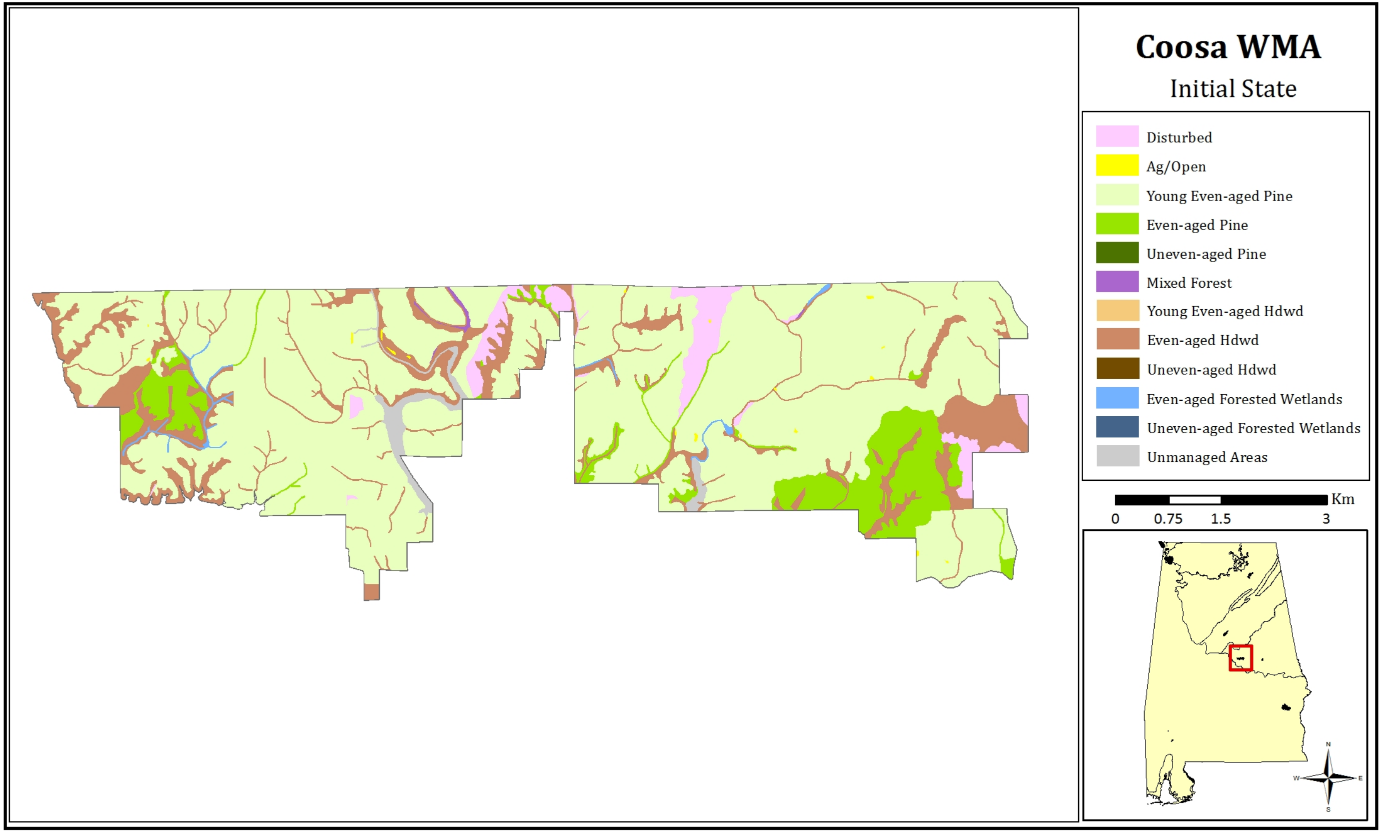

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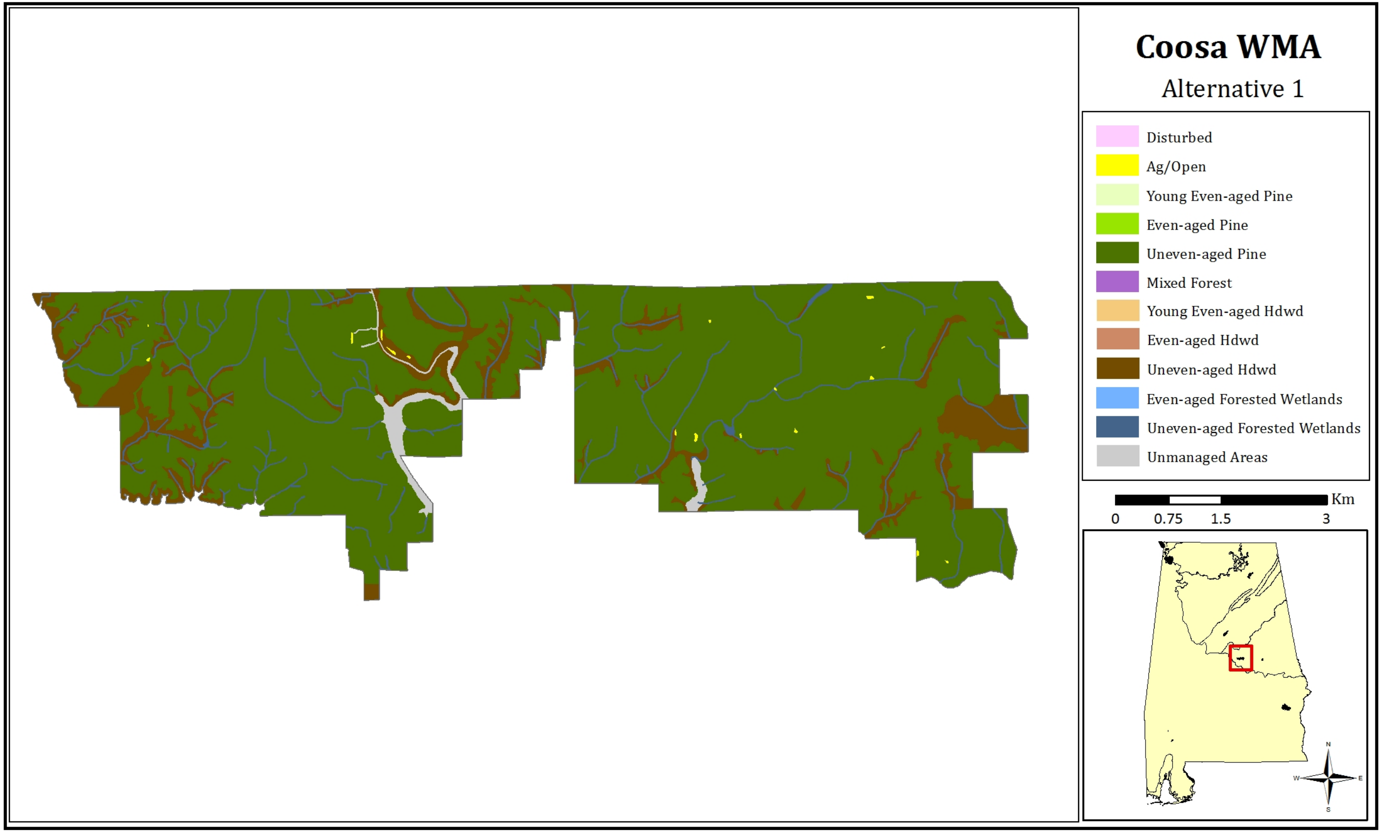

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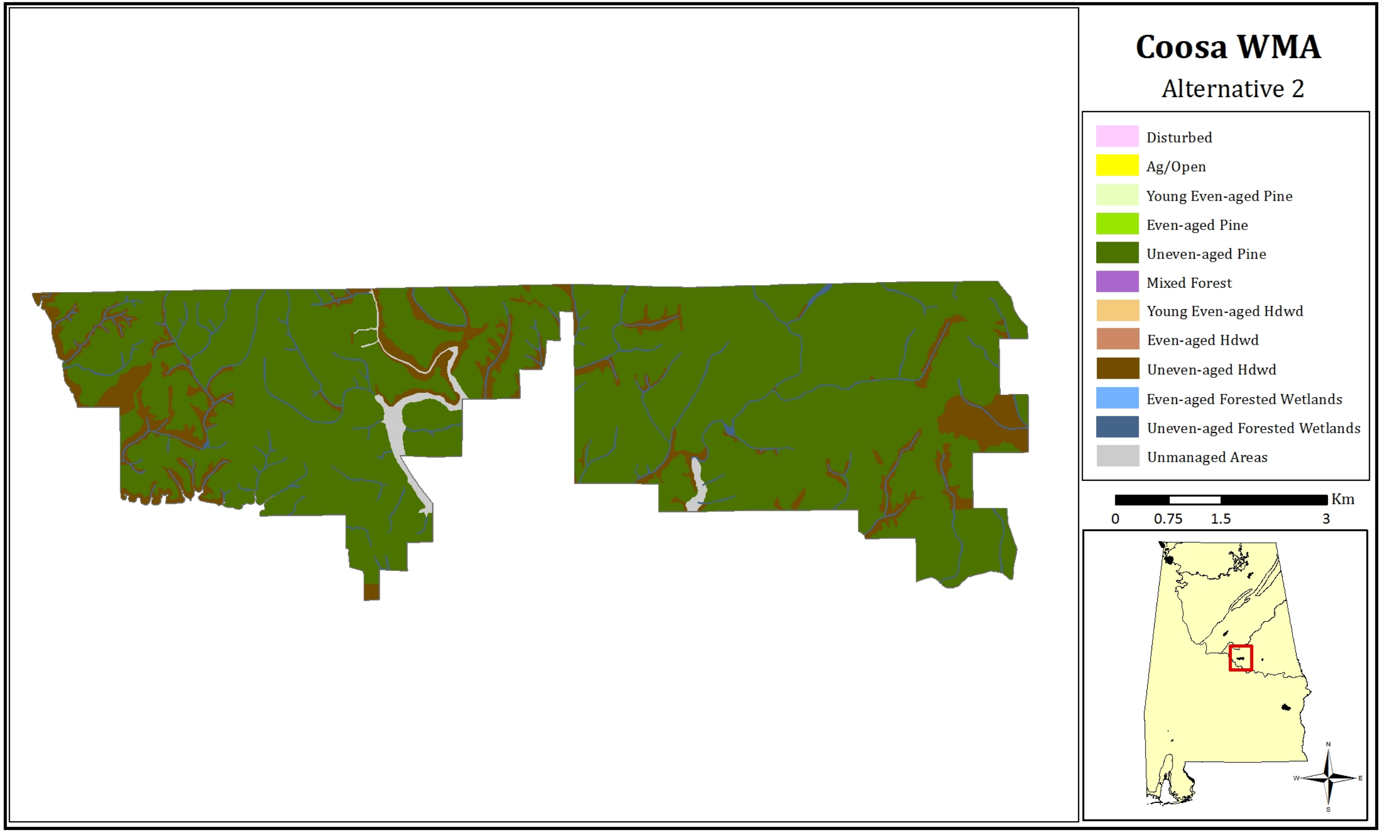

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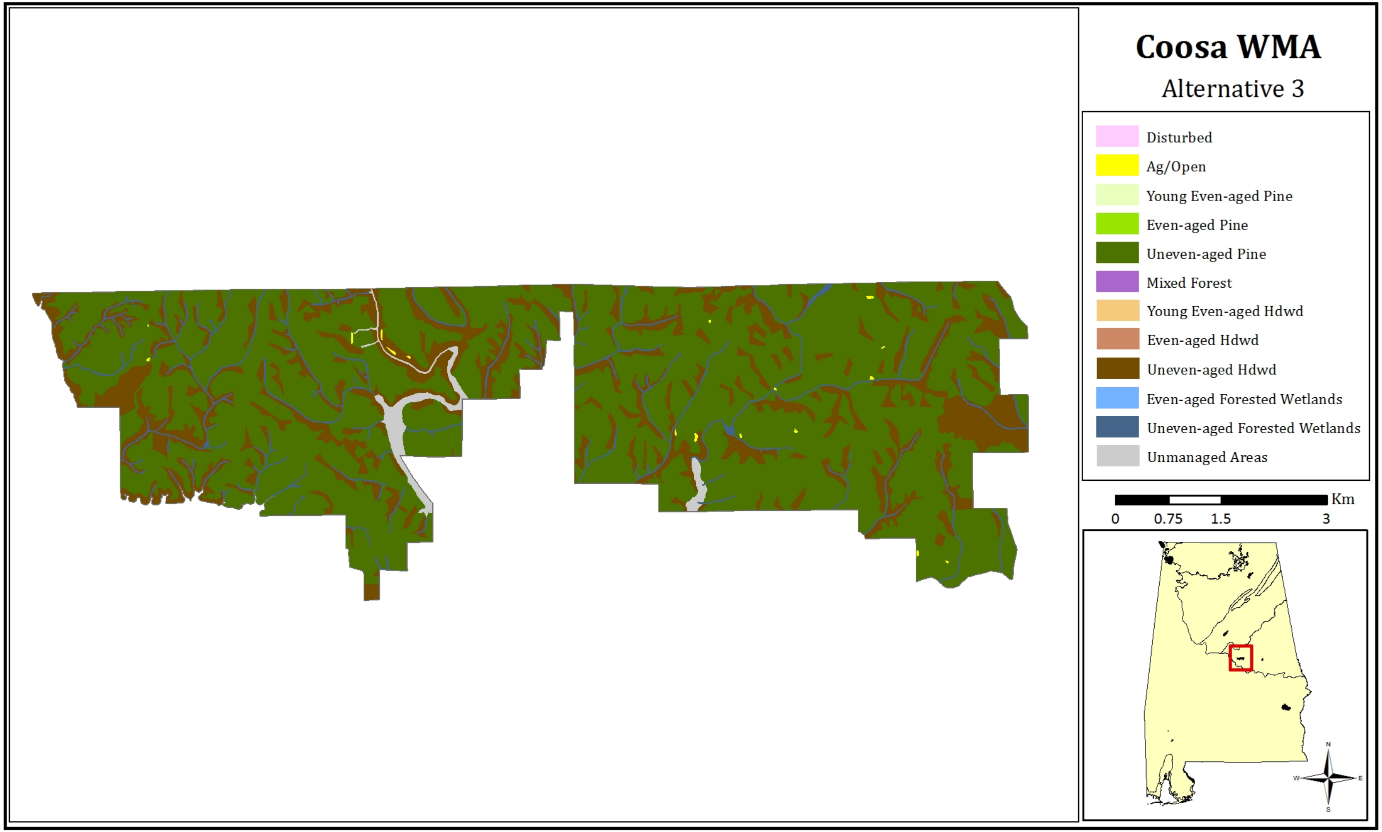

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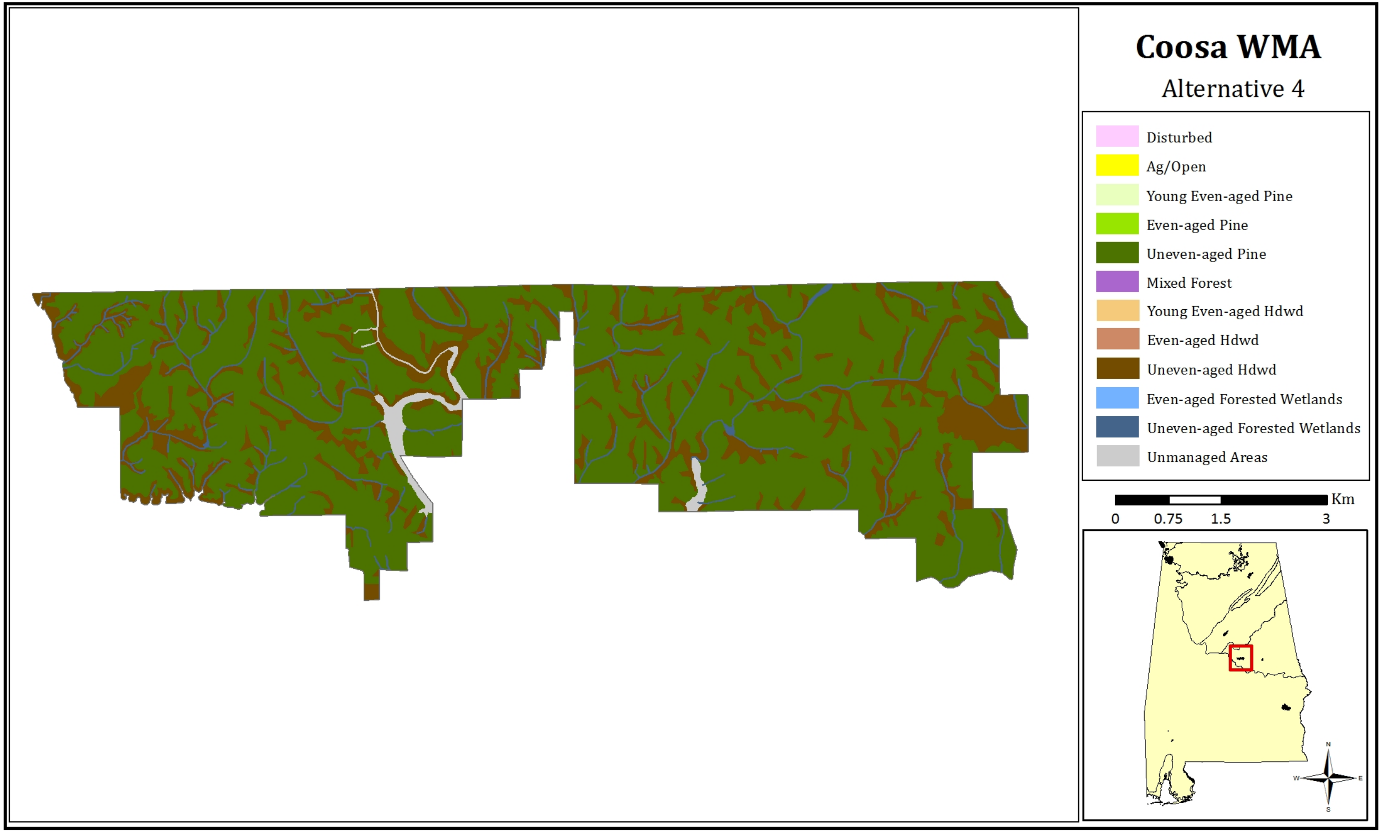

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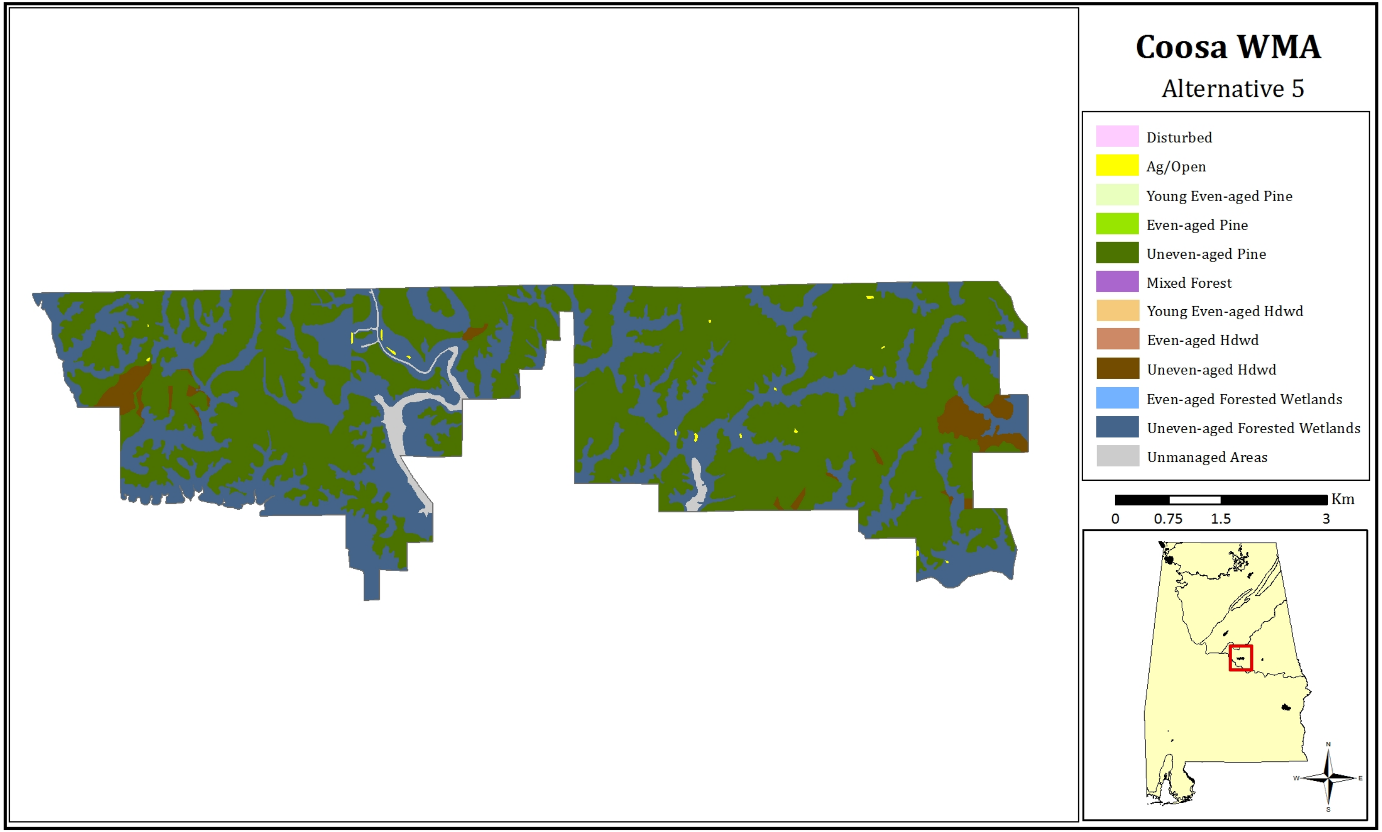

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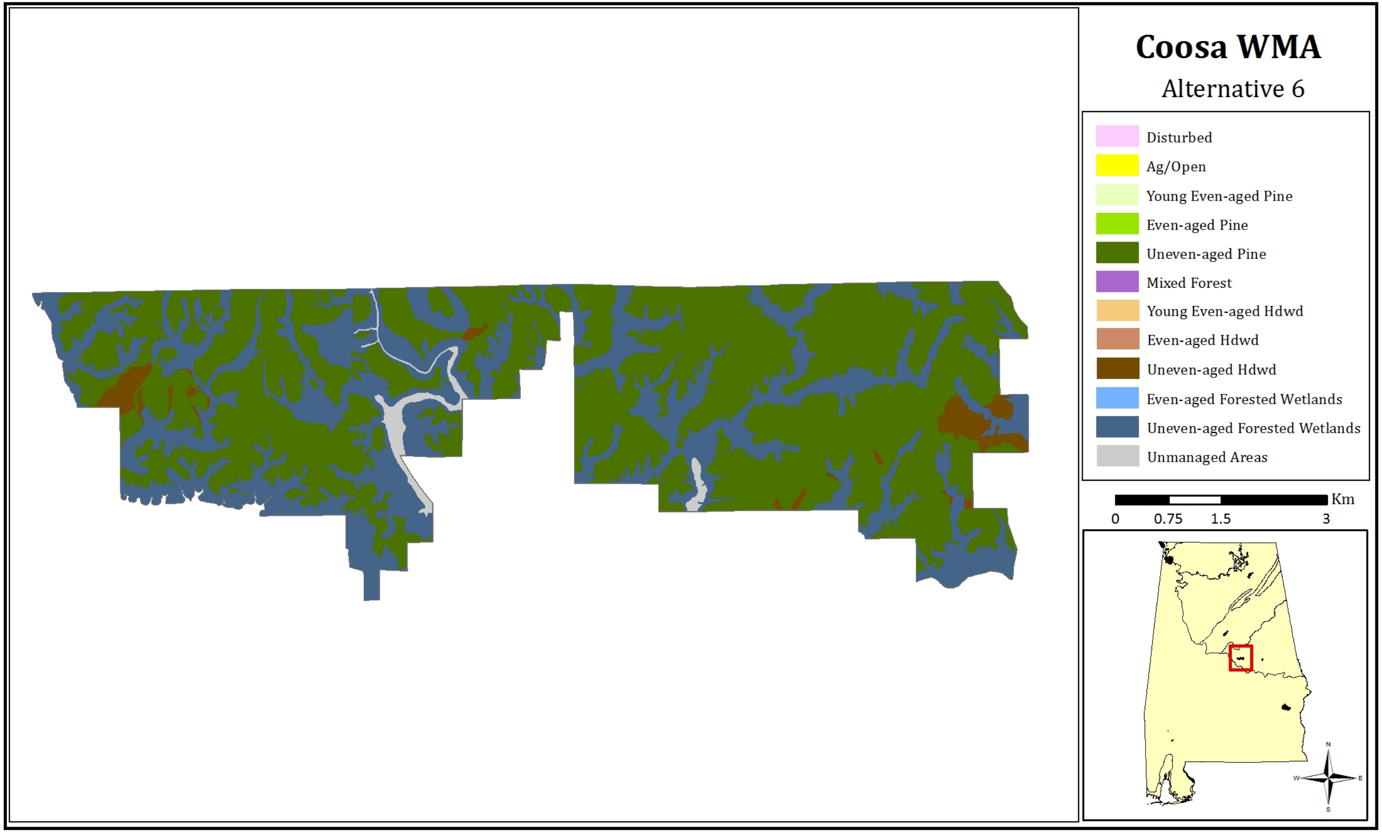

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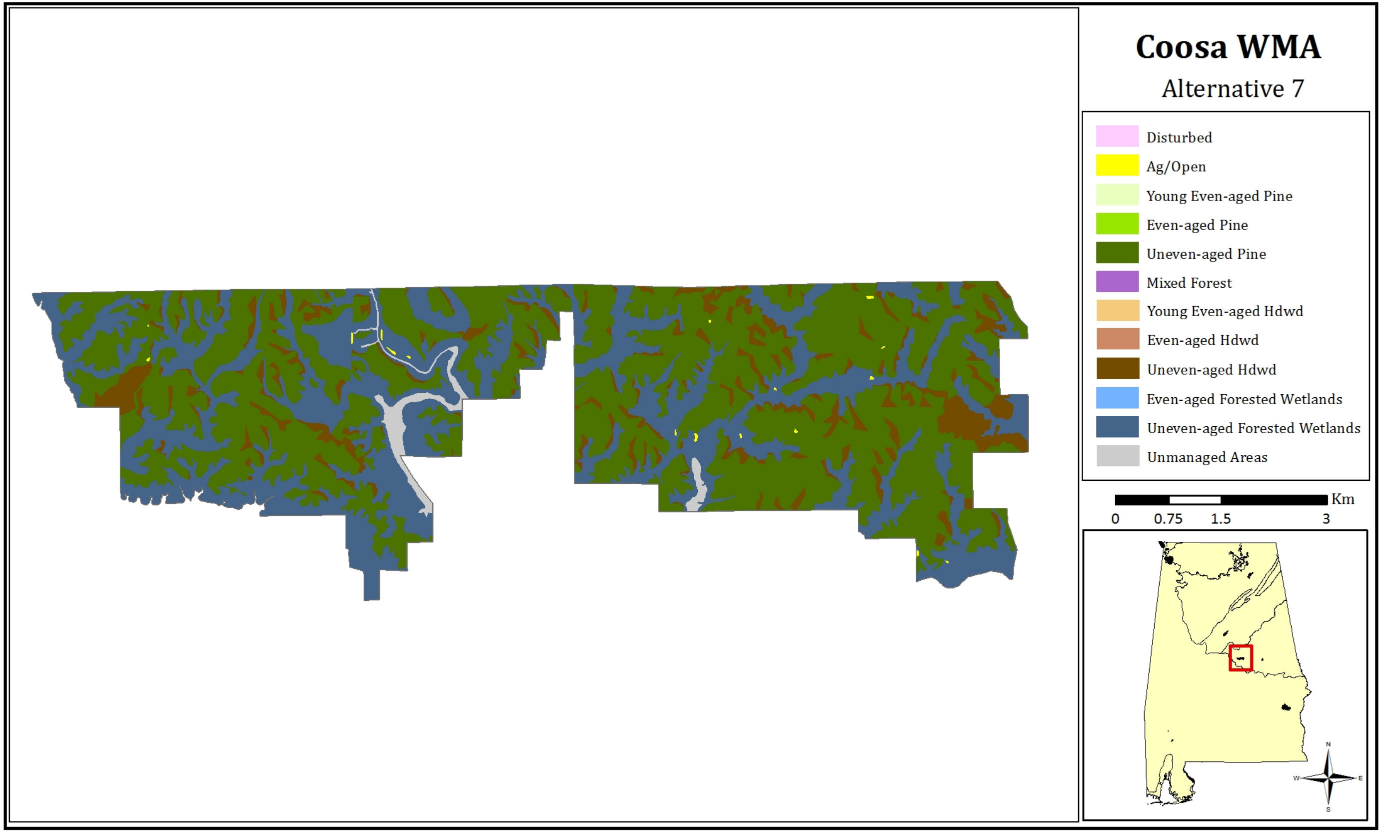

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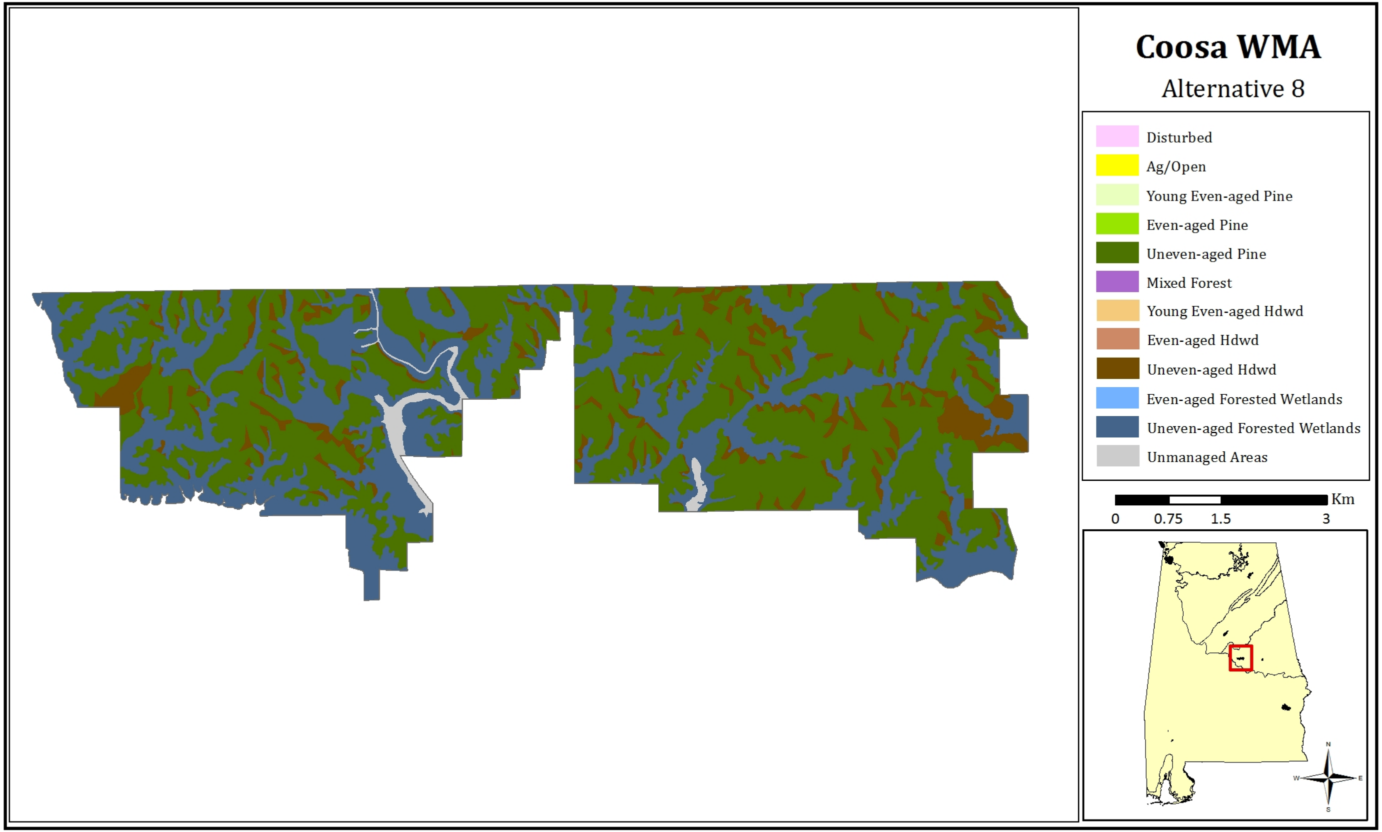

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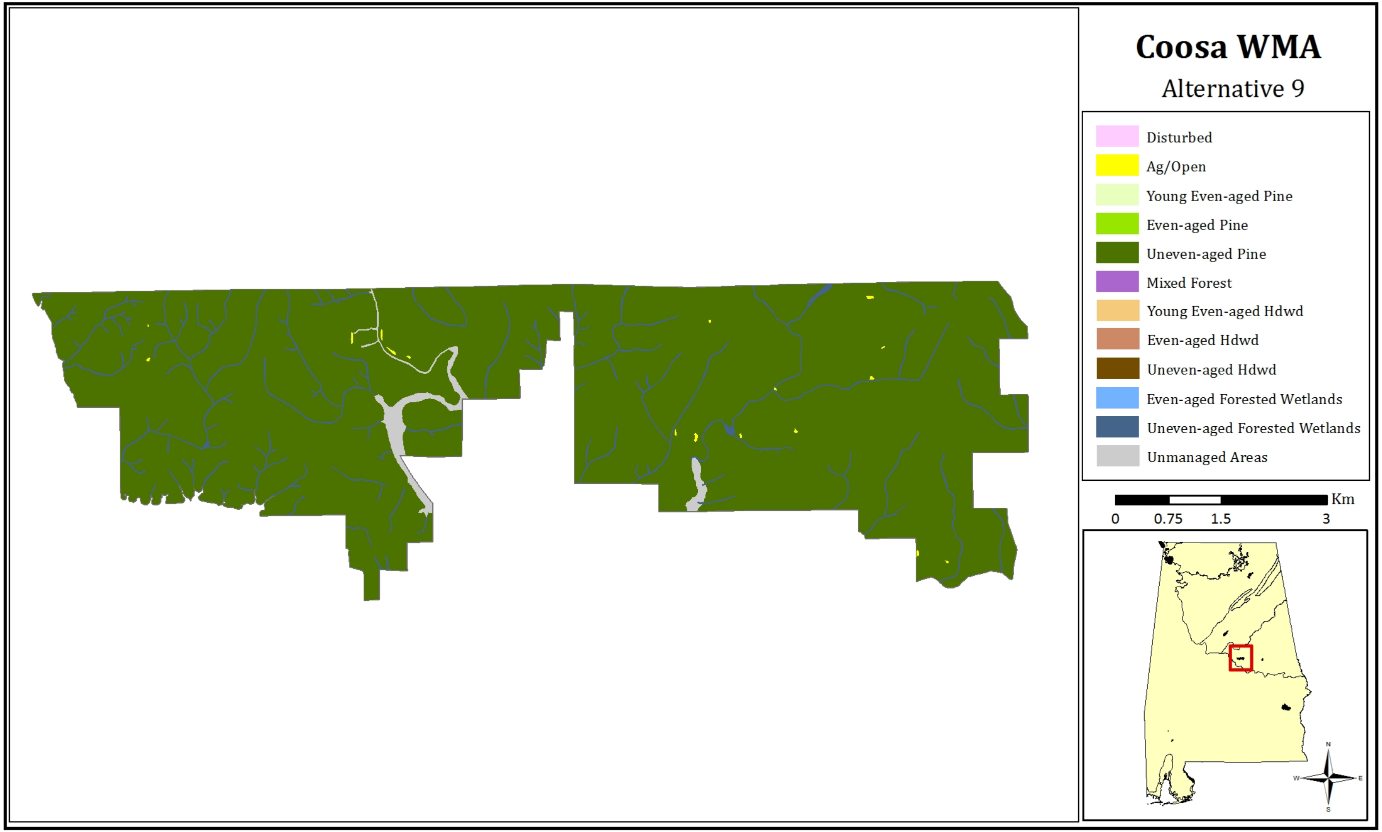

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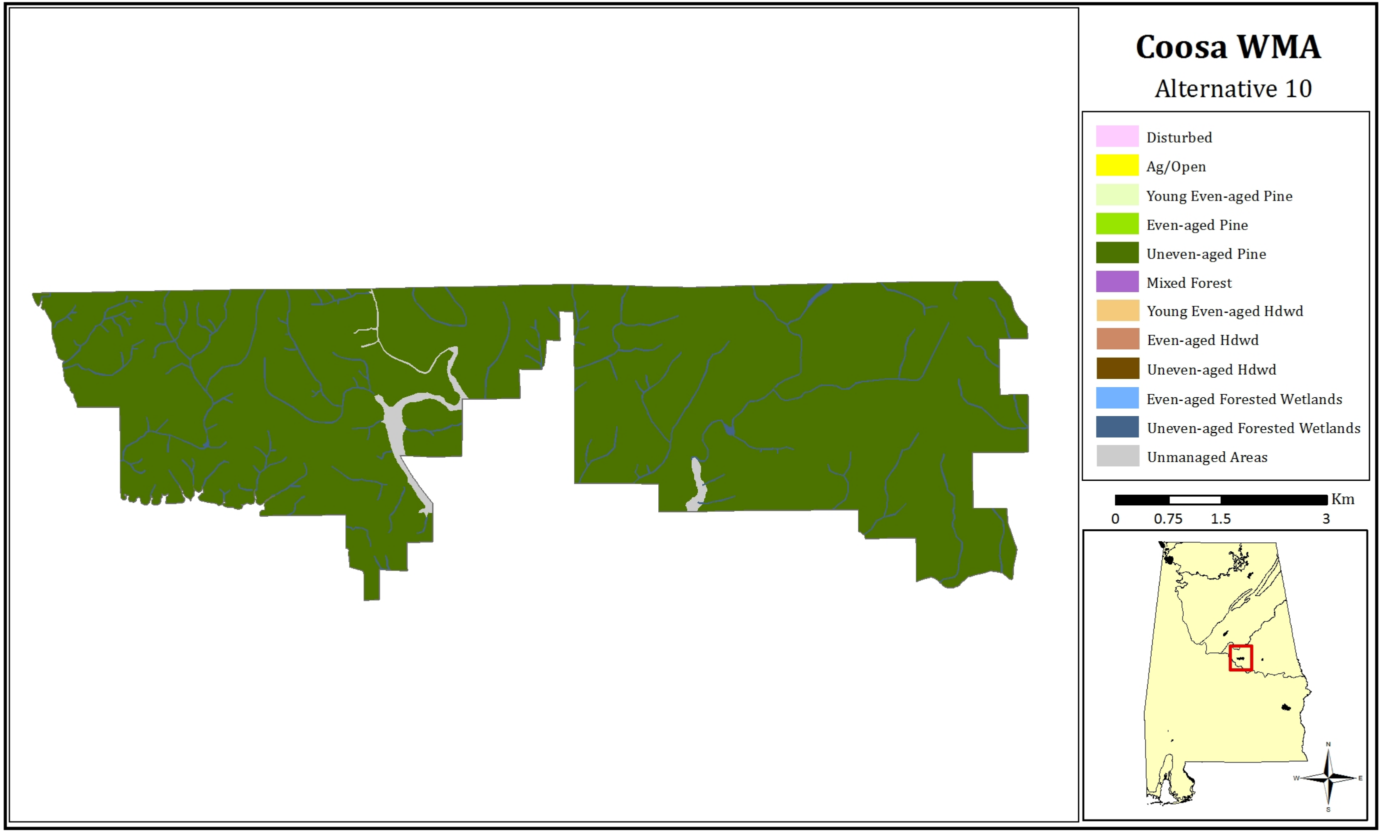

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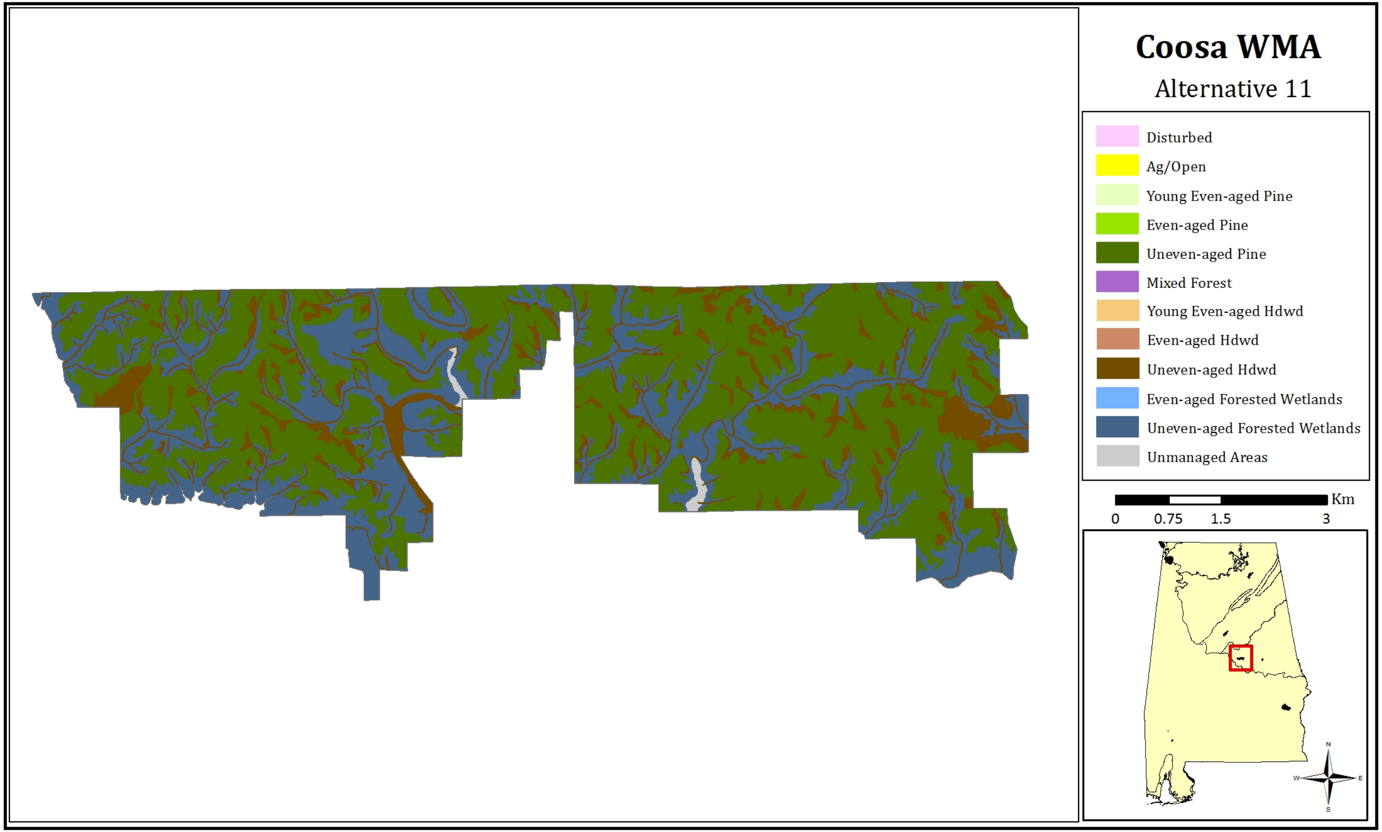

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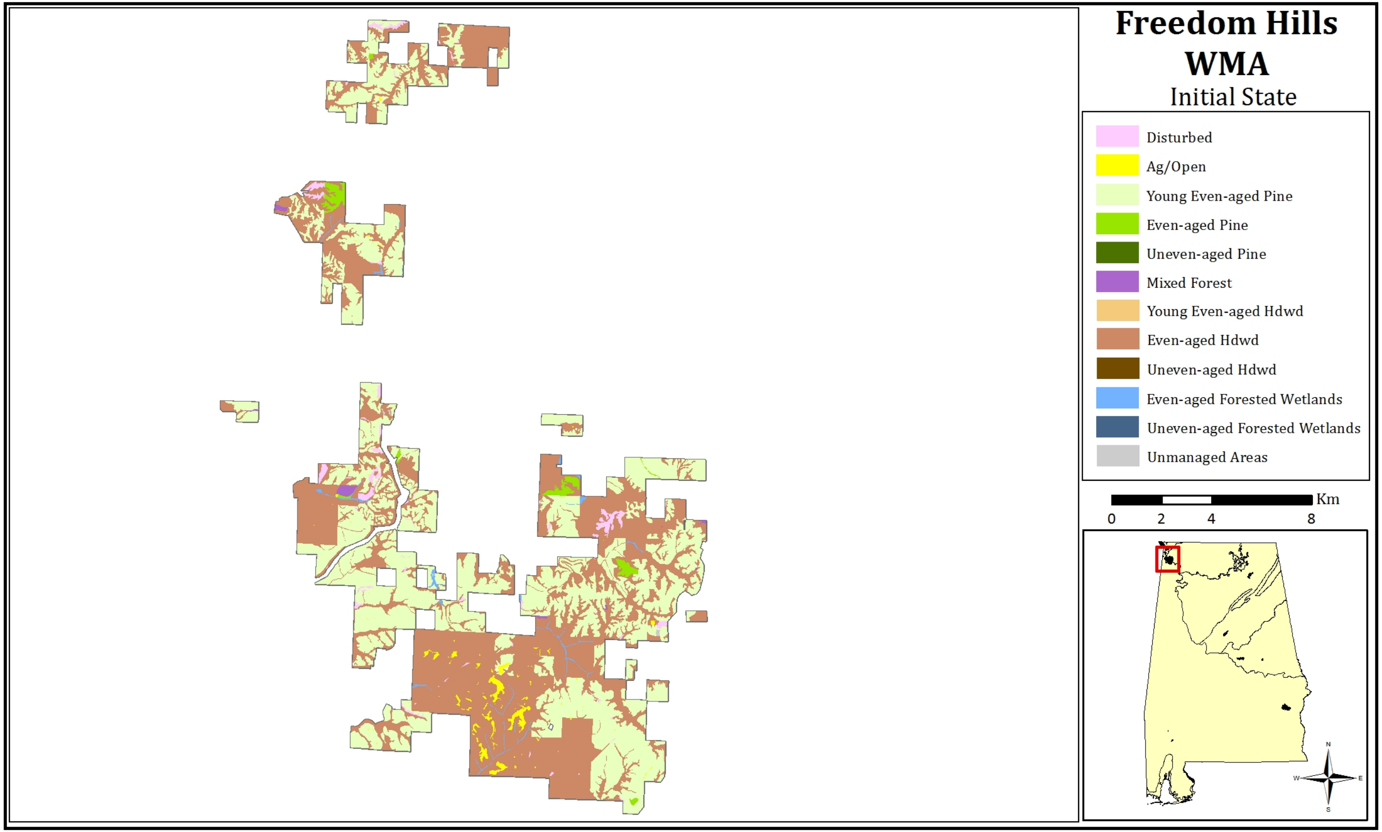

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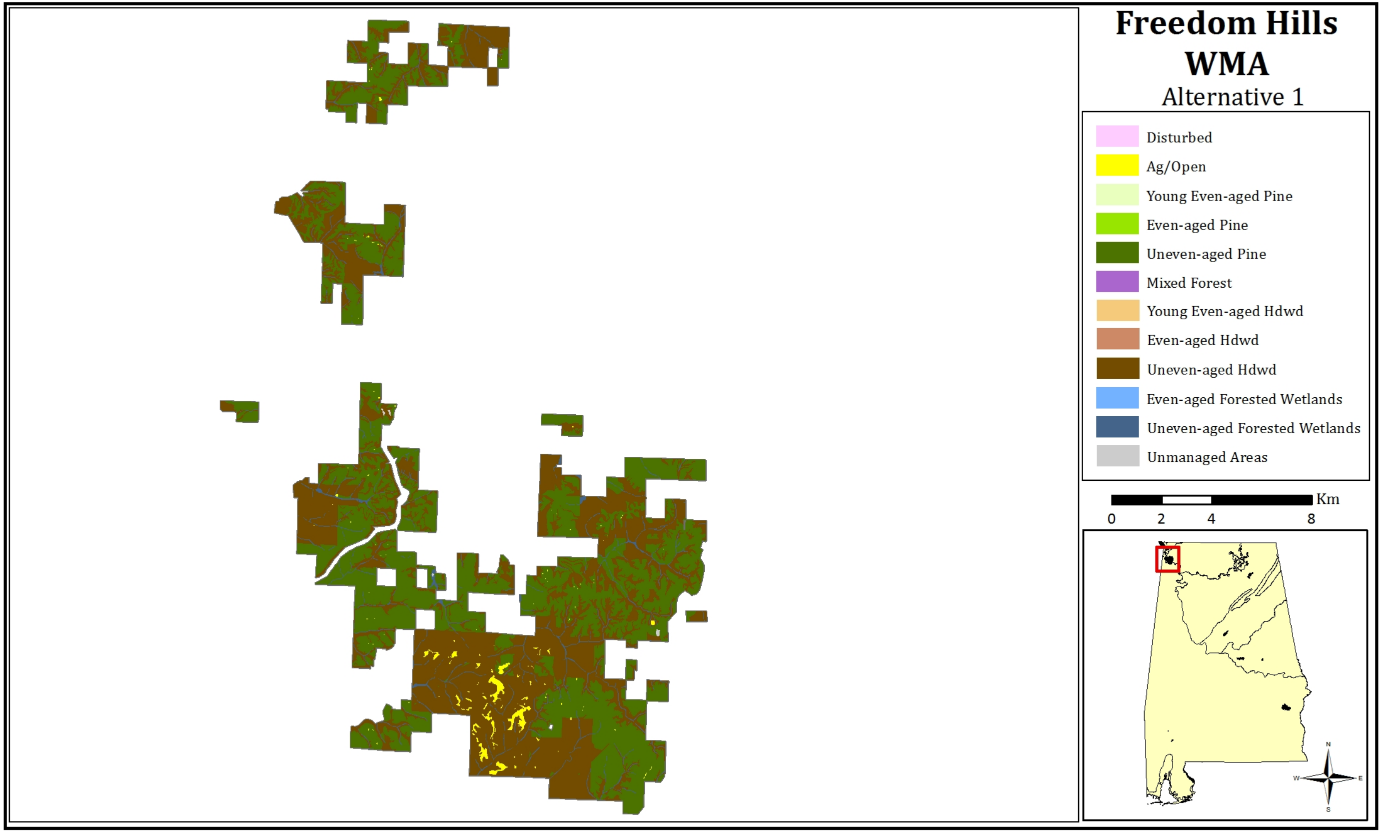

