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Translating national level forest service goals to local level land management: carbon sequestration

Steven McNulty[1] · Emrys Treasure[3] · Lisa Jennings[2] · David Meriwether[3] · David Harris[3] · Paul Arndt[3]

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Abstract The USDA Forest Service has many national level policies related to multiple use management. However, translating national policy to stand level forest management can be difficult. As an example of how a national policy can be put into action, we examined three case studies in which a desired future condition is evaluated at the national, region, and local scale. We chose to use carbon sequestration as the desired future condition because climate change has become a major area of concern during the last decade. Several studies have determined that the 193 million acres of US national forest land currently sequester 11 to 15% of the total carbon emitted as a nation. This paper provides a framework by which national scale strategies for maintaining or enhancing forest carbon sequestration is translated through regional considerations and local constraints in adaptive management practices. Although this framework used the carbon sequestration as a case study, this framework could be used with other national level priorities such as the National Environmental Protection Act (NEPA) or the Endangered Species Act (ESA).

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✉ Steven McNulty
smcnulty@fs.fed.us

[1] Southern Research Station, U.S.D.A. Forest Service, 920 Main Campus Drive, Suite 300, Raleigh, NC 27606, USA

[2] Grandfather Ranger District, Pisgah National Forest, U.S.D.A. Forest Service, 109 East Lawing Drive, Nebo, NC 28761, USA

[3] Region 8 – Southern Regional Office, U.S.D.A Forest Service, 1720 Peachtree Rd, NW, Room 700B North, Atlanta, GA 30309, USA

1 Introduction

The USDA Forest Service was established in 1905, and over time there have been many national level policies. However, the translation of these policies into actional forest practices can be challenging such as Endangered Species Act or the National Environmental Protection Act (NEPA). Both of these examples have major impacts on management, but perhaps the most controversial and impactful issue of the modern era is climate change.

Although some research into climate change was occurring as early as the 1970s, major research funding did not begin until the United States Global Change Research Act of 1991. Early research focused on quantifying the impacts and likelihood of climate change occurrence, but as understanding and confidence in these impacts increased, research began to focus more on adaptation and mitigation strategies for combating climate change. By the early twenty-first century, forest planners of the United States Forest Service (USFS) began to assess how climate change and climate variability could impact the multiple-use management objectives as governed by the Multiple-Use Sustained-Yield Act (MUSYA, USDA 1960) on 193 million acres of national forest and range land within the National Forest System (NFS, USDA 2007). National Climate Assessments and International Panel on Climate Change (IPCC) reports provided guidance on better integrating climate change science into adaptive management. For example, federally funded research concluded that US forest lands annually reduce gross US fossil fuel greenhouse gas (GHG) emissions between 11% (US EPA, 2017) and 15% (Birdsey et al. 2006). In 2014, the United States Department of Agriculture (the parent agency of the USFS) formally stated the additional land use objective of maintaining carbon sequestration on national forest lands (USDA 2014), which was further clarified in the USDA Building Blocks for Climate Smart Agriculture and Forest (USDA 2016). These national carbon sequestration strategies provided general guidance for maintaining the role that national forests have in reducing net US carbon emissions, but there was intentionally little specific information within the strategic plans on how to accomplish this goal. Public land management stakeholders and partners are given the flexibility to interpret the implications of these strategies as they engage formally (e.g., NEPA) and informally to help implement land management planning and activities. Land management actions must be converted to the local (e.g., forest or stand) level if they are going to be useful in the management of NFS units.

Increasing forest carbon sequestration is an example of a national forest goal that is not universally applicable. A framework for providing meaningful consideration regarding the intent of the goal at relevant geographic and temporal scales is needed for optimal land management purposes. In the absence of the framework presented in the proceeding case studies, decision makers and the teams of specialists that support them on national forests, as well as the stakeholders that collaborate in the decision-making process, are challenged to meaningfully consider carbon alongside the many other benefits that drive the purpose and need for management of forests at the project level.

Therefore, this paper examines the national US forest carbon strategies as an example for providing insight for translating national scale strategies to the local scale. This analysis will provide a framework for documenting information on forest type responses and tradeoffs between carbon management and other benefits that can vary across the southern US with the goal of best integrating the national strategic priority of maintaining forest carbon sequestration while also addressing other multiple uses and needs at a local scale. While carbon sequestration is used as the example in this paper, the framework for scaling national level priorities to the local level could be equally well used for other issues such as the Endangered Species Act.

