Ecol 199 Individual Research Report
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Forest Management and Climate Change Impacts on the Uwharrie National Forest and Adjacent Lands

Introduction

"In the eastern and lower counties of the State the most valuable trees are the long-leafed pine, the cypress and the cedar, all trees of magnificent growth, with trunks two to five feet in diameter, and forty to a hundred feet to the branches."

"Next, away from the water border, come the great pine forests for which North Carolina is celebrated. They occupy all the sandy lands, the two great species being the long-leaf southern pine, and the yellow pine. The first-named is the turpentine tree, so long wastefully cut for the manufacture of turpentine and rosin. It grows on the poorest of the sandy soils, to an average of seventy feet high, with a trunk nearly uniform diameter of twenty inches for about fifty feet, forming a beautifully straight columned series of forest arches, crowned with tufted summits of leaves ten or twelve inches long."

Bannister, Cowan & Company (1869)

Forestry, which includes the management regimes of private, commercial, and public forests, has been perhaps the most influential factor that has shaped the character of the Uwharrie area since pre-European times. The forests mainly provided natural resources that were exported to other cities and used for building construction and naval stores, but we see from the description above that the pine-dominated forests also provided an element of wonder to those who viewed them. Today, the Uwharrie area is still intensively used for timber as well as for recreation, conservation of what remains of these vast forests of giant pines, and efforts to restore the area to its natural pre-settlement condition.

History of the Uwharrie National Forest

In 1931 the federal government began purchasing lands in noncontiguous tracts to provide financial help to landowners during the Great Depression. It soon became one of the largest landowners in the area, along with Jordan Lumber, which was founded in 1939. Then in 1961, John F. Kennedy set aside the Uwharrie National Forest, defining a proclamation boundary as marking additional area that the federal government could later purchase to add to the UNF (USDA Forest Service 2005b). In the midst of growing urban populations over much of central NC, his idea was to preserve one of the largest remaining areas of forest for future generations. However, the UNF was far from being a pristine wilderness; it was a conglomeration of disjoint publicly-owned lands, interspersed by private and timber company-owned lands, that all had different land uses and management regimes.

Management of the forest has been a problem because of this mixed-use landscape. Efforts to conduct controlled burns, conservation, and restoration activities must consider the impacts on three different parties, with the US Forest Service and timber companies traditionally having had more control over the process than private landowners. As a result, this mixed-use landscape has created obstacles to effective fire management and restoration efforts for fire-dependent species such as the longleaf pine and the endangered Schweinitz's sunflower. However, forest management has been beneficial since the turn of the when much of the timber had been harvested or replaced by agricultural lands. Since much of the land in the Uwharrie area is more suitable for tree production than agriculture, over time private landowners have changed their land use from agriculture to forestry. The result is that today, there is more forest area present than in the recent past, but the composition of those forests is still very different.

Forest Communities in the UNF

A large component of the forest management regime in the Uwharrie area has been fire suppression, which is the most important factor that has caused the vegetation to deviate from its pre-European settlement condition. An adjunct factor is road construction throughout the area, which has suppressed fire spread by further fragmenting existing fire compartments. From this combination of factors, the landscape has changed from one of mostly pines, grasses, and other species more tolerant of small, frequent fires to one primarily composed of big hardwoods and woody undergrowth.

According to the Continuous Inventory of Stand Condition database (CISC), about 2/3 of the 52,000 acre UNF is dominated by pine or pine-hardwood forests, and about one-third is dominated by hardwood (Table 1) (USDA Forest Service 2004). The most common pines are loblolly and shortleaf pine; the most common hardwoods are chestnut, white, and southern red oak. Of the 22 forest types identified in CISC (Table 2), the most extensive types are *white oak-red oak-hickory* and *loblolly pine*. Together, these types cover ½ of the UNF. Only roughly 2000 of the 52,000 acres are non-forested openings or without a forest type classification; thus, there is little open land.

Table 1. Forest composition, rare species, and special interest areas on the Uwharrie NF.

FOREST COMPOSITION	Total	Sub-basin 03040103	Sub-basin 03040104
Total acres in proclamation boundary	219,090	84,570	134,520
Total acres USFS	52,000	62%	38%
Pine types	22,500	37%	63%
Loblolly pine	12,010	40%	60%
Shortleaf pine	7,900	72%	28%
Longleaf pine	2,240	28%	72%
Mixed Pine-Hardwood	9,280	73%	27%
Hardwood	17,690	76%	24%
white oak-red oak-hickory	14,600	75%	25%
0-40 years old	17,615 (33%)	9,815 (30%)	7,800 (44%)
41-80 years old	6,825 (13%)	4,015 (12%)	2,810 (16%)
81+ years old	19,610 (38%)	13,470 (42%)	6,140 (34%)
age not determined	6,150 (12%)	5,000 (16%)	1,150 (6%)

The Uwharrie Forests Today

The Uwharrie area is within a 2 hour drive of the major population centers of North Carolina, and over 6 million people (USDA Forest Service 2005b). The forested lands within the Uwharrie proclamation boundary have provided people with recreation and wildlife viewing opportunities, ample hunting, and beyond Forest Service lands, timber and jobs harvesting timber. Timber companies like Jordan Lumber operate within the proclamation boundary and provide local communities with jobs harvesting timber, as well as timber products for home, furniture, and paper construction. Private landowners also may allow sustainable harvesting of their trees for additional income.