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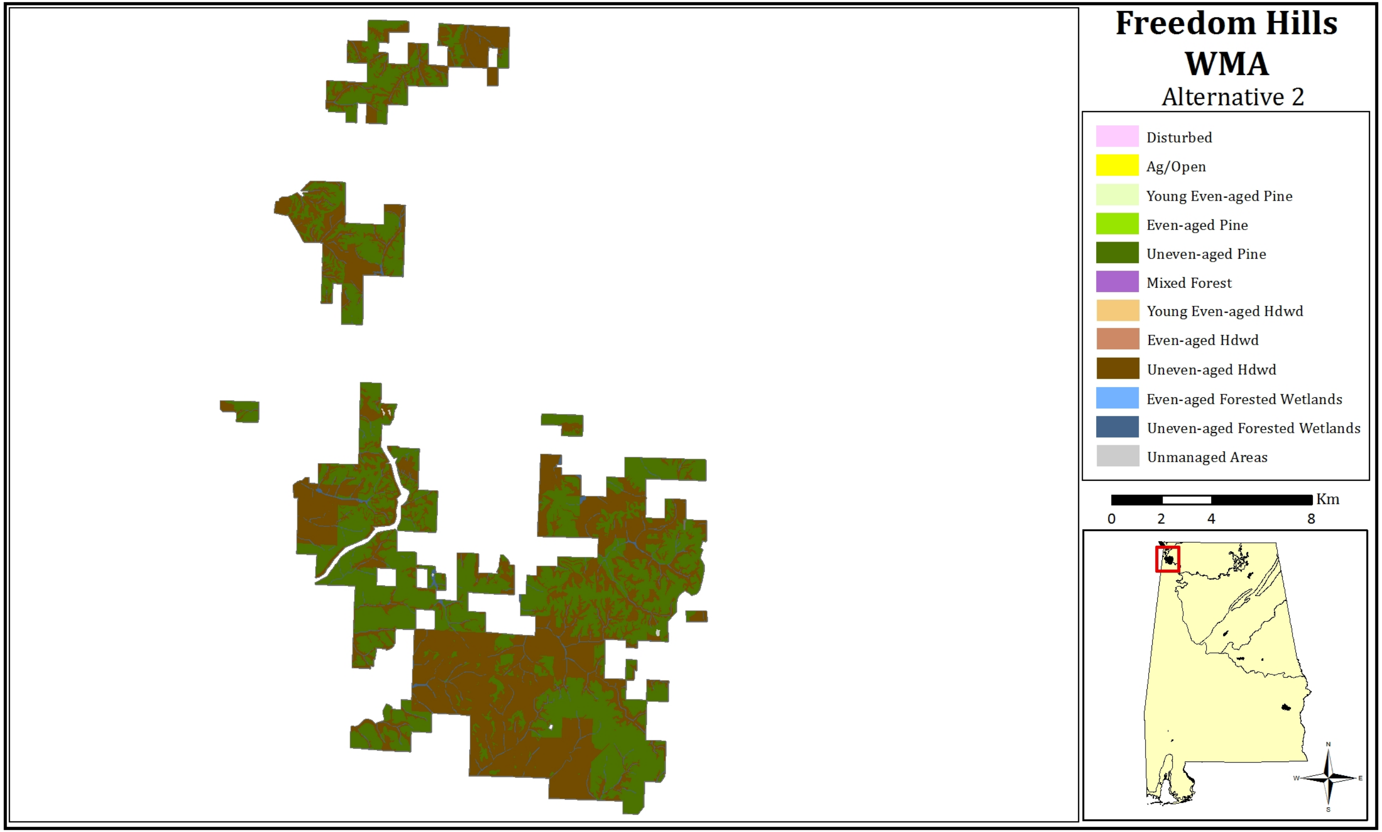

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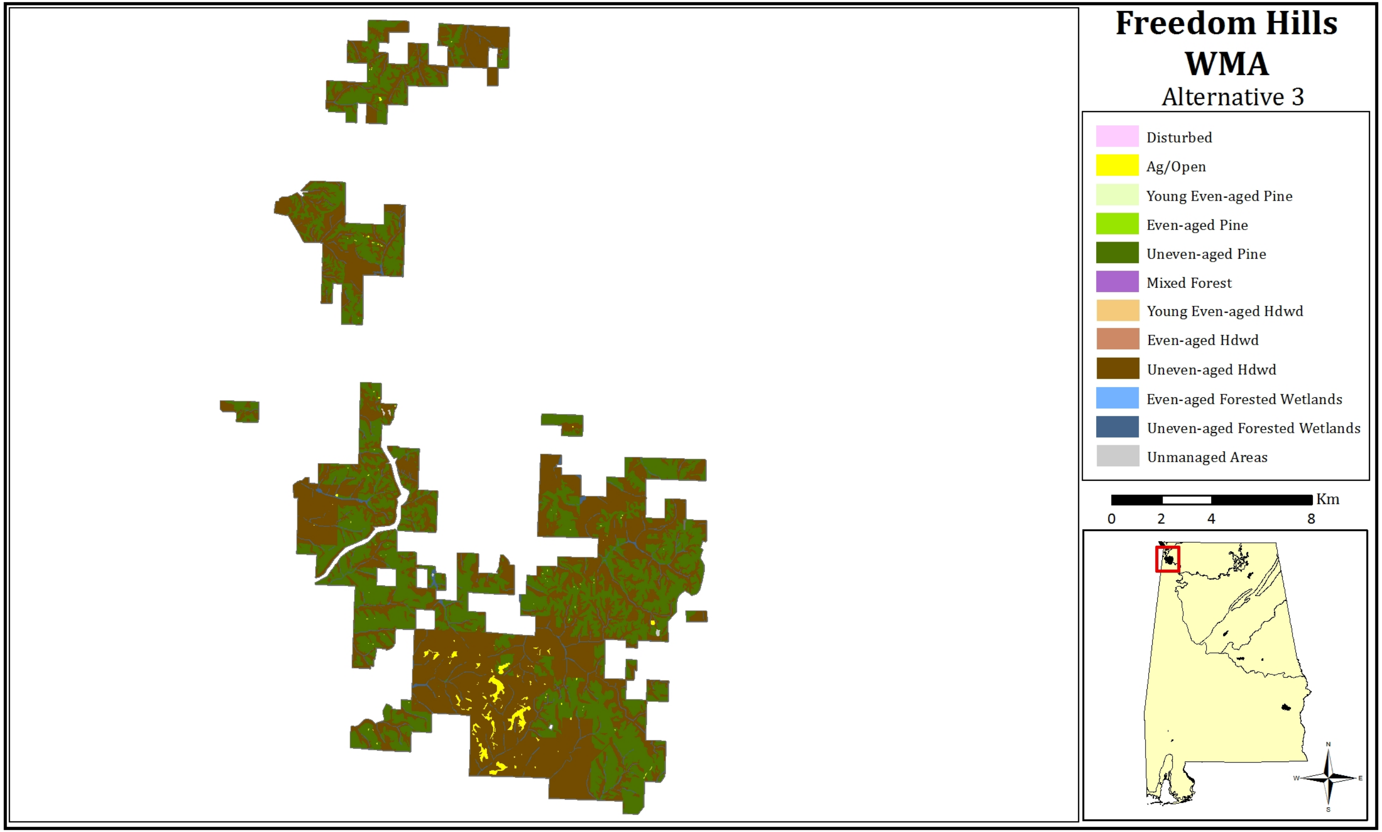

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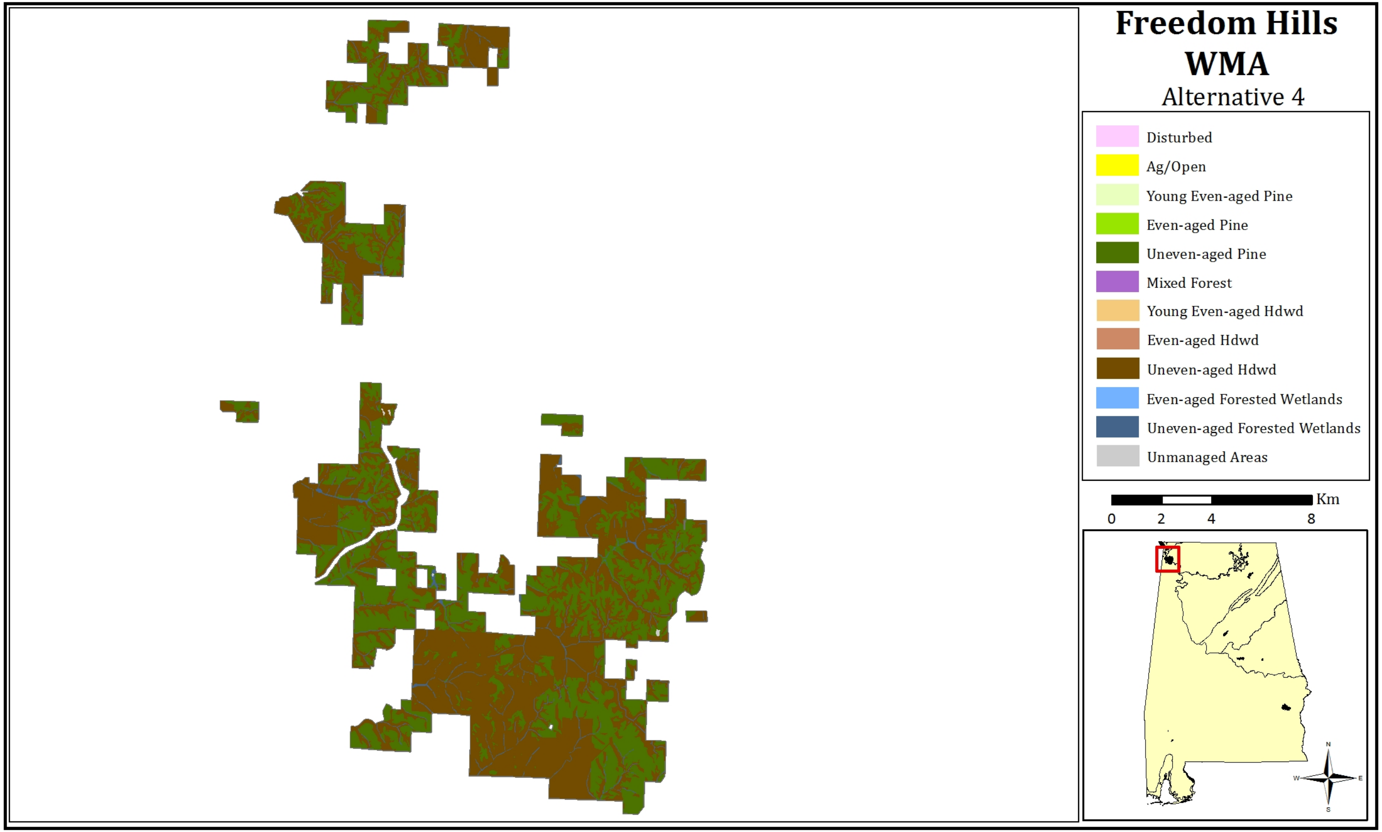

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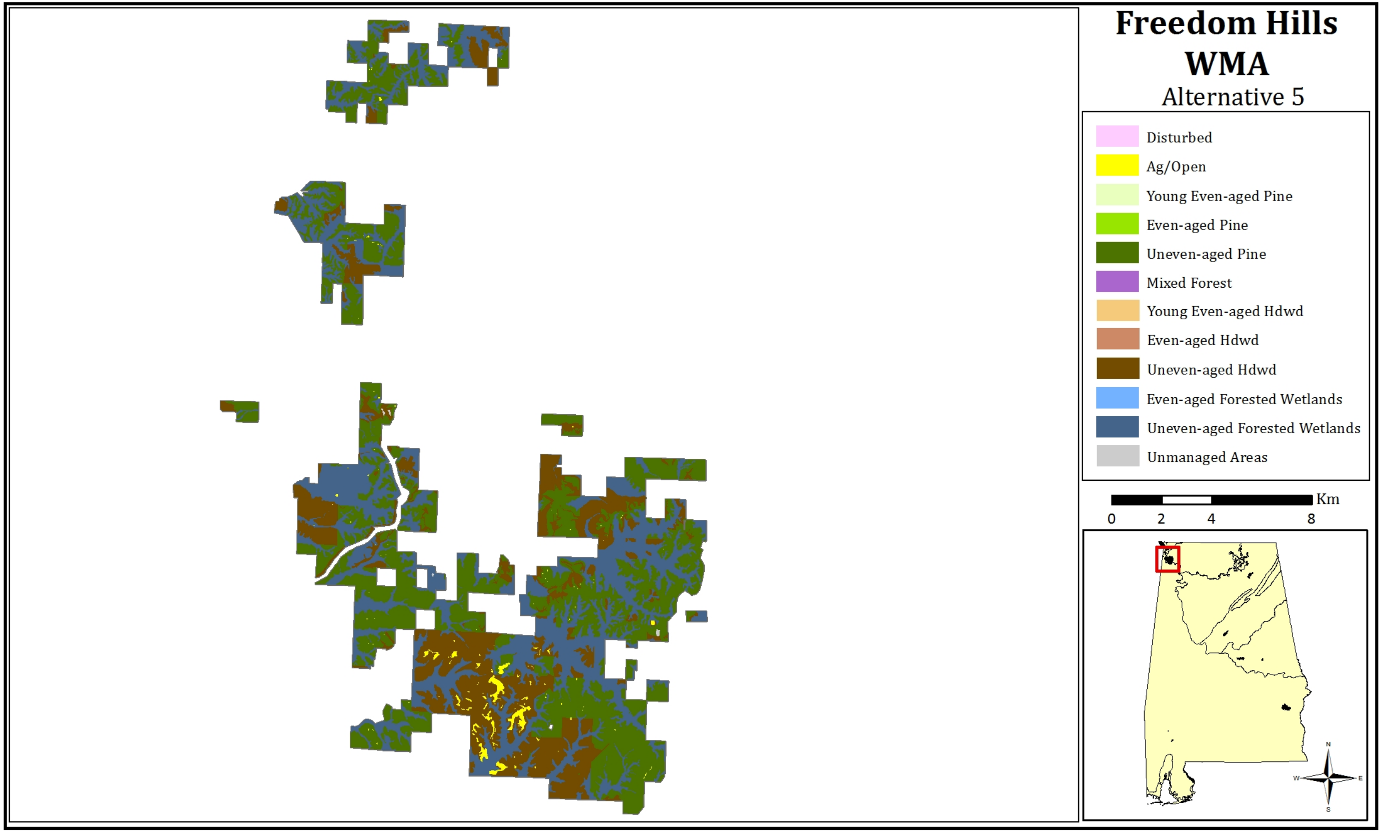

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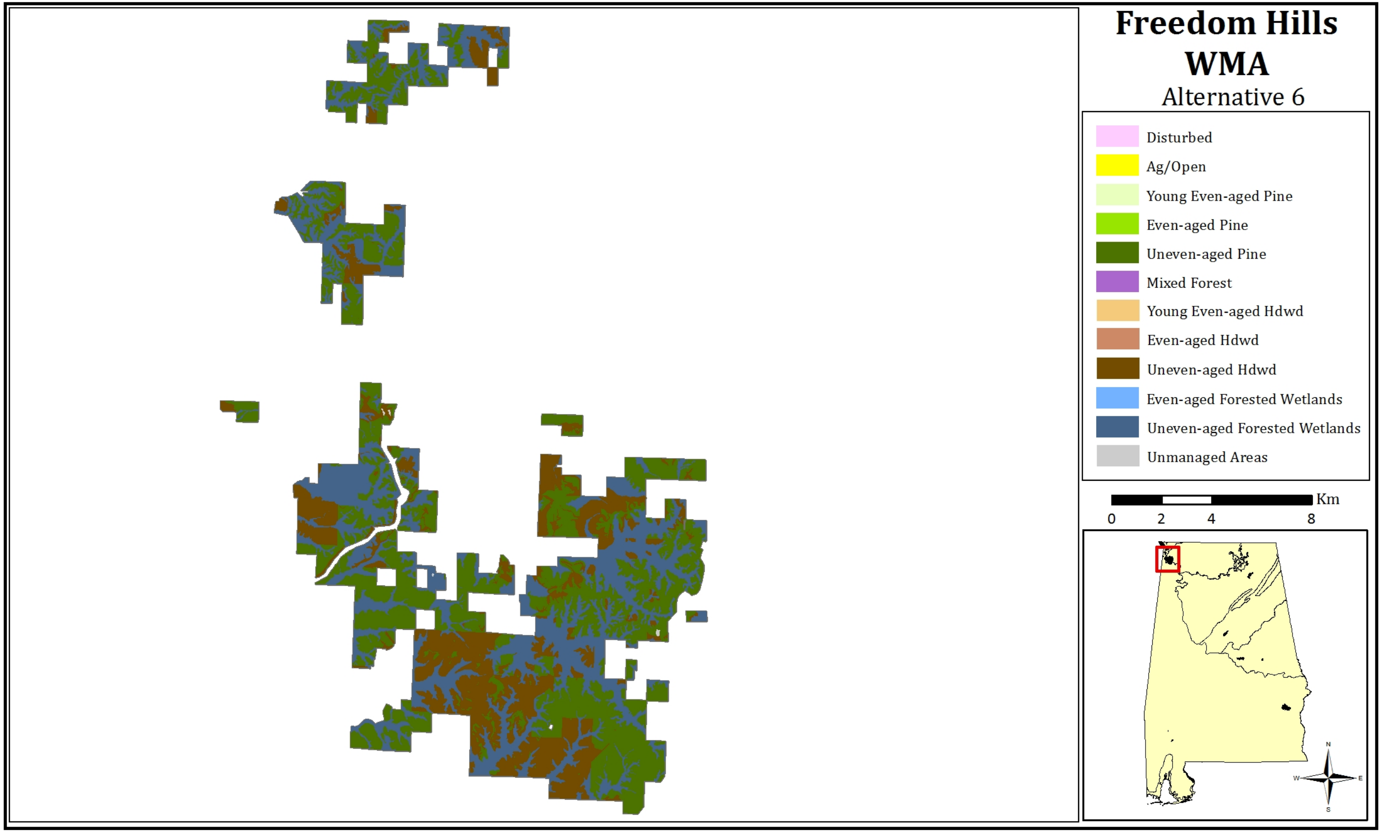

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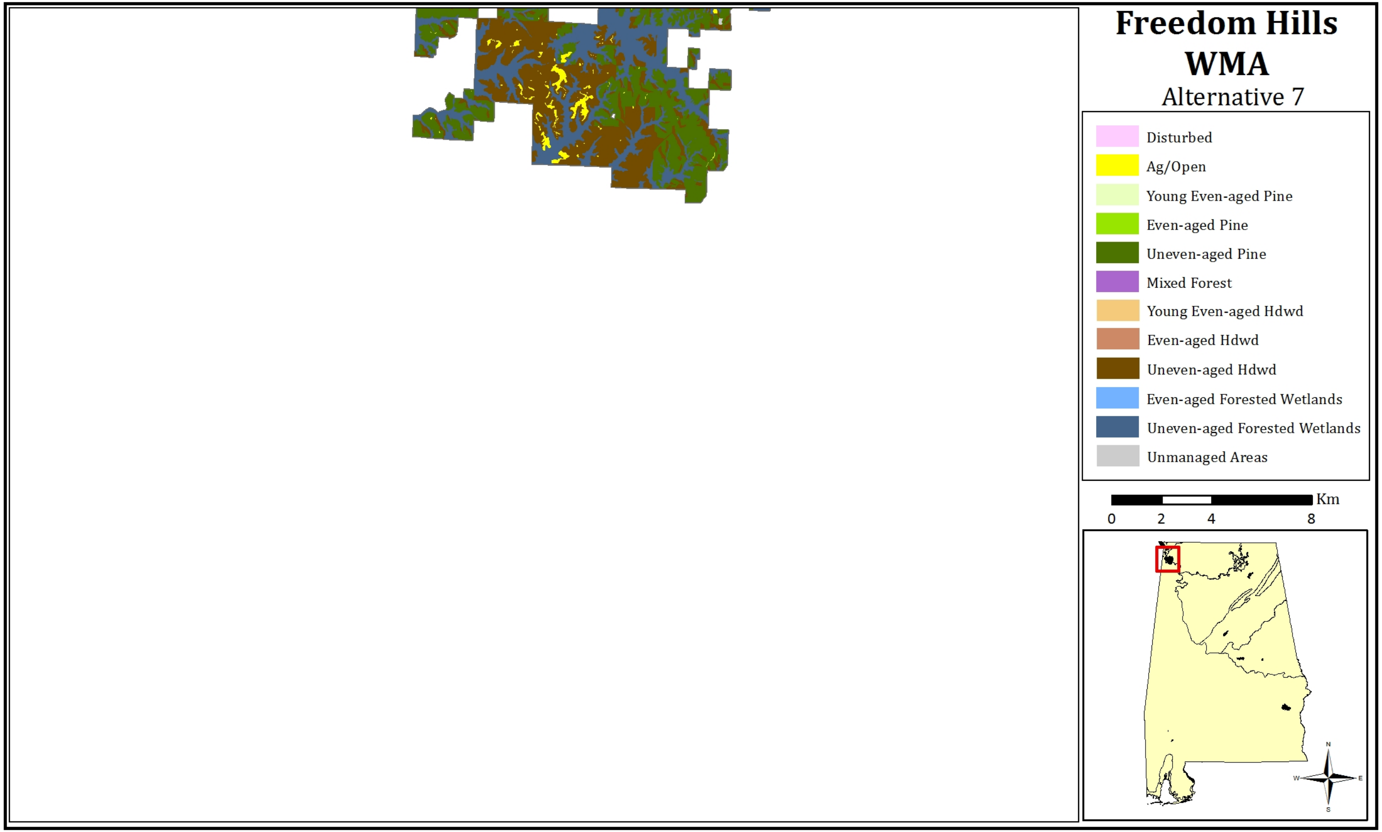

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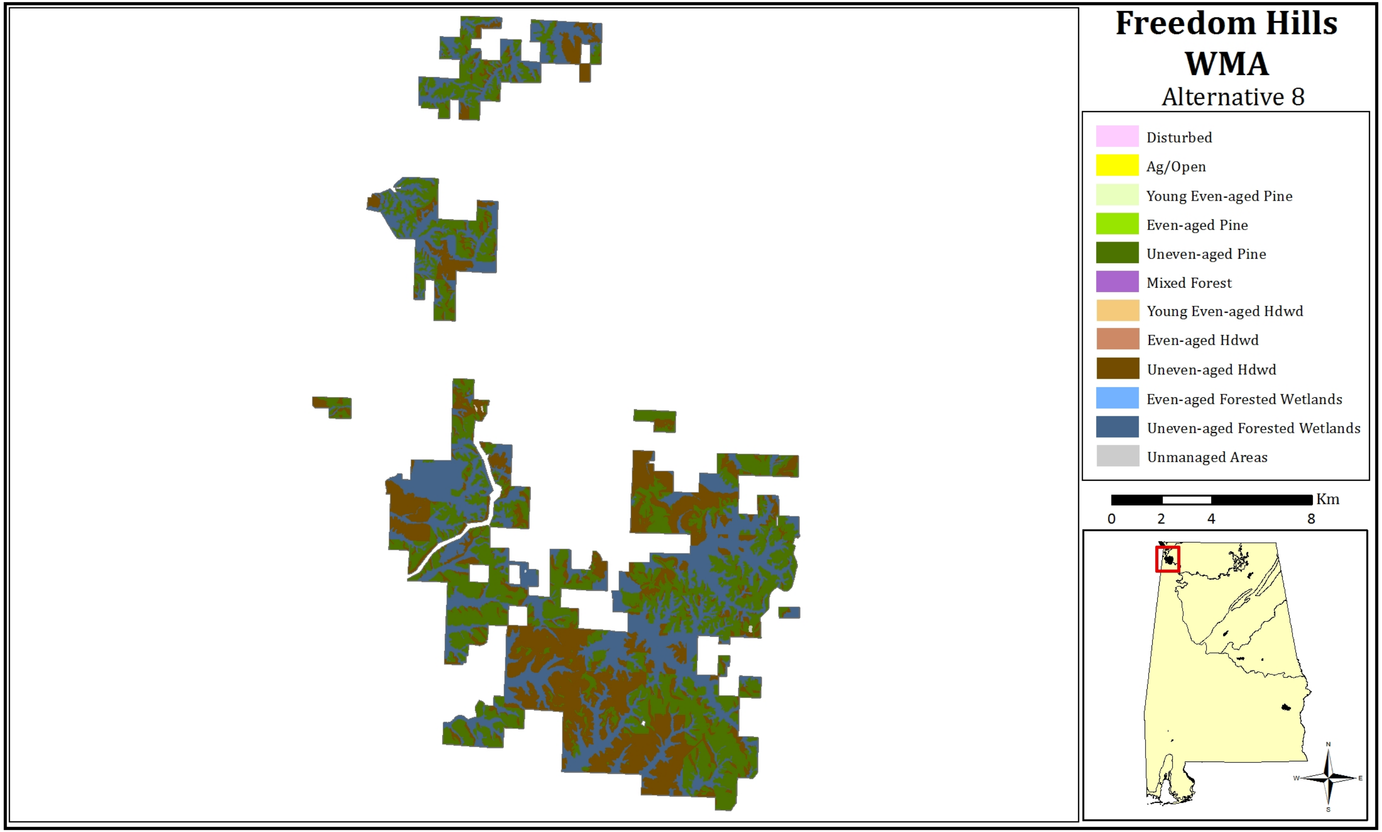

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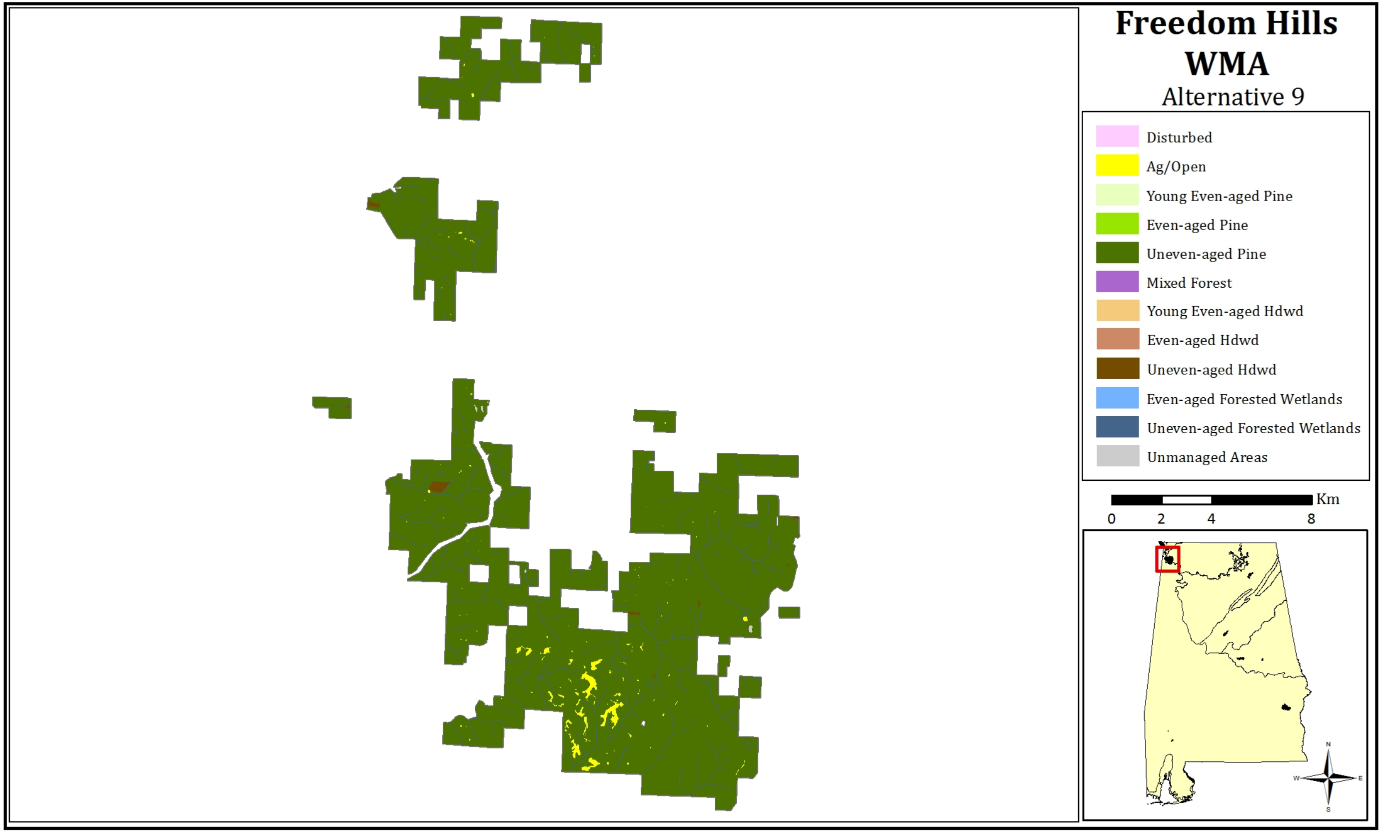

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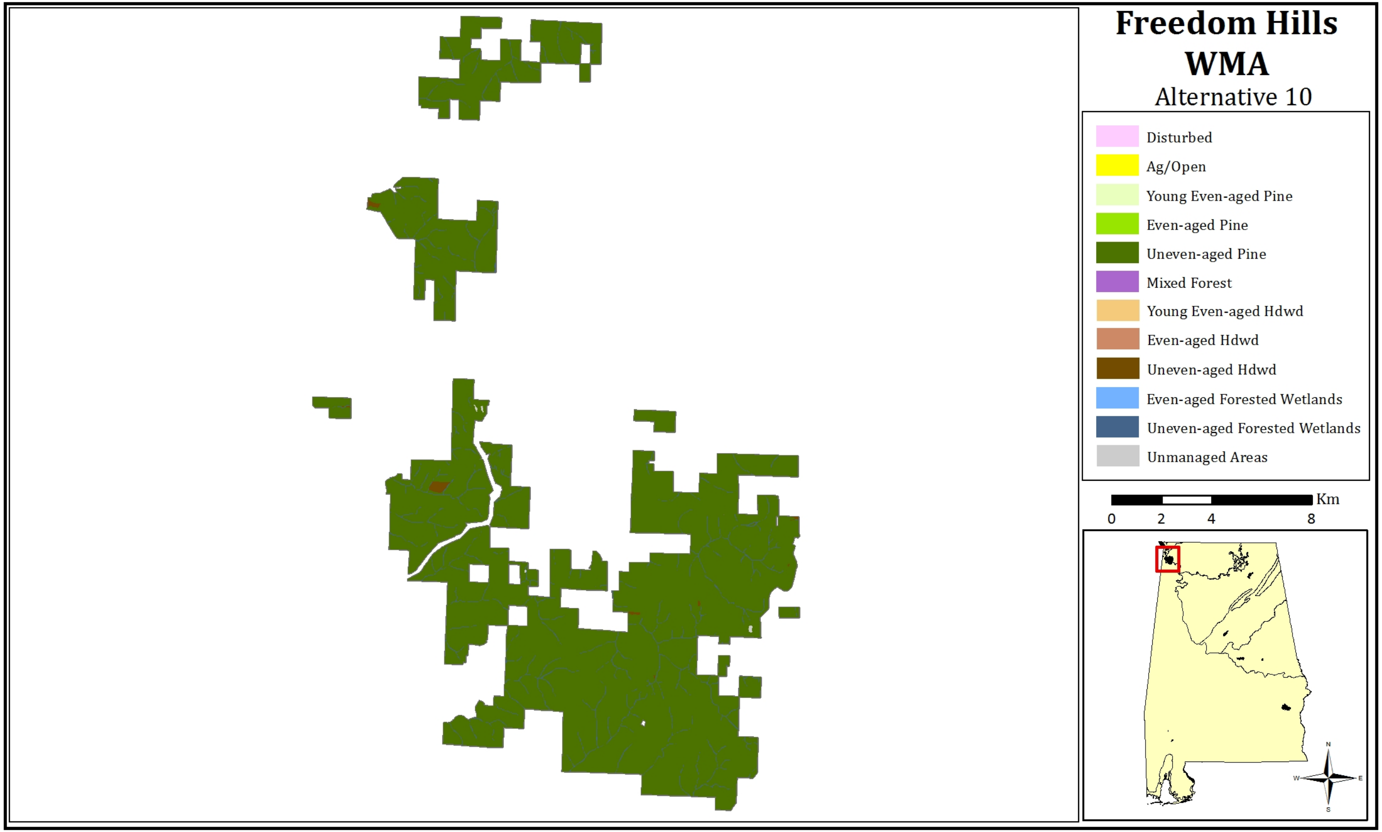

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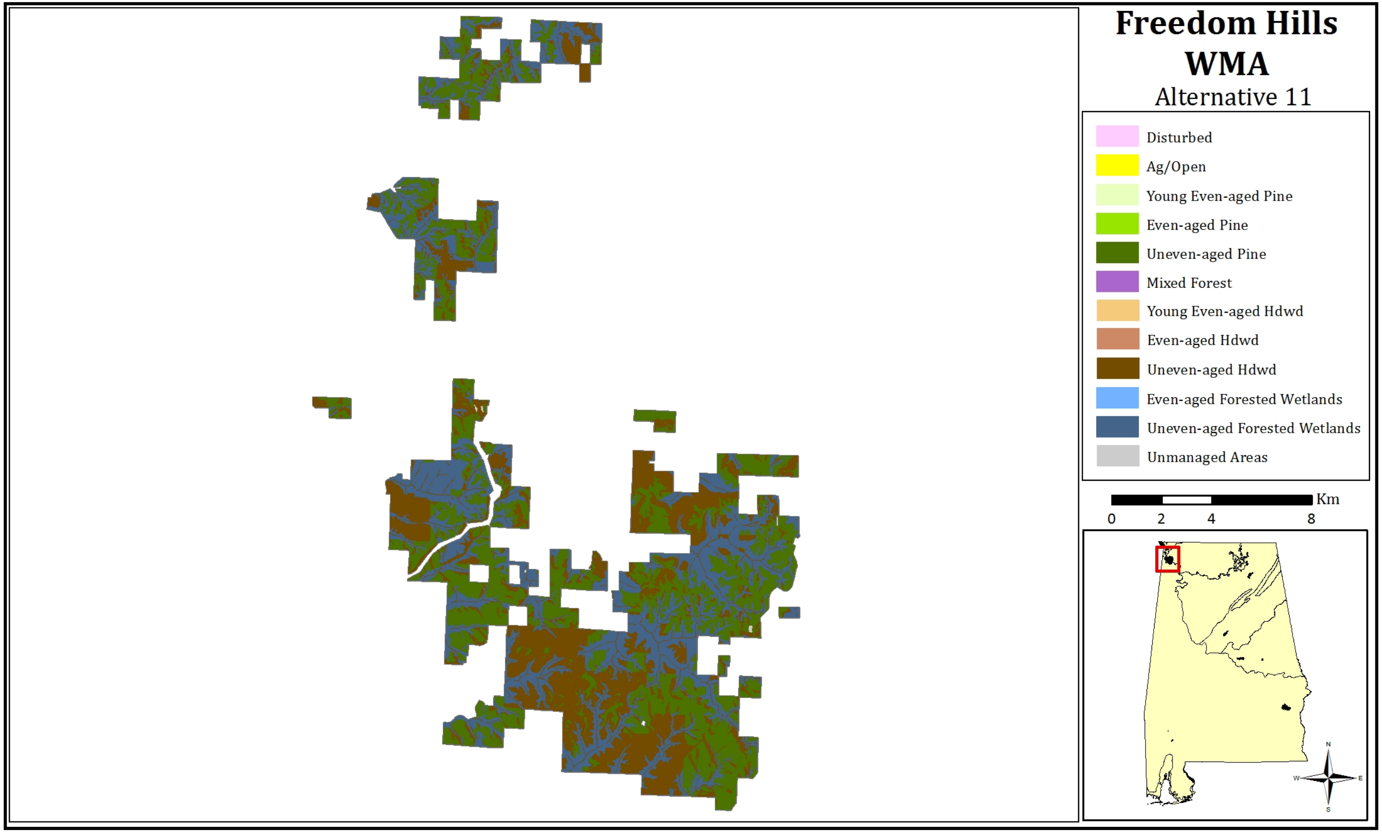

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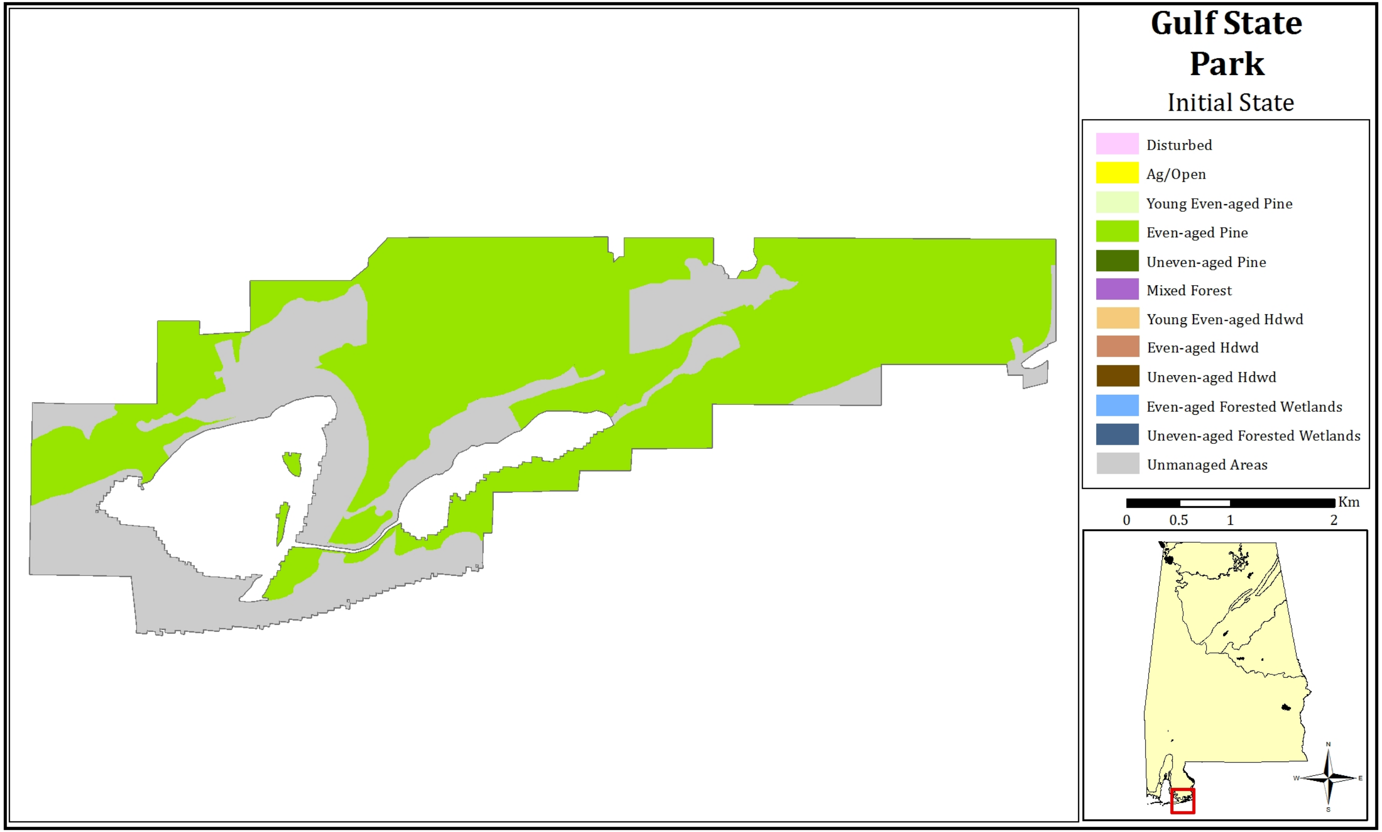

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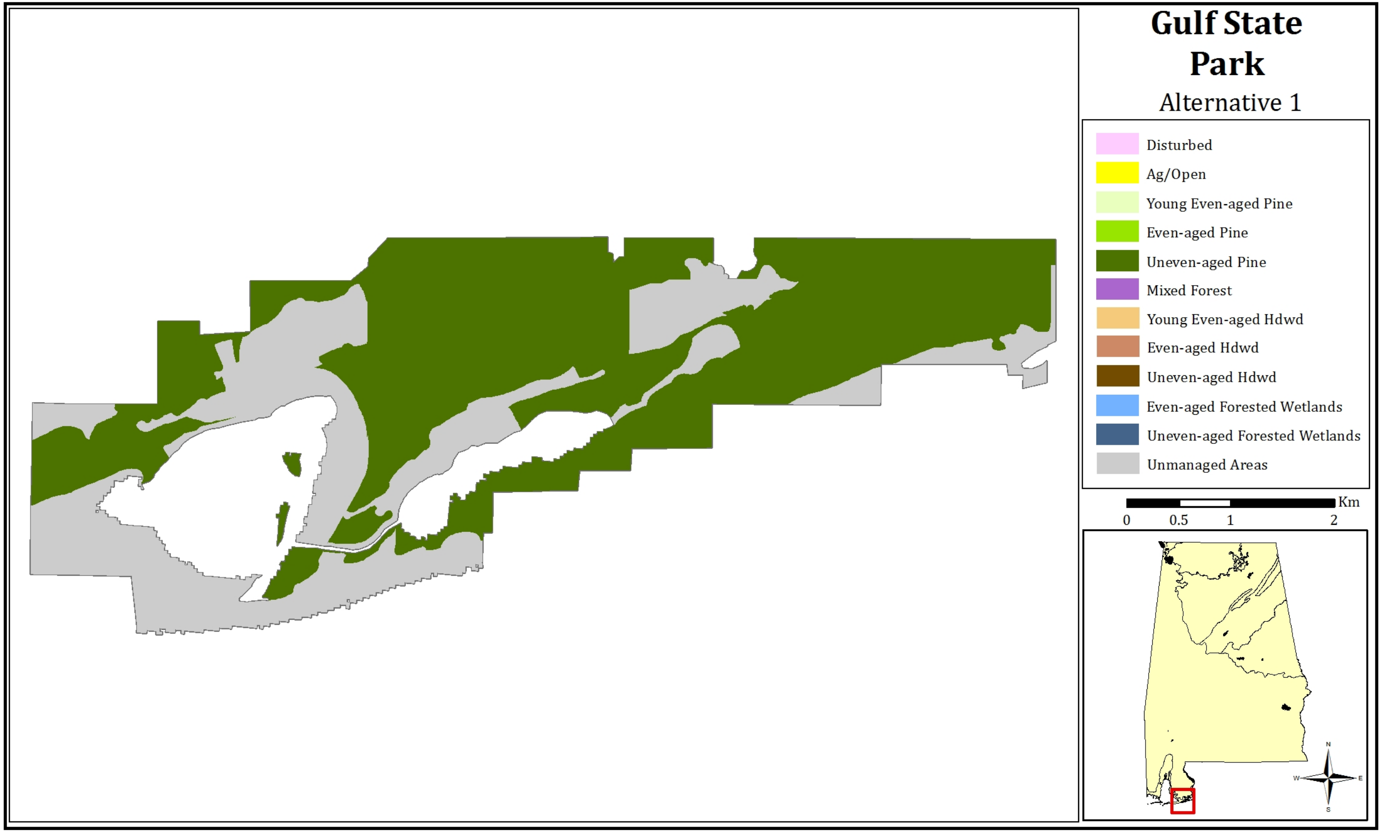

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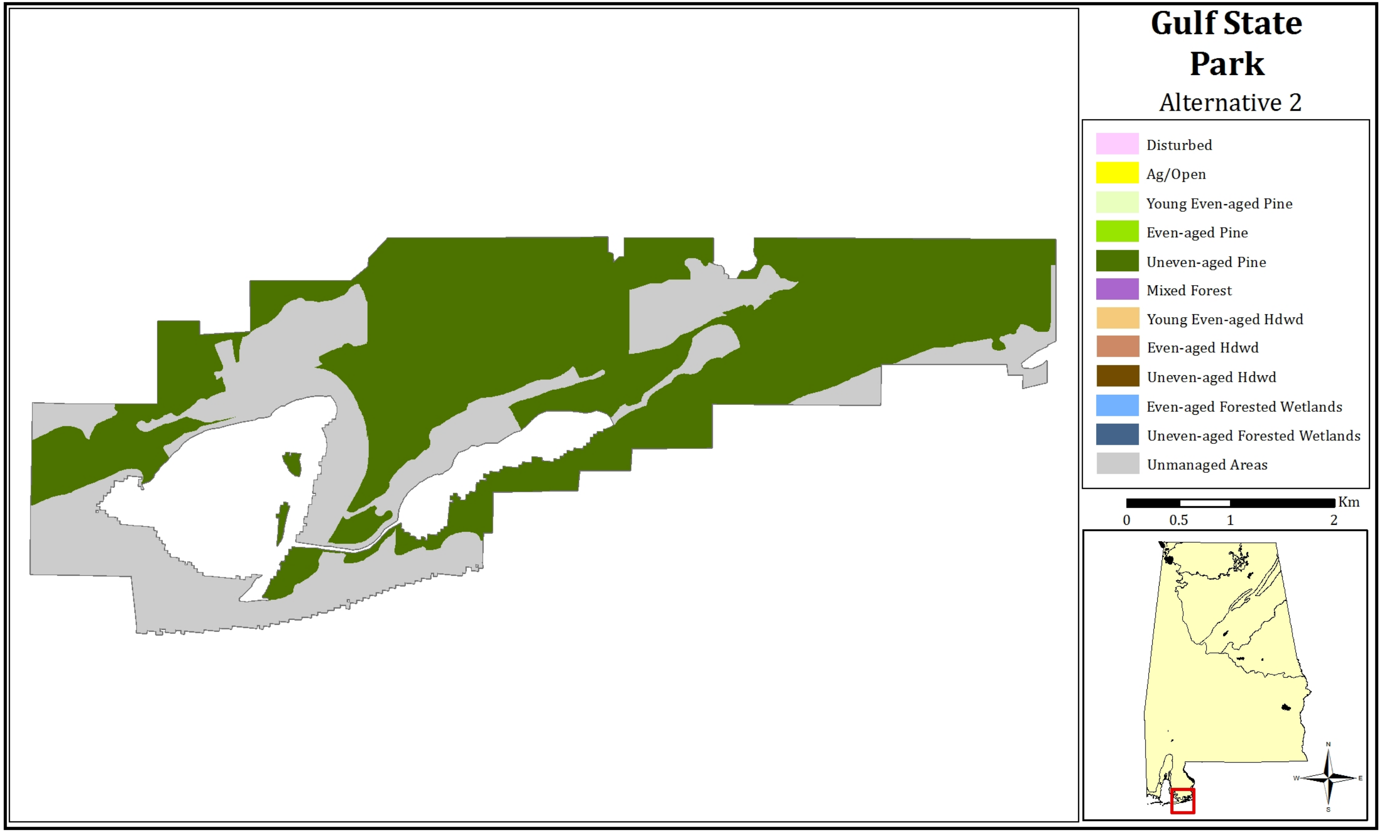

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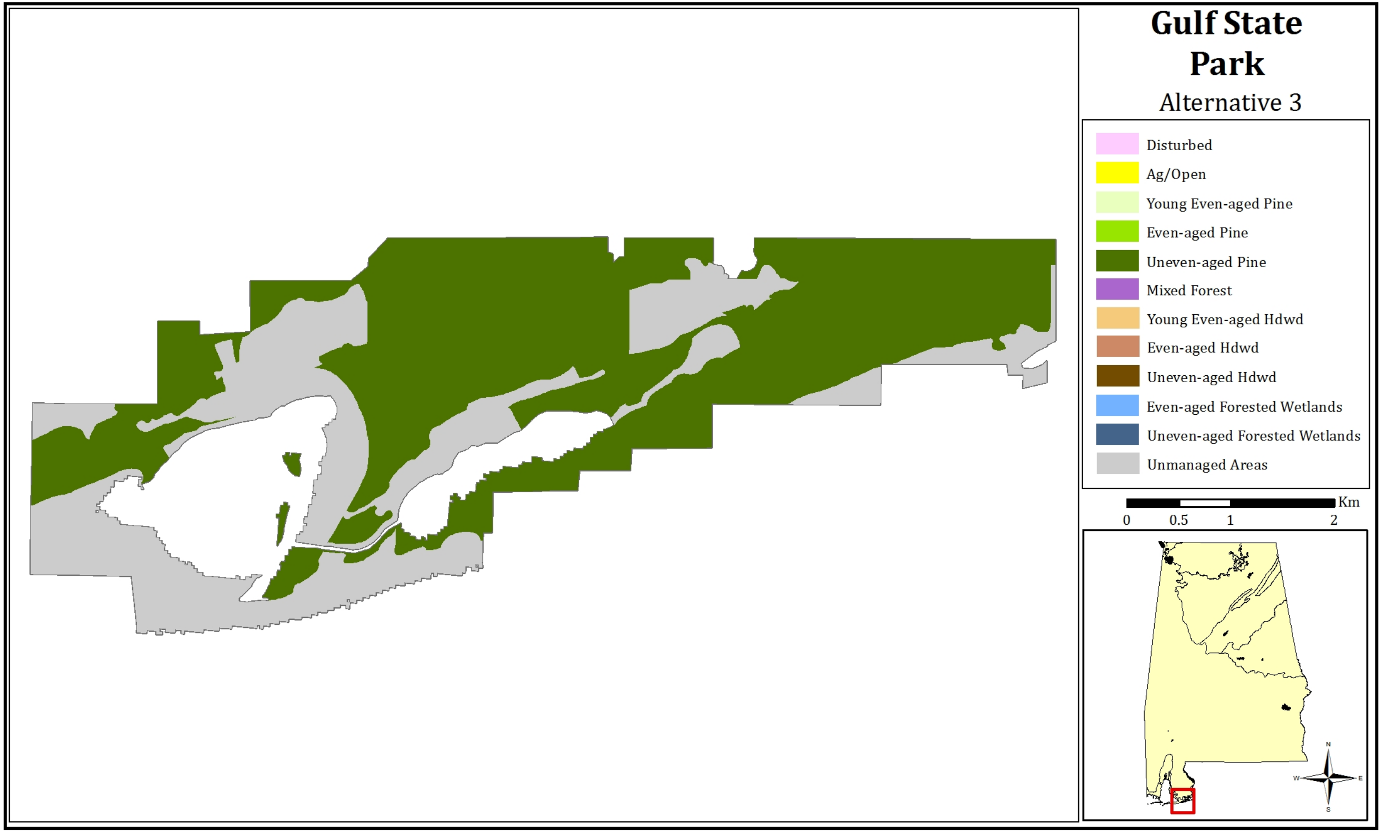

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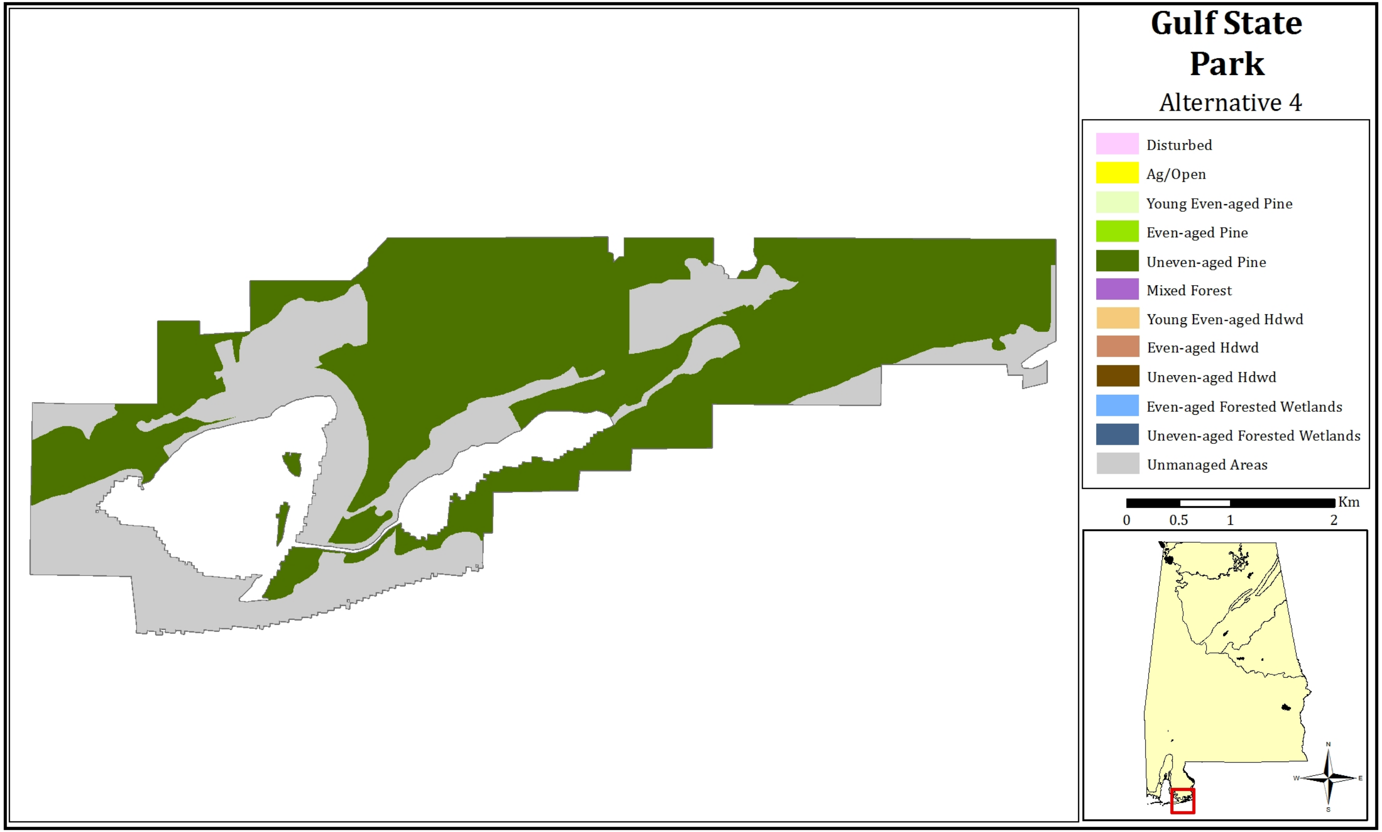