1.1 National level guidance on forest carbon sequestration

There are several documents that provide national level policy and guidance for maintaining forest carbon sequestration, including the Climate Change Considerations in Land Management Plan Revisions (CLMPR, USDA), the USDA 2014–2018 Strategic Plan (USDA 2014) and the USDA Mitigation Buildings Blocks (USDA 2016). However, these documents have limited use in linking agency strategic goals to forest-level planning and project implementation. The CLMPR (USDA) provided specific guidance for NFS units to assess climate change and carbon stocks in land management planning, which was later codified in regulations under the National Forest System Land Management Planning Rule (36 CFR Part 219; USDA 2012). However, the translation of national goals to local practices has yet to be fully implemented through program direction.

1.2 Strategic planning vs. operational management

One of the emerging issues facing the USFS is how to manage for natural resource sustainability and meet public needs while also addressing other desired future conditions such as increasing or maintaining forest carbon sequestration as a tool for climate change mitigation. The USFS looks to research to provide national level guidance on climate change adaptation and mitigation for policy direction to reflect the best available science. Although USFS managers have guidance in the CLMPR (USDA) and the Planning Rule (USDA 2012), substantive program direction and competing stakeholder values at multiple scales are also needed to assess the role of carbon management in developing overall NFS management objectives. In particular, the need for rules for decision-making at scales where interpretations for maintaining carbon sequestration of national forests are applied and analyzed at operational scales. Management guidance should be consistent with the intent of the national strategies, including applications of relevant science at the appropriate geographic and temporal scales and in the context of trade-offs with other benefits.

The literature on managing forests for carbon sequestration is growing, but much of work has been conducted in western ecosystem responses because the vast majority of public lands are in the western US (USDA 2001). For example, the USFS produced a national level scientific synthesis on the effects of climate variability and change on forest ecosystems as part of the National Climate Assessment (NCADAC 2014). This document stated that, "*Protecting old-growth forests and other forests containing high [carbon] stocks may be more effective than strategies that would seek to attain [carbon] offsets associated with wood use, especially if those forests would recover [carbon] very slowly or would not recover in an altered climate*" (Vose et al. 2012). While this may be applicable for some regions and forest types, the structure and function of forests change between regions. Assessing forest ecosystem differences is important when developing alternative forest management sustainability recommendations. For example, in *The Effects of climatic variability and change on forest ecosystems: a comprehensive science synthesis for the U.S. forest sector* (Vose et al. 2012) included a discussion that fuel treatments may not offset the effects of carbon emissions from crown fires and resulting tree mortality based on findings from the northern Rocky Mountains (Reinhardt et al. 2010). However, the Southern Region of the NFS relies on prescribed burning to maintain resilient native ecosystems (Stanturf et al. 2002), to mimic historic fire regimes (Wade et al. 2000), and for reducing the risk of catastrophic wildfire (Millar et al. 2007). While prescribed burning may cause large carbon emissions in certain types of dry forests in the western US, fire behavior is different in the relatively moist forests of the eastern US (Wade et al. 2000). In addition to region-specific variations, forest management strategies should also consider the period over which these plans will be applied. Forest management decisions are made at multiple temporal scales ranging from decades for land allocations to months for stand level silvicultural treatments. Strategic goals are met by first developing broad regional considerations and from those constraints looking at site-specific forest plans.

Finally, national scale strategies for carbon management are not meant to provide a perspective regarding the trade-offs between the potential for sequestering carbon and other multiple use opportunities that managers and planners need to consider in local level decision-making, such as trade-offs between carbon sequestration and biodiversity, wildlife habitat, watershed health, and recreation. Understanding these trade-offs between competing resource needs and opportunities is critical and required for multiple use forest management. The purpose of this paper is to describe a framework that enables decision makers responsible for management of public lands and stakeholders engaged in collaborative processes to give meaningful consideration to maintaining carbon sequestration of the forests alongside other benefits and across geographic and temporal scales.