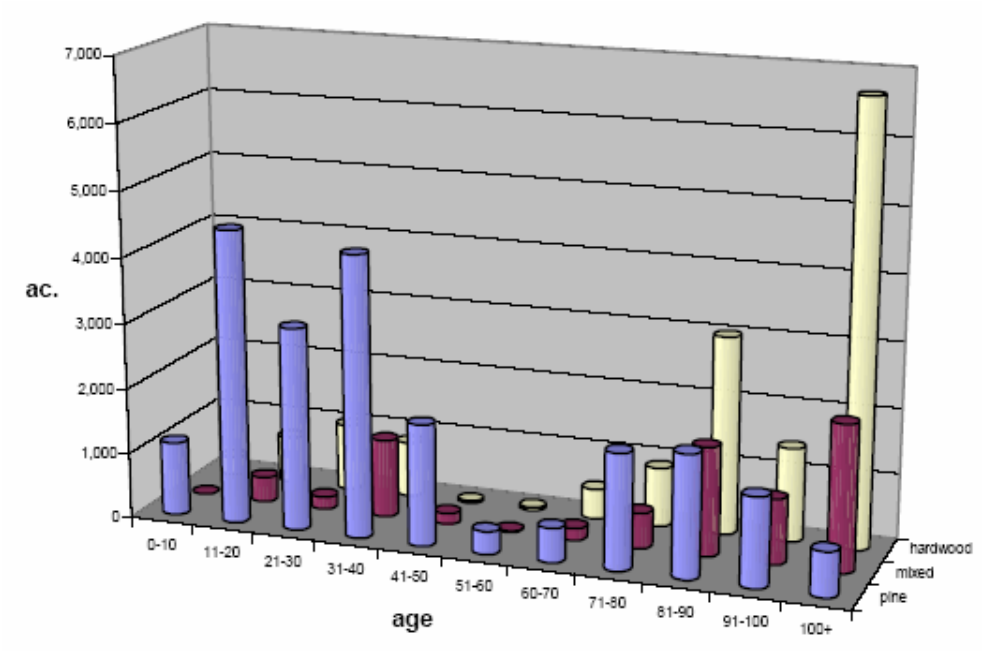
Uwharrie area forests provide habitat and forage to a variety of game animals such as deer, turkey, and quail (NCDENR 2002). Deer were once not an abundant species in the forest, but now they are, because of a lack of natural predators. Turkey and quail are less abundant now than they once were,

largely due to habitat reductions resulting from fire suppression, but their numbers are making a comeback. The forest has the highest hunting use of any game lands in NC (USDA Forest Service 2005b), although hunting is now decreasing in popularity. Rather, more visitors to the Uwharrie area come for recreational purposes, which has had the benefit of boosting the local economy.

Human Impacts on Forests

1. Wildlife Management and Restoration

The forest provides so much for us, but what do people provide forests? One thing we do is to selectively thin older trees to give a larger proportion of trees of the age range that produces the most acorns. However, the primary rationale for this is to increase wildlife abundance, which will provide visitors to the UNF with the hunting or wildlife viewing experience they desire. Unlike pine and mixed pine-hardwood forests, which are often managed for fast production of pine and so have abundant numbers of both young and mature trees, hardwood stands have an overabundance of mature trees and not enough of the middle-aged trees that produce the most acorns.



Stand age by forest type group within all management types (USDA Forest Service 2004).

However, thinning hardwood forests does nothing to help return these areas to a more natural condition as defined by how the forest might have existed prior to European settlement. To do this, hardwood forests need to be removed and replaced by the longleaf and shortleaf pine woodlands that were once there. These woodlands with abundant grass and herb cover would provide optimal habitat for turkey, quail, and other seed-eating species whose numbers have been in decline ever since hardwood communities began to dominate the Uwharrie area.