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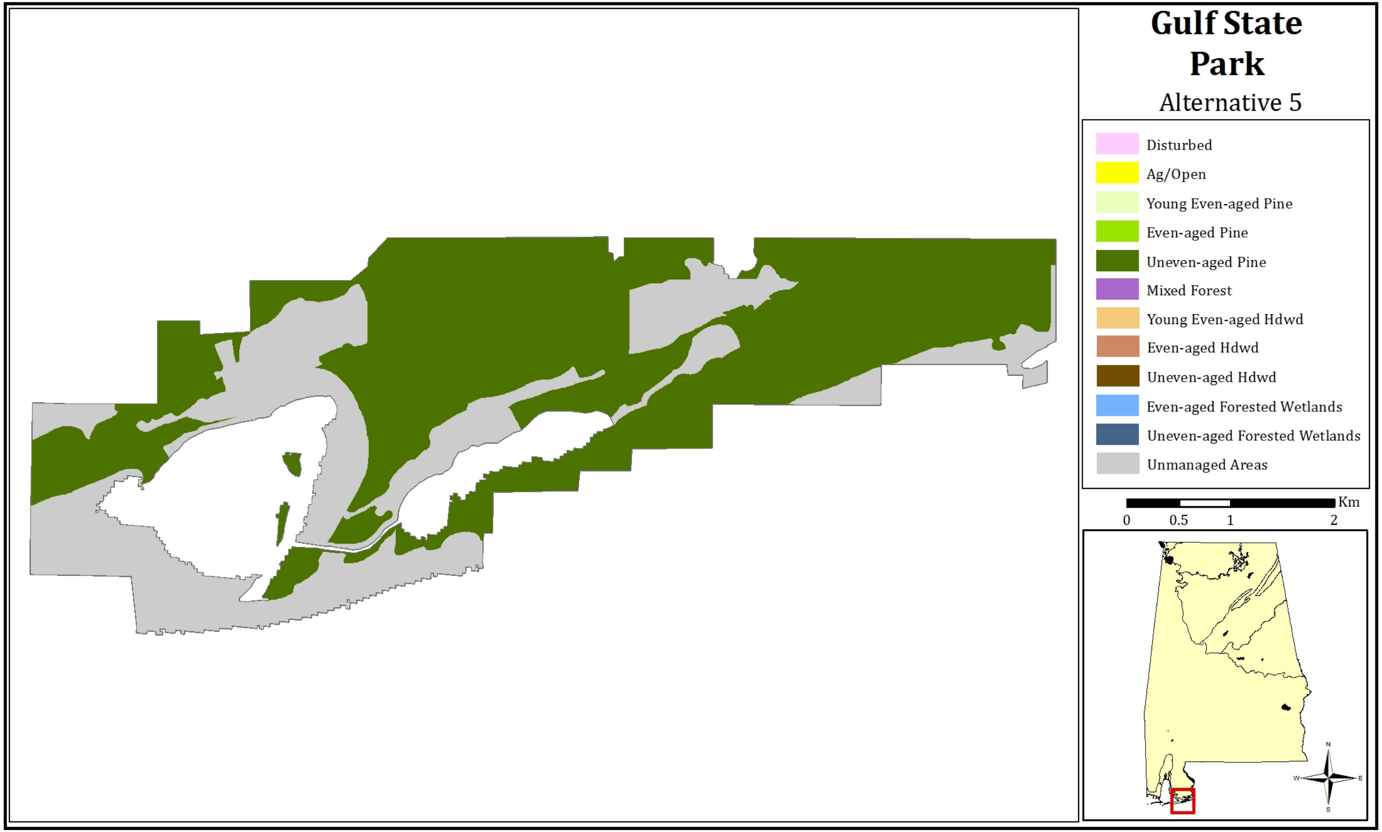

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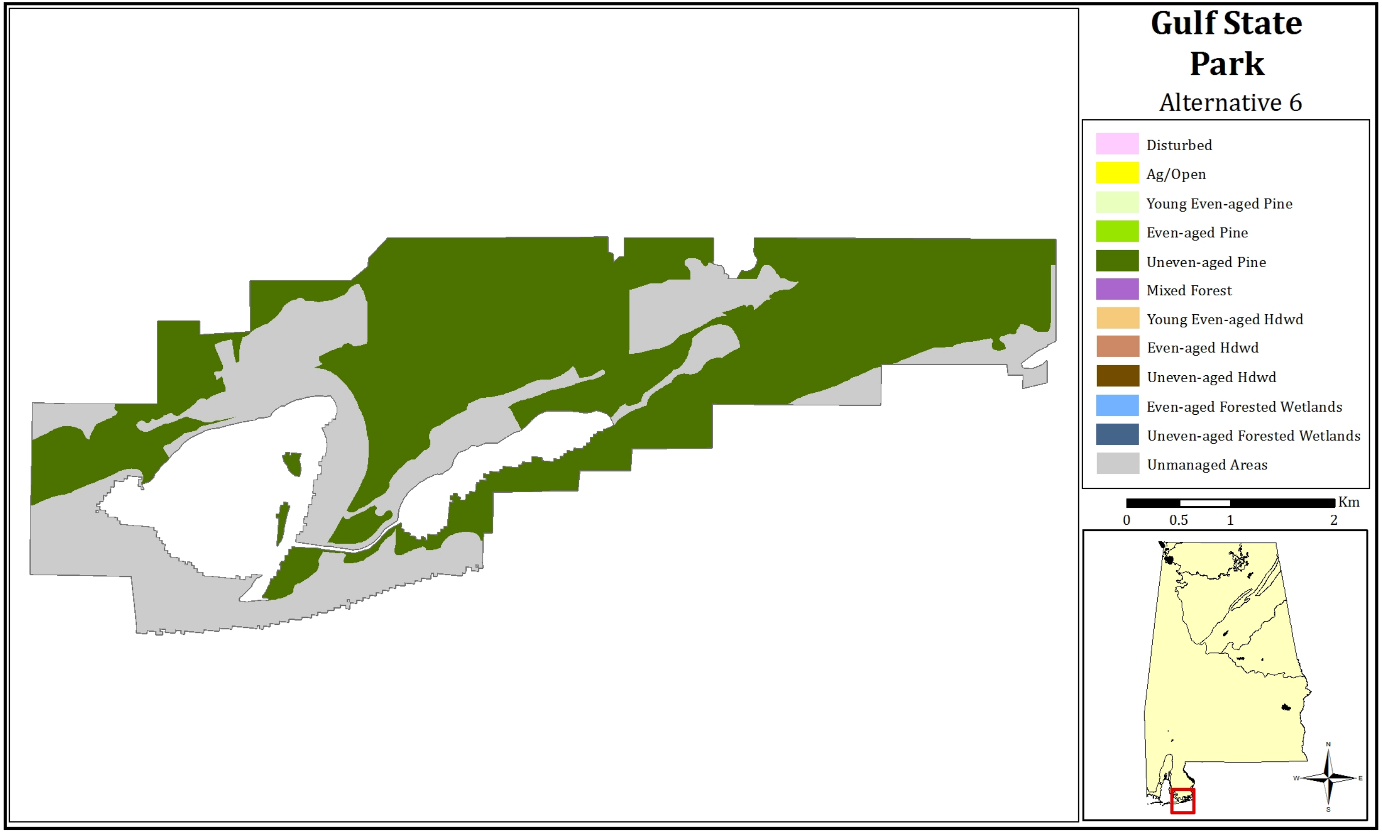

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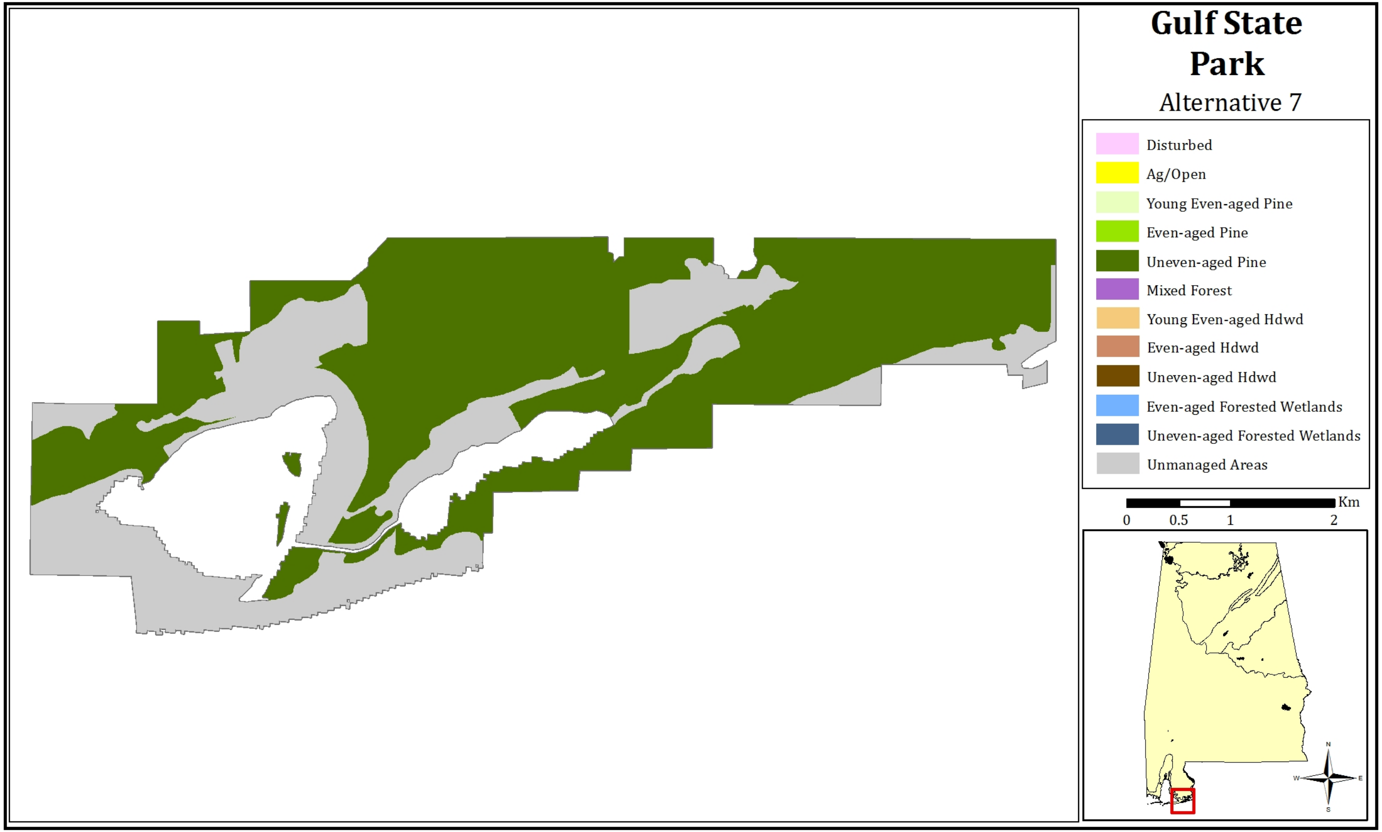

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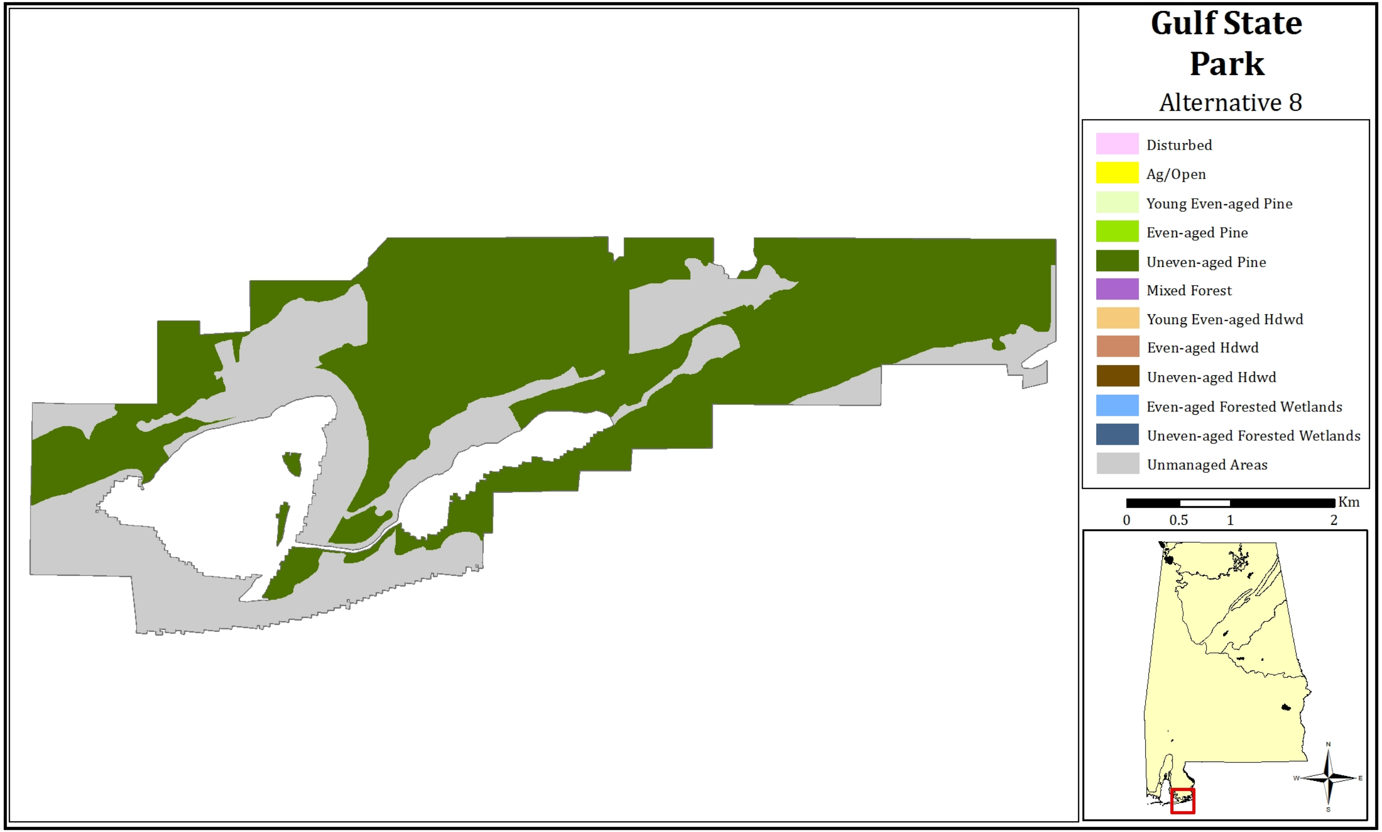

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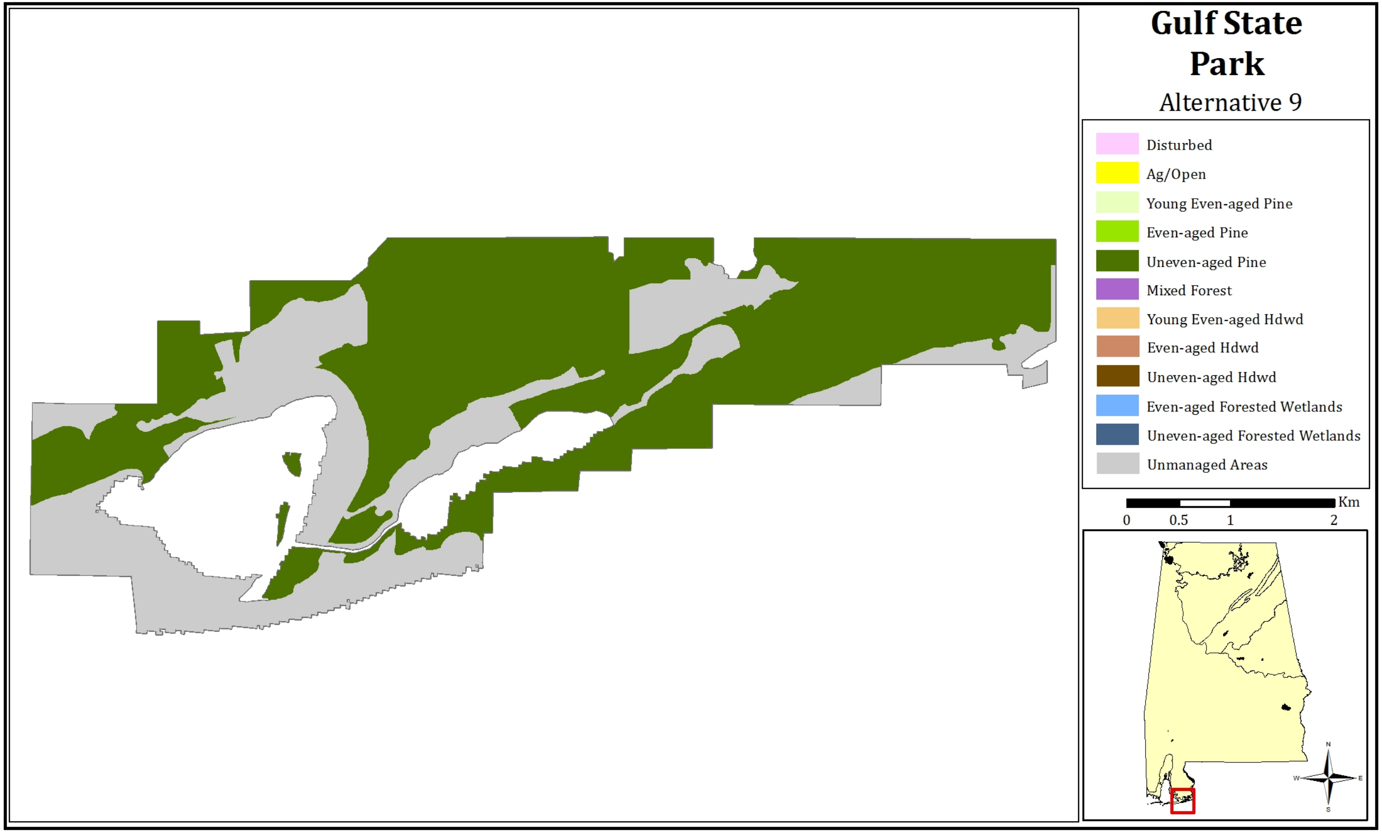

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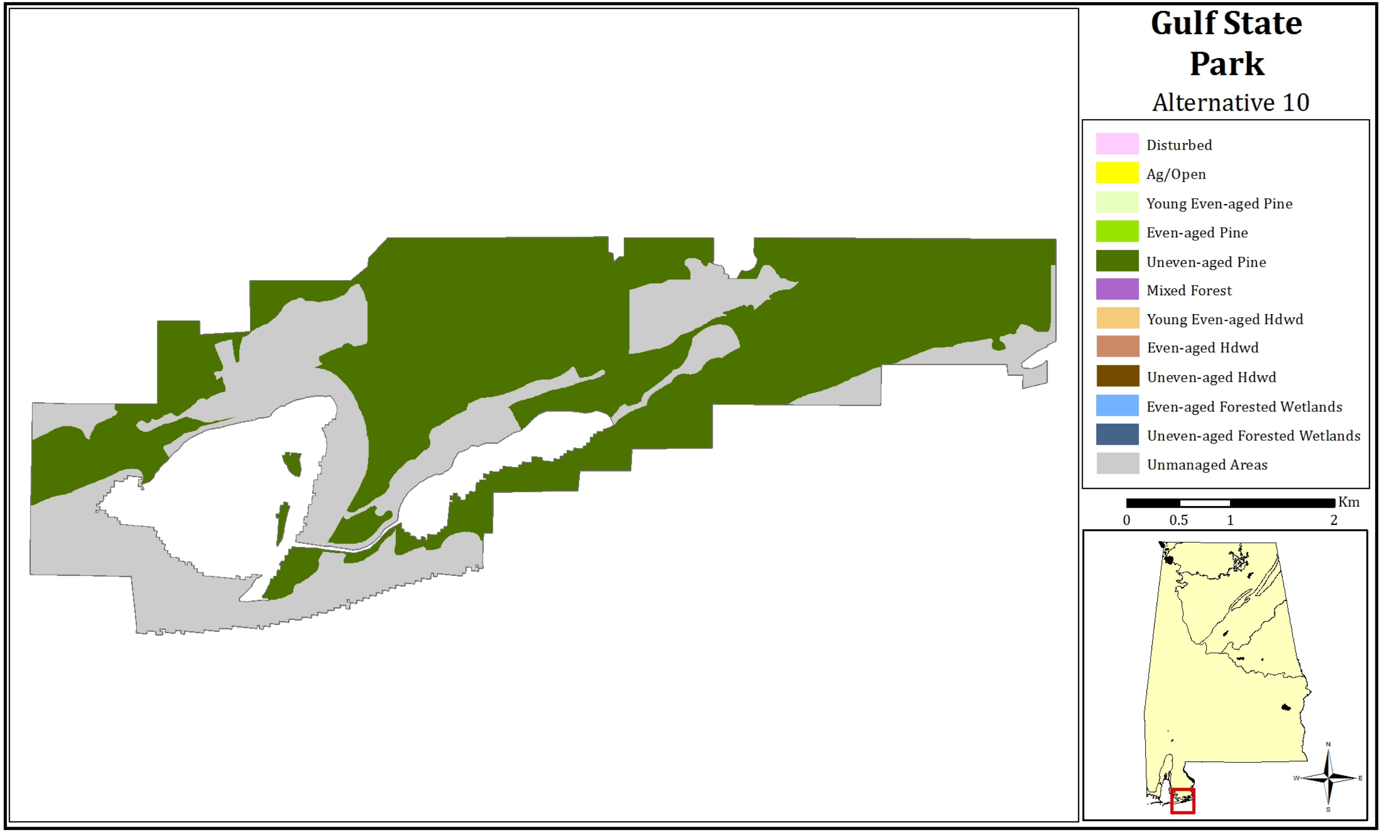

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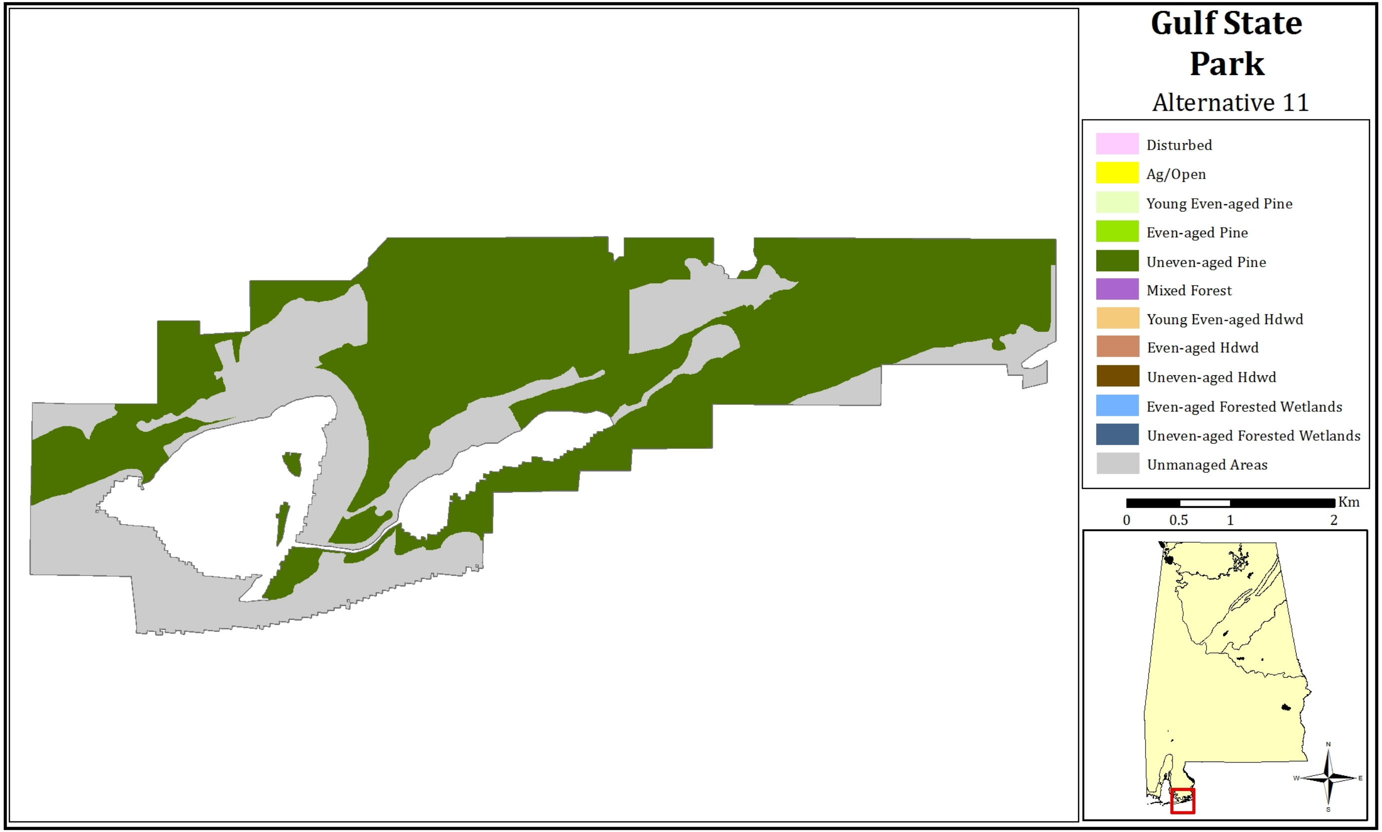

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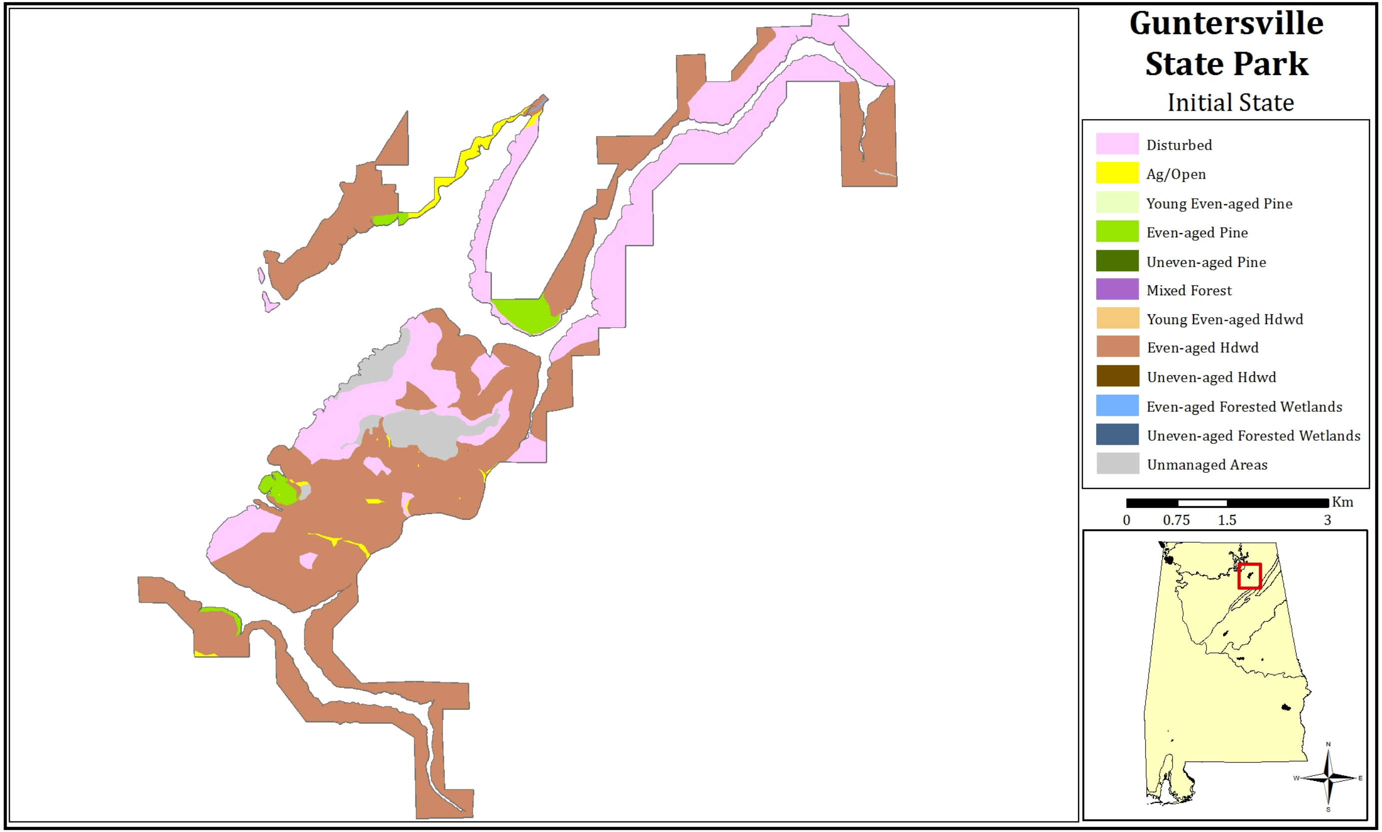

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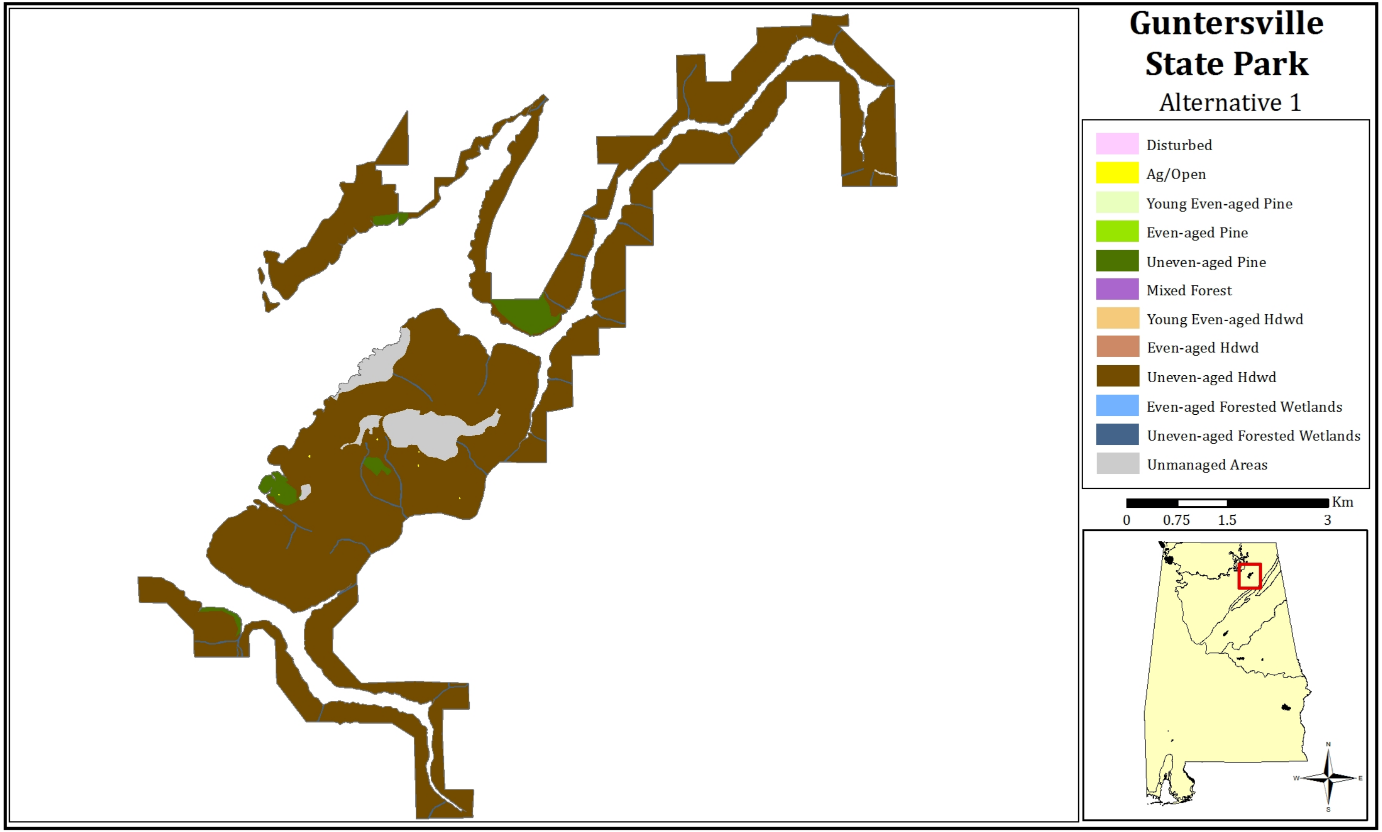

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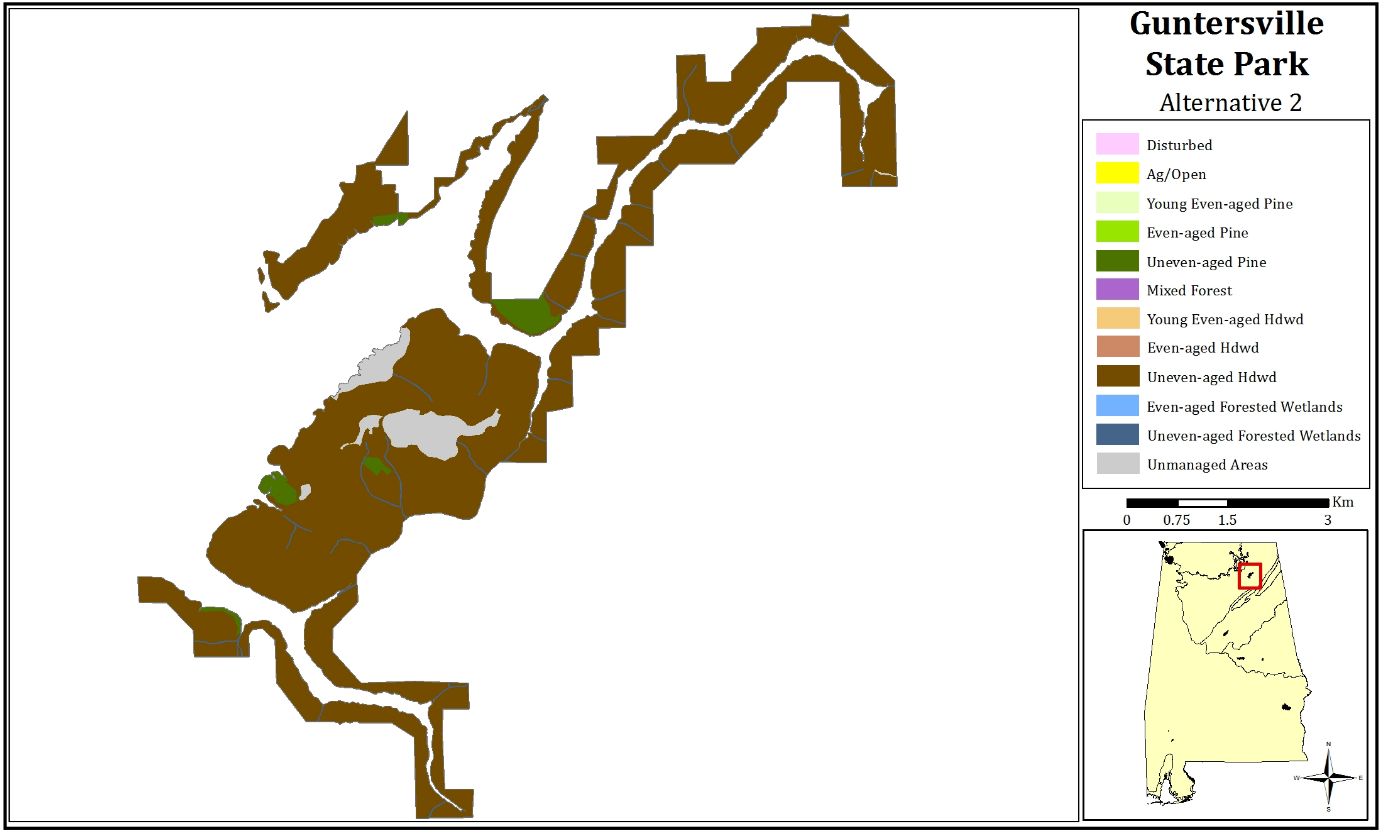

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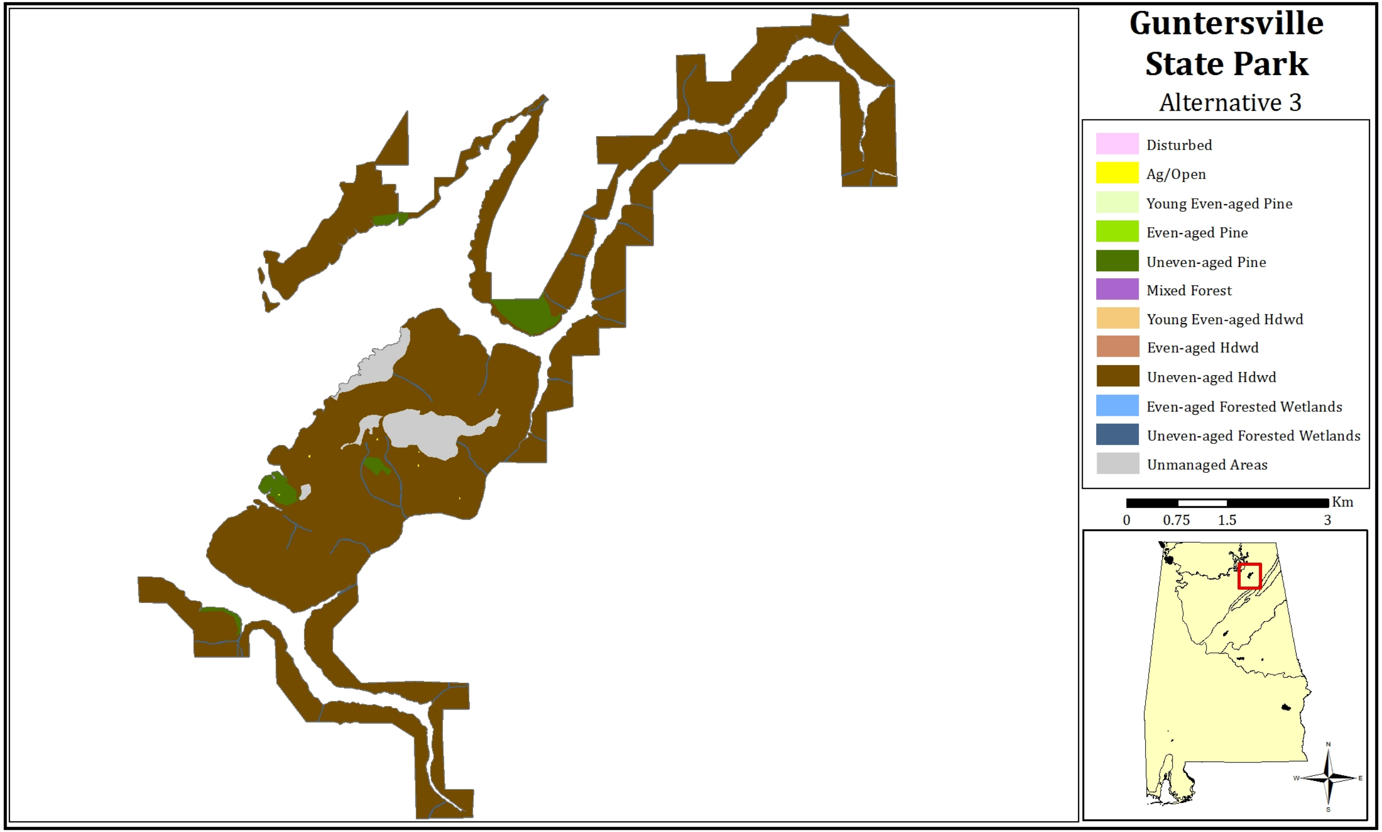

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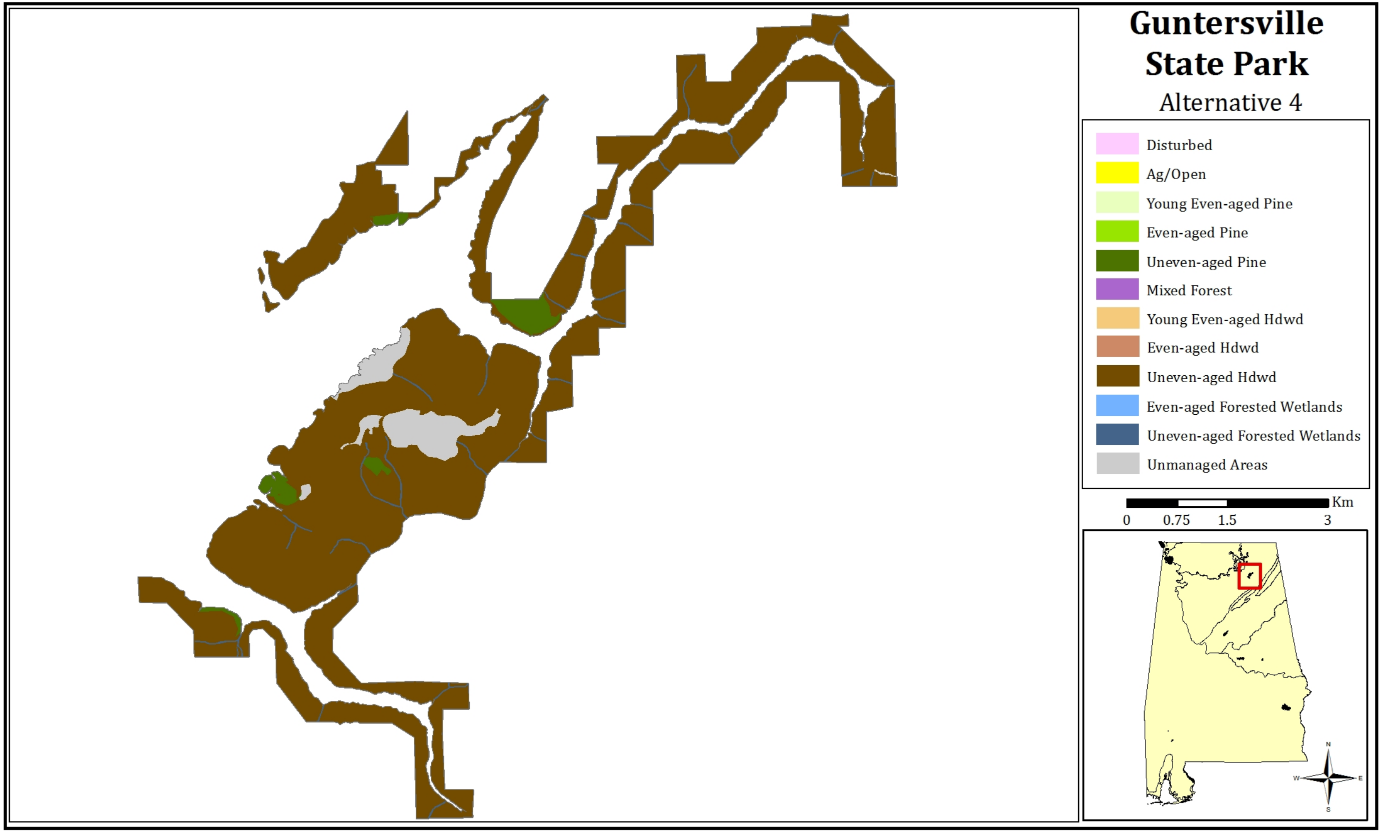

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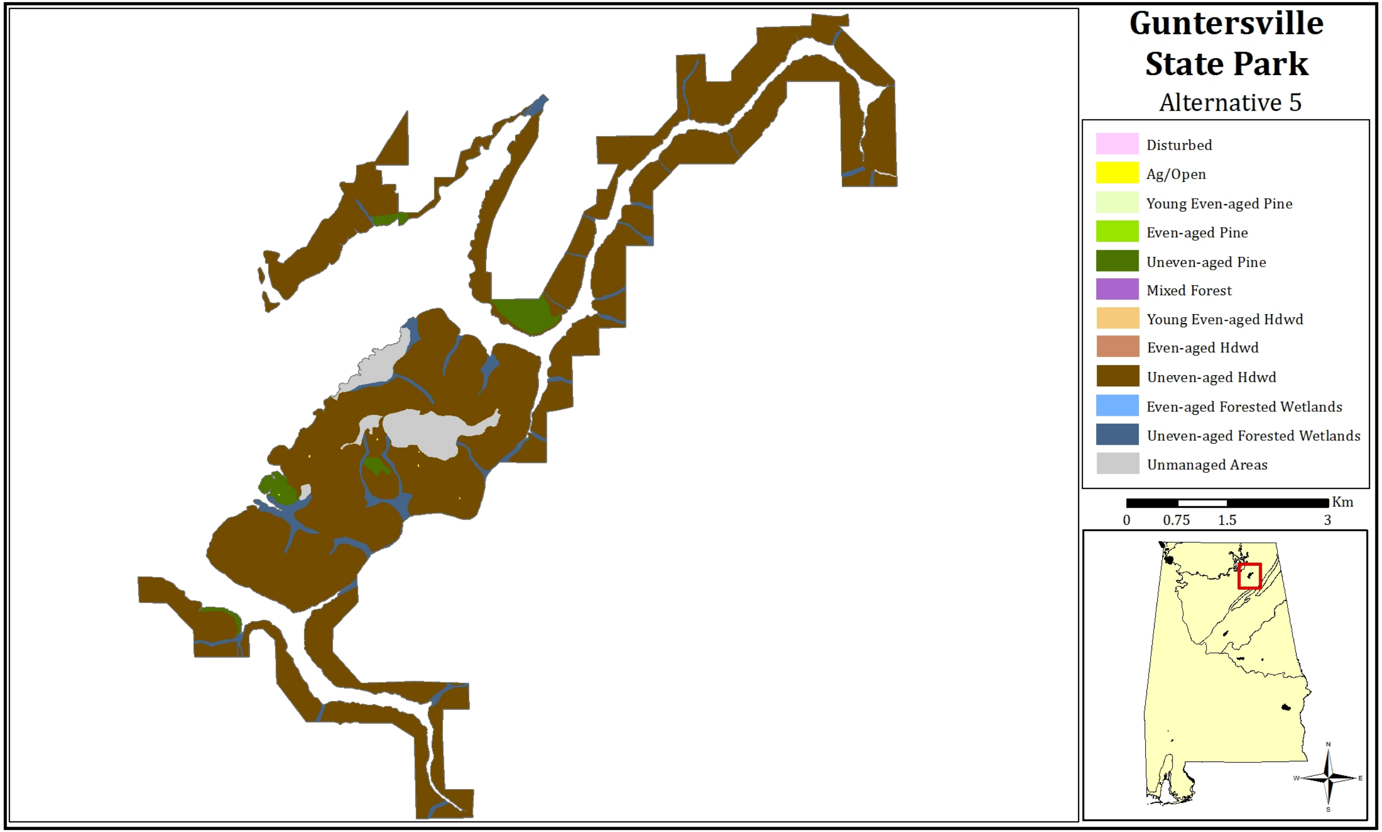

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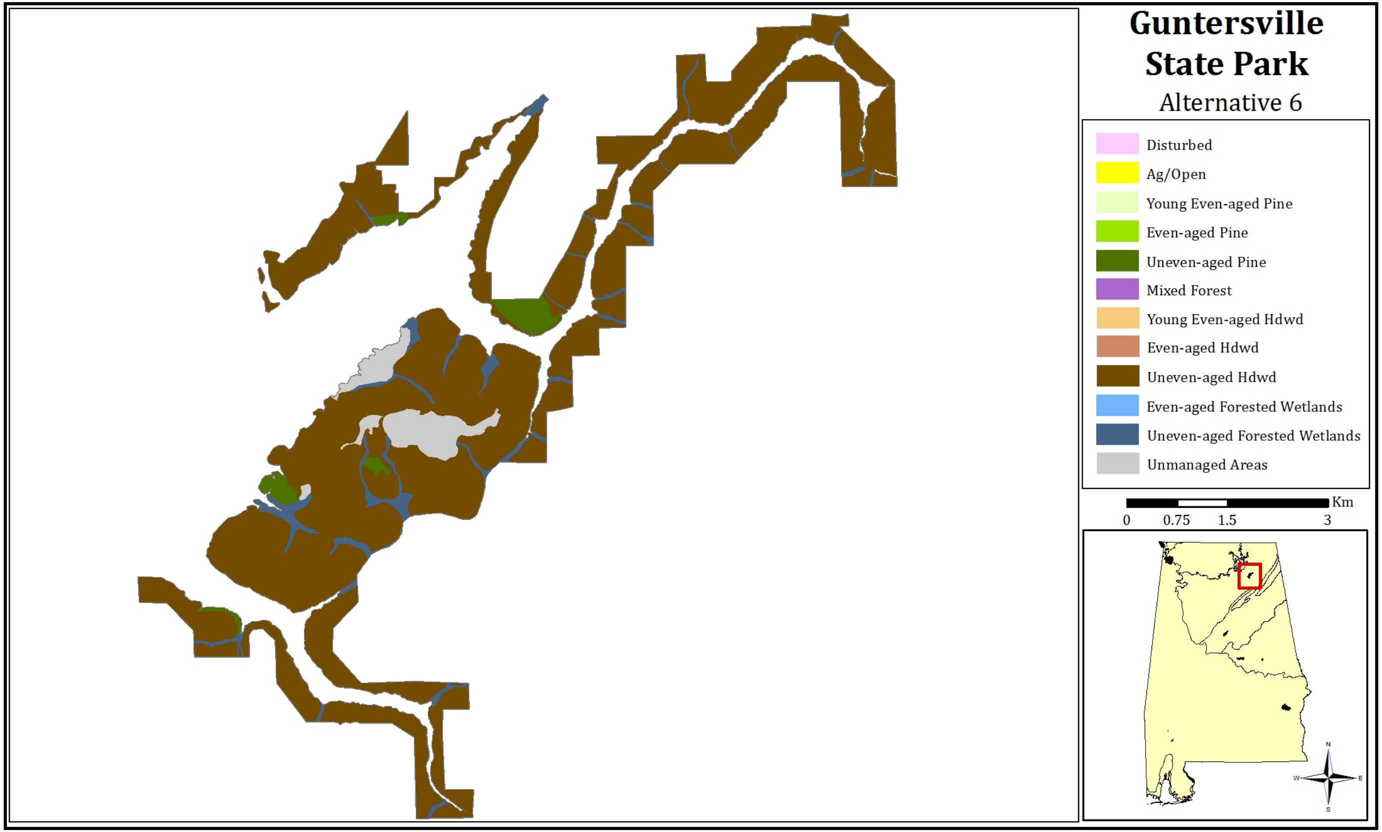