2 Translating strategic goals to operational forest management

2.1 National scale

The coarsest spatial scale the USFS operates is the conterminous US. By definition, findings at this national scale are both broad and general. This is the scale at which many policy decisions are made, and many guidance documents are produced, including the National Climate Assessment (NCADAC 2014). At the national scale, direction on carbon management is general due to the wide range of ecosystems and conditions found across the country. In a general sense, the majority of management activities aimed at increasing forest health and resiliency will also maintain carbon sequestration. Healthy trees have faster growth rates (Hyvonen et al. 2007), accumulate more woody biomass and thus sequester more carbon than more nutrient, water or light limited trees under most climatic conditions (McNulty et al. 2014). An extension of the rotation length or a reduction in timber harvest will also increase carbon sequestration for most areas and ecosystems of the US, so longer rotations are also an appropriate management strategy at a national scale (McKinley et al. 2011).

While national strategies recommend longer rotations across the US, depending on the forest type, a shorter rotation length minimizes the stand to catastrophic carbon loss so long-term carbon gain could be greater with a shorter rotation in some instances (Moore et al. 2012) For example, active management (including harvest) may reduce forest risk of carbon loss by disturbance such as insect outbreak and wildfire (McKinley et al. 2011). National scale carbon sequestration strategies cease to be effective at the regional scale as individual tree species respond differently to management practices such as thinning and prescribed burning (Hyvonen et al. 2007) in sequestering carbon. Once all appropriate options for carbon sequestration are considered, regional strategies for carbon sequestration can then be assessed.

2.2 Regional scale

The next level of resolution is the regional scale. The Forest Service is subject to the MUSYA (USDA 1960), requiring national forest lands to provide resources for outdoor recreation, range, timber, watershed health, and wildlife and fish habitat. Managing stands only for carbon storage, and sequestration can reduce other key ecosystem services (Schwenk et al. 2012). Carbon as a management objective needs to be considered in the broader context of trade-offs with other forest benefits that are managed at the local scale given the emerging interest in slowing global climate change. Some strategic policy decisions are made at the regional scale, including guidance for the various regions of the National Forest System and the regional assessment chapters from the National Climate Assessment (NCADAC 2014). At the regional scale, differences in management strategies for carbon sequestration by forest type emerge. The Southern Region of the NFS (including 11 states east of Texas and Virginia southward) presents a unique bioclimatic area conducive to tree growth. Consequently, the southeast has the highest rates of forest carbon sequestration in the US. In general, the Southeast provides an ideal mix of long growing seasons and abundant moisture (Wear and Greis 2012). Therefore, we will focus on the southeastern US as the region of study in this paper. Although the management conditions may be very different in other regions (e.g., western US), the process for scaling from a national strategy to local management practices will be similar).

Due to a long growing season, ample precipitation, and mild winters, both merchantable and nonmerchantable, trees grow and reproduce quickly across the southeastern region (Johnsen et al. 2013). In many instances, non-commercial trees and shrubs are an important component of the forest with regards to biodiversity (i.e., habitat and food), recreation (e.g., hunting, bird watching), and other goods and services. However, if the objective of a stand is to emphasize timber production, the use of prescribed burning (DiTomaso et al. 2006) in herbicides may be necessary to reduce non-commercial plant growth. Although prescribed burning is used throughout the US, the majority of prescribed burned acreage (~ 70%) is conducted in the southeast (Melvin 2015). Initially, prescribed burning oxidizes carbon as CO_2 as the fire burns away surface vegetation and litter. Additionally, prescribed burning will kill non-fire resistant vegetation, and over time this plant material will decompose and produce more CO_2. However, CO_2 losses are compensated by increased nutrient release (Carter and Foster 2004; Certini 2005) and reduced light and water competition from the burned material (Renninger and other 2013) leading to increased forest growth and carbon sequestration. Therefore, prescribed burning is considered to be a useful tool for increasing forest carbon storage.

The Southeast is also the fastest growing demographic region in the US, and increasingly, concerns over reduced air quality impacts associated with prescribed burning emissions restrict the location and timing of burns (Melvin 2015.). Proper humidity, wind direction, vegetative greenness, and air temperature levels, fire breaks, and sufficient personnel to manage a burn must all be in place before a prescribed burning can be initiated. Within the region, other factors are also important such as forest species, fire tolerance, topography, and forest values.

Managing a burn in steep, inaccessible terrain would be challenging. If all forest species are fire susceptible, then there is little use in conducting a prescribed burn as opposed to a timber harvest. Similarly, prescribed burn preparation and application can be expensive. If the trees are of low quality or poorly spaced (e.g., under stocked, inconsistently spaced) the commercial cost of a prescribed thinning may exceed the value. However, prescribed burns are also useful for other purposes beyond improving forest productivity and carbon sequestration (e.g., wildlife habitat improvement, increasing forest water yield). These factors will vary across the region and need to be considered at the local scale.