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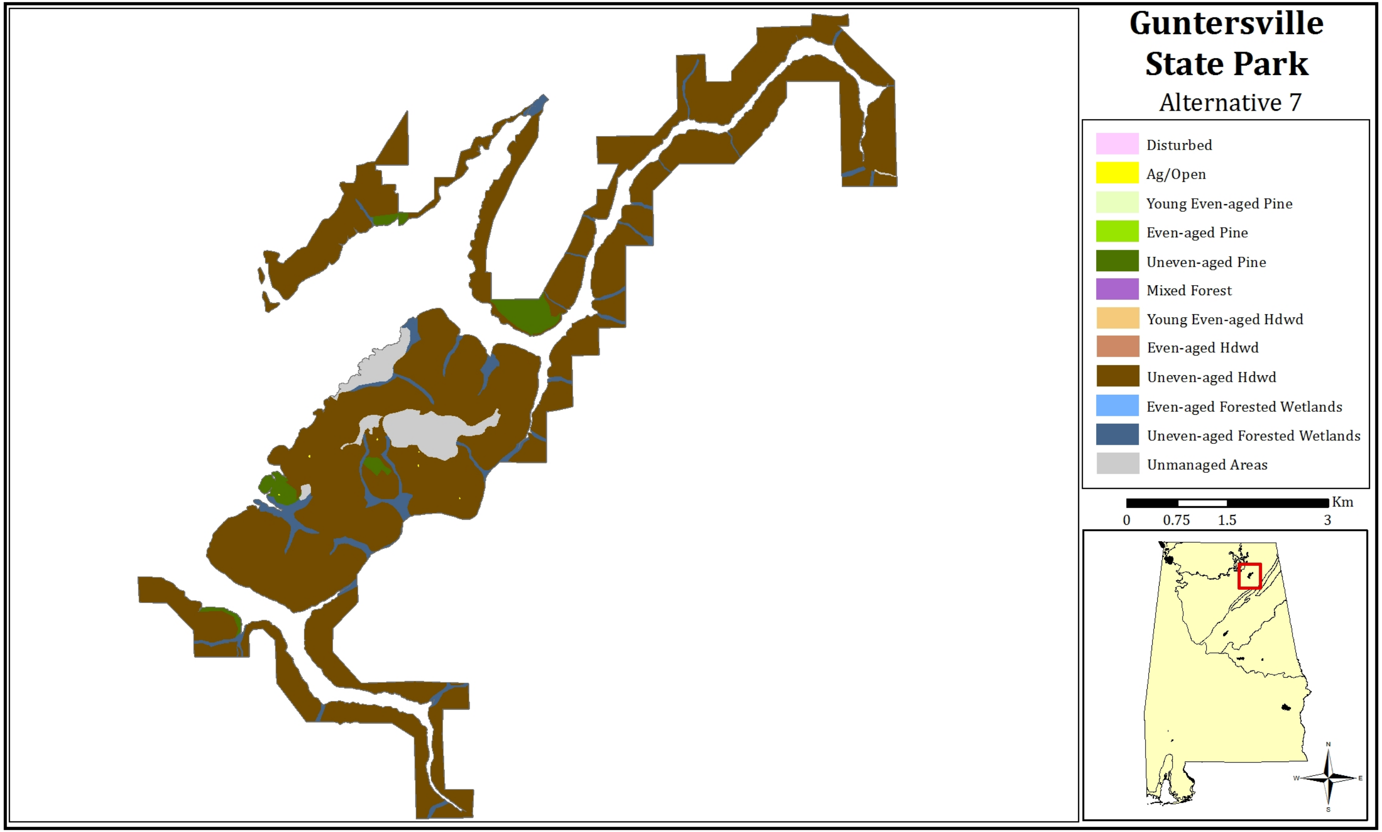

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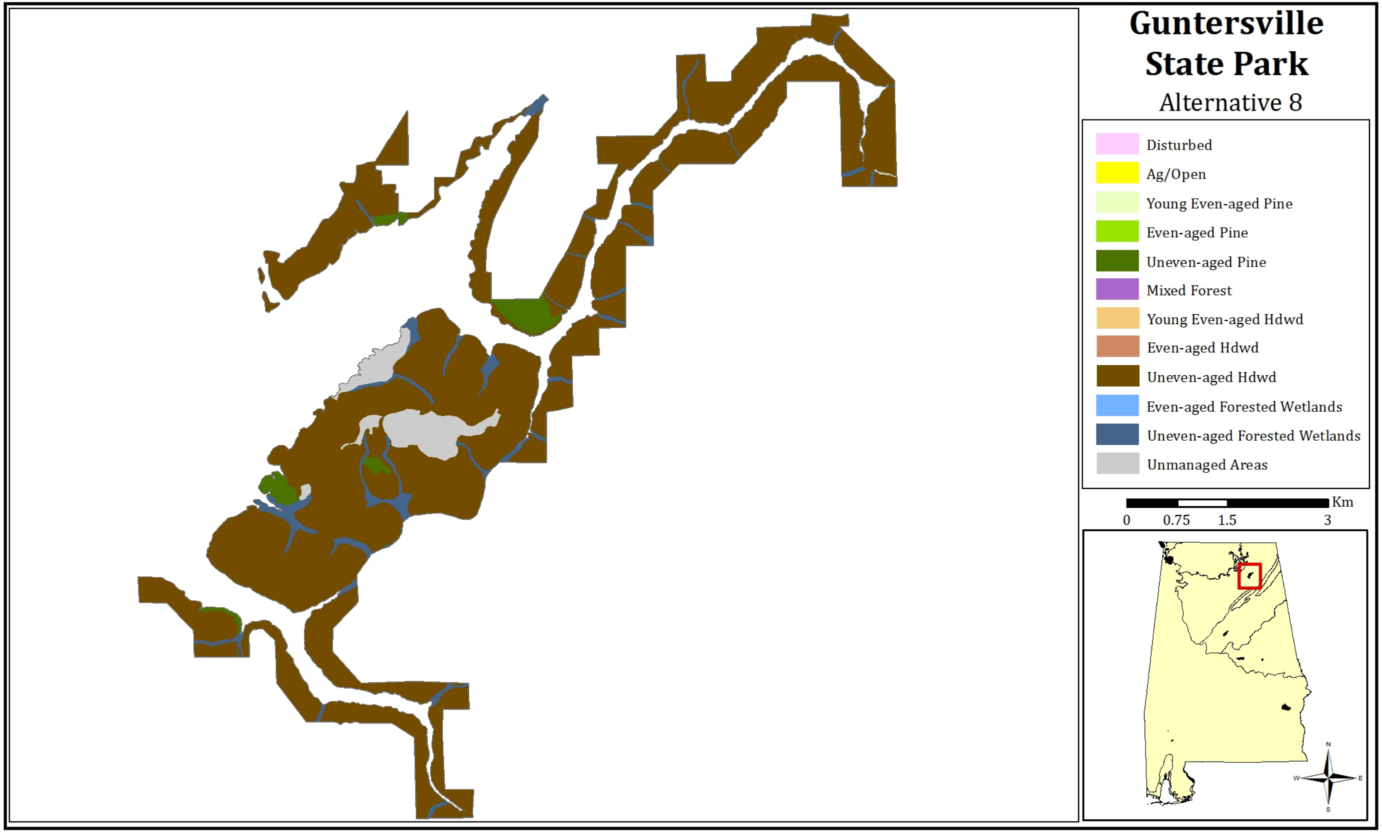

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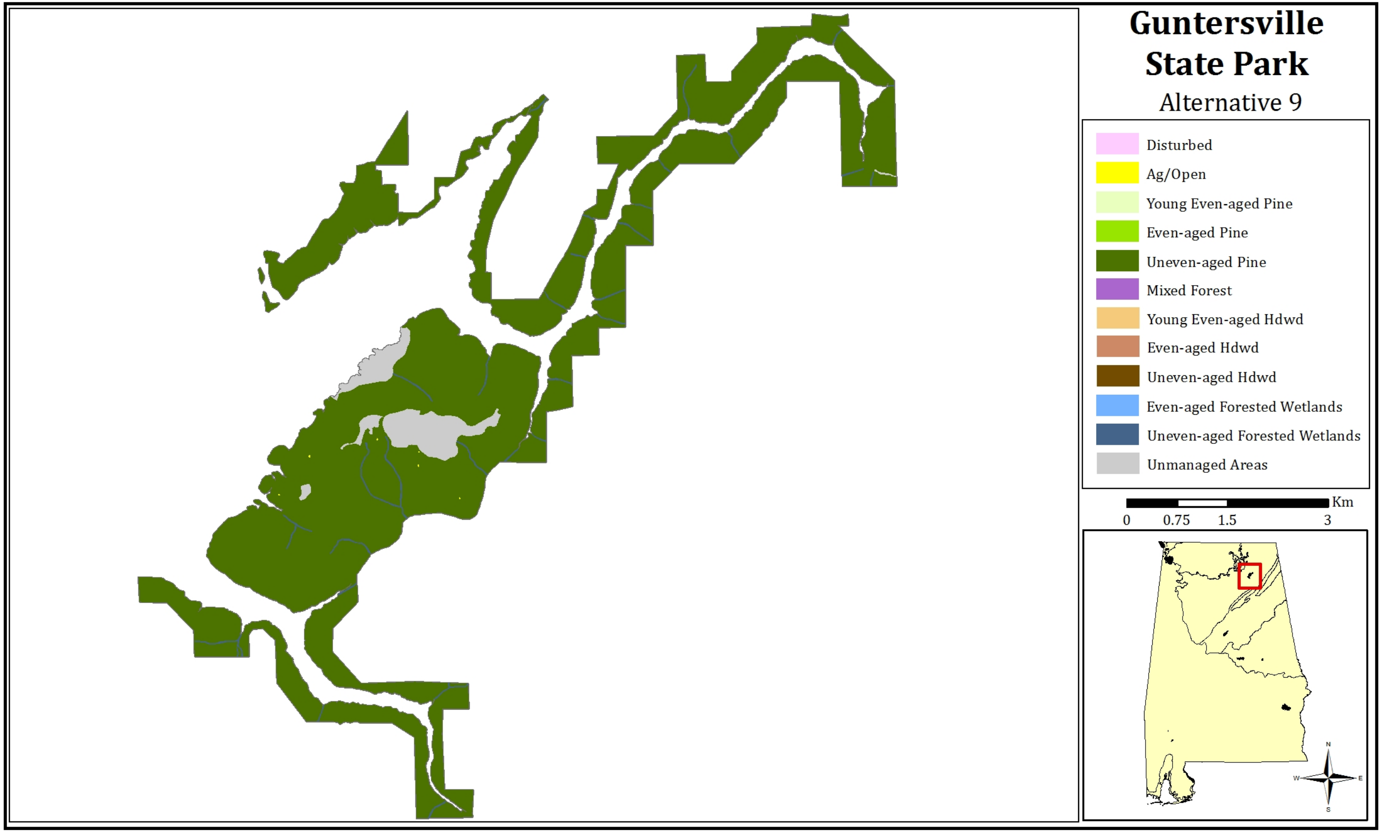

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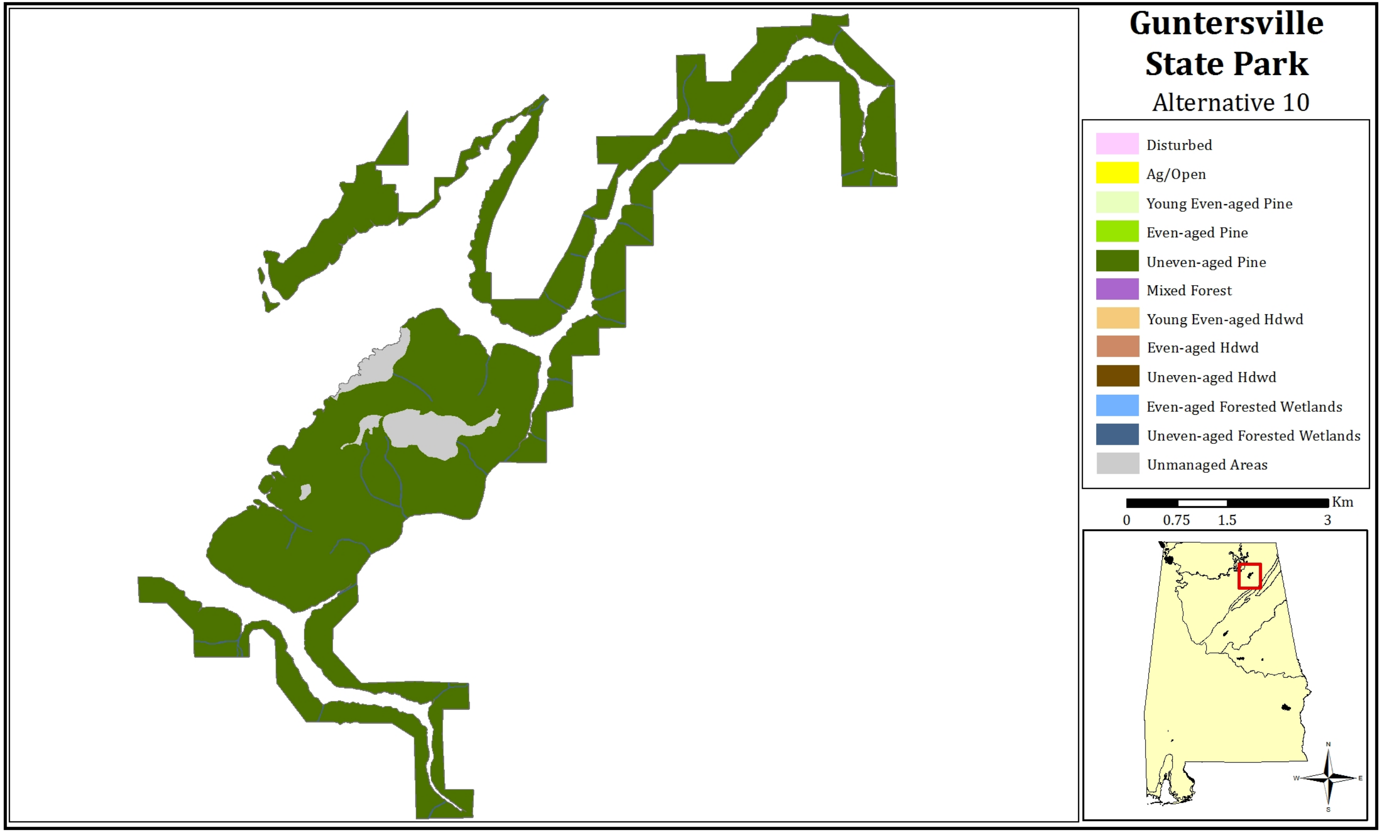

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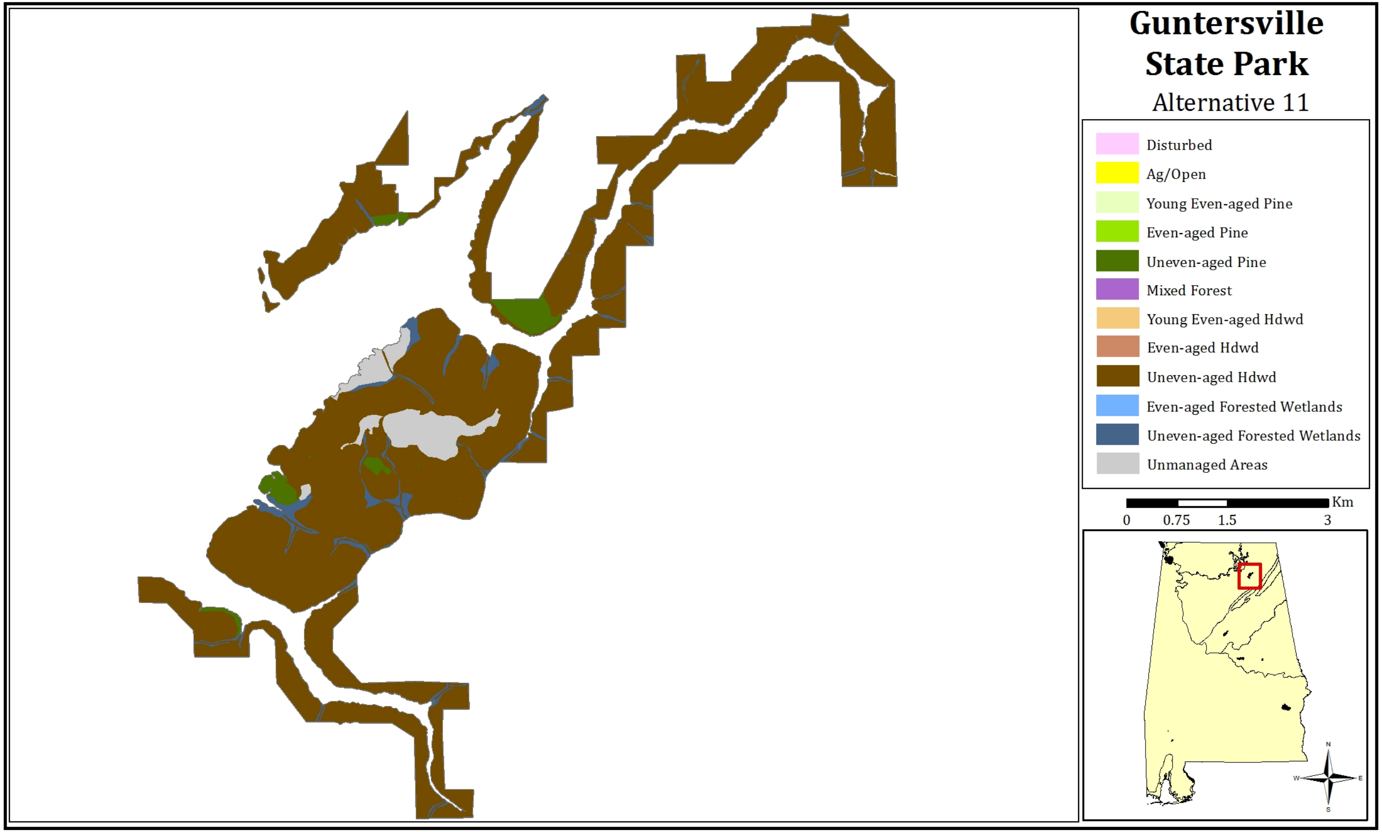

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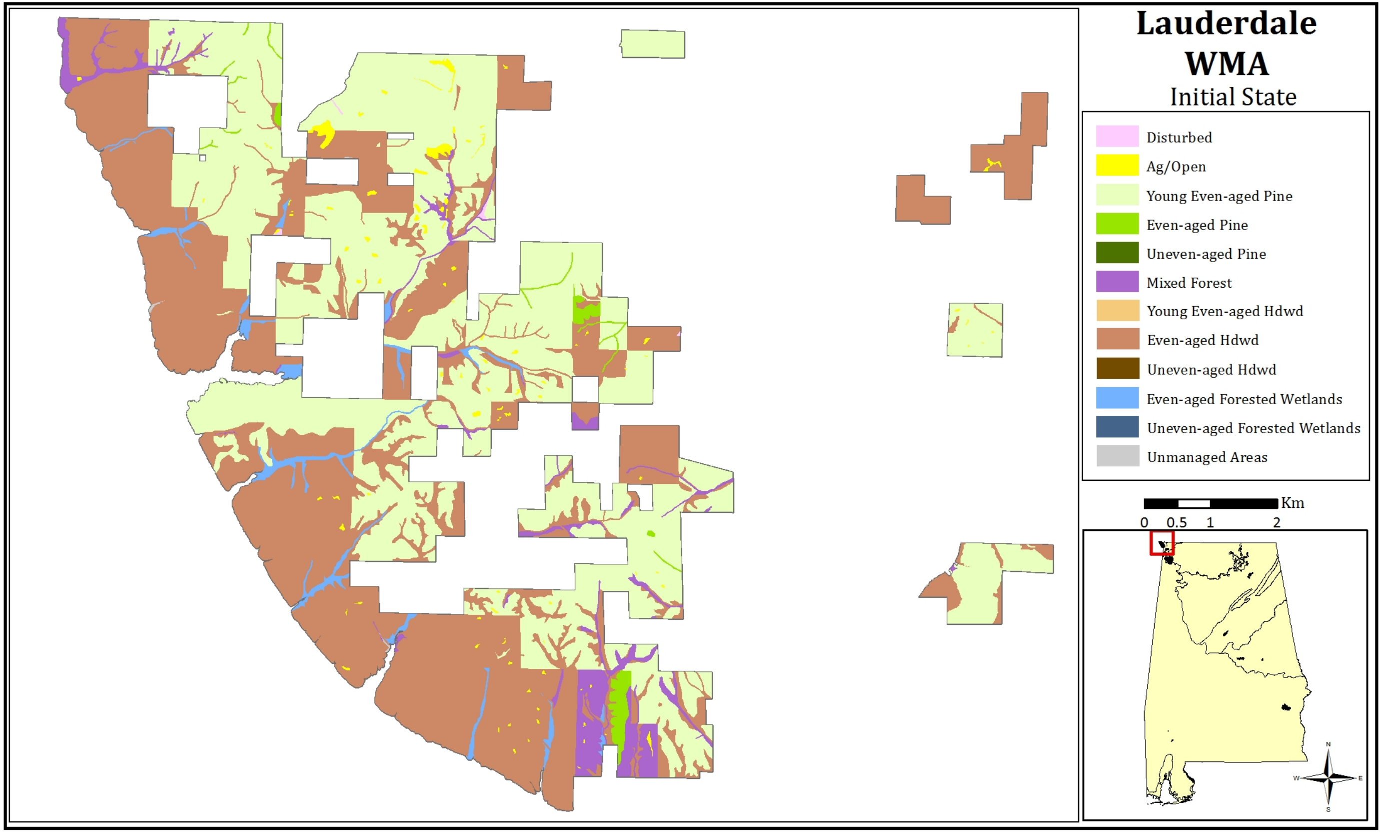

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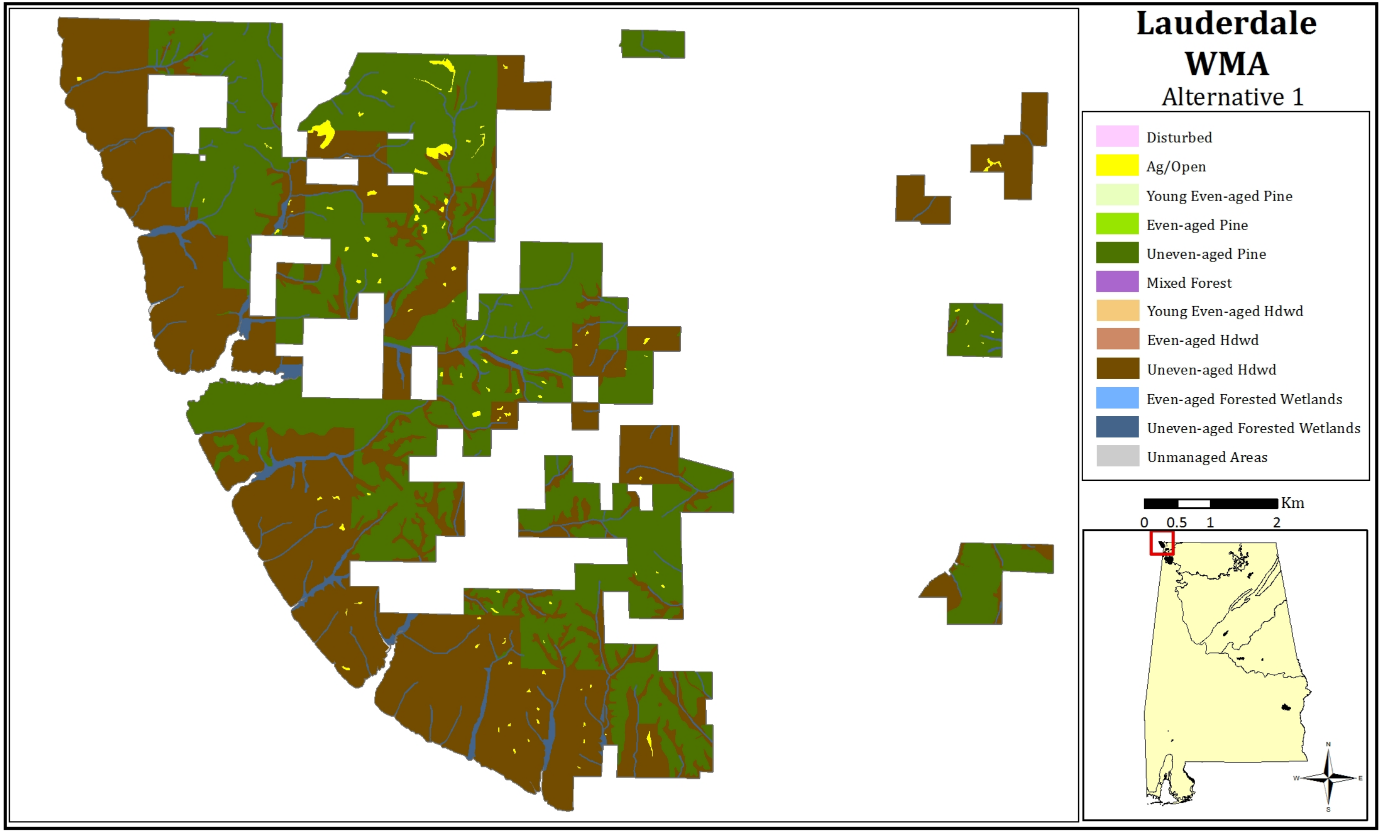

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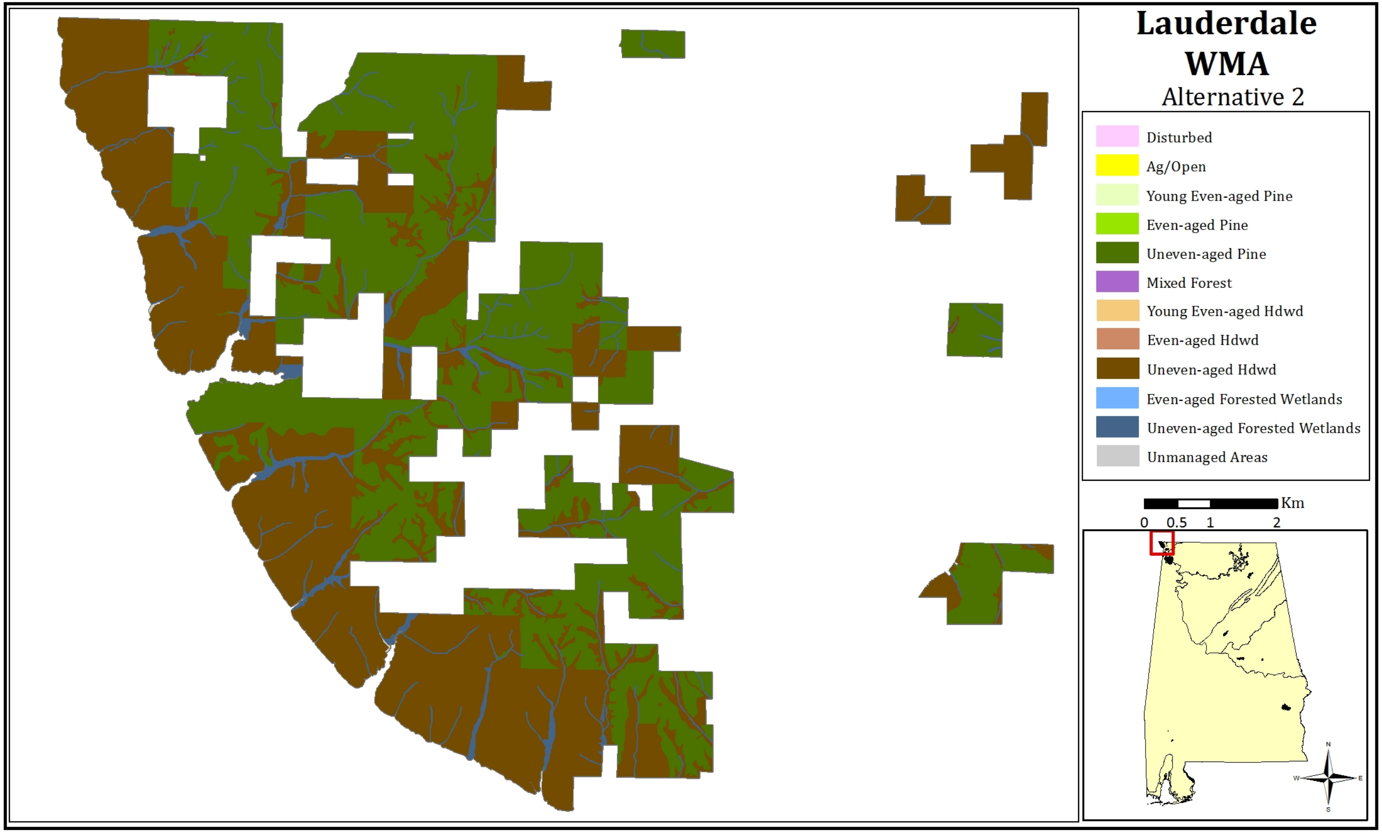

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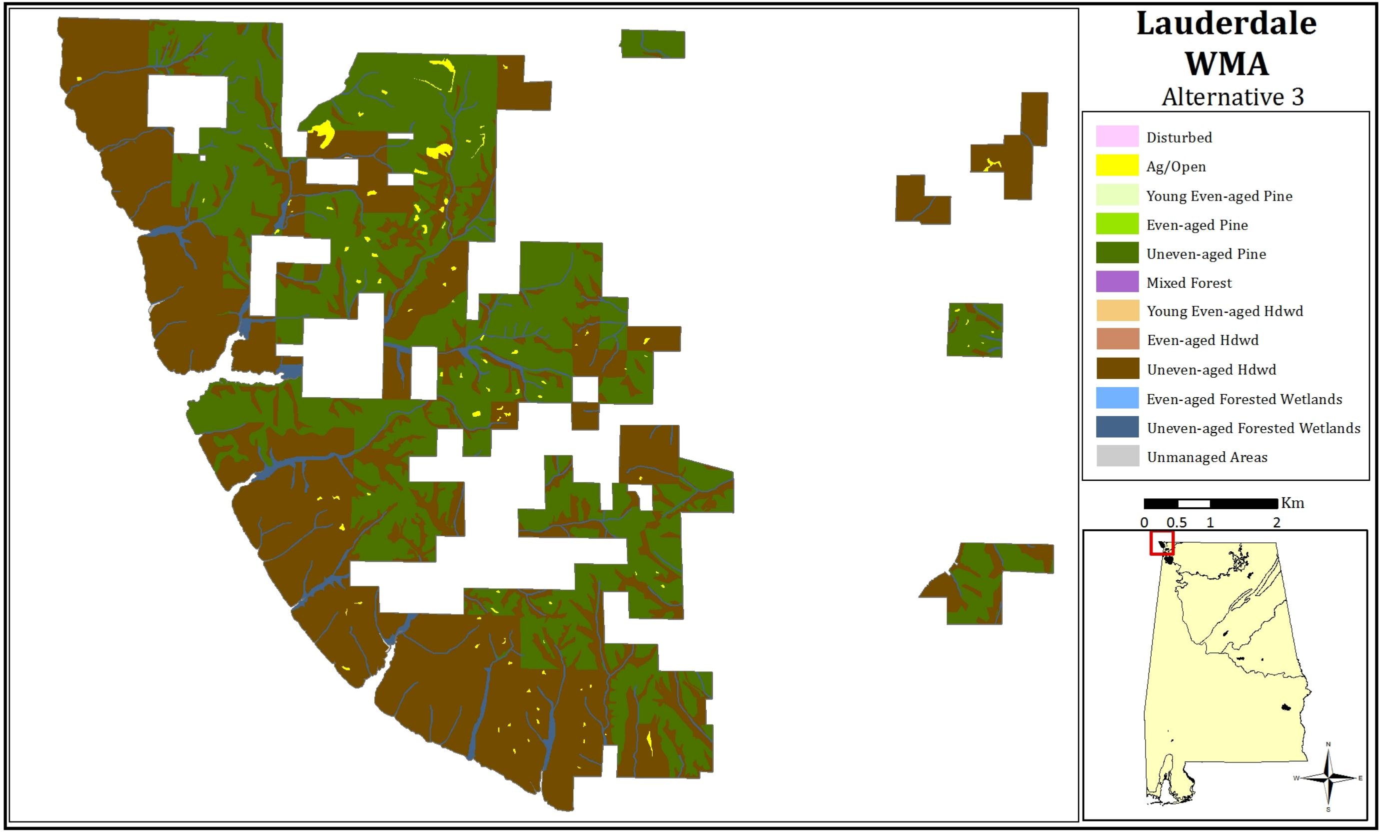

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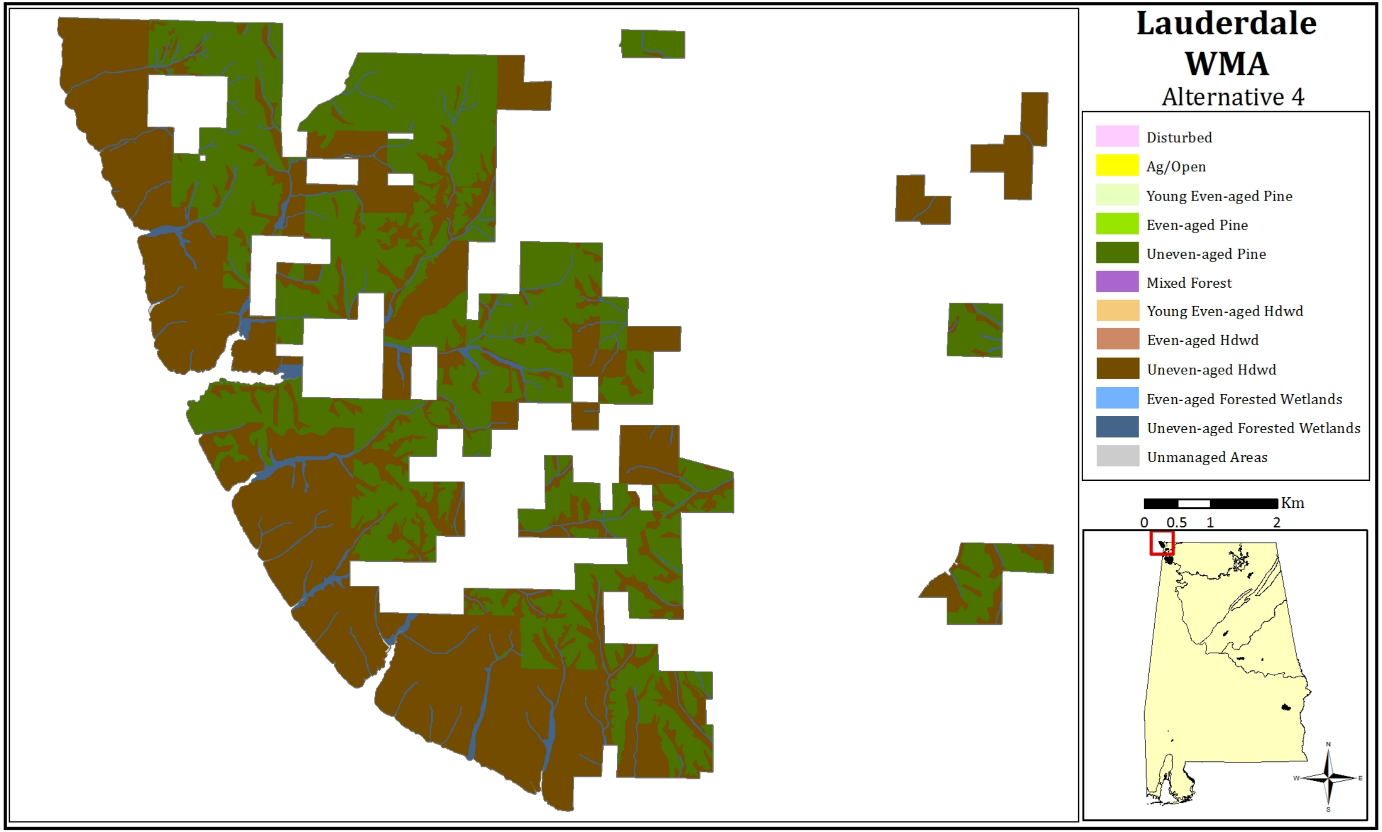

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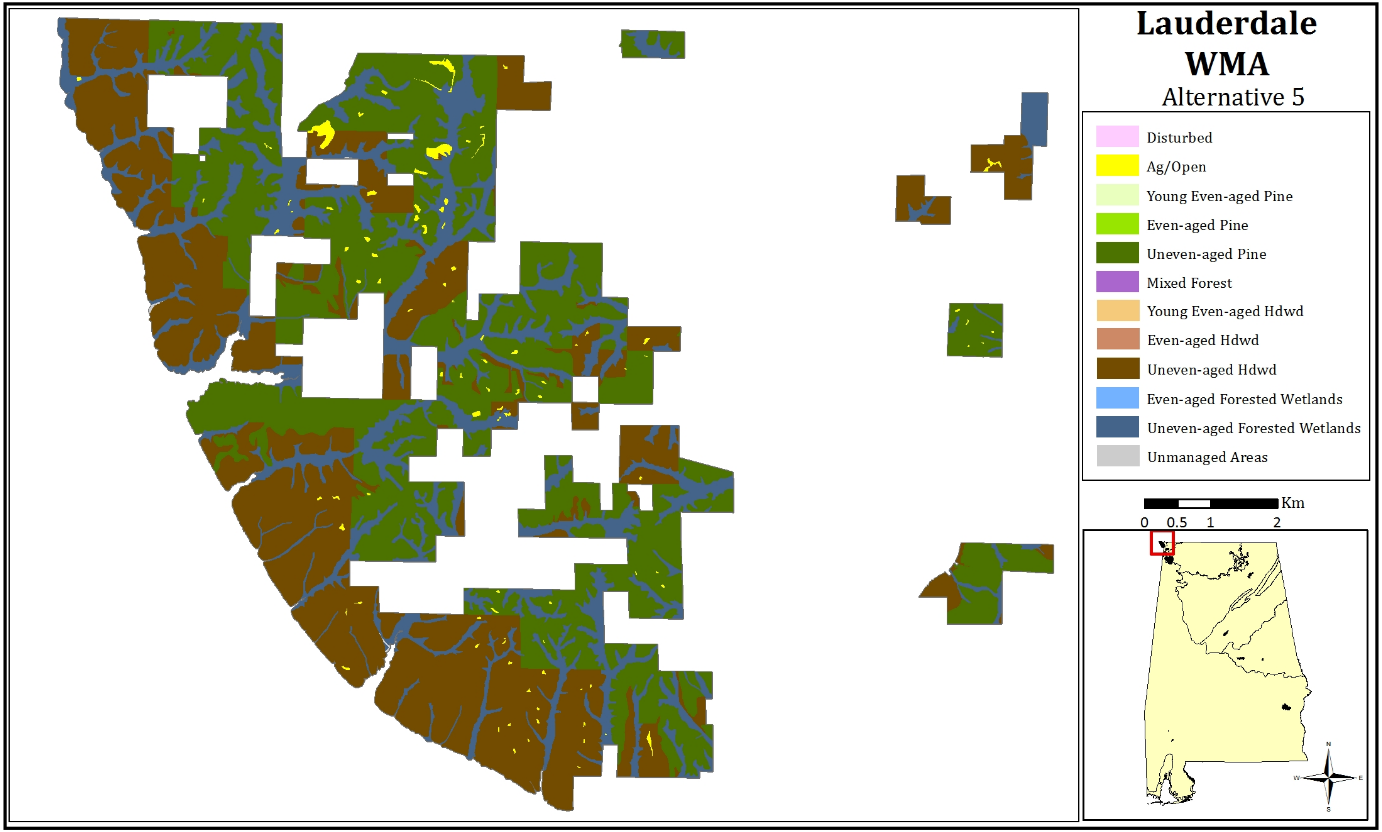

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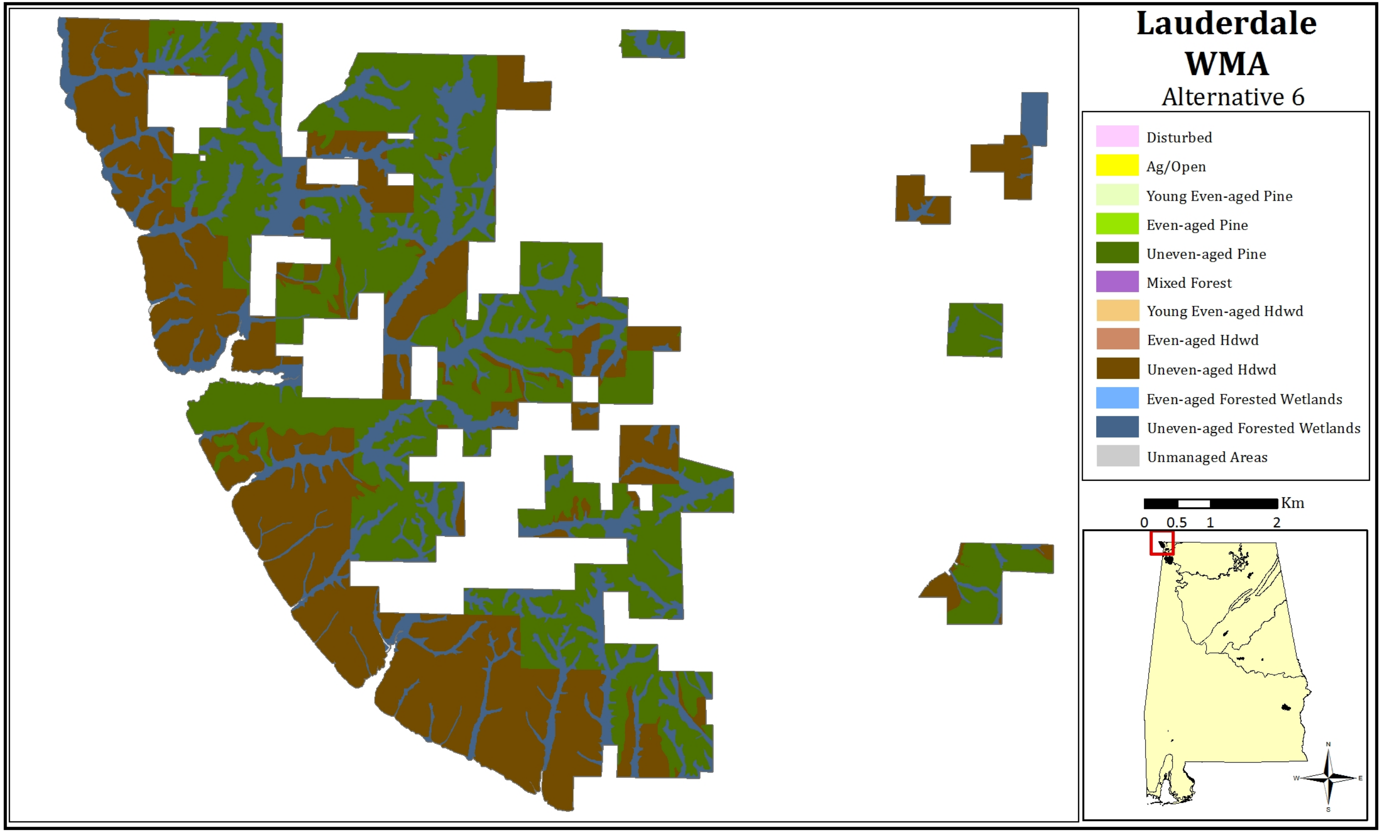

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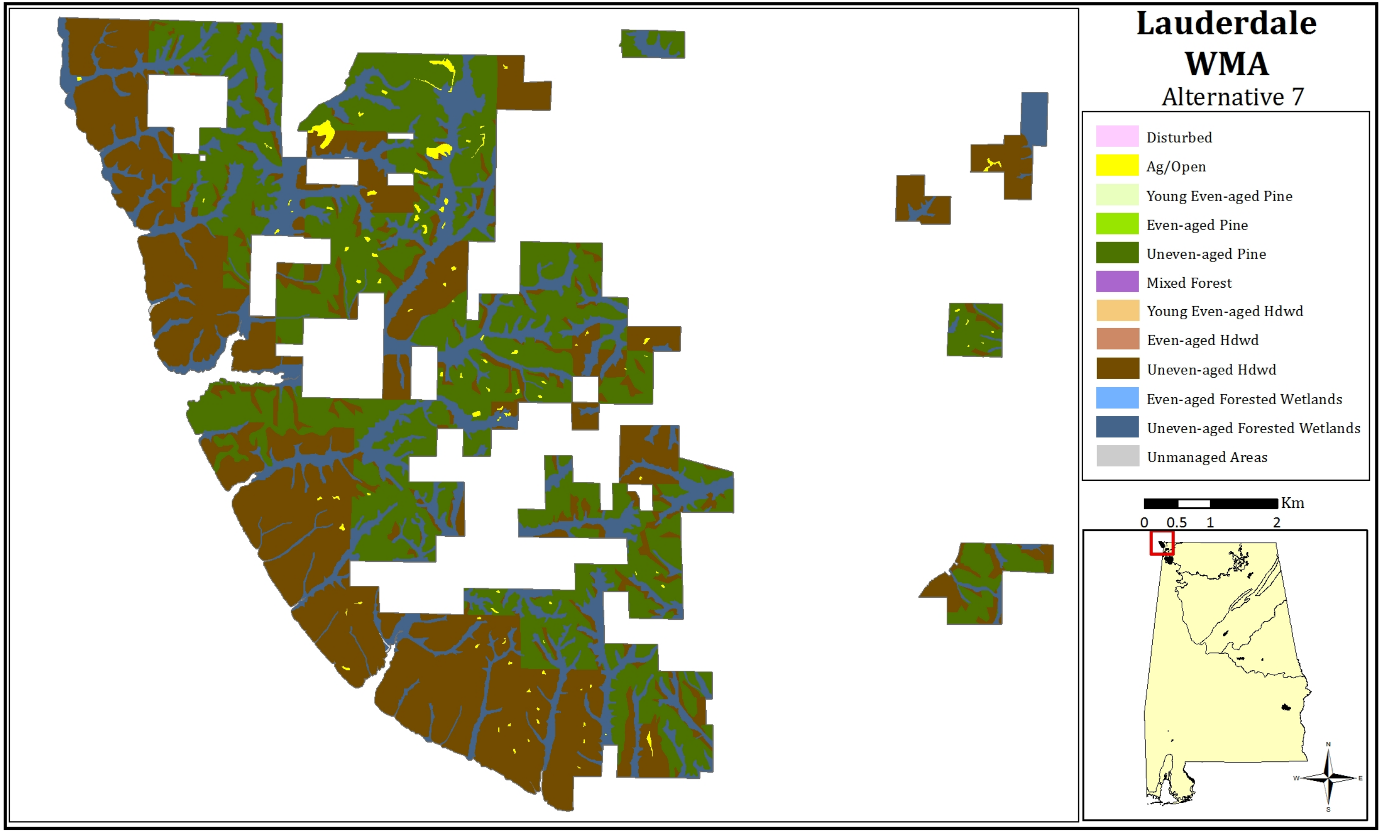

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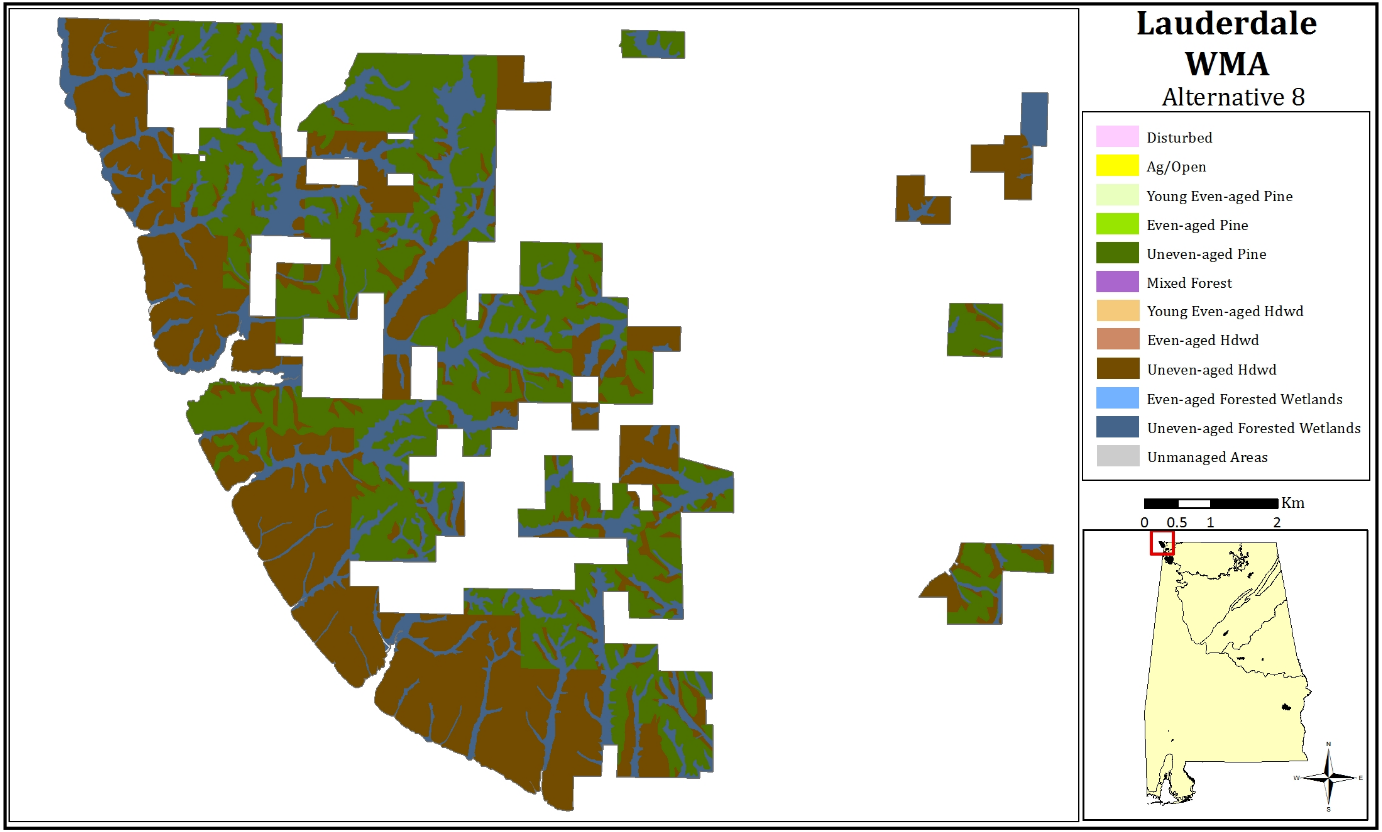