Many other regional factors can also impact forest carbon sequestration across the southeast such as ozone, nitrogen deposition, precipitation, and hurricanes. However, for the case studies in this paper, we will restrict the assessment to management prescriptions.

2.3 Local scale

The local scale is the finest level of resolution that forest operations are conducted. The local scale is also generally considered to be the area within the administrative boundary of a single National Forest and may include sub-units such as ranger districts, watersheds, or individual forest stands. At this scale, forest management actions are conducted to implement management direction in the USDA national forests land management plans. These plans include desired conditions, objectives, standards and guidelines that provide the design criteria for the development and implementation of individual management actions on areas as small as an individual stand or as large as an entire national forest. The local scale is where environmental, social, or economic conditions are considered when meeting site-specific management goals.

Ultimately, all actions are local. There are never region-wide thinnings, plantings, or disturbances. Even the largest hurricanes such as Katrina or droughts such as occurred in 2011 were sub-regional in scale. Additionally, environmental conditions and species variation prevent the application of widely applied management actions. Instead, broad national scale strategies and regional considerations need to be assessed before deciding on which management actions are going to be used at the forest level. These adaptation and mitigation actions are always done at the local scale to achieve specific objectives. Species and location-specific environmental differences emerge when considering whether or not a stand is suitable for increasing forest carbon sequestration potential. We examined three case studies to illustrate how local management factors are considered within the national strategic goal of increasing forest carbon sequestration.

3 Three case studies

Three case studies were evaluated to examine how a national level strategic goal for maintaining forest carbon sequestration could be translated to a local, operational level in the southeastern US. Within this region, one case study was located in the mountain mixed hardwood community, and two case studies were located in coastal plain pine communities. These three case studies were chosen to represent a range of environmental conditions and forest management intensities (Table 1).

National goals All of the case studies will examine common management practices in the context of maintaining national forest carbon sequestration as an overarching national goal. When regional considerations and local constraints are applied, management actions may or may not be conducive to increasing forest productivity or decreasing carbon loss.

Table 1 Overview of case study characteristics and how the national strategy of increasing carbon sequestration relates to regional considerations and local constraints that when considered together inform the carbon sequestration potential of a given resource management decision

Case study	Ecosystem	National strategy	Regional consideration	Local constraints	Carbon sequestration potential
1. Southern Appalachian - Early successional habitat	Mixed hard-wood	Maintain national Carbon Sequestration	High biodiversity potential	Provide early successional habitat	Low
2. South Atlantic Coastal Plain - wildland-urban interface	Pine-Oak	Maintain national carbon sequestration	Wildland fire hazard reduction, multiple use benefits	Smoke and public safety	Moderate
3.South Atlantic Coastal Plain - Longleaf restoration	Long leaf pine	Maintain national carbon sequestration	Providing habitat for threatened and endangered species	None	High

3.1 Case study one: early successional forest in southern Appalachia

The southern Appalachian region is one of the most biologically diverse and sensitive regions in the US. Over 6300 plant species (Kartesz and Meacham 1999), 255 bird species, 78 mammal species, 58 reptile species, and 76 amphibian species are present within the geographic zone (Pickering et al. 2003). To sustain and improve biodiversity, forest lands are often managed primarily for habitat protection and development. This case study examines the compatibility of utilizing these areas for the purpose of maintaining carbon sequestration while also maintaining or improving species habitat.

3.1.1 Regional considerations

Early successional forest conditions are maintained in patches throughout the southern Appalachian forests for biodiversity and wildlife habitat benefits (Rankin and Herbert 2014). Early successional conditions are created soon after a disturbance event that removes the forest canopy (e.g., logging, wind, insect, fire). These areas quickly become a dense woody understory of shrubs and young trees which provide both hiding cover and soft mast for many species. The forested edges created by the openings are prime hunting territory for predators. As the young forest matures into pole-sized trees, the dense overhead cover provides protection from predation from above (Rankin and Herbert 2014). Early successional forest patches vary in size, but many are larger than 20 acres to provide optimal condition for benefited species (Rankin and Herbert 2014).

3.1.2 Local constraints

Following the end of extensive logging throughout the region in the late nineteenth century, the area of early successional forest steadily shrank in size. Additionally, within the last few decades, the suppression of wildland fires and an increase in urbanization also limited the creation of new early successional habitat (Rankin and Herbert 2014). Therefore, early successional habitat is now created largely through active management (Rankin and Herbert 2014). Vegetation management treatments on the landscape are designed and implemented to achieve multiple-use objectives, including successional diversity needed to support wildlife habitat, wildfire hazard reduction, ecosystem restoration, and timber production. Creation of early successional habitat is limited by important competing multiple uses, including lands removed from timber production (i.e., wilderness, historic areas, and natural areas), lands incapable of producing sustainable timber supply, lands that are not economically viable for timber production, and other multiple uses that preclude or limit timber production (i.e., scenic areas, lands within eligible Wild and Scenic River corridors, wetlands, wildland-urban interface (WUI) and developed areas, off-highway vehicle (OHV) areas, special interest areas, and old-growth areas). Timber harvests that produce early successional habitat reduce the long-term carbon sequestration relative to light thinning or no thinning (Davis et al 2009, Keyser and Stanley 2012). Carbon sequestration rates are further reduced by repeated harvesting (Davis et al. 2009). For these reasons, this case study would not be compatible with the national strategy of maintaining carbon sequestration potential and is better suited for early successional habitat management.

3.2 Case studies two and three: two contrasting south Atlantic coastal forests

South Atlantic coastal plain forests are among the fastest growing and most productive within the US (Fox et al. 2007). Historically, this area was dominated by longleaf pine (*Pinus palustris*), but during the twentieth century, much of the longleaf pine was converted to loblolly pine (*Pinus taeda*) (Frost 1993). Both pine species extend across a wide variety of growing conditions within the southeast region. Therefore, both naturally regenerated and plantation pine stands have the potential to meet a broad range of ecosystem management objectives including sequestering carbon.

3.2.1 Case study two: wildland-urban interface coastal forest

In addition to being an area of high forest productivity and biodiversity, the region is also an area of rapid population growth. The loss of land due to urbanization and the resulting increase in the WUI imposes constraints on forest management.

Regional considerations Concern for public safety and air quality issues related to both human health and visibility impacts are two factors that limit the opportunities for application of prescribed burns in WUI areas. Given the potential for smoke from prescribed burns to travel great distances (Achtemeier et al. 2011) and the abundance of densely populated areas dispersed across the southeast region, opportunities for prescribed burning are limited to conditions where managers can minimize risks and impacts (Melvin 2015). Even when conditions are optimal for smoke management, concern for public safety limits the size and proximity of prescribed burns to human development.

Without forest management or wildfire, forests tend to build-up fuel loads over time. A suppression of wildfire was one of the primary reasons for the current increase in wildfire acreage. Prescribed burning is one of the primary tools used by southern forest managers to rapidly and efficiently restore and maintain fire-adapted species while reducing catastrophic wildfire risk (Melvin 2015; Wade and Lundsford 1990). In settings where prescribed burning is infeasible due to smoke and public safety concerns, mixed pine-oak ecosystems (with a loblolly component) are the attainable desired dominant forest type species (Gilliam and Platt 1999; Glitzenstein and other 1995).

Local constraints In this case study, concerns about a loss of maintenance of biodiversity (i.e., foraging habitat for red-cockaded woodpecker) exist due to the inability to conduct prescribed burning operations because of public safety and smoke concerns. The management area is situated in a landscape that is close to a major metropolitan area, and the forest is fragmented by inholding communities and highly traveled road networks. Therefore, this forest is largely characterized as WUI area. Therefore, this management area is best suited for multiple-use management that is compatible with both recreational opportunities as well as the limited production of timber and the creation early successional habitat. As a result of these local constraints, this site has only moderate carbon sequestration potential, relative to the potential under restored conditions in a maintenance management regime.

3.2.2 Case study three: rural coastal plain pine forest on a high site index soil

Longleaf pine (*Pinus paulustris*) ecosystems are composed of vegetation that is adapted to frequent, low-intensity fires.

Restoring and maintaining these fire-adapted ecosystems and associated plant and animal communities is a priority of national forests in the South Atlantic Coastal Plain and across the historic range of the longleaf pine. Natural fire regimes are replicated at a frequency of every 1–3 years at a scale of hundreds of thousands of acres burned annually in areas where the Forest Service can manage smoke and public safety associated with prescribed burning.