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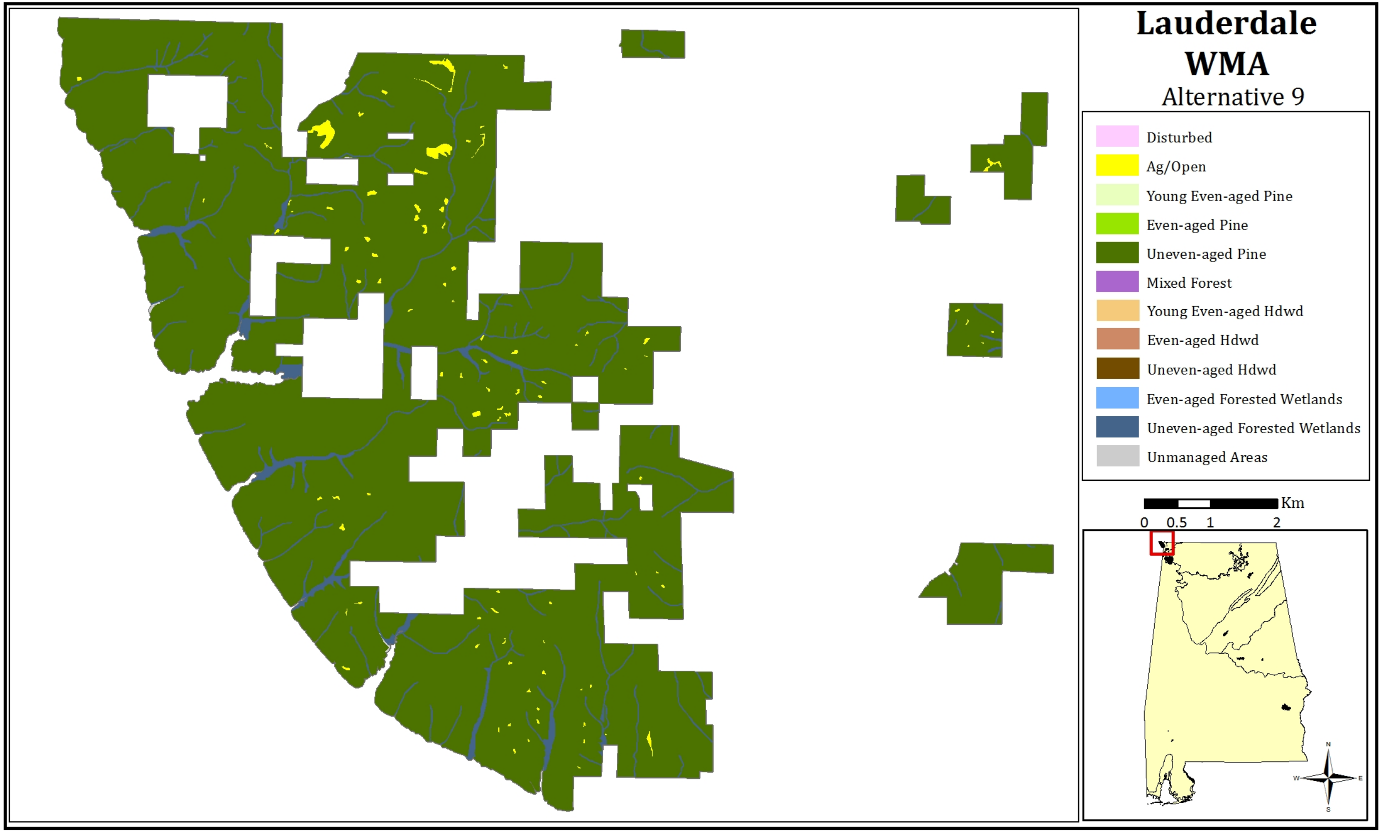

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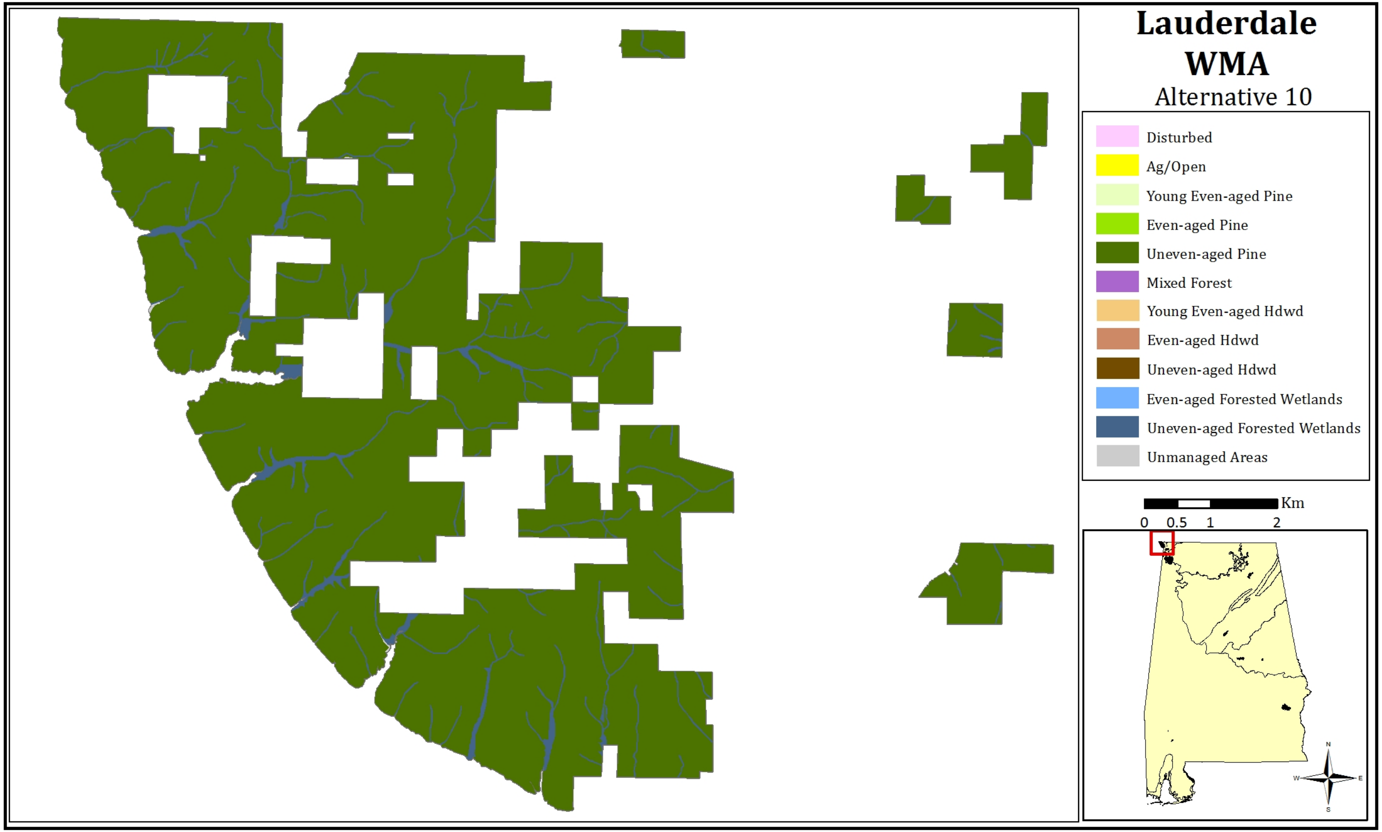

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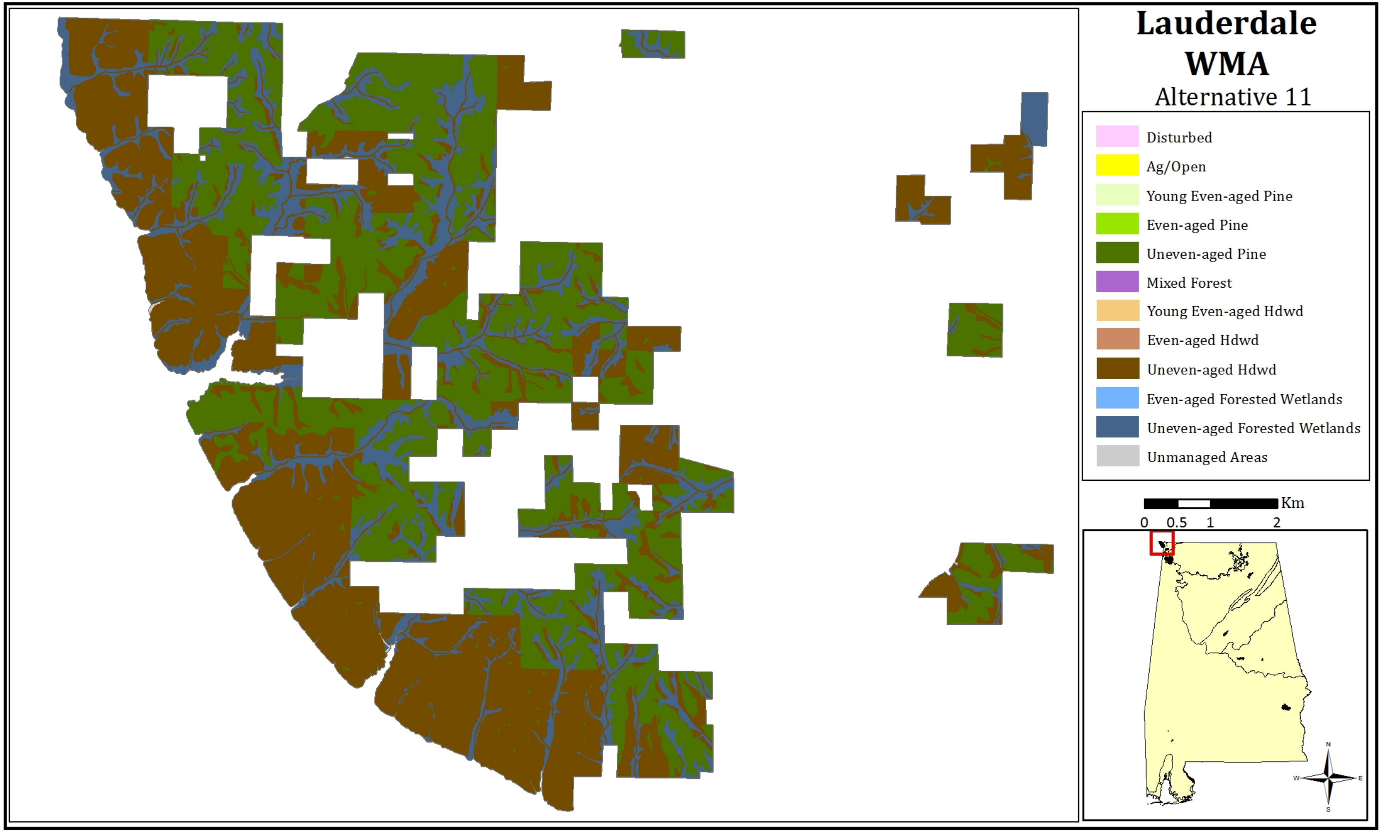

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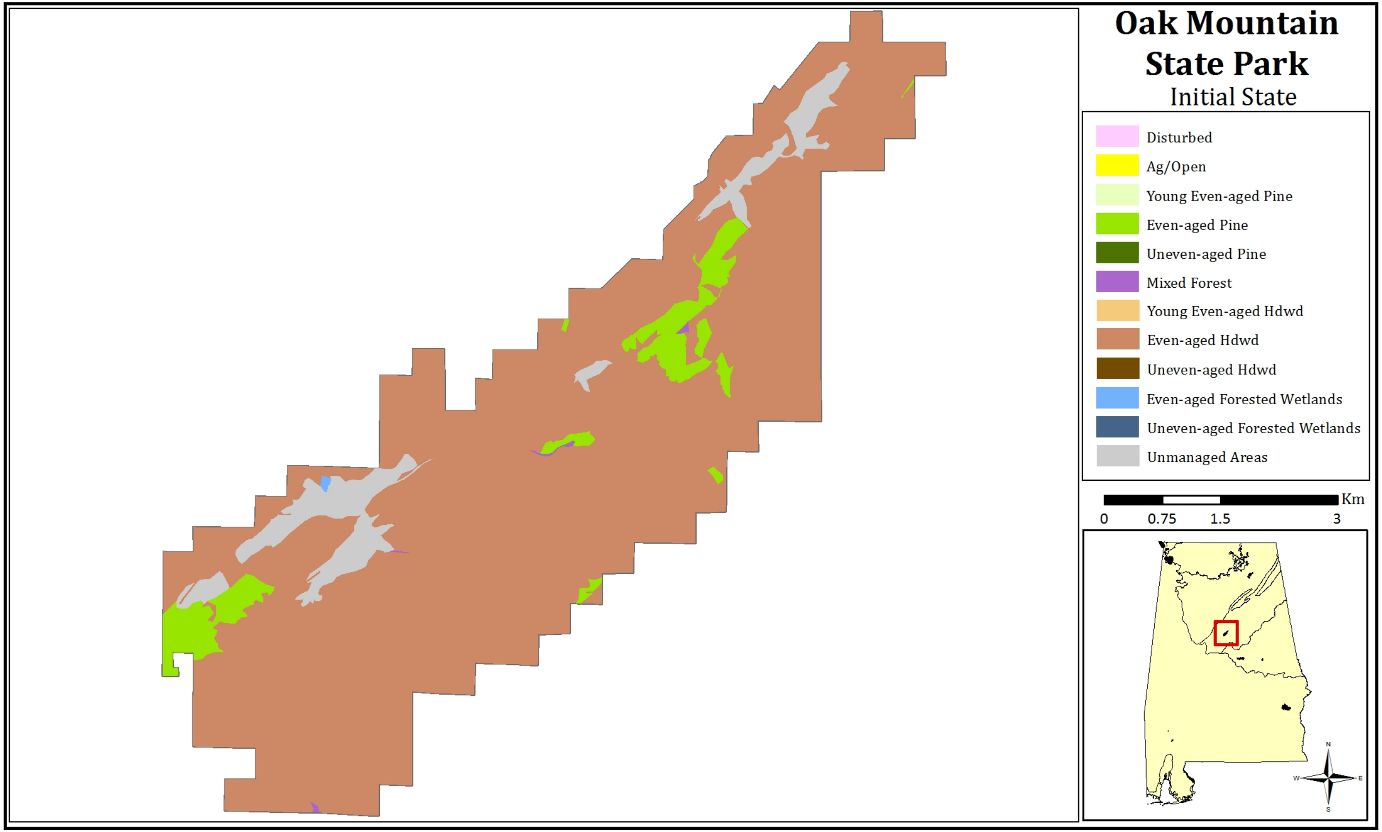

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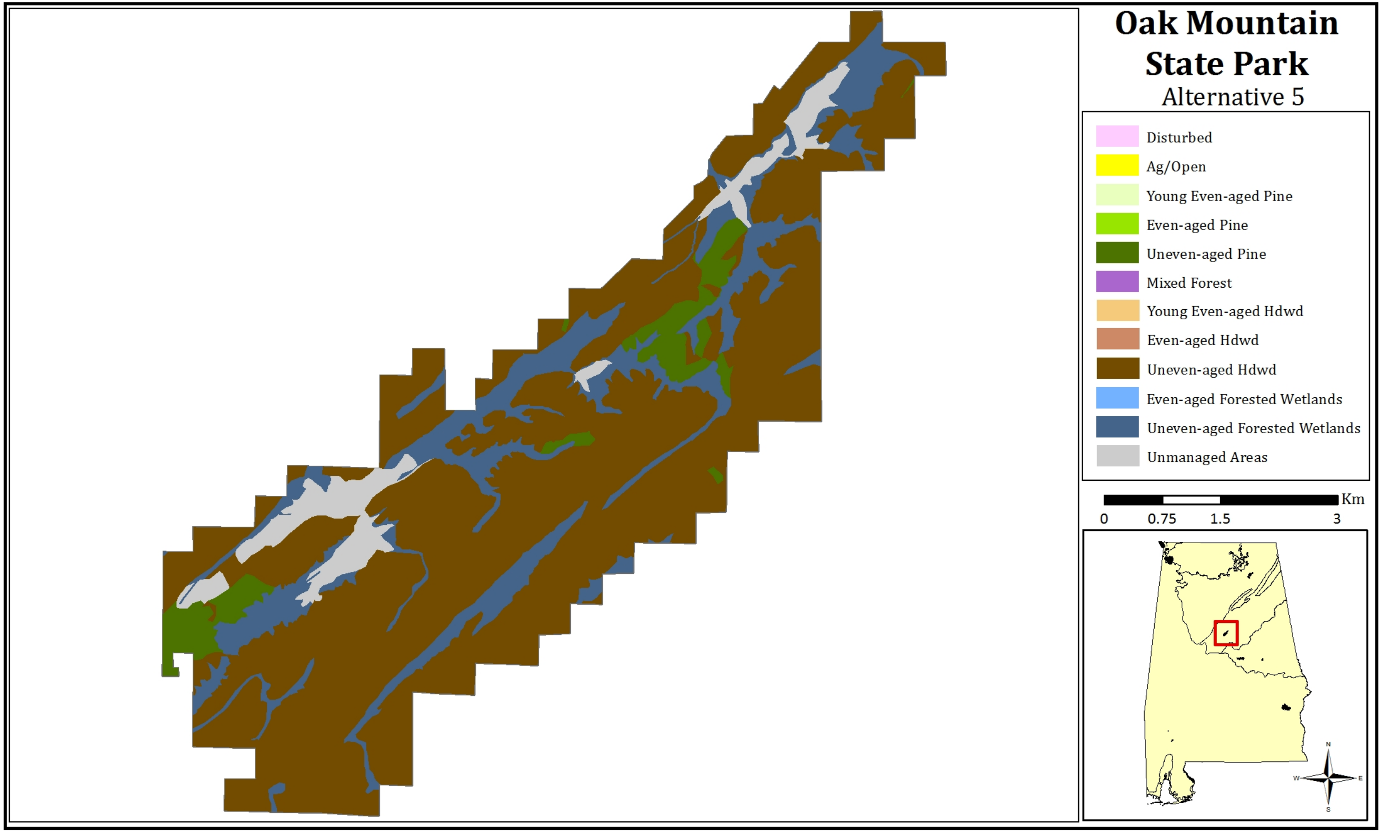

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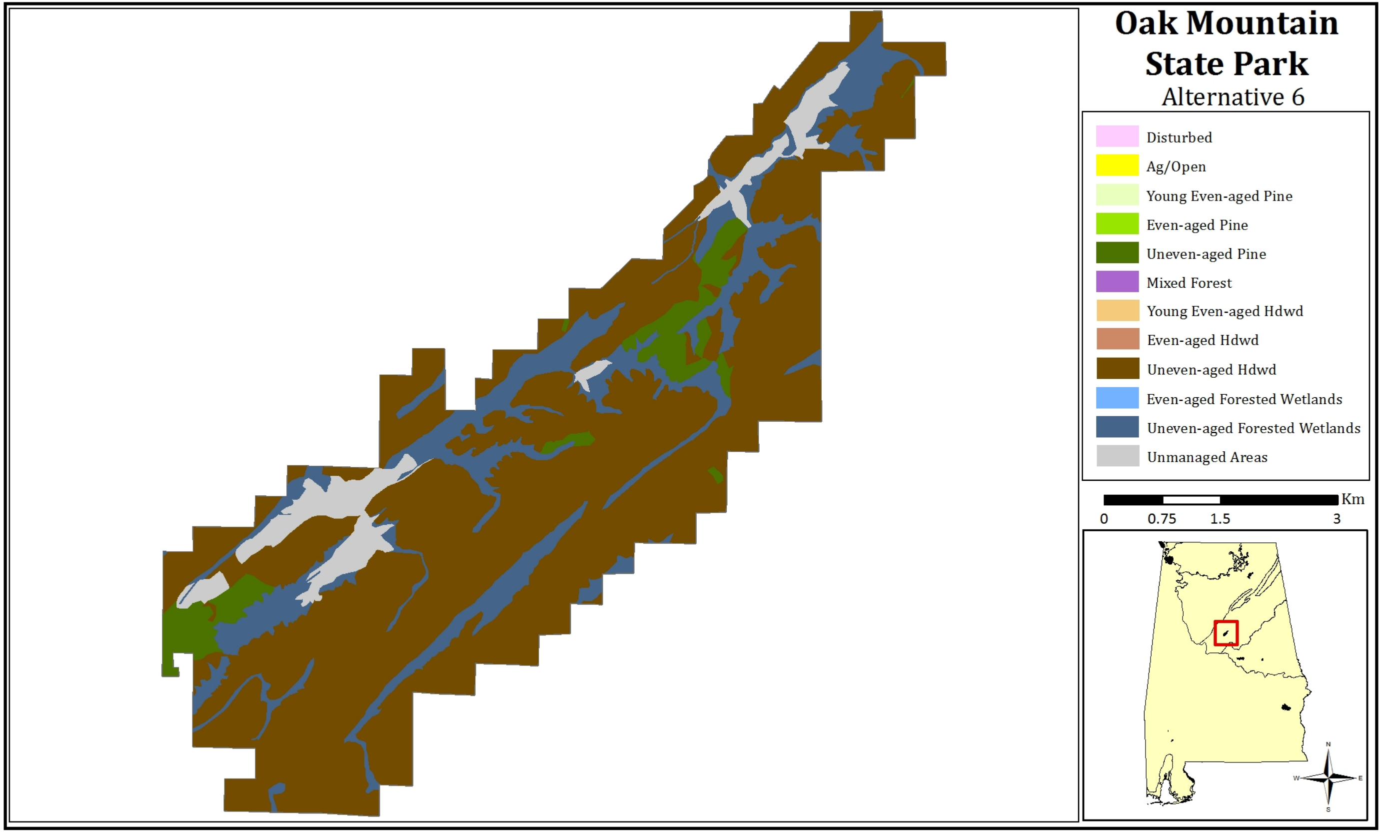

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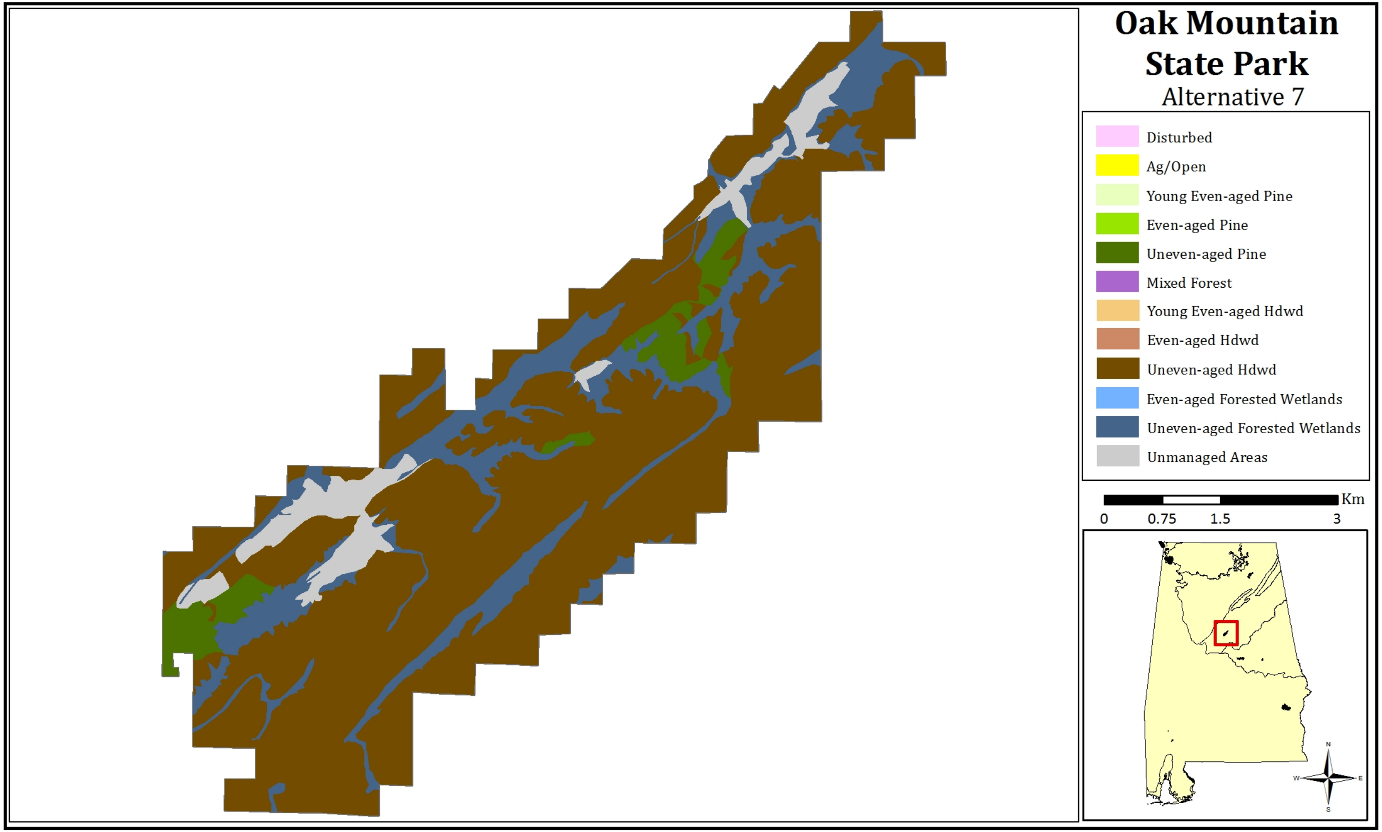

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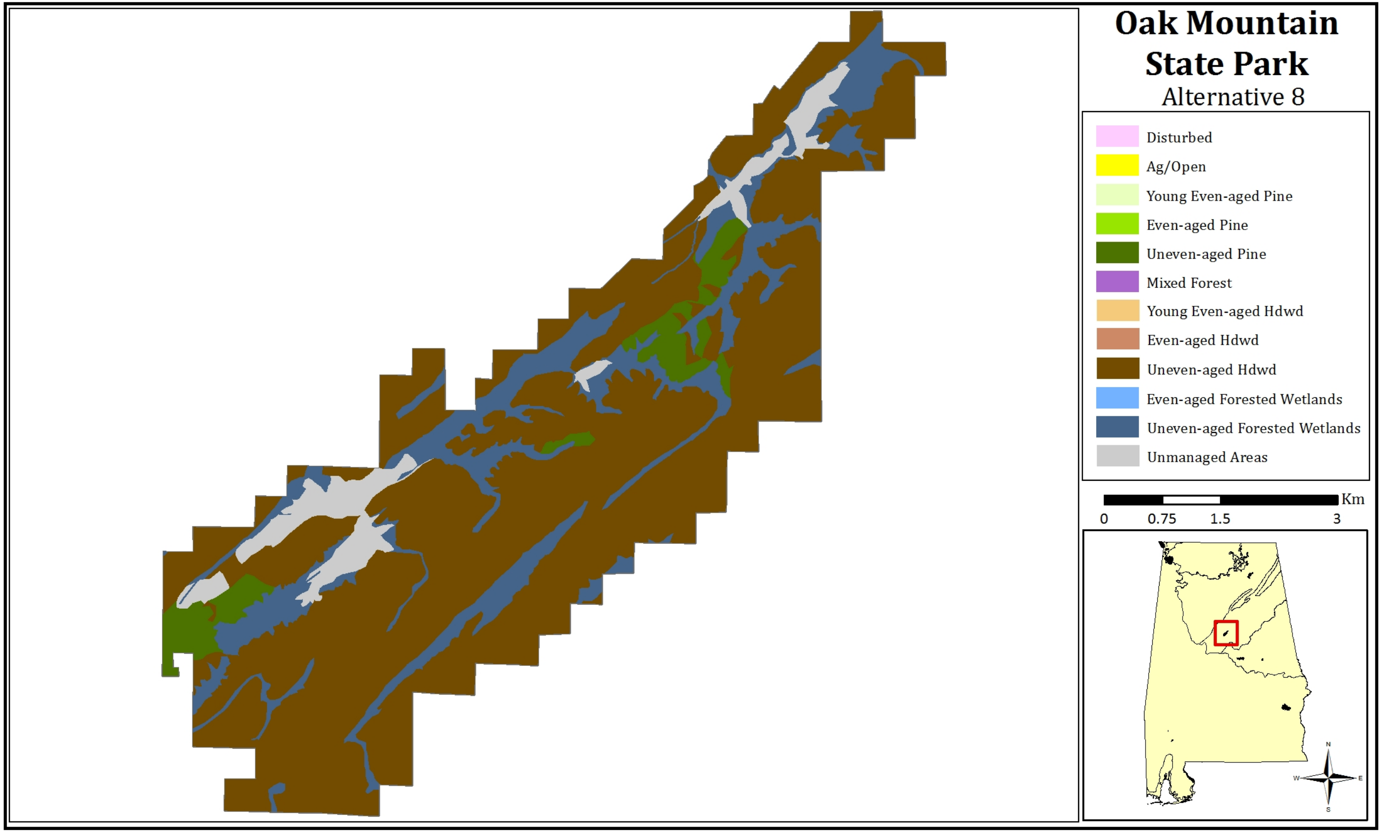

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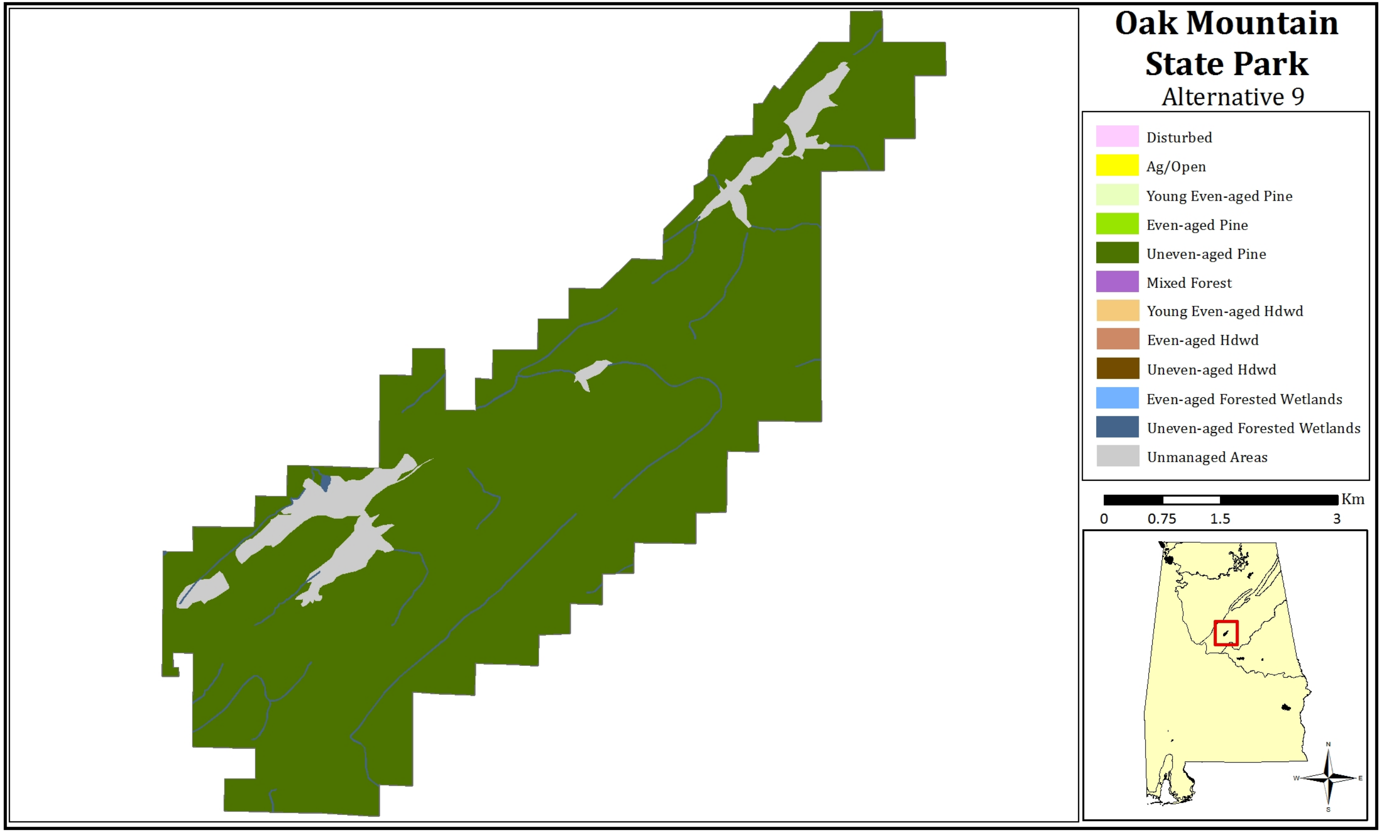

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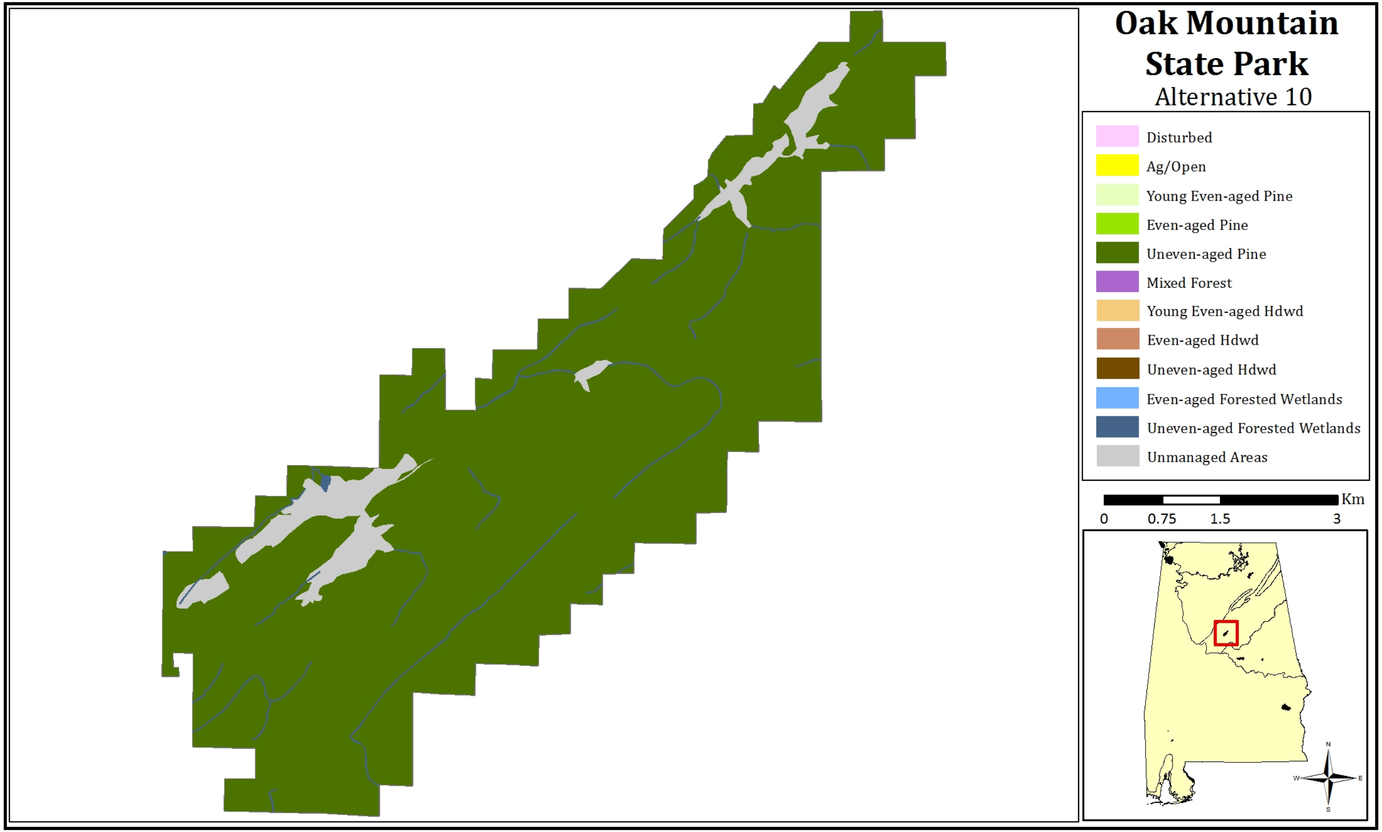

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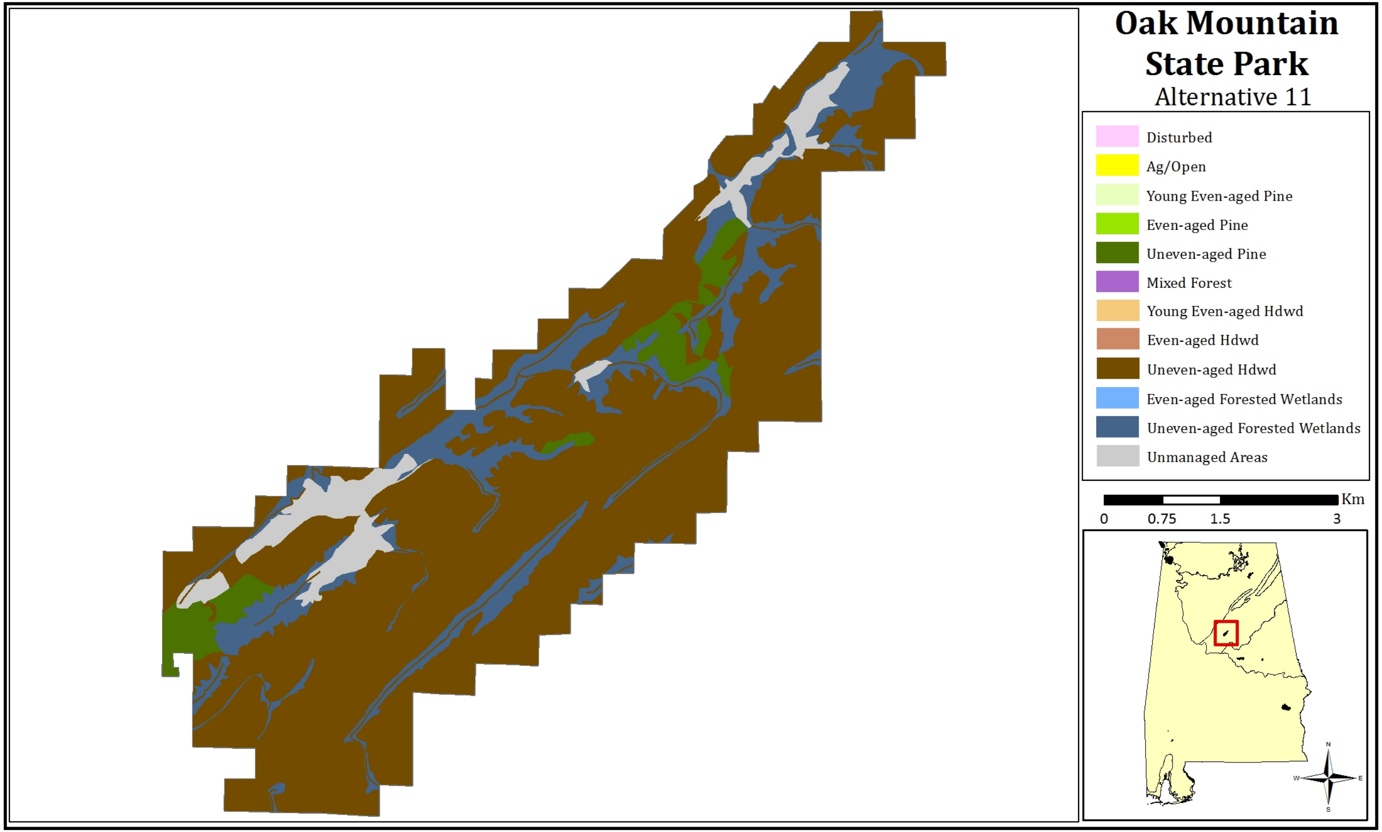

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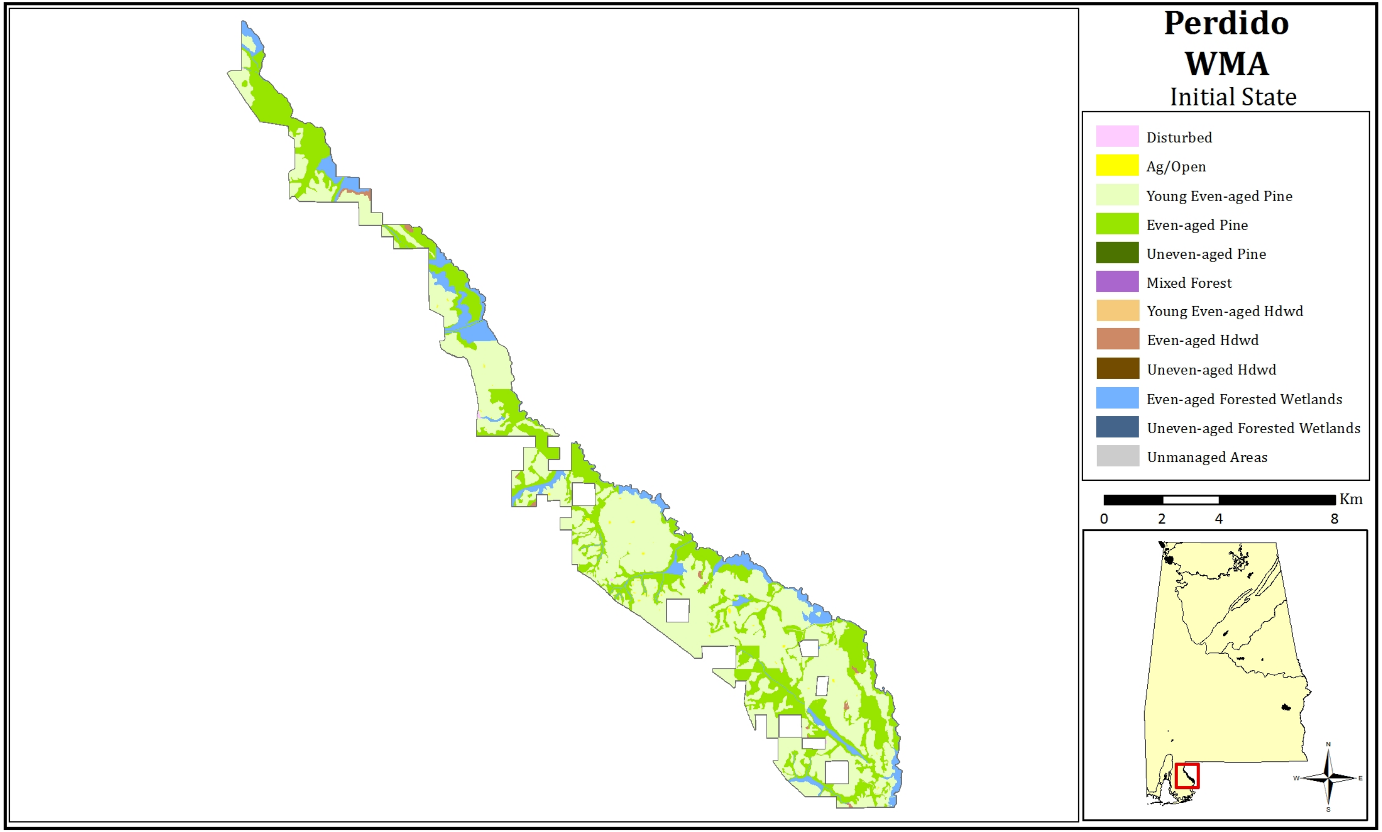

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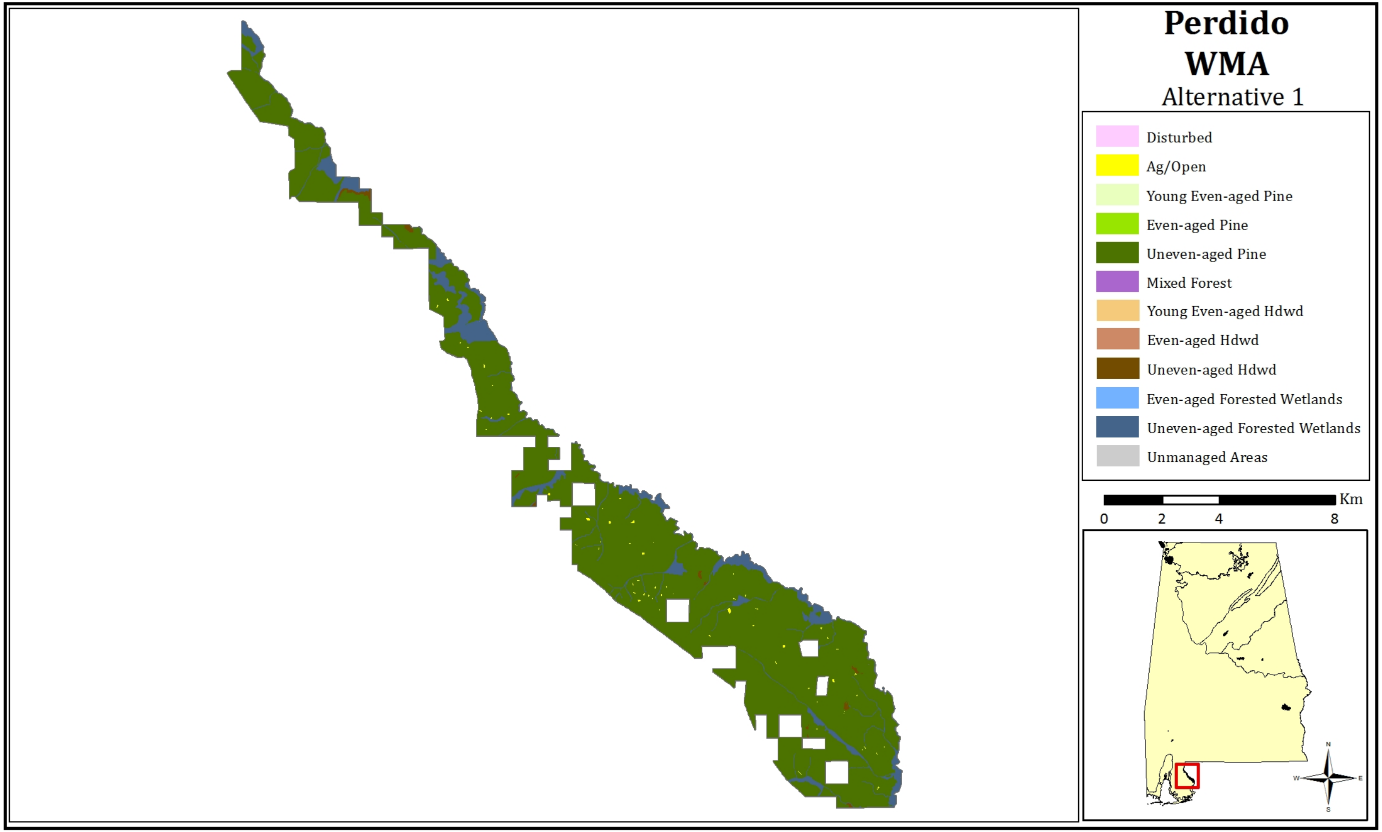

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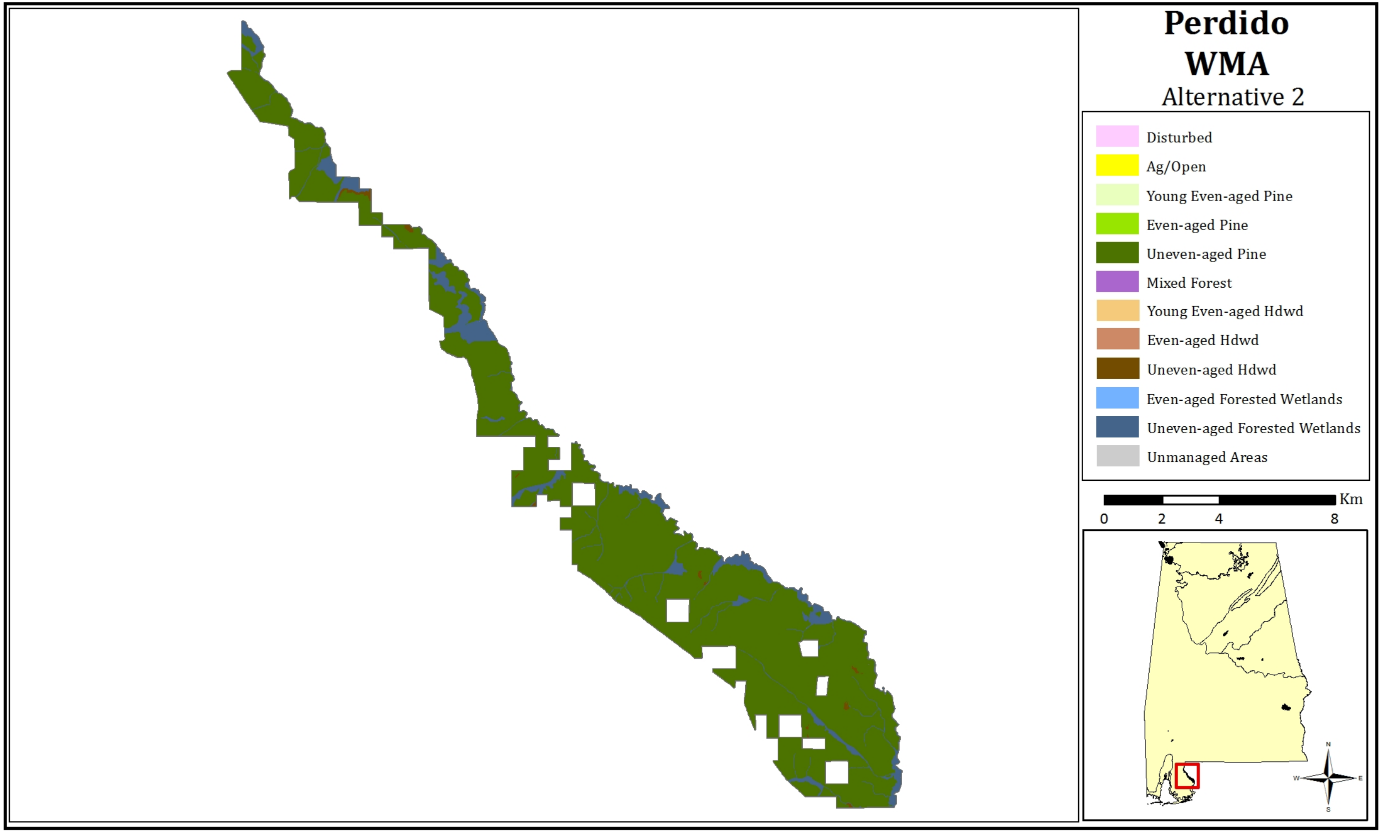

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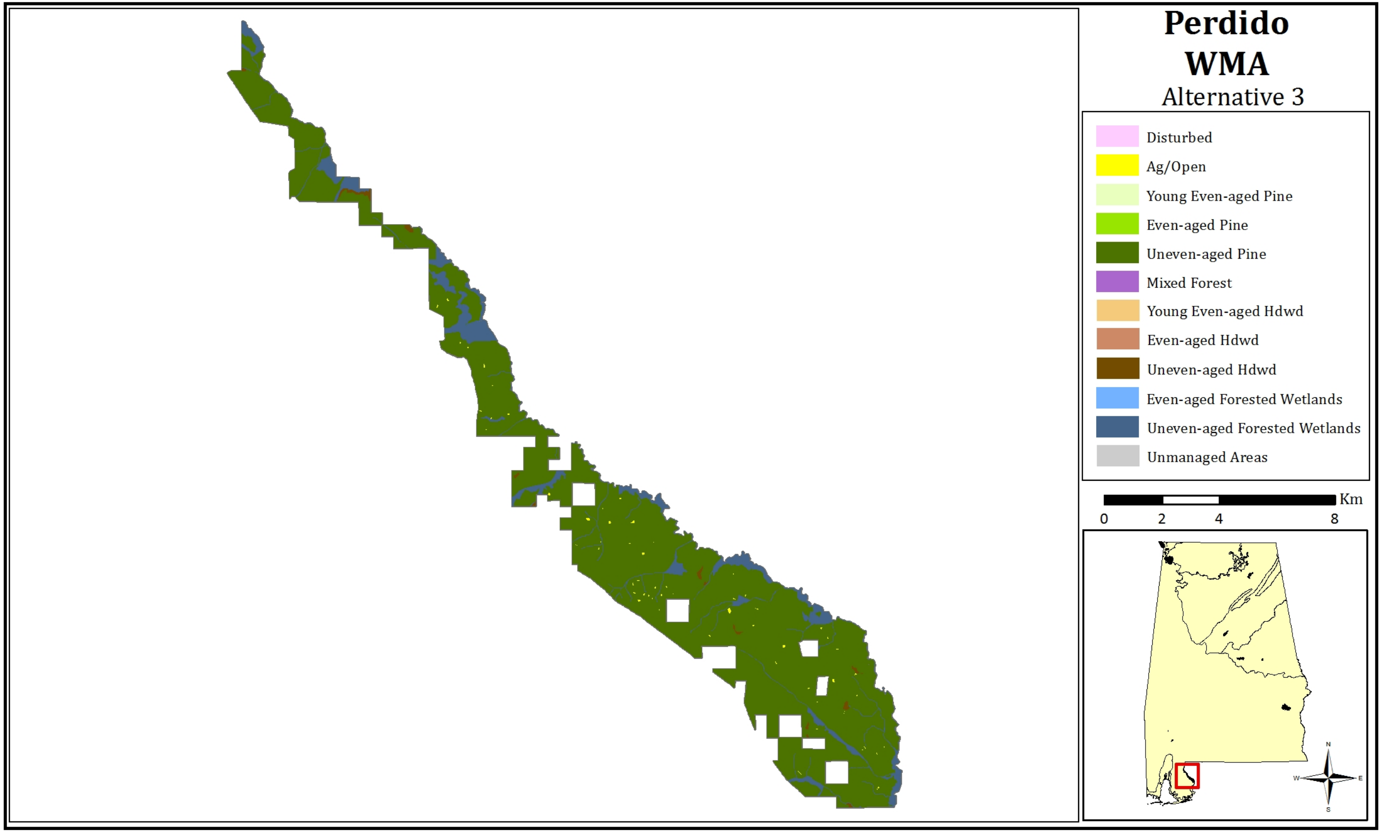

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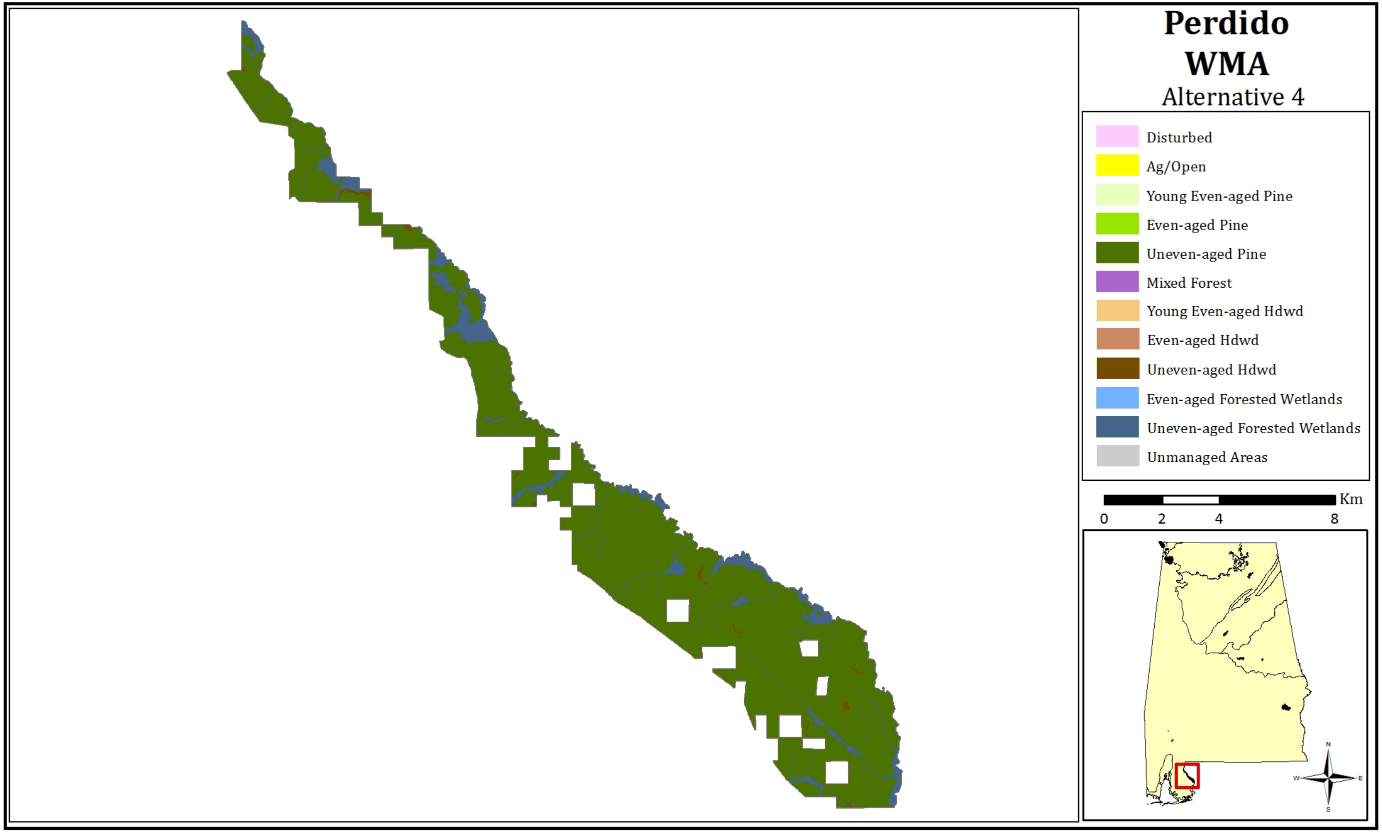

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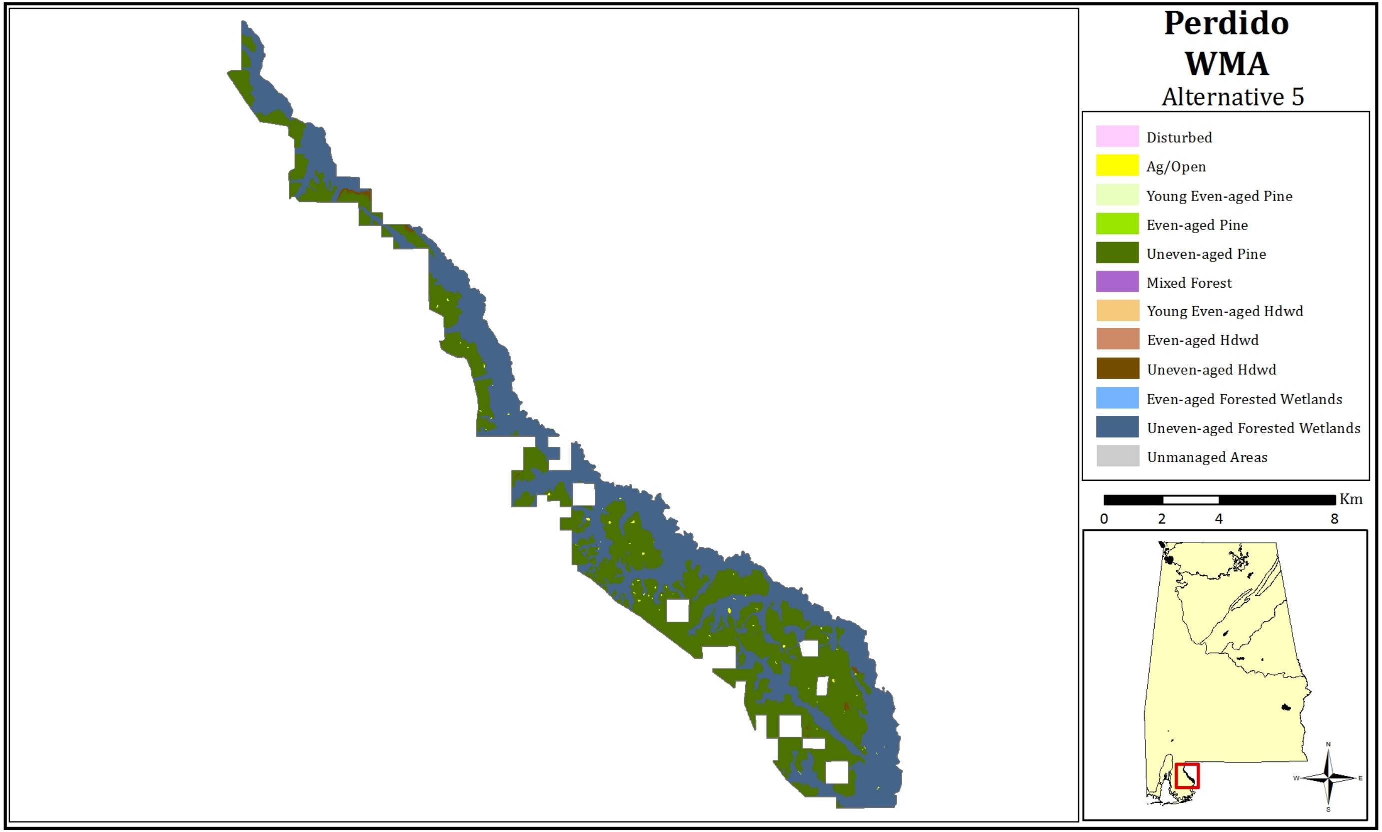

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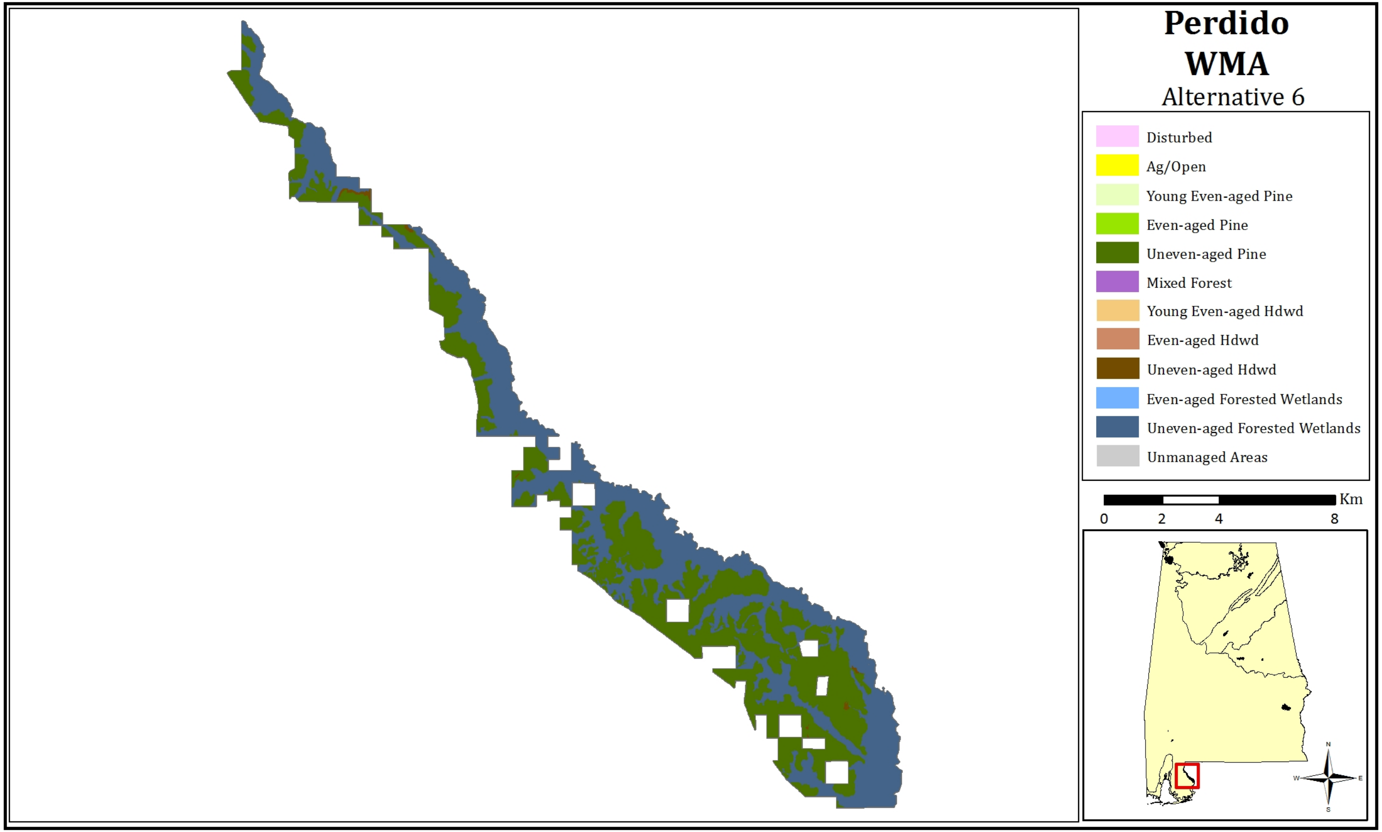

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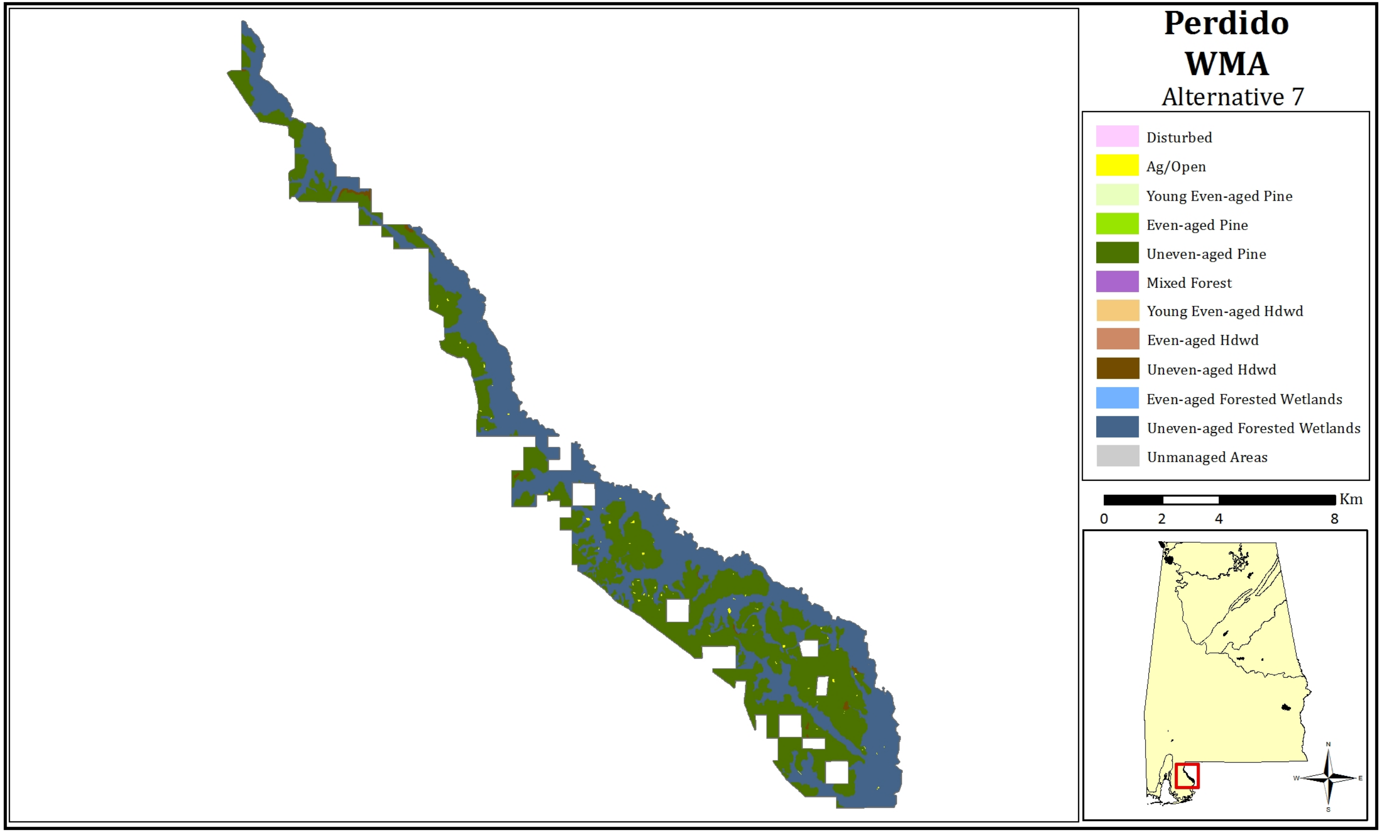

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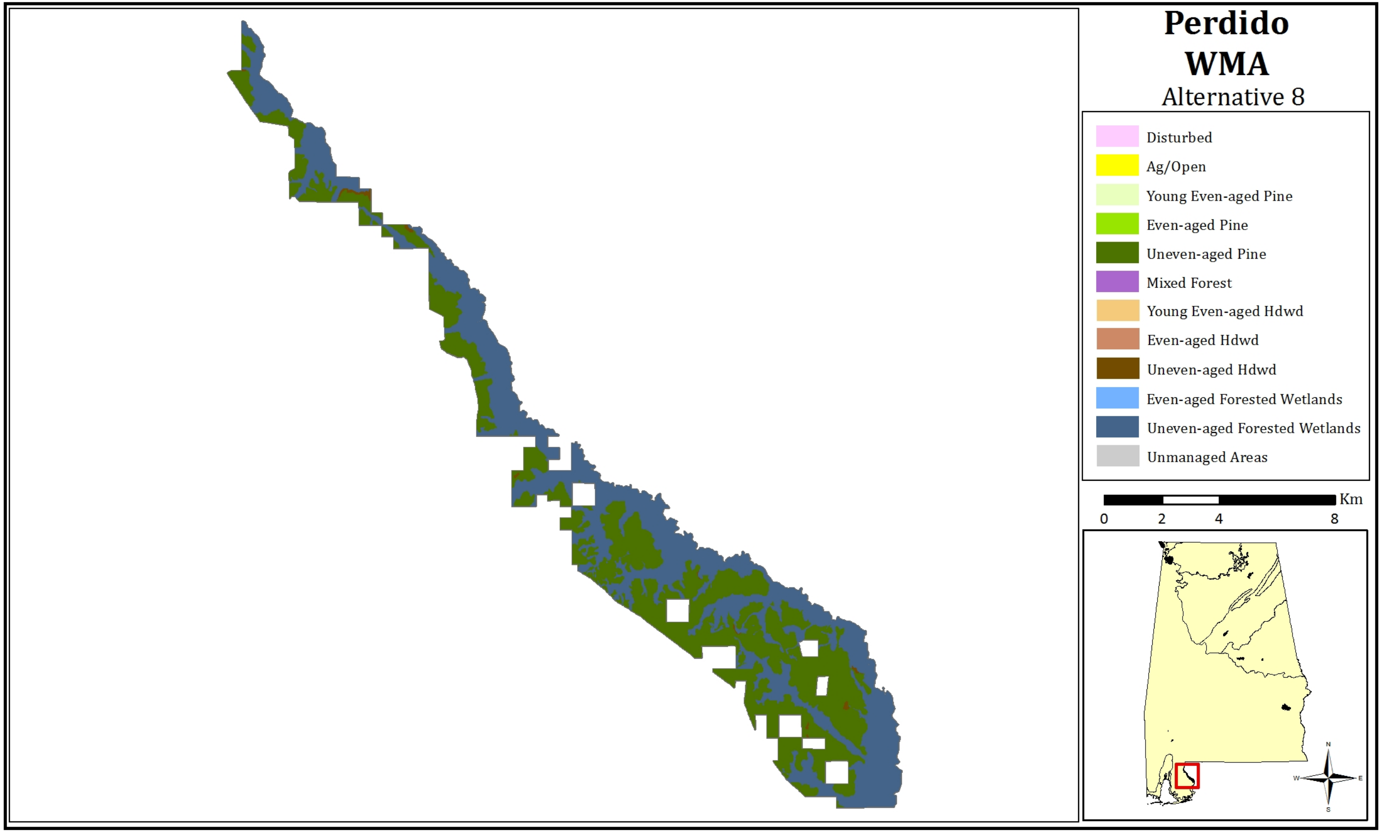

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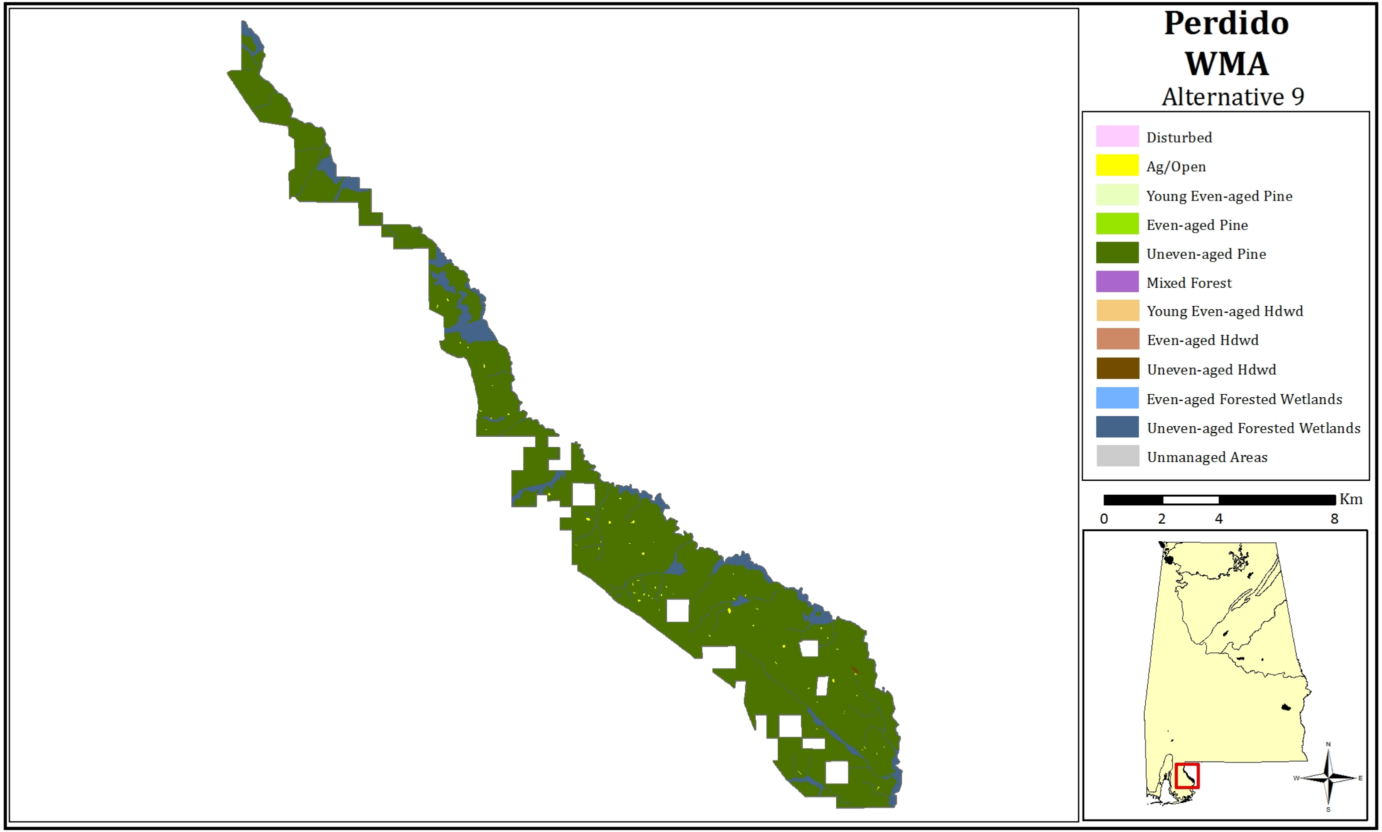

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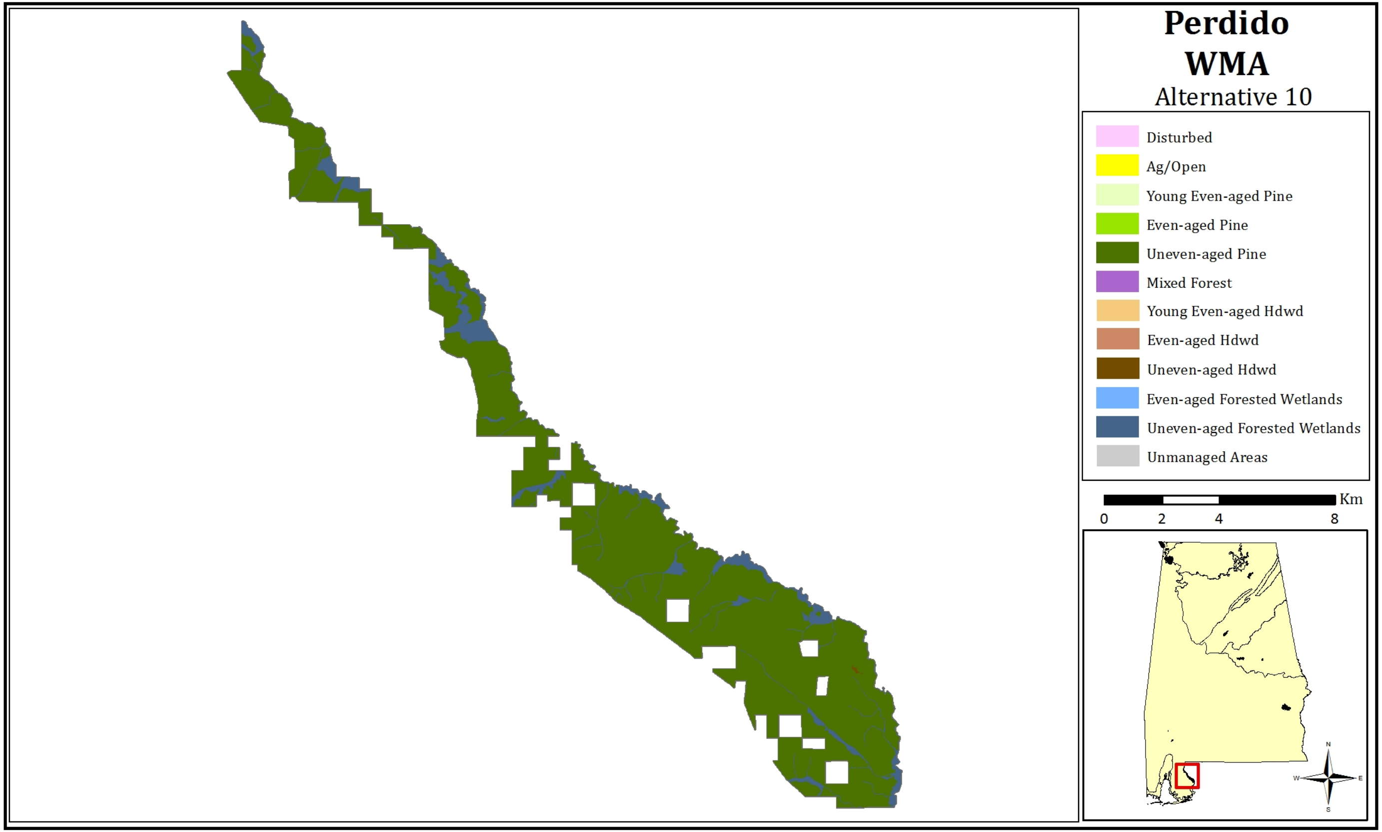

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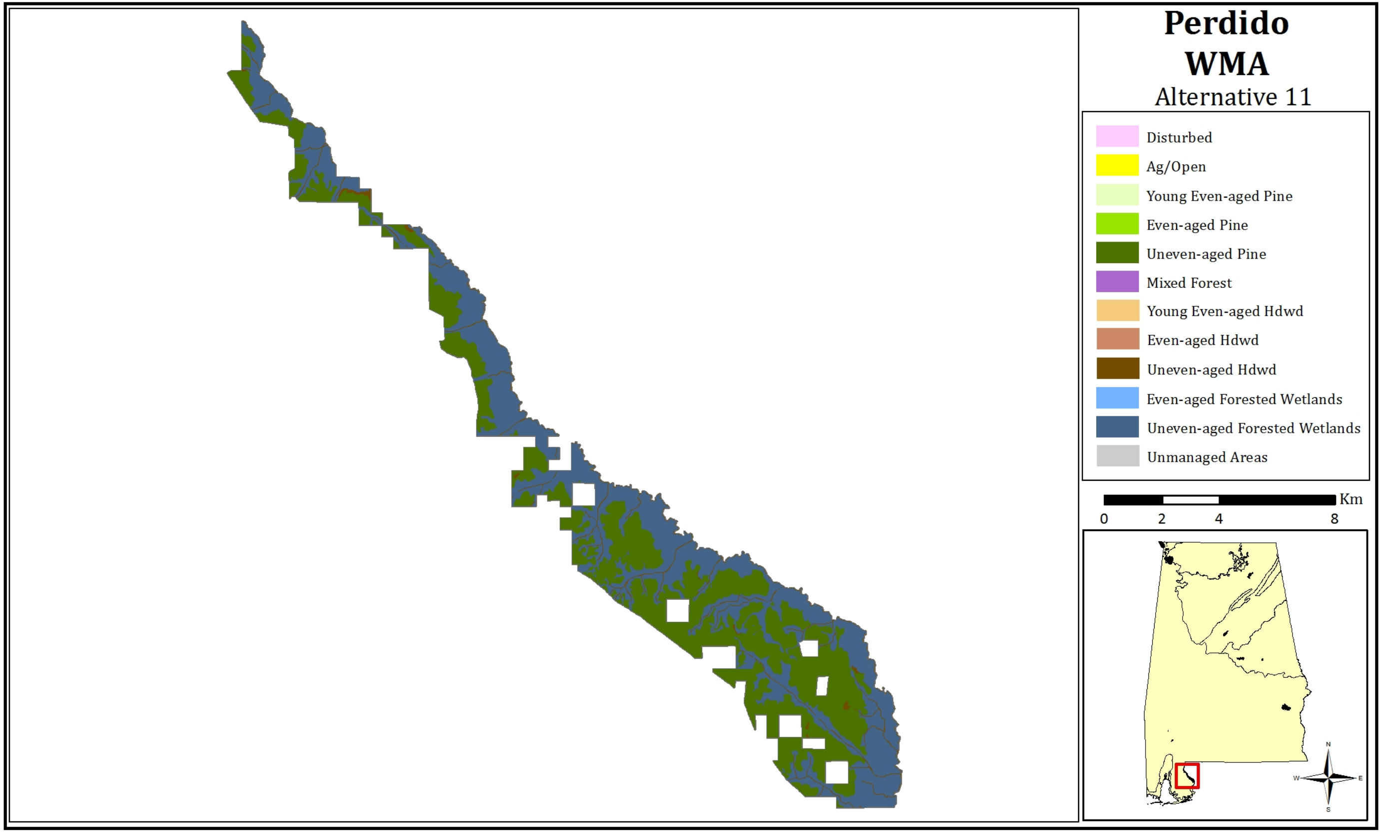

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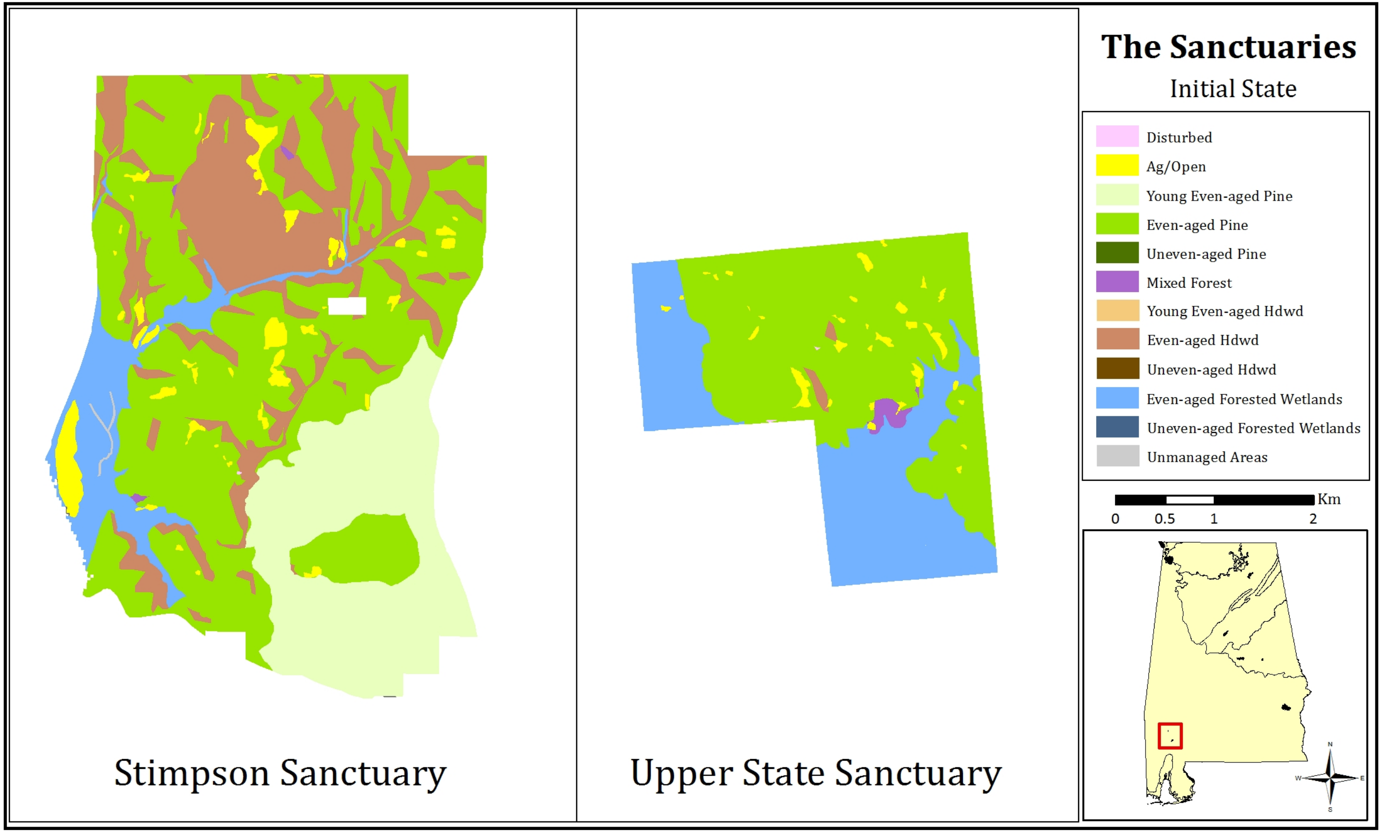

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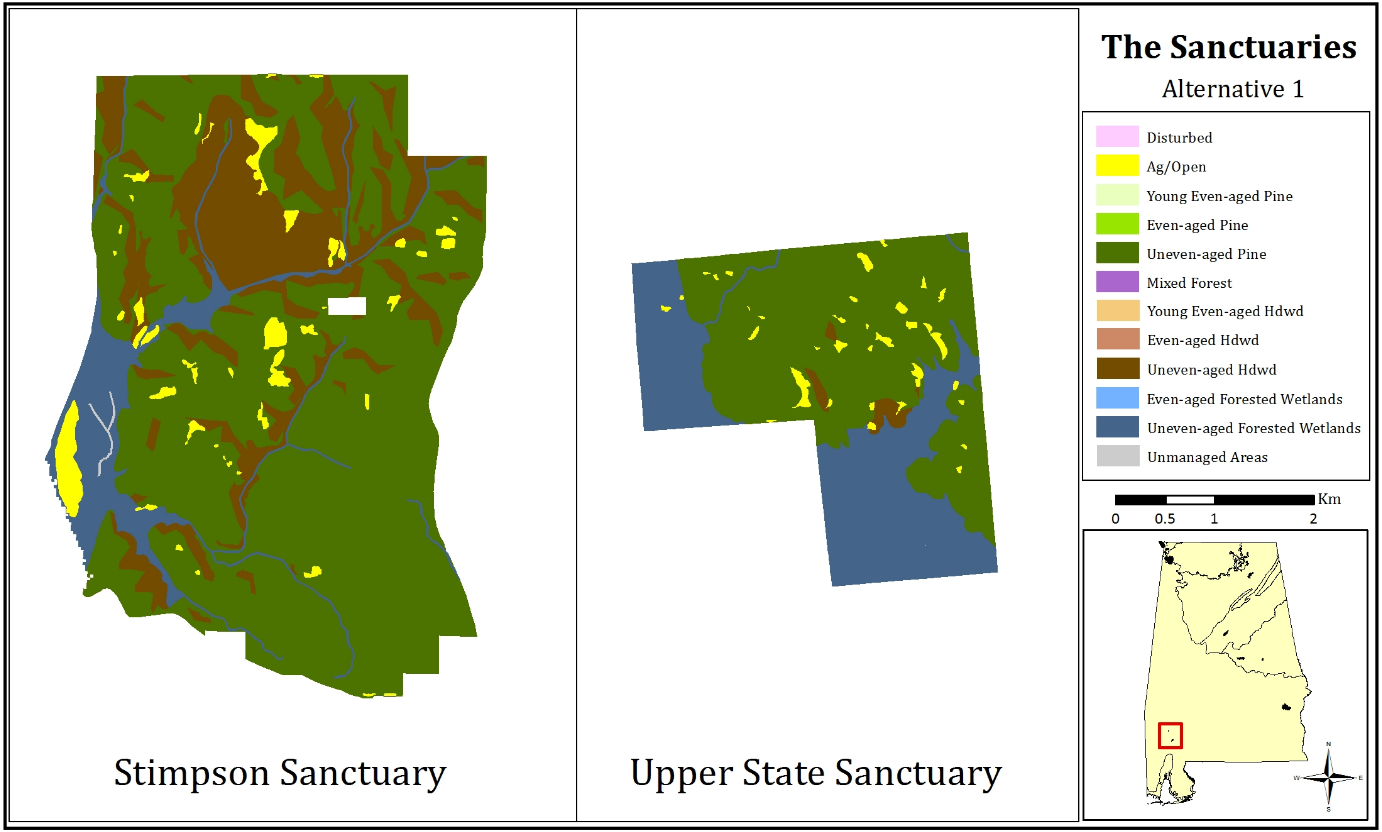

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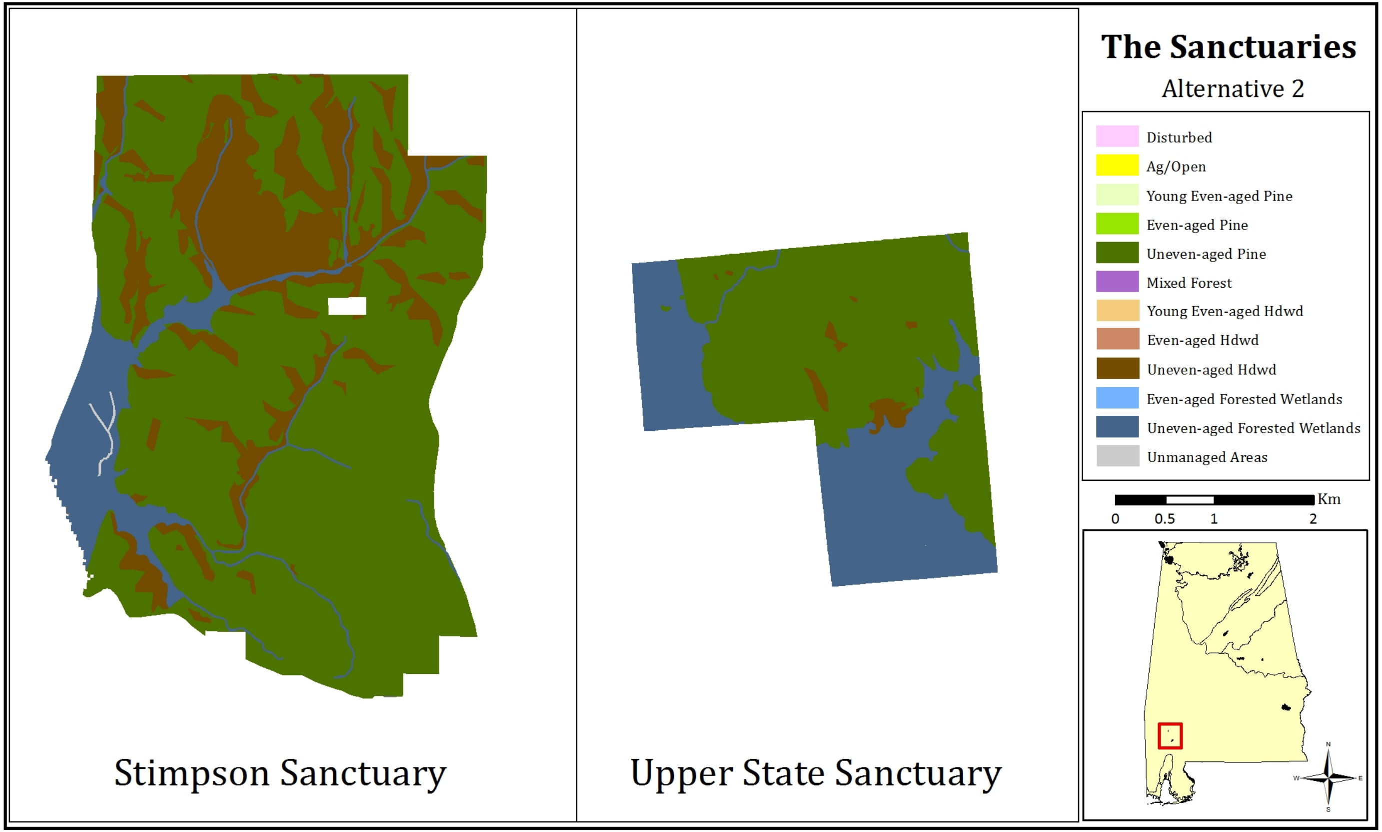

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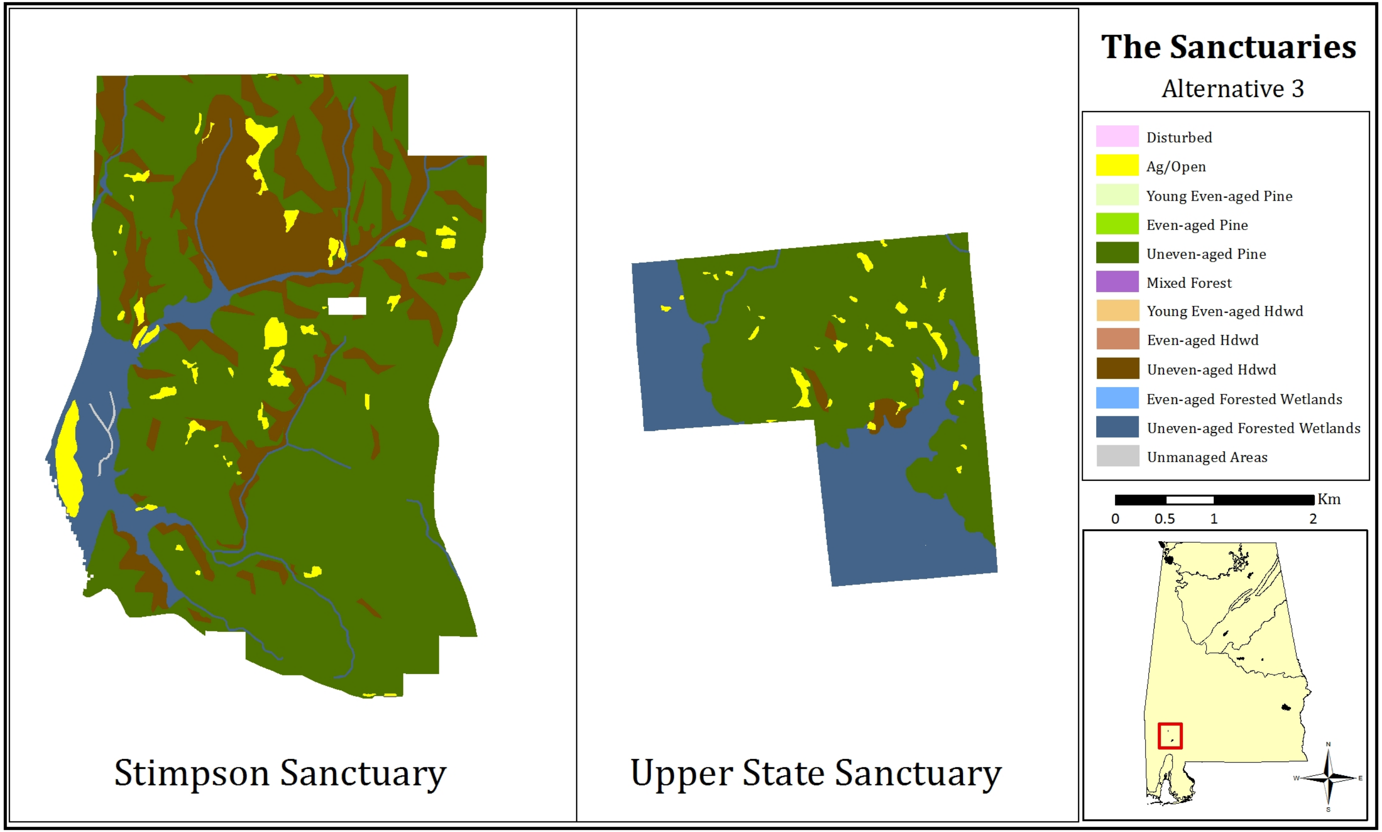

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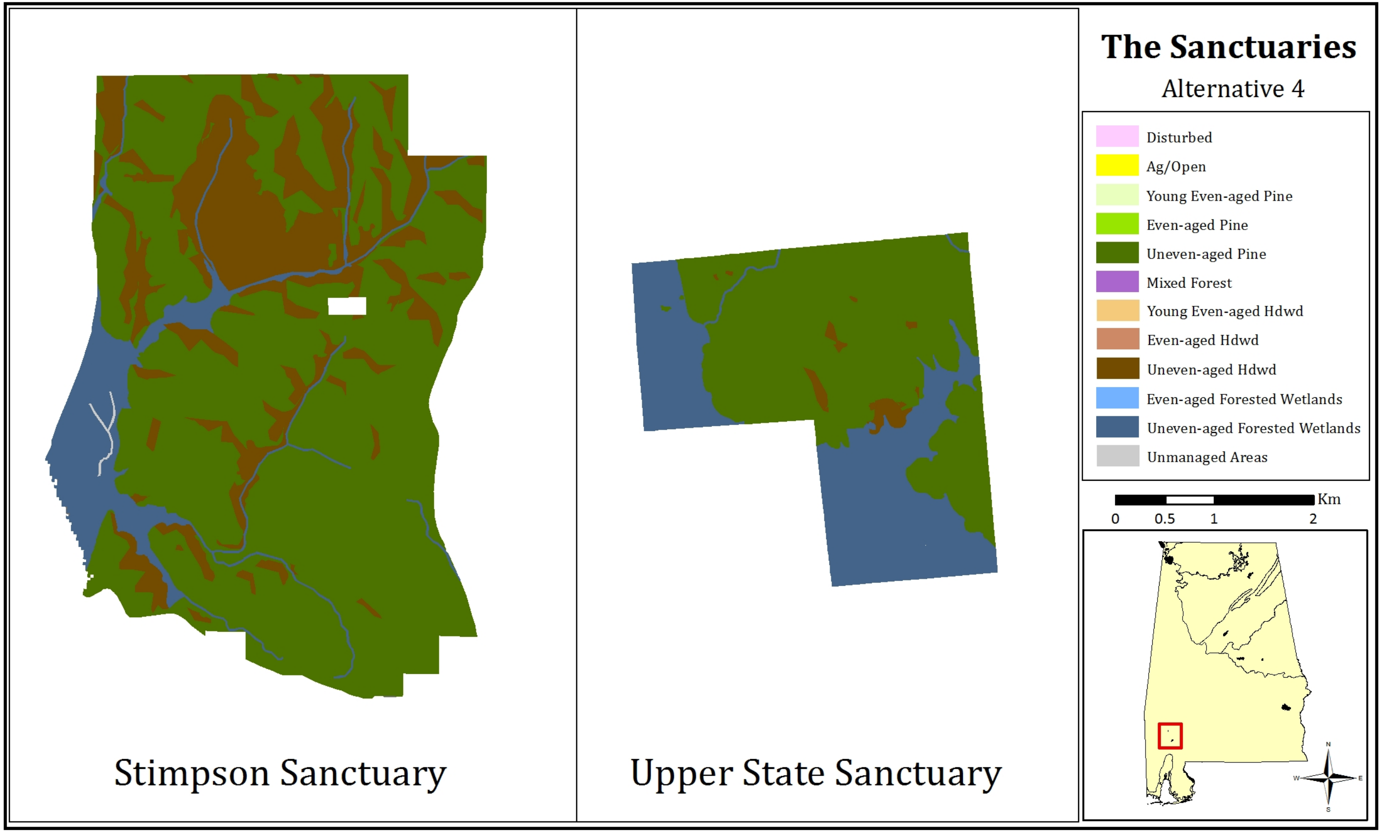
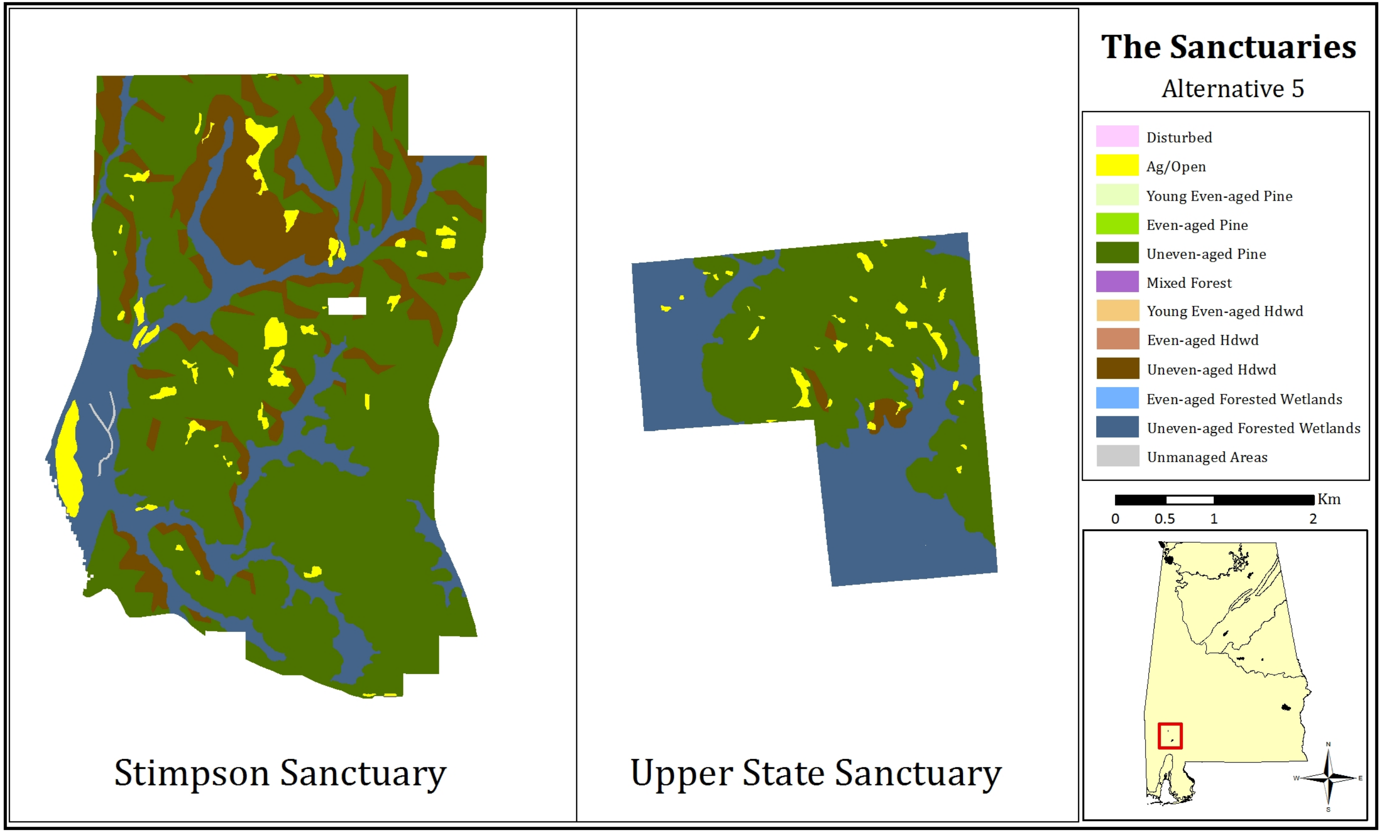
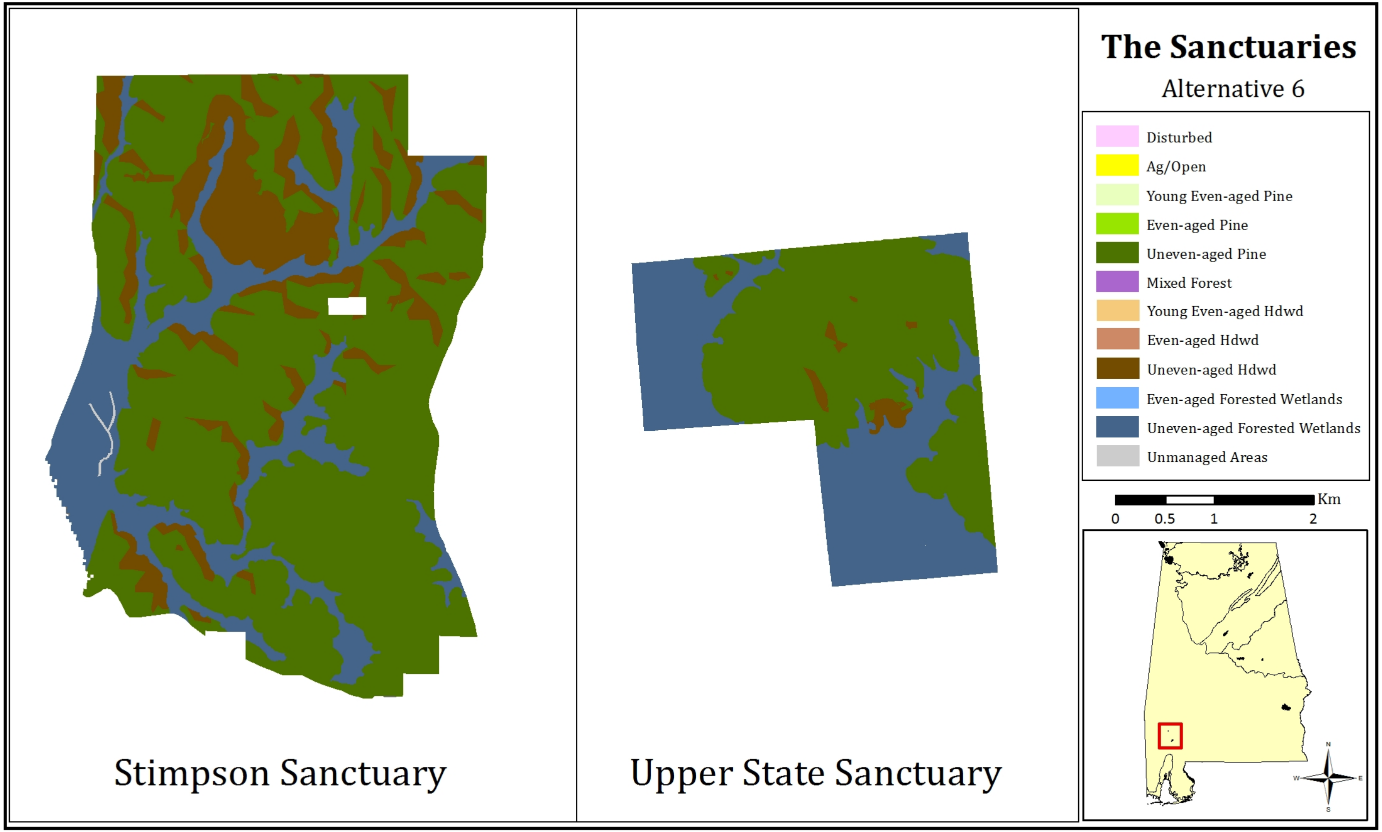