The structure of longleaf pine ecosystems is characterized by open-canopy or savanna conditions developed through the recurrent low-intensity fires that burn the live and dead fuels but have little effect on fire-tolerant trees (Boyer 1990; Landers 1995). Diverse communities of plants exist, along with associated species of pollinators and habitat for foraging and cover for wildlife.

Longleaf pine colonizes sites over time due to the species fire-adapted characteristics stands are dominated by mid-to-late successional age classes as longleaf pine is a relatively long-lived tree species that are resilient to biotic and abiotic stressors (Landers 1995).

Restoration of longleaf pine is the primary means of maintaining and restoring red-cockaded woodpecker habitat (Dilustro et al. 2002; USFWS 2003). In addition to being better able to withstand wildfires, longleaf pine requires fire for regeneration (Croker and Boyer 1975). The tree is highly resilient to fire at this stage of the seedling lifecycle. However, competition for light, water, and nutrients by other vegetation can severely restrict growth and maturation.

Therefore, fire (both wild and prescribed) can significantly and positively impact seedling development by reducing competition. Although fire tolerance makes longleaf an ideal species for addressing many of the challenges of climate change and variability, the ability to effectively apply prescribed burning to an increasingly fragmented and urbanized landscape is a primary factor limiting the restoration of longleaf pine (Costanza et al. 2015). Without fire or some other way to suppress early stage longleaf pine competition, tree regeneration is very difficult.

Regional considerations Although loblolly pine (*Pinus taeda*) has long been considered a faster-growing species compared to longleaf, interest in longleaf pine has recently increased for several reasons. Longleaf is considered to be more drought and fire tolerant; both of which are expected to increase with continued climate change over the coming decades (NCADAC 2014). Exclusion of wildfire, the conversion of natural forests to agriculture, and the development of plantation forests using faster-growing pine species such as loblolly pine (Glitzenstein et al. 1995; Landers et al. 1995) has led to the decline of longleaf and the federally endangered red-cockaded woodpecker. Longleaf pine exists in only 3% of its historical range across the US Coastal Plain (Outcalt and Sheffield 1996). Longleaf is also more wind, ice storms, insect, and fire resistant than loblolly pine (Johnsen et al. 2009; Kush et al., 2004; Landers et al. 1995).

Local constraints The conditions in this case study have little in the way of local management constraints. The forest has a rural location that allows for the use of prescribed burning as a tool to reduce unwanted herbaceous and hardwood regeneration and growth. This stand would be ideally suited for longleaf pine restoration. When managed over an extended rotation, longleaf pine provides carbon sequestration rates that are superior to those of short-rotation loblolly pine (Martin et al. 2015). Additionally, as old-growth longleaf stands are a prime habitat for the endangered red-cockaded woodpecker, once established and actively managed, the forest represents a case study that would have both high potential for maintaining carbon sequestration at the full potential of the ecosystem, while also enhancing endangered species protection and recovery.

4 Conclusions

This paper presents the complexities of translating national scale carbon sequestration strategies into active management options at the forest level. Although national scale goals are useful in crafting policy, the implementation of a goal must be aligned with regional scale considerations and local scale constraints. In each of these case studies, maintaining carbon sequestration was evaluated for each forest use based on a national level strategy for maintaining carbon gain. However in this example using the southeastern US, other factors such as biodiversity potential was also important as an overriding consideration. The three case studies provided a range of compliance success with regards to maintaining forest carbon sequestration. In the southern Appalachian forest case study, high rates of rainfall would support increasing carbon sequestration, but low temperatures and the unique opportunities for increasing biodiversity outweighed the opportunities for maintaining forest carbon gain through shifts in adaptive management. The second case study in the lower coastal plain had the ideal climate for carbon sequestration, but the proximity to urban areas prohibited intensive management. Better uses for recreational management resulted in moderate carbon sequestration potential. Finally, in the third case study both national goals and regional considerations aligned which allowed for both high rates of carbon sequestration and improved habitat for threatened and endangered southeastern species. Although this paper does not propose to represent all the different scenarios that could exist for converting national level strategic plans to local level implementation, we believe that the multi-scale decision process used in this study can guide land managers who are trying to implement other national level goals.

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