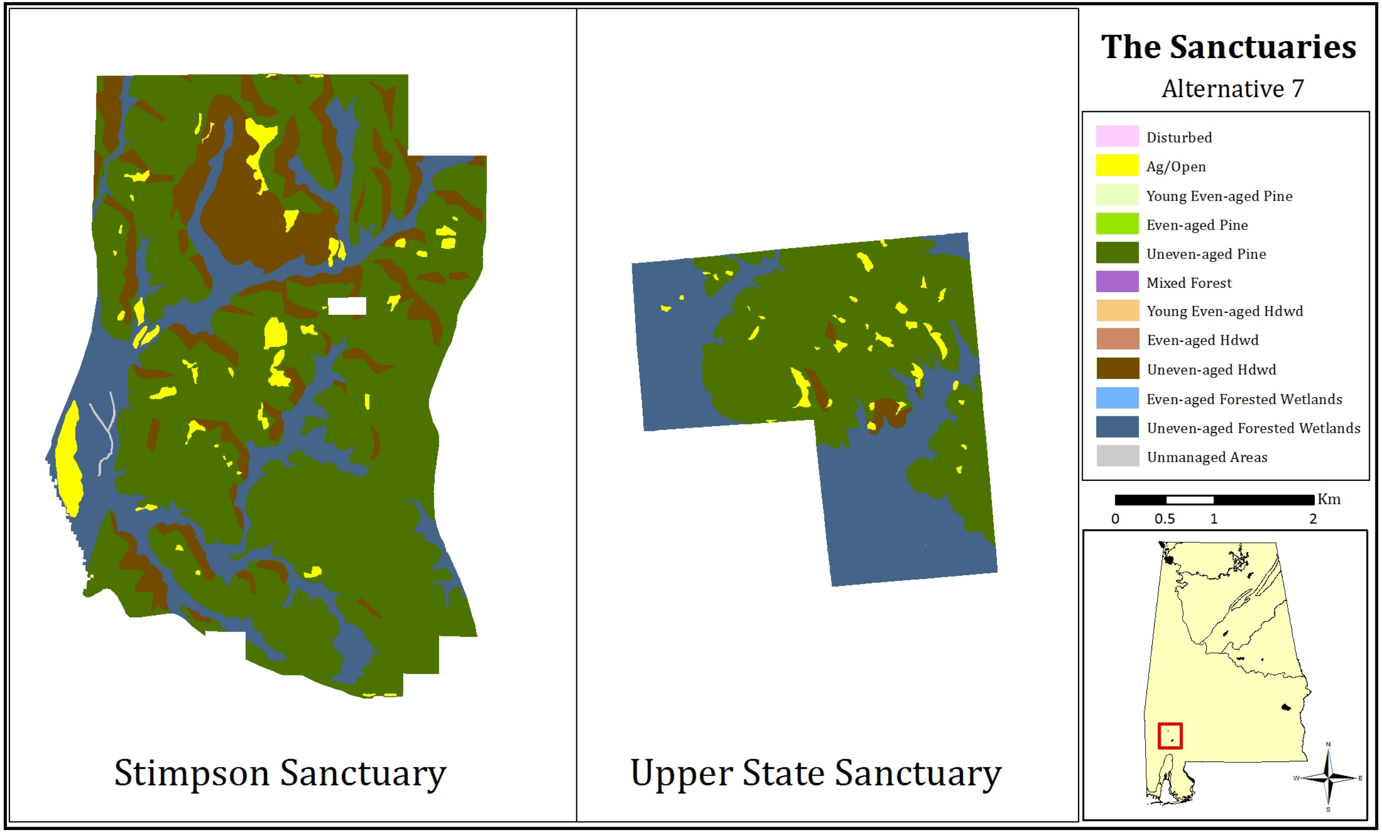
Appendix 1. Initial landscape conditions circa 2011 and targeted landscape composition and configuration at year 100 for each alternative for each study area.



Appendix 1. Initial landscape conditions circa 2011 and targeted landscape composition and configuration at year 100 for each alternative for each study area.



Appendix 1. Initial landscape conditions circa 2011 and targeted landscape composition and configuration at year 100 for each alternative for each study area.



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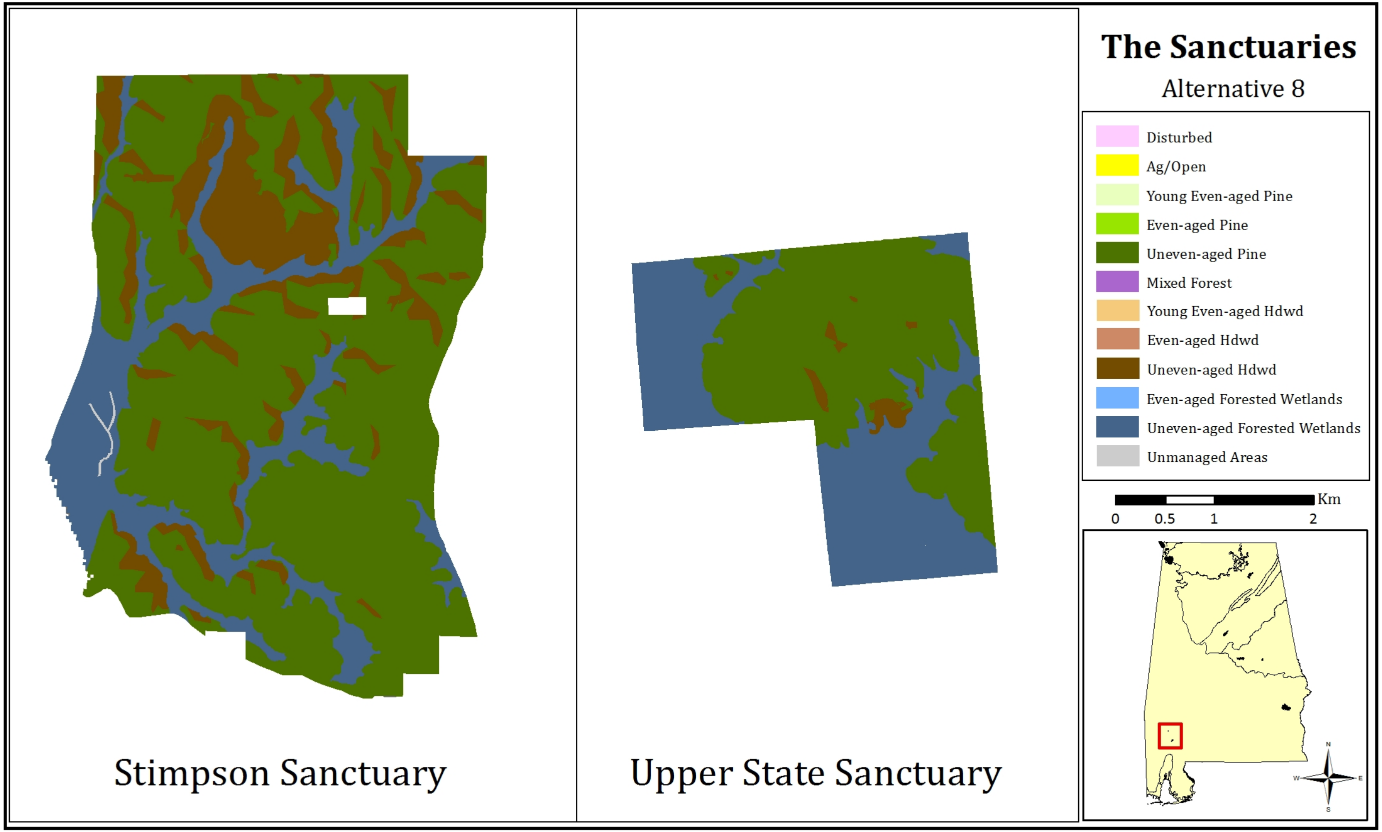
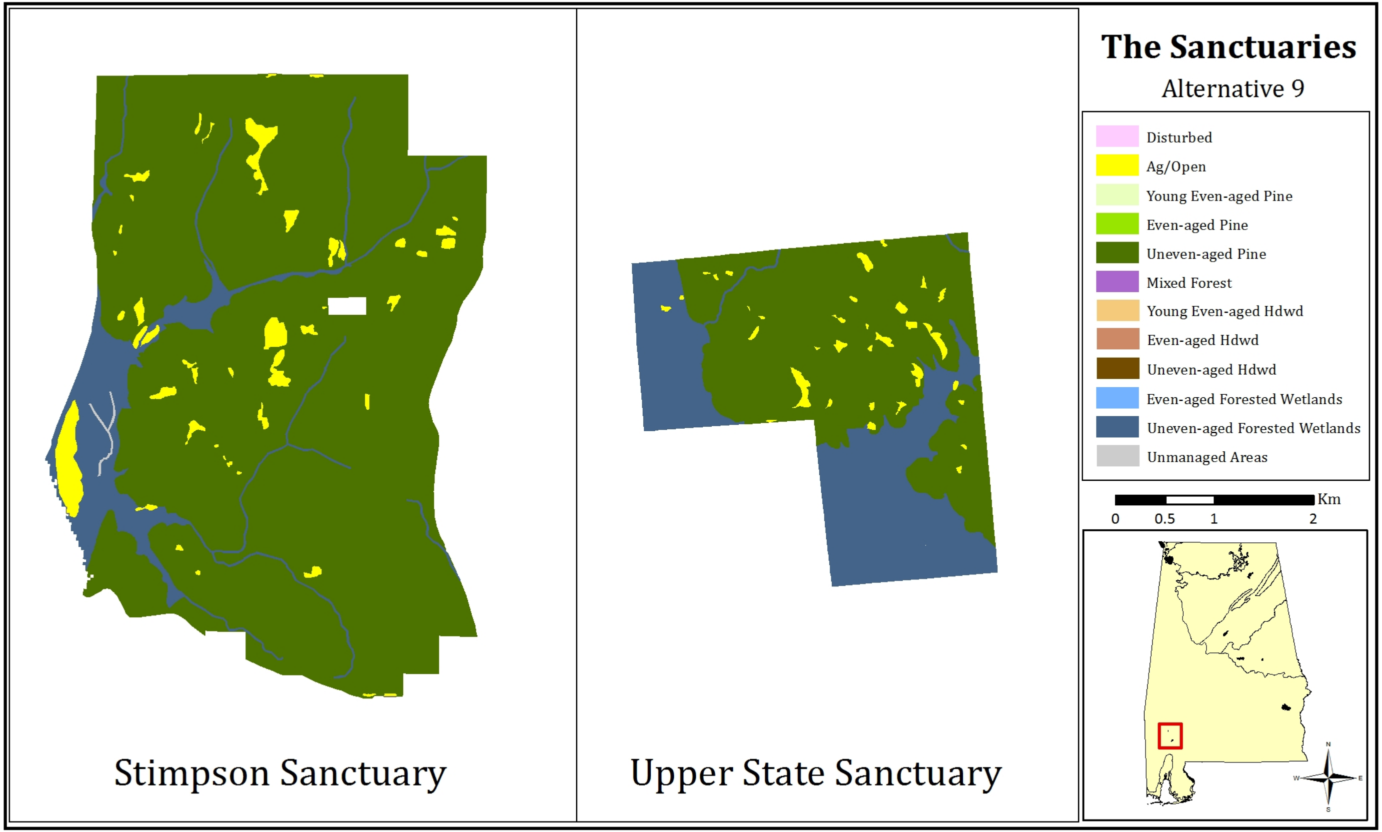
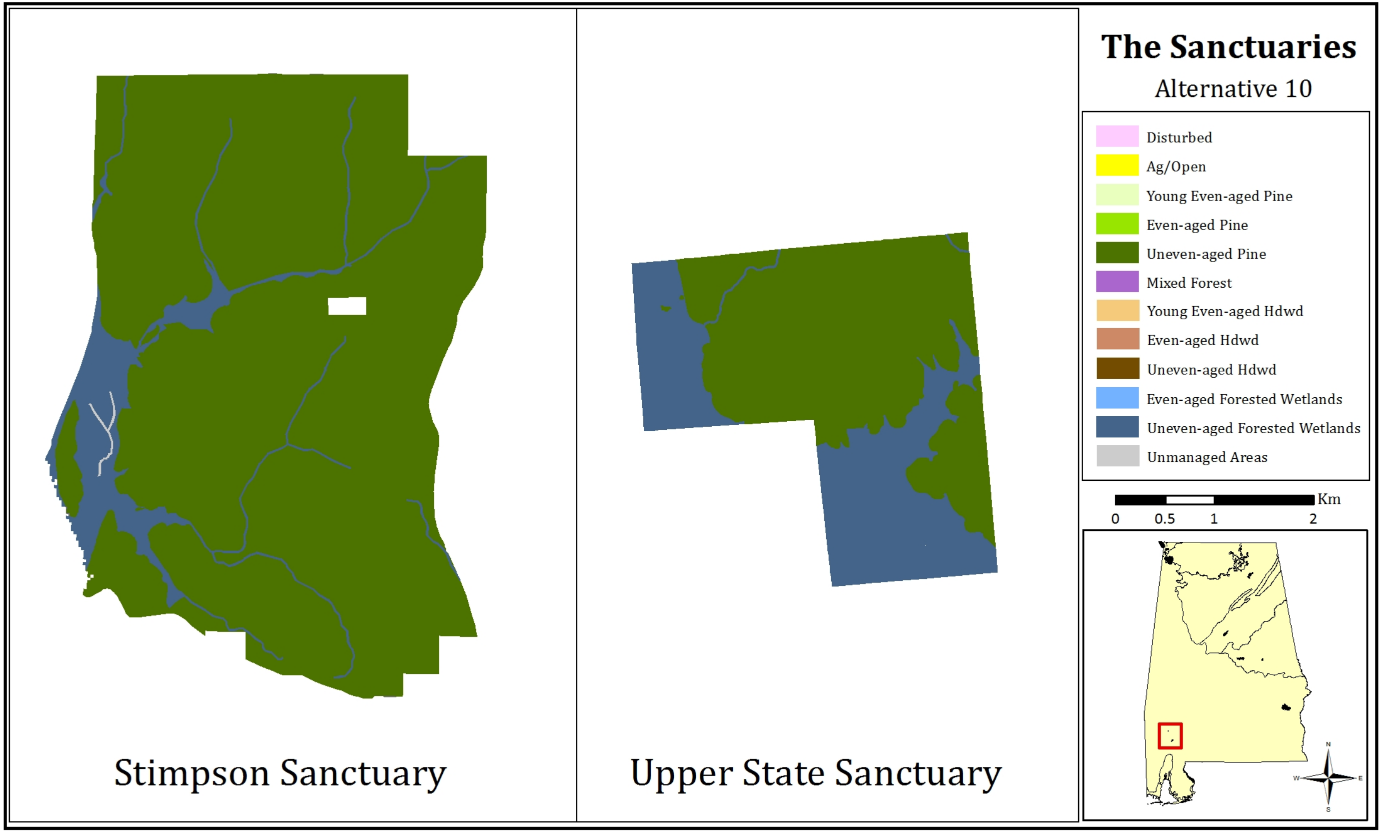


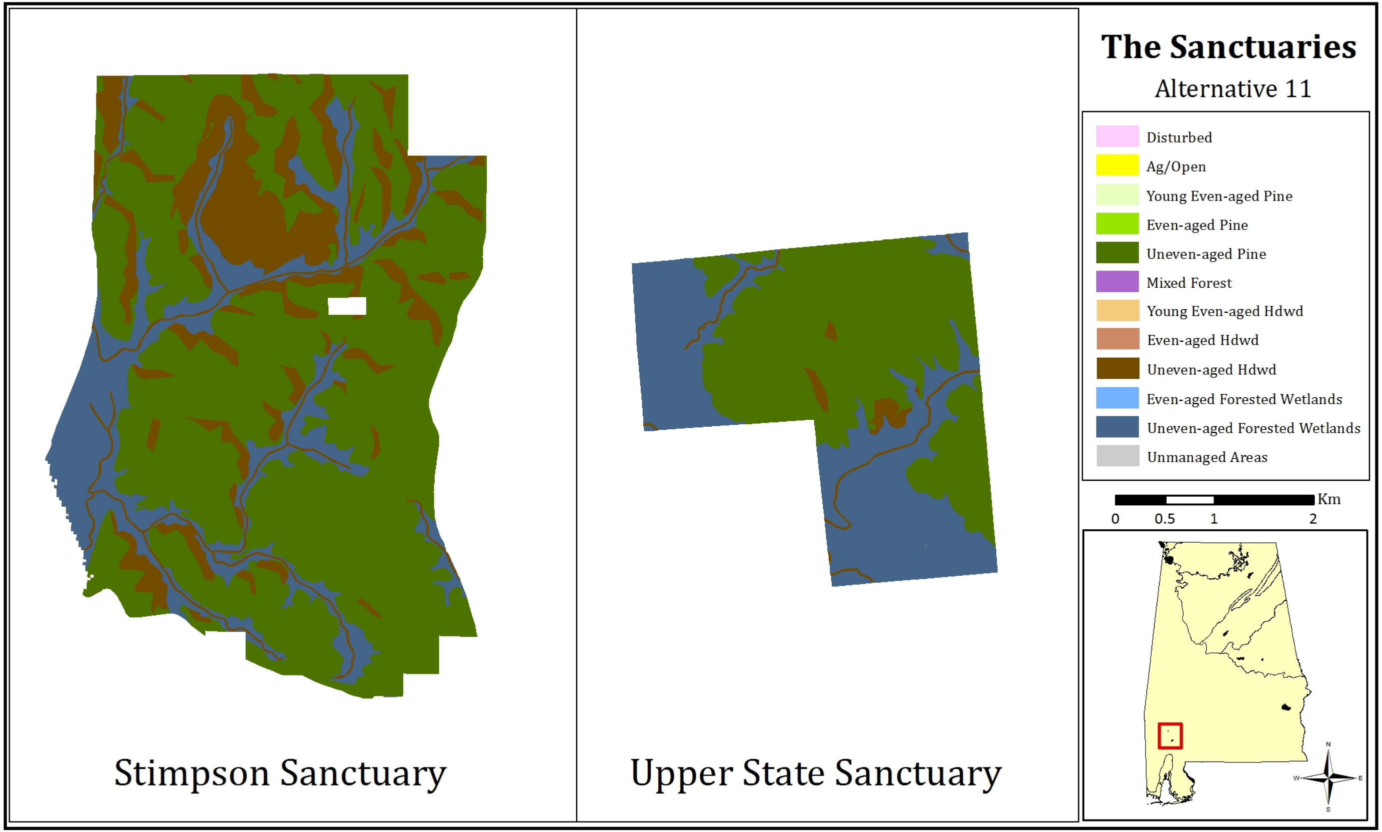
Appendix 1. Initial landscape conditions circa 2011 and targeted landscape composition and configuration at year 100 for each alternative for each study area.



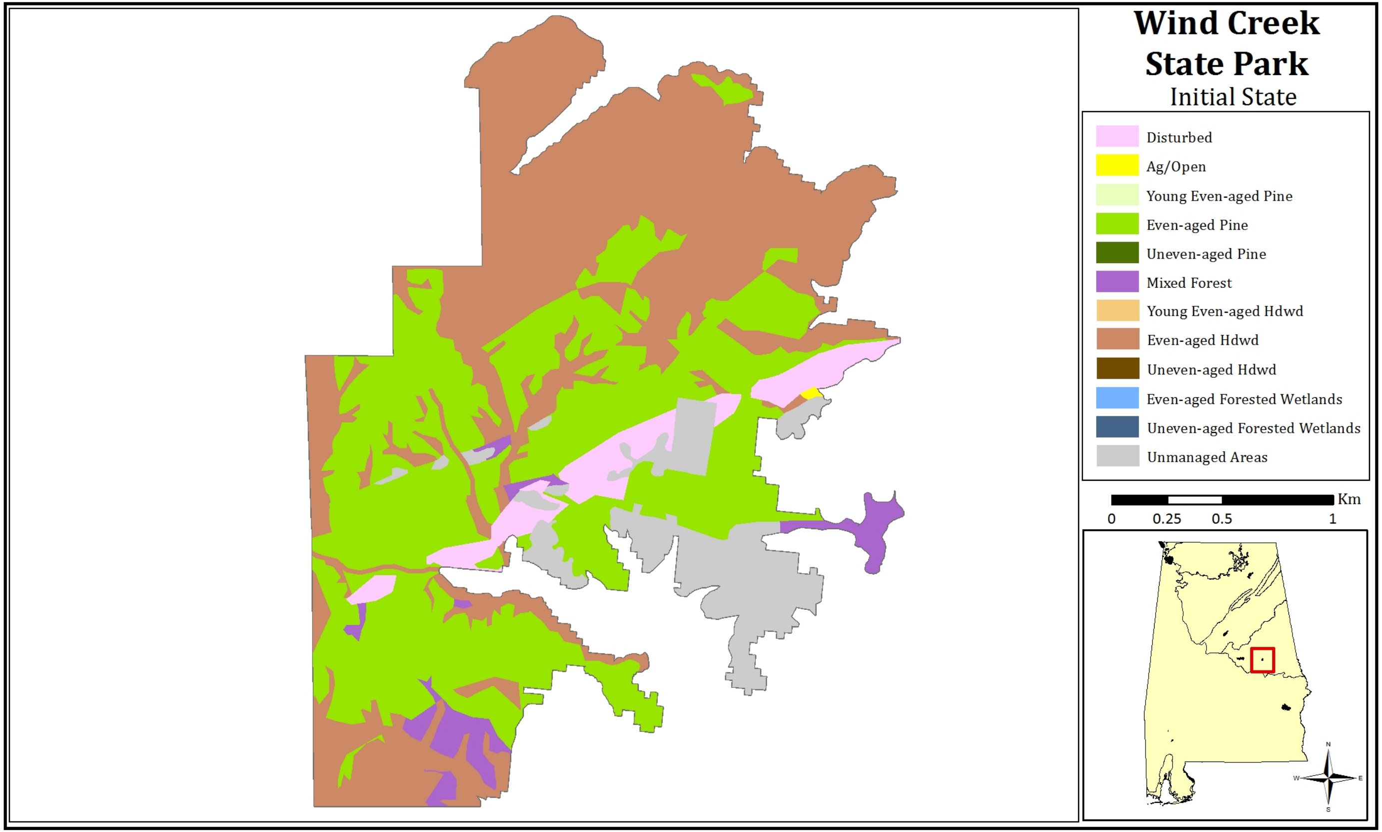
Appendix 1. Initial landscape conditions circa 2011 and targeted landscape composition and configuration at year 100 for each alternative for each study area.



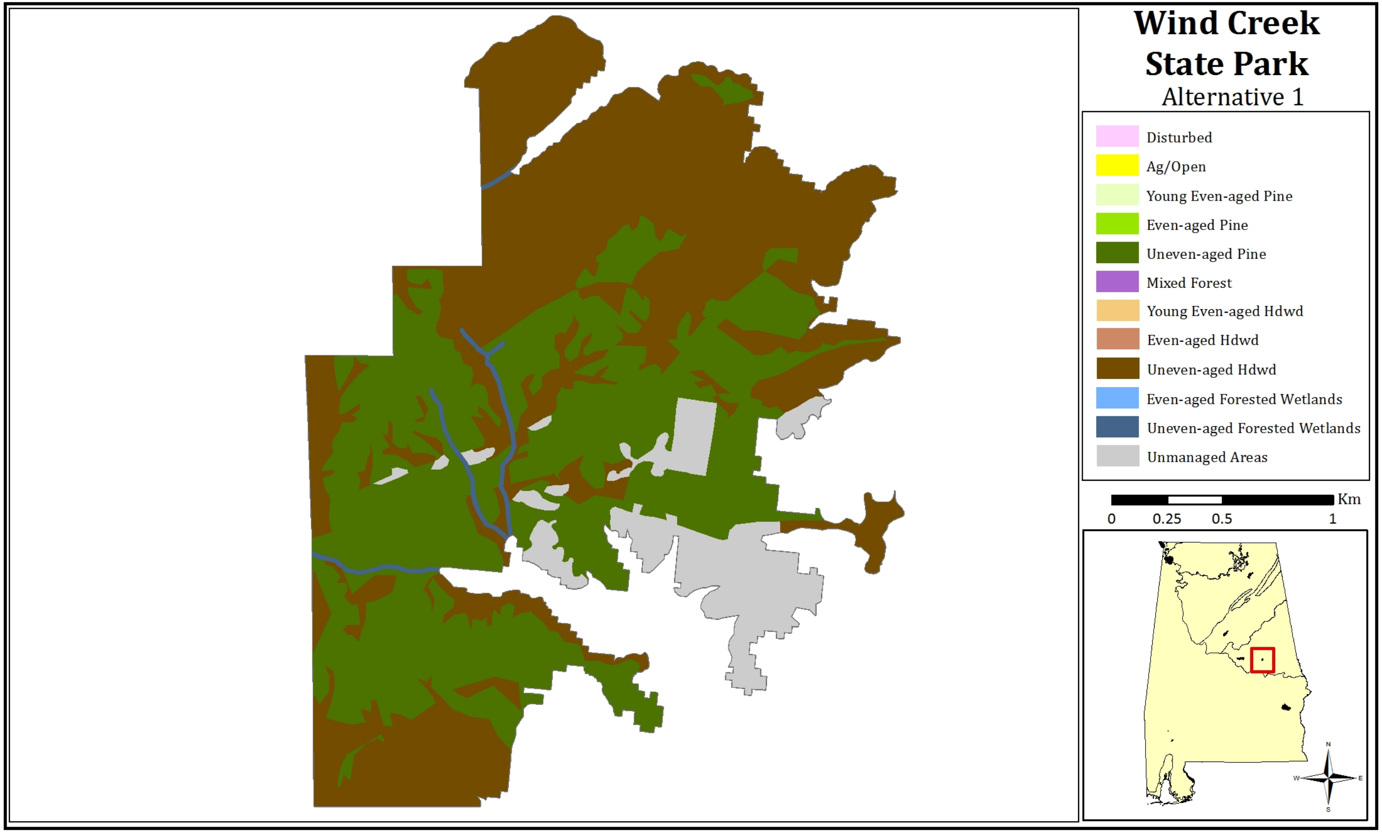
Appendix 1. Initial landscape conditions circa 2011 and targeted landscape composition and configuration at year 100 for each alternative for each study area.



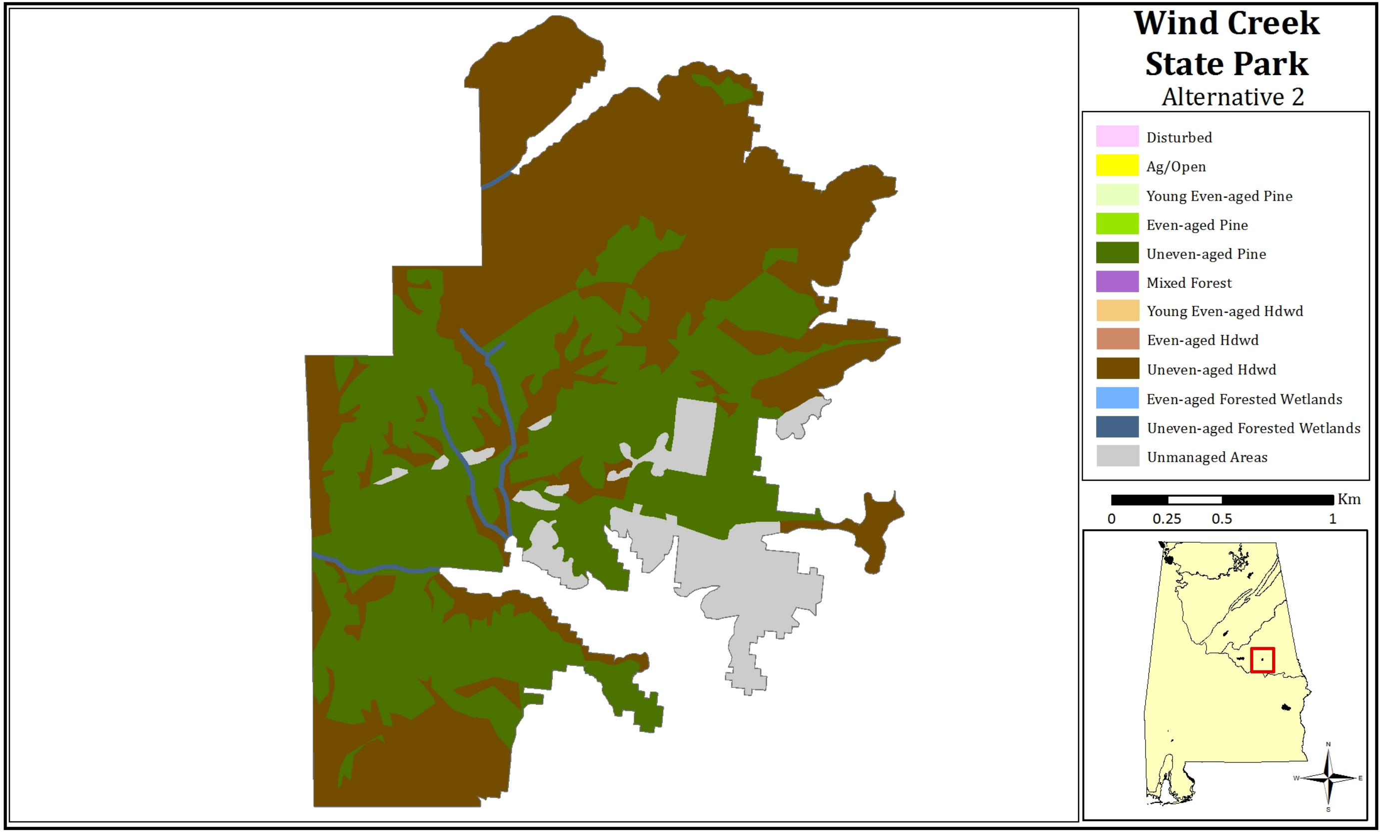
Appendix 1. Initial landscape conditions circa 2011 and targeted landscape composition and configuration at year 100 for each alternative for each study area.



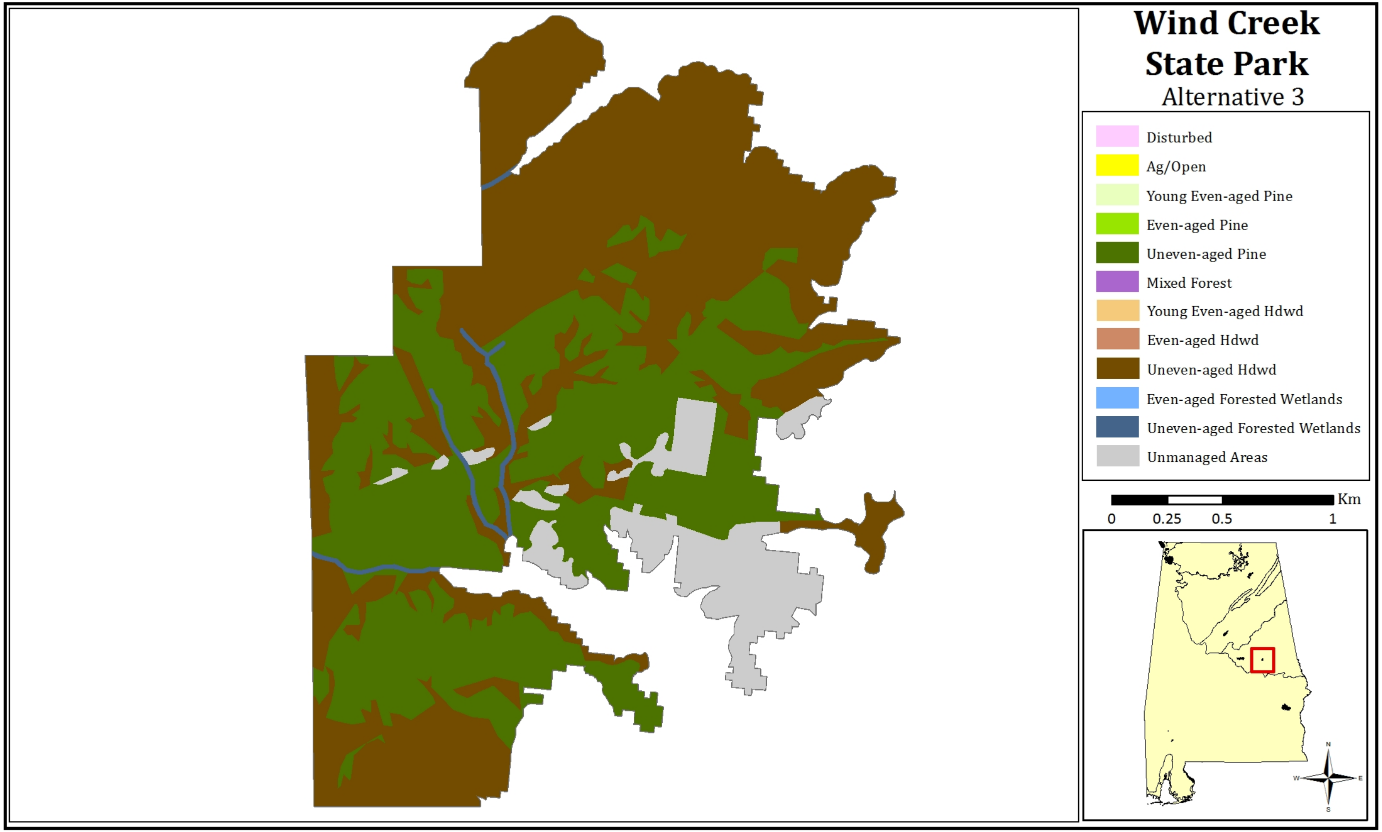
Appendix 1. Initial landscape conditions circa 2011 and targeted landscape composition and configuration at year 100 for each alternative for each study area.



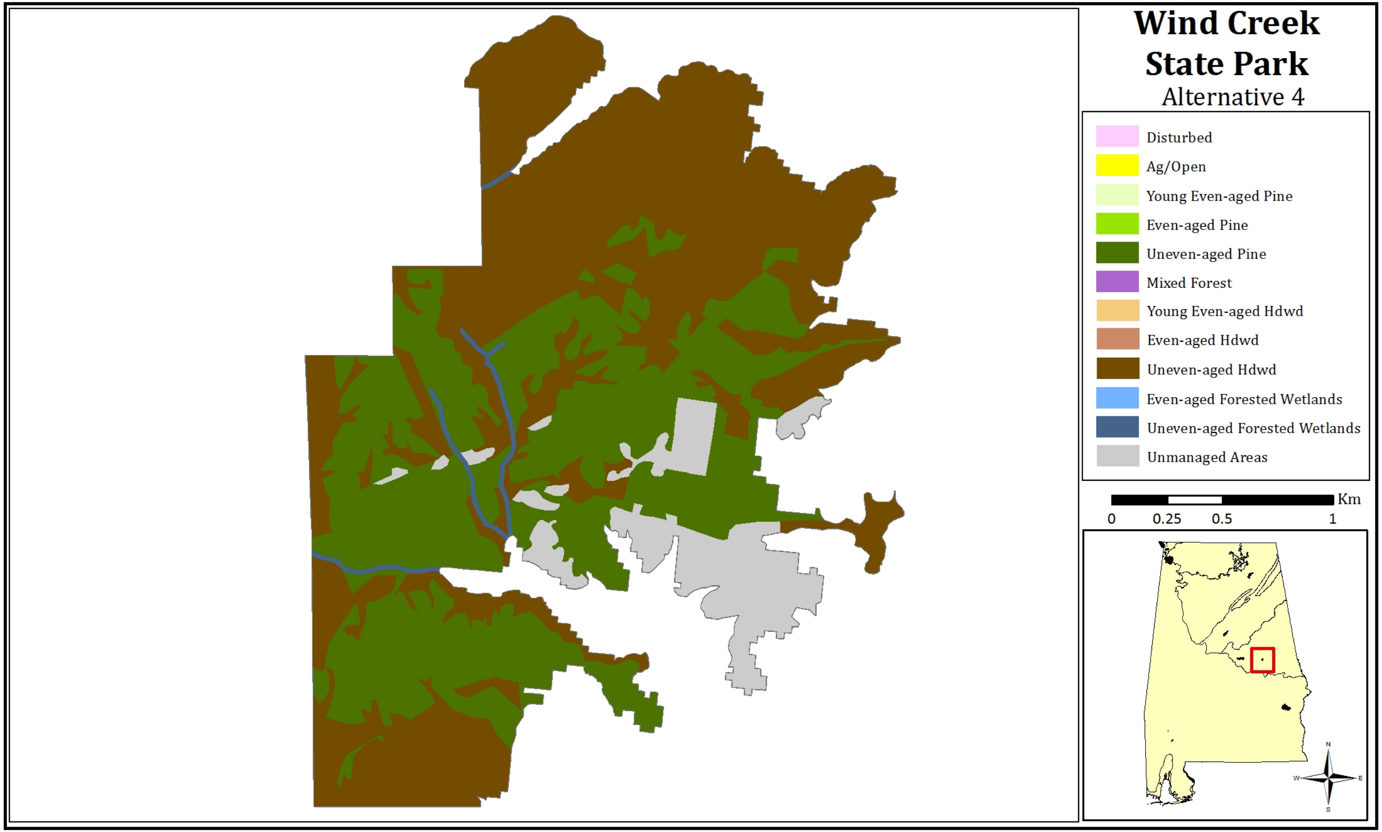
Appendix 1. Initial landscape conditions circa 2011 and targeted landscape composition and configuration at year 100 for each alternative for each study area.



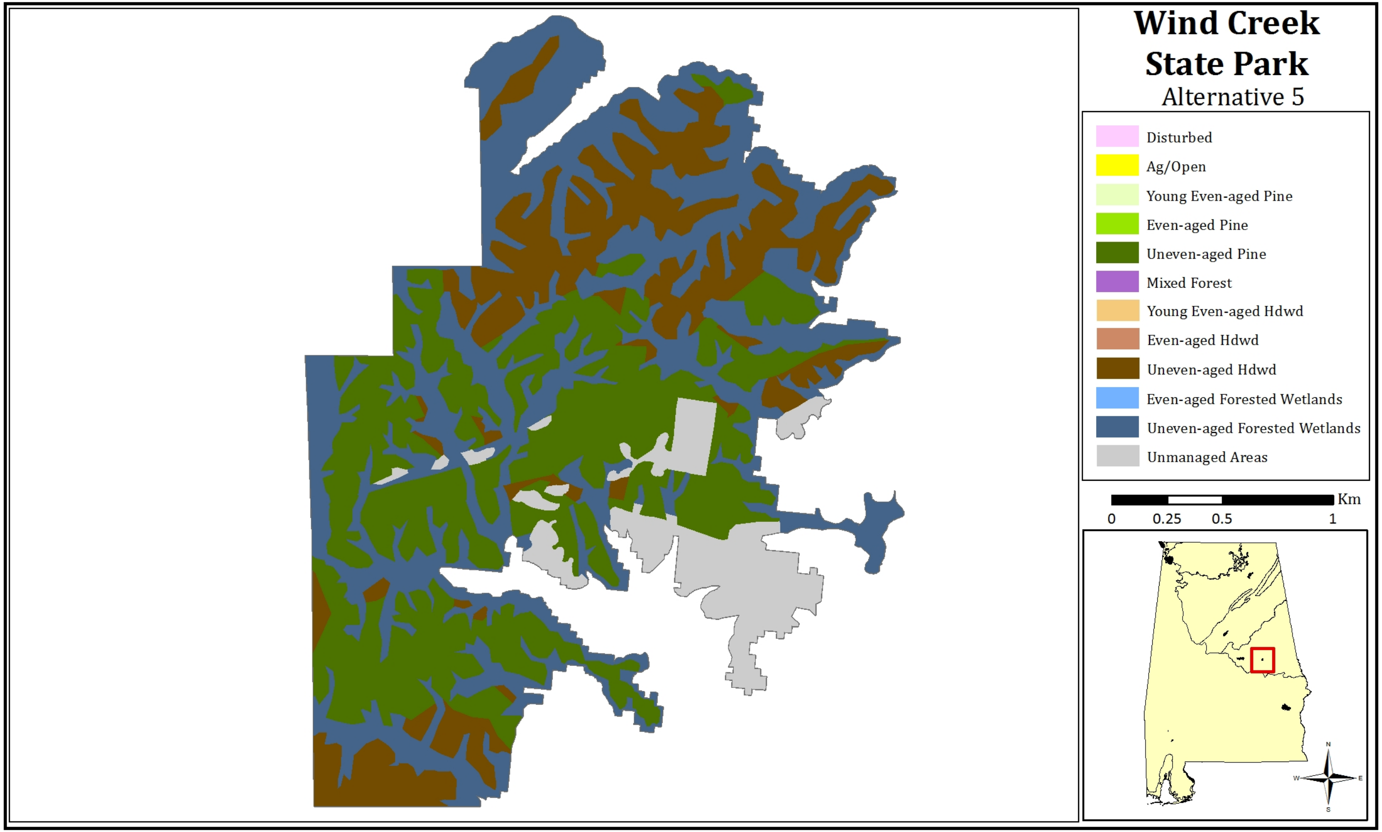
Appendix 1. Initial landscape conditions circa 2011 and targeted landscape composition and configuration at year 100 for each alternative for each study area.



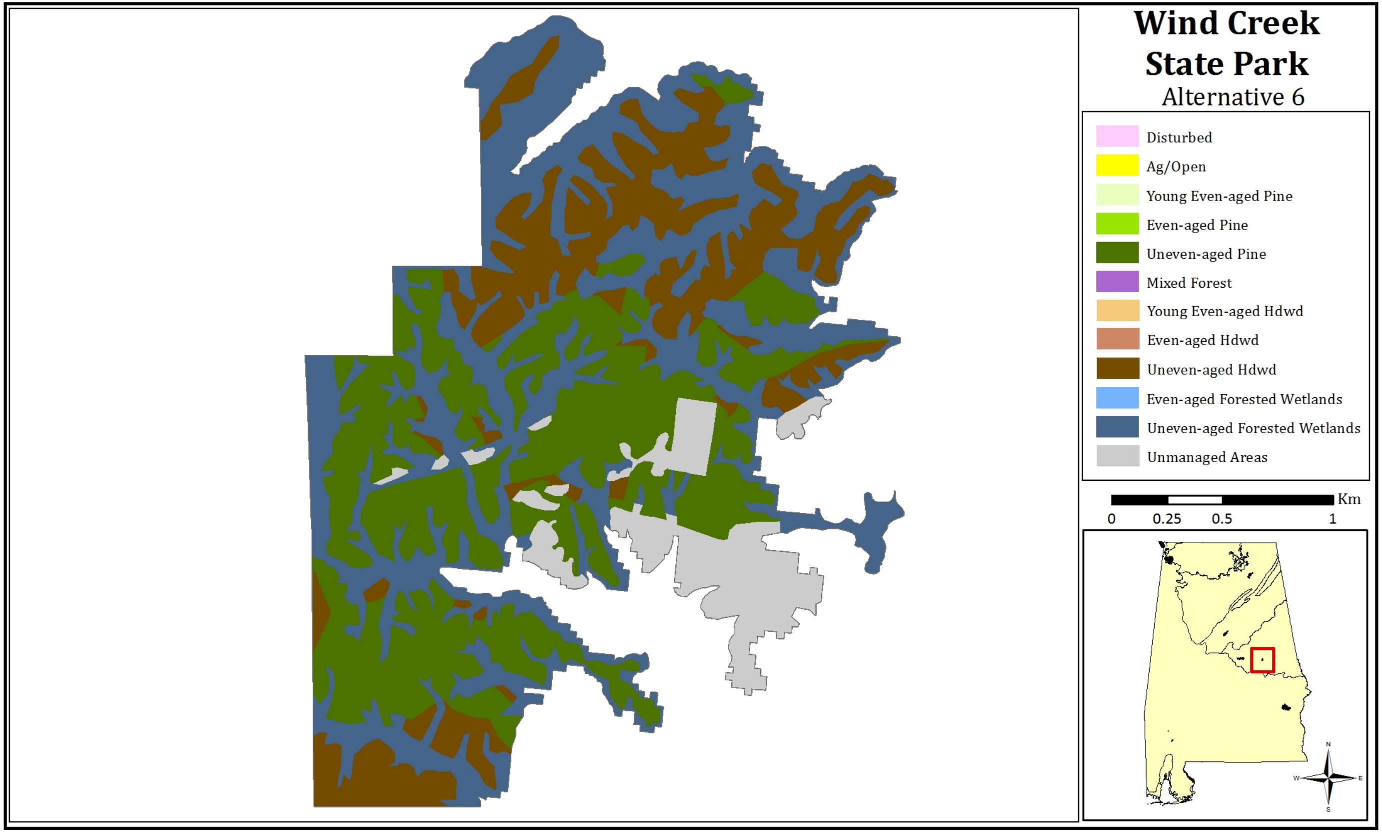
Appendix 1. Initial landscape conditions circa 2011 and targeted landscape composition and configuration at year 100 for each alternative for each study area.



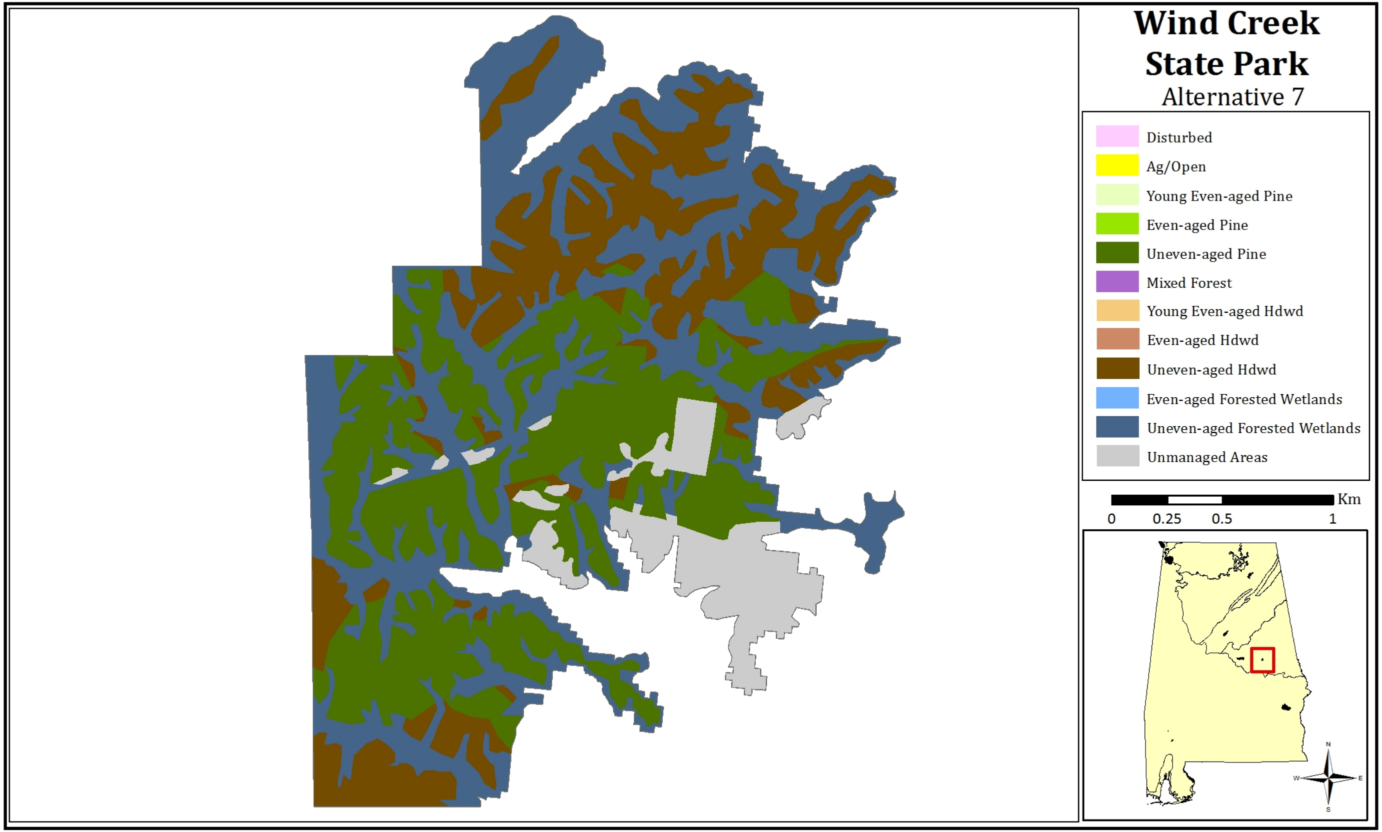
Appendix 1. Initial landscape conditions circa 2011 and targeted landscape composition and configuration at year 100 for each alternative for each study area.



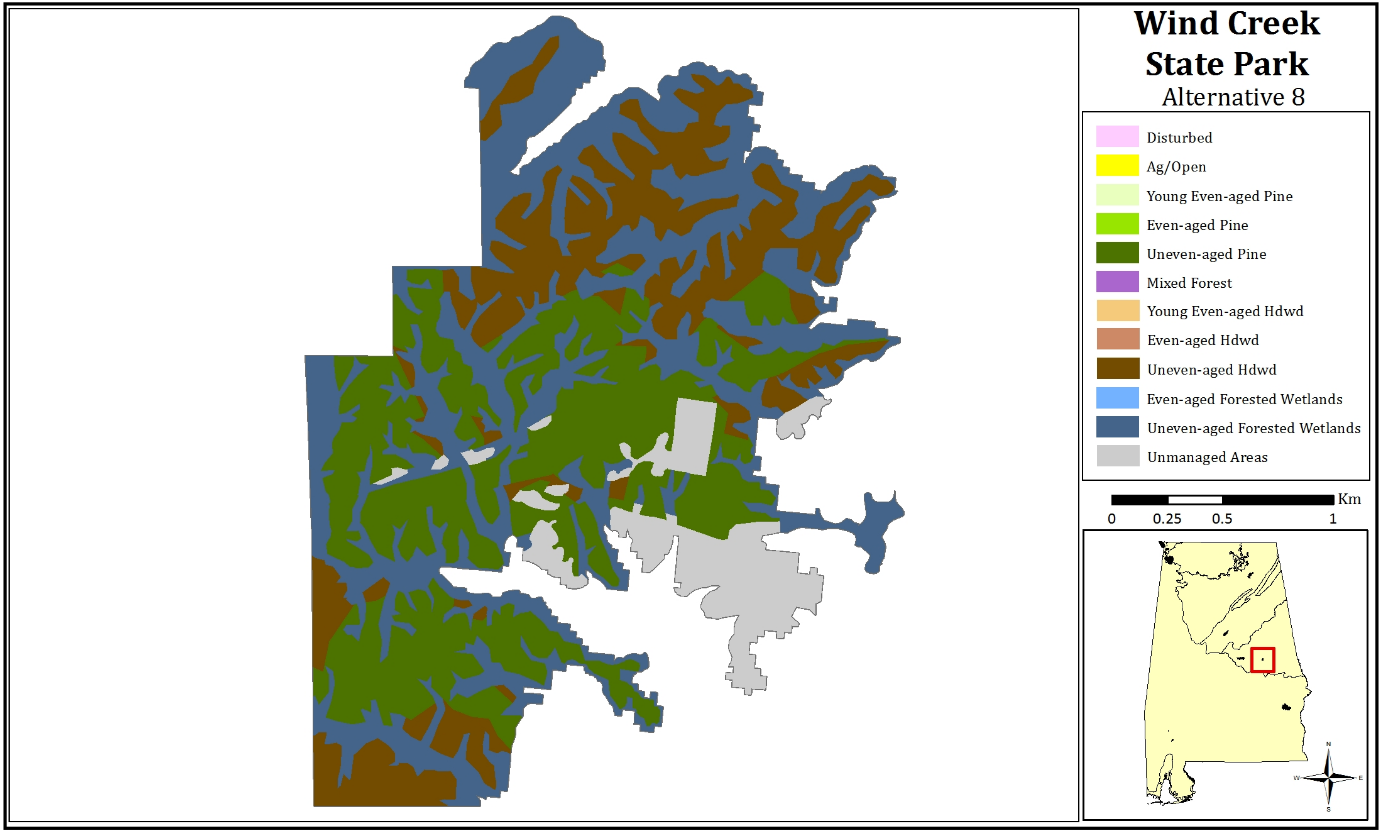
Appendix 1. Initial landscape conditions circa 2011 and targeted landscape composition and configuration at year 100 for each alternative for each study area.



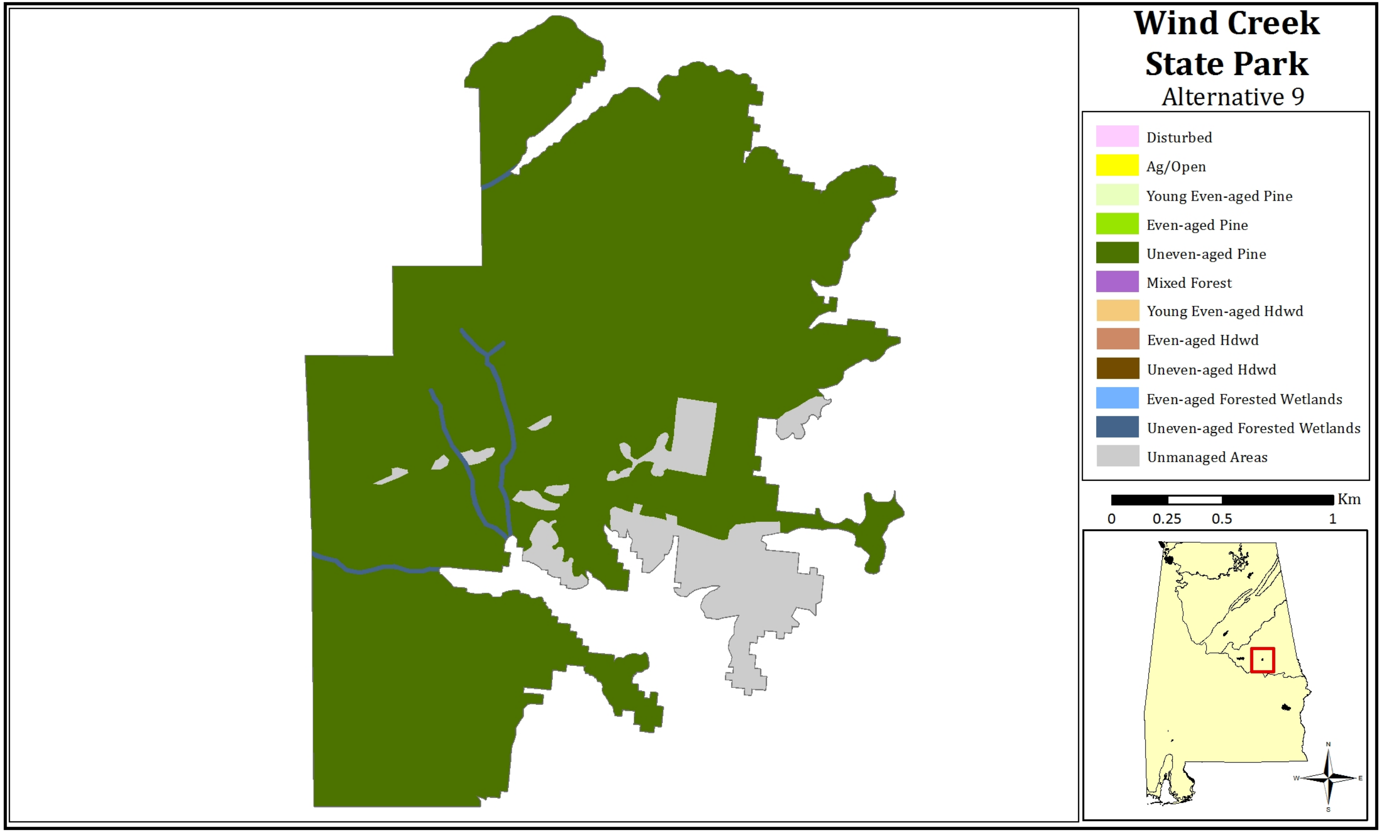
Appendix 1. Initial landscape conditions circa 2011 and targeted landscape composition and configuration at year 100 for each alternative for each study area.



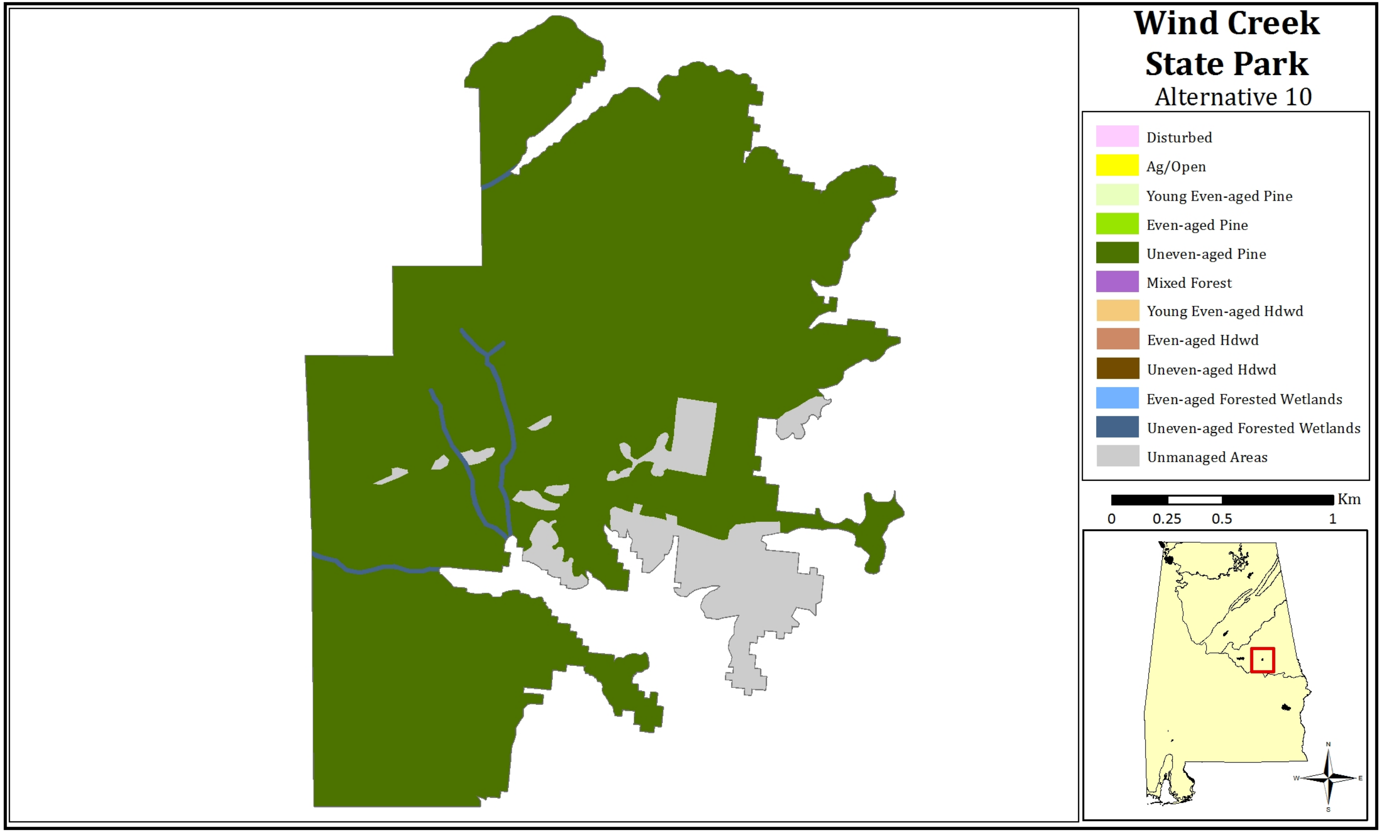
Appendix 1. Initial landscape conditions circa 2011 and targeted landscape composition and configuration at year 100 for each alternative for each study area.



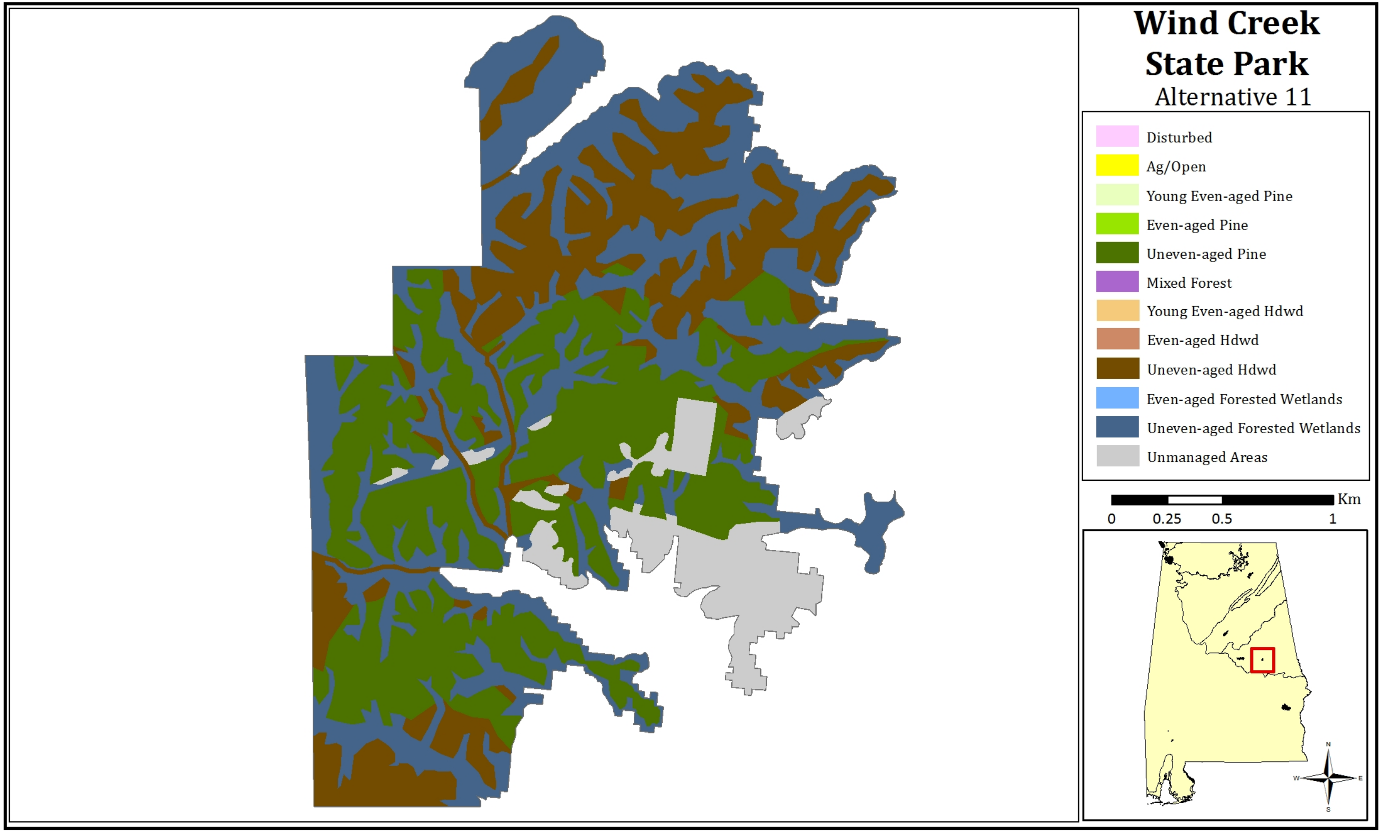
Appendix 1. Initial landscape conditions circa 2011 and targeted landscape composition and configuration at year 100 for each alternative for each study area.



Appendix 1. Initial landscape conditions circa 2011 and targeted landscape composition and configuration at year 100 for each alternative for each study area.



Appendix 1. Initial landscape conditions circa 2011 and targeted landscape composition and configuration at year 100 for each alternative for each study area.



Appendix 2: Matrices of annual transition rates use to project land cover type over time under 11 management alternatives for Alabama Department of Conservation and Natural Resources lands.

Table 1. Annual tranistion rates among land cover types (states) in stream-side management zone (SMZ) on Alabama Department of Conservation and Natural Resources lands. SMZ transition rates were used in management units falling within 11m of streams for alternative 1-10).

From(➔) To(⬇)	Land Cover State Number	Agriculture (Pine) 1	Open (Pine) 2	Disturbed (to Pine) 3	Hardwood 4	Mixed Pine/Hardwood 5	Even-age Forested Wetland 6	Seedling/Sapling pine 7	Poles/Small trees pine 8	Trees >12dbh pine 9	Two age pine 10	Uneven-aged Pine 11	Hardwood savannah 12	Agriculture (Hardwood) 13	Open (Hardwood) 14	Disturbed (to Hardwood) 15	Hardwood 16	Mixed Pine/Hardwood 17	Uneven-age Forested Wetland 18	Seedling/Sapling hardwood 19	Poles/Small trees hardwood 20	Trees >12dbh hardwood 21	Two age hardwood 22	Uneven-aged Hardwood 23	Water 24	Developed 25
Agriculture (Pine)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Open (Pine)	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Disturbed (to Pine)	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mixed Pine/Hardwood	5	0	0	0	0	0.499	0	0	0	0.200	0.200	0.050	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Forested Wetland	6	0	0	0	0	0	0.978	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Seedling/Sapling pine	7	0	0	0	0	0	0	0.798	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poles/Small trees pine	8	0	0	0	0	0	0	0.200	0.898	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trees >12dbh pine	9	0	0	0	0	0	0	0	0.100	0.798	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Two age pine	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unevenaged Pine	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hardwood savannah	12	0	0	0	0	0	0	0	0	0	0	0	1.000	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture (Hardwood)	13	0	0	0	0	0	0	0	0	0	0	0	0	1.000	0	0	0	0	0	0	0	0	0	0	0	0
Open (Hardwood)	14	0	0	0	0	0	0	0	0	0	0	0	0	0	1.000	0	0	0	0	0	0	0	0	0	0	0
Disturbed (to Hardwood)	15	0	0	0	0	0.002	0.002	0.002	0.002	0.002	0.800	0.950	0	0	0	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0	0
Hardwood	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.998	0.020	0	0	0	0	0	0	0	0
Mixed Pine/Hardwood	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.978	0	0	0	0	0	0	0	0
Forested Wetland	18	0	0	0	0	0	0.020	0	0	0	0	0	0	0	0	0	0	0	0.998	0	0	0.040	0.080	0.250	0	0
Seedling/Sapling hardwood	19	1.000	1.000	1.000	0	0	0	0	0	0	0	0	0	0	0	0.998	0	0	0	0.848	0	0	0	0	0	0
Poles/Small trees hardwood	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.150	0.918	0	0	0	0	0
Trees >12dbh hardwood	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.080	0.938	0	0	0	0
Two age hardwood	22	0	0	0	0	0.499	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.020	0.898	0	0	0
Unevenaged Hardwood	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.020	0.749	0	0
Water	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.000	0
Developed	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.000

Appendix 2: Matrices of annual transition rates use to project land cover type over time under 11 management alternatives for Alabama Department of Conservation and Natural Resources lands.

Table 2. Annual tranistion rates among land cover types (states) for Alternative 1 thorugh 10 on Alabama Department of Conservation and Natural Resources lands. Transition rates were used for management units wtihin a landscape that were maintined at the exsiting land cover type circa 2011 (i.e minimum management prescription or Status Quo).

From(➔) To(⬇)	Land Cover State Number	Agriculture (Pine)	Open (Pine)	Disturbed (to Pine)	Hardwood	Mixed Pine/Hardwood	Even-age Forested Wetland	Seedling/Sapling pine	Poles/Small trees pine	Trees >12dbh pine	Two age pine	Uneven-aged Pine	Hardwood savannah	Agriculture (Hardwood)	Open (Hardwood)	Disturbed (to Hardwood)	Hardwood	Mixed Pine/Hardwood	Uneven-age Forested Wetland	Seedling/Sapling hardwood	Poles/Small trees hardwood	Trees >12dbh hardwood	Two age hardwood	Uneven-aged Hardwood	Water	Developed
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Agriculture (Pine)	1	1.000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Open (Pine)	2	0	1.000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Disturbed (to Pine)	3	0	0	0.100	0	0.001	0	0.001	0.001	0.001	0.001	0.001	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mixed Pine/Hardwood	5	0	0	0	0	0.978	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Forested Wetland	6	0	0	0	0	0	0.978	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Seedling/Sapling pine	7	0	0	0.900	0	0	0	0.798	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poles/Small trees pine	8	0	0	0	0	0	0	0.200	0.898	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trees >12dbh pine	9	0	0	0	0	0	0	0	0.100	0.898	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Two age pine	10	0	0	0	0	0	0	0	0	0.100	0.898	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unevenaged Pine	11	0	0	0	0	0	0	0	0	0	0.100	0.998	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hardwood savannah	12	0	0	0	0	0	0	0	0	0	0	0	1.000	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture (Hardwood)	13	0	0	0	0	0	0	0	0	0	0	0	0	1.000	0	0	0	0	0	0	0	0	0	0	0	0
Open (Hardwood)	14	0	0	0	0	0	0	0	0	0	0	0	0	0	1.000	0	0	0	0	0	0	0	0	0	0	0
Disturbed (to Hardwood)	15	0	0	0	0	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0	0	0	0.102	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0	0
Hardwood	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.998	0.020	0	0	0	0	0	0	0	0
Mixed Pine/Hardwood	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.978	0	0	0	0	0	0	0	0
Forested Wetland	18	0	0	0	0	0	0.020	0	0	0	0	0	0	0	0	0	0	0	0.998	0	0	0	0	0	0	0
Seedling/Sapling hardwood	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.898	0	0	0	0.848	0	0	0	0	0	0
Poles/Small trees hardwood	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.150	0.918	0	0	0	0	0
Trees >12dbh hardwood	21	0	0	0	0	0.020	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.080	0.978	0	0	0	0
Two age hardwood	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.020	0.978	0	0	0
Unevenaged Hardwood	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.020	0.998	0	0
Water	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.000	0
Developed	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.000

Appendix 2: Matrices of annual transition rates use to project land cover type over time under 11 management alternatives for Alabama Department of Conservation and Natural Resources lands.

Table 3. Annual tranistion rates among land cover types (states) for Alternative 2 on Alabama Department of Conservation and Natural Resources lands. Transition rates were used in management units that were classed as wildlife openings (i.e. agriculture, open green fields), where planting of pine or hardwood saplings was a function of the managment unit in which the wildife opening unit was nested.

From(➔) / To(🡇)	Land Cover State Number	Agriculture (Pine)	Open (Pine)	Disturbed (to Pine)	Hardwood	Mixed Pine/Hardwood	Even-age Forested Wetland	Seedling/Sapling pine	Poles/Small trees pine	Trees >12dbh pine	Two age pine	Uneven-aged Pine	Hardwood savannah	Agriculture (Hardwood)	Open (Hardwood)	Disturbed (to Hardwood)	Hardwood	Mixed Pine/Hardwood	Uneven-age Forested Wetland	Seedling/Sapling hardwood	Poles/Small trees hardwood	Trees >12dbh hardwood	Two age hardwood	Uneven-aged Hardwood	Water	Developed
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Agriculture (Pine)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Open (Pine)	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Disturbed (to Pine)	3	0	0	0	0	0.001	0	0.001	0.001	0.001	0.001	0.001	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mixed Pine/Hardwood	5	0	0	0	0	0.978	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Forested Wetland	6	0	0	0	0	0	0.978	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Seedling/Sapling pine	7	1.000	1.000	1.000	0	0	0	0.798	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poles/Small trees pine	8	0	0	0	0	0	0	0.200	0.898	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trees >12dbh pine	9	0	0	0	0	0	0	0	0.100	0.898	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Two age pine	10	0	0	0	0	0	0	0	0	0.100	0.898	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unevenaged Pine	11	0	0	0	0	0	0	0	0	0	0.100	0.998	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hardwood savannah	12	0	0	0	0	0	0	0	0	0	0	0	1.000	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture (Hardwood)	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Open (Hardwood)	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Disturbed (to Hardwood)	15	0	0	0	0	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0	0	0	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0	0
Hardwood	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.998	0.020	0	0	0	0	0	0	0	0
Mixed Pine/Hardwood	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.978	0	0	0	0	0	0	0	0
Forested Wetland	18	0	0	0	0	0	0.020	0	0	0	0	0	0	0	0	0	0	0	0.998	0	0	0	0	0	0	0
Seedling/Sapling hardwood	19	0	0	0	0	0	0	0	0	0	0	0	0	1.000	1.000	0.998	0	0	0	0.848	0	0	0	0	0	0
Poles/Small trees hardwood	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.150	0.918	0	0	0	0	0
Trees >12dbh hardwood	21	0	0	0	0	0.020	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.080	0.978	0	0	0	0
Two age hardwood	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.020	0.978	0	0	0
Unevenaged Hardwood	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.020	0.998	0	0
Water	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.000	0
Developed	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.000

Appendix 2: Matrices of annual transition rates use to project land cover type over time under 11 management alternatives for Alabama Department of Conservation and Natural Resources lands.

Table 4. Annual tranistion rates among land cover types (states) for Alternative 3, 4 and 7, 8 on Alabama Department of Conservation and Natural Resources lands. Transition rates were used in management units that were on areas on north-facing slopes.

From(➔) / To(🡻)	Land Cover State Number	Agriculture (Pine)	Open (Pine)	Disturbed (to Pine)	Hardwood	Mixed Pine/Hardwood	Even-age Forested Wetland	Seedling/Sapling pine	Poles/Small trees pine	Trees >12dbh pine	Two age pine	Uneven-aged Pine	Hardwood savannah	Agriculture (Hardwood)	Open (Hardwood)	Disturbed (to Hardwood)	Hardwood	Mixed Pine/Hardwood	Uneven-age Forested Wetland	Seedling/Sapling hardwood	Poles/Small trees hardwood	Trees >12dbh hardwood	Two age hardwood	Uneven-aged Hardwood	Water	Developed
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Agriculture (Pine)	1	1.000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Open (Pine)	2	0	1.000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Disturbed (to Pine)	3	0	0	0.100	0	0.001	0	0.001	0.001	0.001	0.001	0.001	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mixed Pine/Hardwood	5	0	0	0	0	0.993	0	0.200	0.100	0.050	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Forested Wetland	6	0	0	0	0	0	0.978	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Seedling/Sapling pine	7	0	0	0	0	0	0	0.798	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poles/Small trees pine	8	0	0	0	0	0	0	0	0.898	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trees >12dbh pine	9	0	0	0	0	0	0	0	0	0.948	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Two age pine	10	0	0	0	0	0	0	0	0	0	0.988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unevenaged Pine	11	0	0	0	0	0	0	0	0	0	0.010	0.998	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hardwood savannah	12	0	0	0	0	0	0	0	0	0	0	0	1.000	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture (Hardwood)	13	0	0	0	0	0	0	0	0	0	0	0	0	1.000	0	0	0	0	0	0	0	0	0	0	0	0
Open (Hardwood)	14	0	0	0	0	0	0	0	0	0	0	0	0	0	1.000	0	0	0	0	0	0	0	0	0	0	0
Disturbed (to Hardwood)	15	0	0	0	0	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0	0	0	0.102	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0	0
Hardwood	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.998	0.020	0	0	0	0	0	0	0	0
Mixed Pine/Hardwood	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.978	0	0	0	0	0	0	0	0
Forested Wetland	18	0	0	0	0	0	0.020	0	0	0	0	0	0	0	0	0	0	0	0.998	0	0	0	0	0	0	0
Seedling/Sapling hardwood	19	0	0	0.900	0	0	0	0	0	0	0	0	0	0	0	0.898	0	0	0	0.848	0	0	0	0	0	0
Poles/Small trees hardwood	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.150	0.918	0	0	0	0	0
Trees >12dbh hardwood	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.080	0.978	0	0	0	0
Two age hardwood	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.020	0.978	0	0	0
Unevenaged Hardwood	23	0	0	0	0	0.005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.020	0.998	0	0
Water	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.000	0
Developed	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.000

Appendix 2: Matrices of annual transition rates use to project land cover type over time under 11 management alternatives for Alabama Department of Conservation and Natural Resources lands.

Table 5. Annual tranistion rates among land cover types (states) for Alternative 4 and 8 on Alabama Department of Conservation and Natural Resources lands. Transition rates were used in management units that were on areas on north-facing slopes and classed as wildlife openings (i.e. agriculture, open green fields).

From(→) To(↓)	Land Cover State Number	Agriculture (Pine)	Open (Pine)	Disturbed (to Pine)	Hardwood	Mixed Pine/Hardwood	Even-age Forested Wetland	Seedling/Sapling pine	Poles/Small trees pine	Trees >12dbh pine	Two age pine	Uneven-aged Pine	Hardwood savannah	Agriculture (Hardwood)	Open (Hardwood)	Disturbed (to Hardwood)	Hardwood	Mixed Pine/Hardwood	Uneven-age Forested Wetland	Seedling/Sapling hardwood	Poles/Small trees hardwood	Trees >12dbh hardwood	Two age hardwood	Uneven-aged Hardwood	Water	Developed
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Agriculture (Pine)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Open (Pine)	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Disturbed (to Pine)	3	0	0	0	0	0.001	0	0.001	0.001	0.001	0.001	0.001	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mixed Pine/Hardwood	5	0	0	0	0	0.978	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Forested Wetland	6	0	0	0	0	0	0.978	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Seedling/Sapling pine	7	0	0	0	0	0	0	0.798	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poles/Small trees pine	8	0	0	0	0	0	0	0.200	0.898	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trees >12dbh pine	9	0	0	0	0	0	0	0	0.100	0.898	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Two age pine	10	0	0	0	0	0	0	0	0	0.100	0.898	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unevenaged Pine	11	0	0	0	0	0	0	0	0	0	0.100	0.998	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hardwood savannah	12	0	0	0	0	0	0	0	0	0	0	0	1.000	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture (Hardwood)	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Open (Hardwood)	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Disturbed (to Hardwood)	15	0	0	0.002	0	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0	0	0	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0	0
Hardwood	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.998	0.020	0	0	0	0	0	0	0	0
Mixed Pine/Hardwood	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.978	0	0	0	0	0	0	0	0
Forested Wetland	18	0	0	0	0	0	0.020	0	0	0	0	0	0	0	0	0	0	0	0.998	0	0	0	0	0	0	0
Seedling/Sapling hardwood	19	1.000	1.000	0.998	0	0	0	0	0	0	0	0	0	1.000	1.000	0.998	0	0	0	0.848	0	0	0	0	0	0
Poles/Small trees hardwood	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.150	0.918	0	0	0	0	0
Trees >12dbh hardwood	21	0	0	0	0	0.020	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.080	0.978	0	0	0	0
Two age hardwood	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.020	0.978	0	0	0
Unevenaged Hardwood	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.020	0.998	0	0
Water	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.000	0
Developed	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.000

Appendix 2: Matrices of annual transition rates use to project land cover type over time under 11 management alternatives for Alabama Department of Conservation and Natural Resources lands.

Table 6. Annual tranistion rates among land cover types (states) for Alternative 5, 6 and 7, 8 on Alabama Department of Conservation and Natural Resources lands. Transition rates were used in management units that were within delineated natural floodplains (i.e. maximized topographic floodplain).

From(➔) To(⬇)	Land Cover State Number	Agriculture (Pine)	Open (Pine)	Disturbed (to Pine)	Hardwood	Mixed Pine/Hardwood	Even-age Forested Wetland	Seedling/Sapling pine	Poles/Small trees pine	Trees >12dbh pine	Two age pine	Uneven-aged Pine	Hardwood savannah	Agriculture (Hardwood)	Open (Hardwood)	Disturbed (to Hardwood)	Hardwood	Mixed Pine/Hardwood	Uneven-age Forested Wetland	Seedling/Sapling hardwood	Poles/Small trees hardwood	Trees >12dbh hardwood	Two age hardwood	Uneven-aged Hardwood	Water	Developed
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Agriculture (Pine)	1	1.000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Open (Pine)	2	0	1.000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Disturbed (to Pine)	3	0	0	0	0	0.001	0	0.001	0.001	0.001	0.001	0.001	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mixed Pine/Hardwood	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Forested Wetland	6	0	0	0	0	0	0.978	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Seedling/Sapling pine	7	0	0	0	0	0	0	0.798	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poles/Small trees pine	8	0	0	0	0	0	0	0.200	0.898	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trees >12dbh pine	9	0	0	0	0	0	0	0	0.100	0.798	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Two age pine	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unevenaged Pine	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hardwood savannah	12	0	0	0	0	0	0	0	0	0	0	0	1.000	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture (Hardwood)	13	0	0	0	0	0	0	0	0	0	0	0	0	1.000	0	0	0	0	0	0	0	0	0	0	0	0
Open (Hardwood)	14	0	0	0	0	0	0	0	0	0	0	0	0	0	1.000	0	0	0	0	0	0	0	0	0	0	0
Disturbed (to Hardwood)	15	0	0	0	0	0.001	0.002	0.001	0.001	0.201	0.999	0.999	0	0	0	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0	0
Hardwood	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.998	0.020	0	0	0	0	0	0	0	0
Mixed Pine/Hardwood	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.978	0	0	0	0	0	0	0	0
Forested Wetland	18	0	0	0	0	0.010	0.020	0	0	0	0	0	0	0	0	0	0	0	0.998	0	0	0.040	0.080	0.250	0	0
Seedling/Sapling hardwood	19	0	0	1.000	0	0	0	0	0	0	0	0	0	0	0	0.998	0	0	0	0.848	0	0	0	0	0	0
Poles/Small trees hardwood	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.150	0.918	0	0	0	0	0
Trees >12dbh hardwood	21	0	0	0	0	0.988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.080	0.938	0	0	0	0
Two age hardwood	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.020	0.898	0	0	0
Unevenaged Hardwood	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.020	0.749	0	0
Water	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.000	0
Developed	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.000

Appendix 2: Matrices of annual transition rates use to project land cover type over time under 11 management alternatives for Alabama Department of Conservation and Natural Resources lands.

Table 7. Annual tranistion rates among land cover types (states) for Alternative 6 and 8 on Alabama Department of Conservation and Natural Resources lands. Transition rates were used in management units falling within delineated natural floodplains (i.e. maximized topographic floodplain) and classed as wildlife openings (i.e. agriculture, open green fields).

From(→) To(↓)	Land Cover State Number	Agriculture (Pine)	Open (Pine)	Disturbed (to Pine)	Hardwood	Mixed Pine/Hardwood	Even-age Forested Wetland	Seedling/Sapling pine	Poles/Small trees pine	Trees >12dbh pine	Two age pine	Uneven-aged Pine	Hardwood savannah	Agriculture (Hardwood)	Open (Hardwood)	Disturbed (to Hardwood)	Hardwood	Mixed Pine/Hardwood	Uneven-age Forested Wetland	Seedling/Sapling hardwood	Poles/Small trees hardwood	Trees >12dbh hardwood	Two age hardwood	Uneven-aged Hardwood	Water	Developed
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Agriculture (Pine)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Open (Pine)	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Disturbed (to Pine)	3	0	0	0	0	0.001	0	0.001	0.001	0.001	0.001	0.001	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mixed Pine/Hardwood	5	0	0	0	0	0.978	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Forested Wetland	6	0	0	0	0	0	0.978	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Seedling/Sapling pine	7	0	0	0	0	0	0	0.798	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poles/Small trees pine	8	0	0	0	0	0	0	0.200	0.898	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trees >12dbh pine	9	0	0	0	0	0	0	0	0.100	0.898	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Two age pine	10	0	0	0	0	0	0	0	0	0.100	0.898	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unevenaged Pine	11	0	0	0	0	0	0	0	0	0	0.100	0.998	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hardwood savannah	12	0	0	0	0	0	0	0	0	0	0	0	1.000	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture (Hardwood)	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Open (Hardwood)	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Disturbed (to Hardwood)	15	0	0	0.002	0	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0	0	0	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0	0
Hardwood	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.998	0.020	0	0	0	0	0	0	0	0
Mixed Pine/Hardwood	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.978	0	0	0	0	0	0	0	0
Forested Wetland	18	0	0	0	0	0	0.020	0	0	0	0	0	0	0	0	0	0	0	0.998	0	0	0	0	0	0	0
Seedling/Sapling hardwood	19	1.000	1.000	0.998	0	0	0	0	0	0	0	0	0	1.000	1.000	0.998	0	0	0	0.848	0	0	0	0	0	0
Poles/Small trees hardwood	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.150	0.918	0	0	0	0	0
Trees >12dbh hardwood	21	0	0	0	0	0.020	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.080	0.978	0	0	0	0
Two age hardwood	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.020	0.978	0	0	0
Unevenaged Hardwood	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.020	0.998	0	0
Water	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.000	0
Developed	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.000

Appendix 2: Matrices of annual transition rates use to project land cover type over time under 11 management alternatives for Alabama Department of Conservation and Natural Resources lands.

Table 8. Annual tranistion rates among land cover types (states) for Alternative 9 on Alabama Department of Conservation and Natural Resources lands. Transition rates were used in all management units not within streamside zone management (SMZ) areas under this alternative.

From(→) To(↓)	Land Cover State Number	Agriculture (Pine) 1	Open (Pine) 2	Disturbed (to Pine) 3	Hardwood 4	Mixed Pine/Hardwood 5	Even-age Forested Wetland 6	Seedling/Sapling pine 7	Poles/Small trees pine 8	Trees >12dbh pine 9	Two age pine 10	Uneven-aged Pine 11	Hardwood savannah 12	Agriculture (Hardwood) 13	Open (Hardwood) 14	Disturbed (to Hardwood) 15	Hardwood 16	Mixed Pine/Hardwood 17	Uneven-age Forested Wetland 18	Seedling/Sapling hardwood 19	Poles/Small trees hardwood 20	Trees >12dbh hardwood 21	Two age hardwood 22	Uneven-aged Hardwood 23	Water 24	Developed 25
Agriculture (Pine)	1	1.000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Open (Pine)	2	0	1.000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Disturbed (to Pine)	3	0	0	0.100	0	0.001	0	0.001	0.001	0.001	0.001	0.001	0	0	0	0	0	0	0	0	0	0.998	0.998	0.998	0	0
Mixed Pine/Hardwood	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Forested Wetland	6	0	0	0	0	0	0.978	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Seedling/Sapling pine	7	0	0	0.900	0	0	0	0.798	0	0	0	0	0	0	0	0.998	0	0	0	0	0	0	0	0	0	0
Poles/Small trees pine	8	0	0	0	0	0	0	0.200	0.898	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trees >12dbh pine	9	0	0	0	0	0	0	0	0.100	0.898	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Two age pine	10	0	0	0	0	0.998	0	0	0	0.100	0.898	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unevenaged Pine	11	0	0	0	0	0	0	0	0	0	0.100	0.998	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hardwood savannah	12	0	0	0	0	0	0	0	0	0	0	0	1.000	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture (Hardwood)	13	0	0	0	0	0	0	0	0	0	0	0	0	1.000	0	0	0	0	0	0	0	0	0	0	0	0
Open (Hardwood)	14	0	0	0	0	0	0	0	0	0	0	0	0	0	1.000	0	0	0	0	0	0	0	0	0	0	0
Disturbed (to Hardwood)	15	0	0	0	0	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0	0	0	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0	0
Hardwood	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.998	0.020	0	0	0	0	0	0	0	0
Mixed Pine/Hardwood	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.978	0	0	0	0	0	0	0	0
Forested Wetland	18	0	0	0	0	0	0.020	0	0	0	0	0	0	0	0	0	0	0	0.998	0	0	0	0	0	0	0
Seedling/Sapling hardwood	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.848	0	0	0	0	0	0
Poles/Small trees hardwood	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.150	0.918	0	0	0	0	0
Trees >12dbh hardwood	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.080	0	0	0	0	0
Two age hardwood	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unevenaged Hardwood	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.000	0
Developed	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.000

Appendix 2: Matrices of annual transition rates use to project land cover type over time under 11 management alternatives for Alabama Department of Conservation and Natural Resources lands.

Table 9. Annual tranistion rates among land cover types (states) for Alternative 10 on Alabama Department of Conservation and Natural Resources lands. Transition rates were used in all management units not within streamside zone management (SMZ) areas and classed as classed as wildlife openings (i.e. agriculture, open green fields).

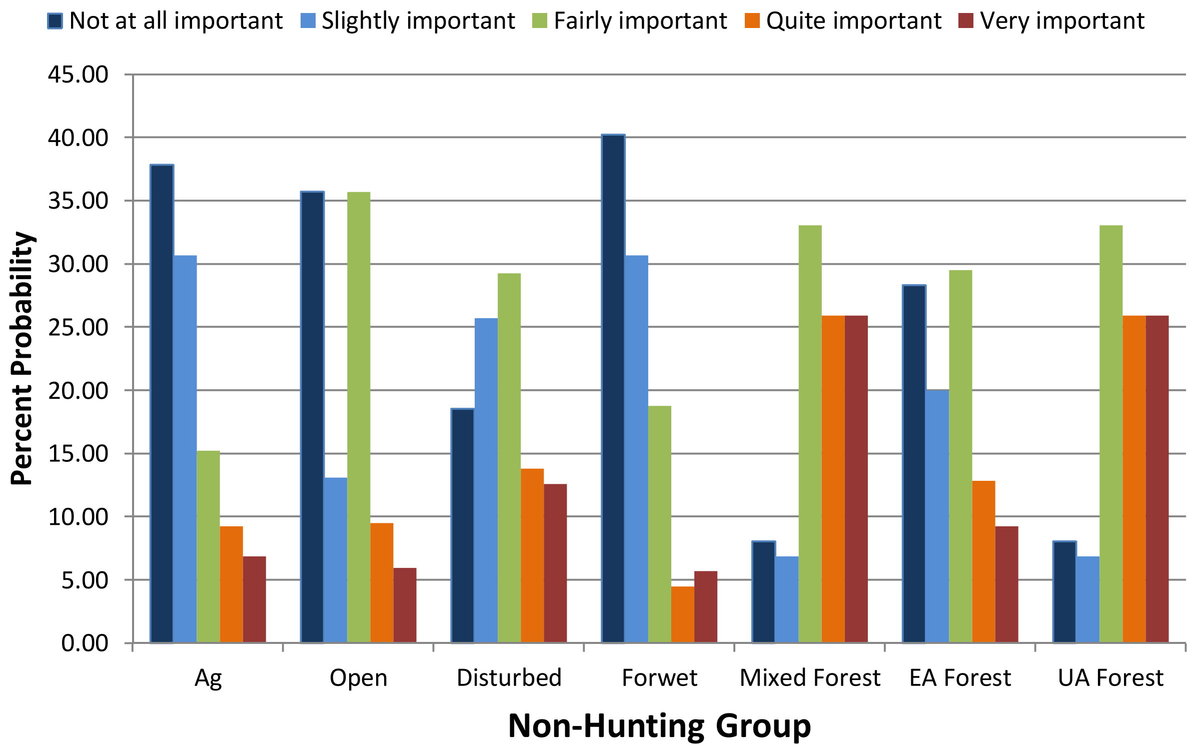
From(➔) To(🡇)	Land Cover State Number	Agriculture (Pine)	Open (Pine)	Disturbed (to Pine)	Hardwood	Mixed Pine/Hardwood	Even-age Forested Wetland	Seedling/Sapling pine	Poles/Small trees pine	Trees >12dbh pine	Two age pine	Uneven-aged Pine	Hardwood savannah	Agriculture (Hardwood)	Open (Hardwood)	Disturbed (to Hardwood)	Hardwood	Mixed Pine/Hardwood	Uneven-age Forested Wetland	Seedling/Sapling hardwood	Poles/Small trees hardwood	Trees >12dbh hardwood	Two age hardwood	Uneven-aged Hardwood	Water	Developed
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Agriculture (Pine)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Open (Pine)	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Disturbed (to Pine)	3	0	0	0	0	0.001	0	0.001	0.001	0.001	0.001	0.001	0	0	0	0	0	0	0	0	0	0.998	0.998	0.998	0	0
Mixed Pine/Hardwood	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Forested Wetland	6	0	0	0	0	0	0.978	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Seedling/Sapling pine	7	1.000	1.000	1.000	0	0	0	0.798	0	0	0	0	0	1.000	1.000	0.998	0	0	0	0	0	0	0	0	0	0
Poles/Small trees pine	8	0	0	0	0	0	0	0.200	0.898	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trees >12dbh pine	9	0	0	0	0	0	0	0	0.100	0.898	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Two age pine	10	0	0	0	0	0.998	0	0	0	0.100	0.898	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unevenaged Pine	11	0	0	0	0	0	0	0	0	0	0.100	0.998	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hardwood savannah	12	0	0	0	0	0	0	0	0	0	0	0	1.000	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture (Hardwood)	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Open (Hardwood)	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Disturbed (to Hardwood)	15	0	0	0	0	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0	0	0	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0	0
Hardwood	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.998	0.020	0	0	0	0	0	0	0	0
Mixed Pine/Hardwood	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.978	0	0	0	0	0	0	0	0
Forested Wetland	18	0	0	0	0	0	0.020	0	0	0	0	0	0	0	0	0	0	0	0.998	0	0	0	0	0	0	0
Seedling/Sapling hardwood	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.848	0	0	0	0	0	0
Poles/Small trees hardwood	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.150	0.918	0	0	0	0	0
Trees >12dbh hardwood	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.080	0	0	0	0	0
Two age hardwood	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unevenaged Hardwood	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.000	0
Developed	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.000

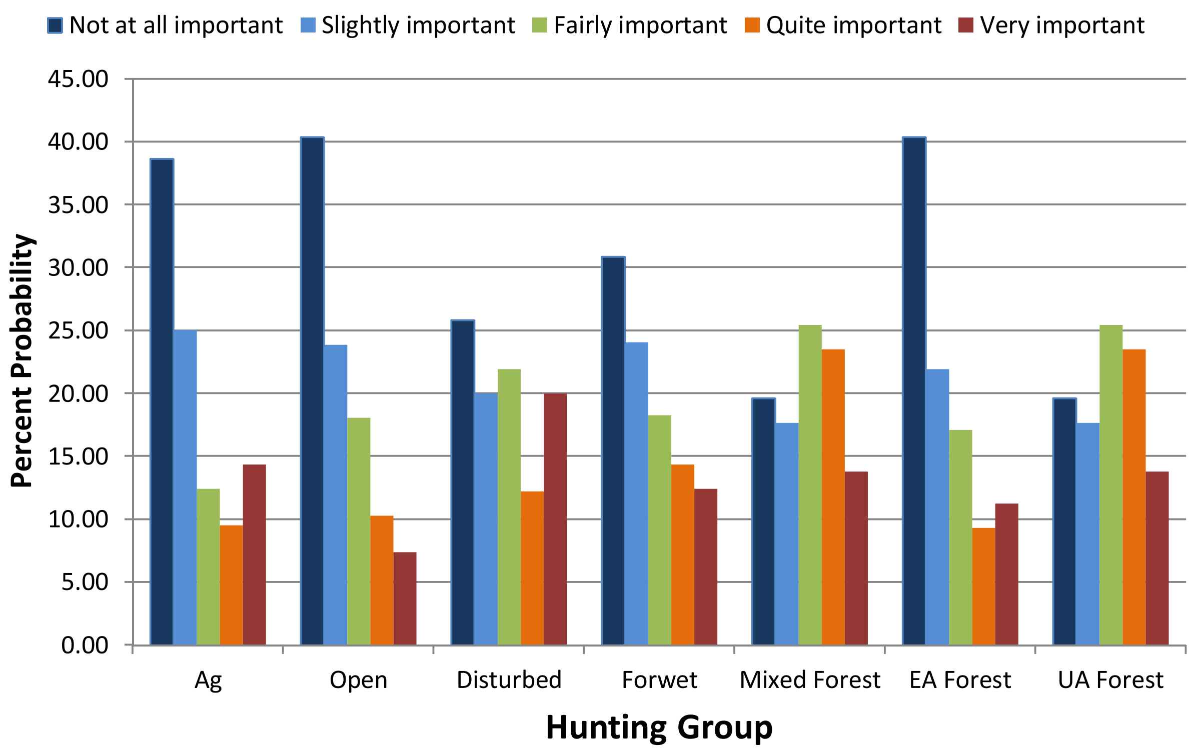
Appendix 2: Matrices of annual transition rates use to project land cover type over time under 11 management alternatives for Alabama Department of Conservation and Natural Resources lands.

Table 10. Annual tranistion rates among land cover types (states) for Alternative 11 on Alabama Department of Conservation and Natural Resources lands. Transition rates were used for all management units under this alternative.

From(➔) To(🡇)	Land Cover State Number	Agriculture (Pine)	Open (Pine)	Disturbed (to Pine)	Hardwood	Mixed Pine/Hardwood	Even-age Forested Wetland	Seedling/Sapling pine	Poles/Small trees pine	Trees >12dbh pine	Two age pine	Uneven-aged Pine	Hardwood savannah	Agriculture (Hardwood)	Open (Hardwood)	Disturbed (to Hardwood)	Hardwood	Mixed Pine/Hardwood	Uneven-age Forested Wetland	Seedling/Sapling hardwood	Poles/Small trees hardwood	Trees >12dbh hardwood	Two age hardwood	Uneven-aged Hardwood	Water	Developed
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Agriculture (Pine)	1	0.980	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Open (Pine)	2	0	0.980	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Disturbed (to Pine)	3	0.020	0.020	0.200	0	0.001	0	0.001	0.001	0.001	0.001	0.001	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mixed Pine/Hardwood	5	0	0	0	0	0.993	0	0.002	0.002	0.002	0	0.002	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Forested Wetland	6	0	0	0	0	0	0.996	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Seedling/Sapling pine	7	0	0	0.400	0	0	0	0.798	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Poles/Small trees pine	8	0	0	0	0	0	0	0.198	0.898	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trees >12dbh pine	9	0	0	0	0	0	0	0	0.098	0.976	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Two age pine	10	0	0	0	0	0	0	0	0	0	0.988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unevenaged Pine	11	0	0	0	0	0	0	0	0	0.020	0.010	0.996	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hardwood savannah	12	0	0	0	0	0	0	0	0	0	0	0	1.000	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture (Hardwood)	13	0	0	0	0	0	0	0	0	0	0	0	0	0.980	0	0	0	0	0	0	0	0	0	0	0	0
Open (Hardwood)	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0.980	0	0	0	0	0	0	0	0	0	0	0
Disturbed (to Hardwood)	15	0	0	0	0	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0	0.020	0.020	0.980	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0	0
Hardwood	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.998	0.020	0	0	0	0	0	0	0	0
Mixed Pine/Hardwood	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.978	0	0	0	0	0	0	0	0
Forested Wetland	18	0	0	0	0	0	0.002	0	0	0	0	0	0	0	0	0	0	0	0.998	0	0	0	0	0	0	0
Seedling/Sapling hardwood	19	0	0	0.400	0	0	0	0	0	0	0	0	0	0	0	0.020	0	0	0	0.846	0	0	0	0	0	0
Poles/Small trees hardwood	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.152	0.916	0	0	0	0	0
Trees >12dbh hardwood	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.082	0.996	0	0	0	0
Two age hardwood	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.988	0	0	0
Unevenaged Hardwood	23	0	0	0	0	0.005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.002	0.010	0.998	0	0
Water	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.000	0
Developed	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.000

Appendix 3: Conditional probability distribution of responses by user group to evaluate user value on ADCNR managed lands





Appendix 3: Conditional probability distribution of responses by user group to evaluate user value on ADCNR managed lands