2. Forest Fragmentation and Plant Community Change

Forest fragmentation has been an important agent of change in the Uwharrie area prior to its inception, and will likely continue to shape the composition and spatial pattern of plant communities. Not only does fragmentation create more disturbed edge areas around forests, which opens up opportunities for invasion by exotic species, but fragmentation also reduces the size of fire compartments, and thus directly alters the fire regime for each of the forest fragments. **Fig. 1** at the back of this report shows two typical examples of forest fragmentation in the Uwharrie area. The images were obtained for areas within the Uwharrie proclamation boundary within Randolph and Davidson counties; unfortunately, no aerial photos could be obtained for comparison from Montgomery County, which contains the majority of the Uwharrie administrative region as well as the UNF.

Historical fire regimes and their effects

The historical landscape (prior to European settlement) saw very little fragmentation except for isolated Native American agricultural plots. If any burning was done to clear land, it was done in the cool season to keep fire intensities low. The fire regime, according to an interview with Cecil Frost, was likely not that different from what the natural fire regime would have been—low intensity, 1-3 or 4-6 year fire frequencies depending on the location. Fire has been the most important disturbance agent in the historic Uwharrie landscape, and has largely been responsible for shaping and maintaining plant communities there. Two species, such as oak and longleaf pine, would otherwise be able to grow in the same climate and soil conditions, but depending on the fire regime, either oak (low fire frequency) or pine (high fire frequency) would be selected for. A study done in the less fragmented boreal forests of Canada

confirmed this, that the interval between fires is a strong predictor of the abundance, extinction, or expansion of one tree species over another (Le Goff and Sirois 2004).

Forest fragmentation in the Uwharrie area has subdivided historic fire compartments into much smaller ones, which has altered the natural fire regime throughout the landscape. This, in turn, has changed the character of the forest from one that was historically a longleaf pine savanna to one dominated by hardwoods, often with a thick understory shrub layer (USDA Forest Service 2005b). Consequently, herb diversity has either sharply declined or vanished in many areas. The Schweinitz's sunflower, a federally endangered species, is an example of an herb that has become restricted largely to roadsides and power line rights-of-way because only these areas have a frequent enough disturbance regime (one that approximates historic fire frequencies) to keep out woody vegetation.

Sources of Forest Fragmentation in the UNF

Two major sources of forest fragmentation exist. The first originated from the initial process of land acquisition by the federal government beginning in 1931. This is the largest-scale source of forest fragmentation, partitioning the area within the national forest proclamation boundary into National Forest land, private lands, and timber company-owned lands. The second source of forest fragmentation covers the same extent of territory, but works at smaller scales. This is the network of roads and trails forming a web across the landscape.

According to the December 2003 Roads Analysis Process Report (USDA), the Uwharrie NF consists of a classified road system of 98 roads totaling approximately 107 miles in length, as well as additional roads not formally classified as part of the Forest Service road system (such as abandoned travel ways and old OHV tracks) that total approximately 33 miles. There are also 50 miles of hiking-only trails, 40 miles of horse trails in the Badin Lake area, 16.6 miles of mountain bike trails, and a 16 mile OHV trail system. All trails are open for hiking.

A separation between two areas of forest as narrow as a trail might seem insignificant when considering fire spread, but trails can and do effectively partition the forest into smaller fire compartments. We witnessed this firsthand on our February 11 trip to the Uwharrie NF when hiking into an area of bottomland forest with very little understory vegetation. The trail itself, containing no vegetation, did not

burn; rather, either due to human assistance or a strong wind, the fire managed to cross the trail. On days with no wind, the trail would have served as a firebreak to a natural, lightning-caused fire.

3. Soil Erosion – Impacts on Forest Health and Water Quality

Soil erosion is important not only to forest health, but also to water quality. Strong erosion can remove nutrients and organic matter from forests and nutrient-heavy former agricultural lands, and deposit them in streams, where they can cause eutrophication. Of interest would be to see how soil erosion might be affected by land ownership and land use. To do this, data had to be acquired on soil erosion, forest fragmentation, and the national forest, private, and timber company-owned land boundaries in the Uwharrie proclamation area. Only the first three data sources were accessible online. A UNF Soil Erosion Map produced by Steve McNulty was superimposed using Adobe Photoshop on the September 2005 Base Planning Map from the Uwharrie NF Plan Revision Website (USDA Forest Service 2005a). The planning map showed all roads and trails, which can be used as proxies for forest fragmentation, and also showed the proclamation area and UNF boundaries.

Interesting results were obtained as shown in **Fig. 2** at the back of this report. Areas with minor erosion (blue) had a very clumped distribution that were generally located near roads. Remarkably, these clumped areas were almost always found outside or adjacent to national forest lands, meaning the minor erosion was taking place on private or timber company-owned land. Without a map of either of these I cannot tell for sure, but these clumped areas could correspond to areas where forests have been recently clearcut. After clearcuts, there have been many observations of heavy downstream runoff immediately after the first rain. Poor water quality will continue until vegetation recolonizes the area and stabilizes the soil layer.

These large blue areas might be labeled as having minor erosion, but because these areas are so large in extent and likely drain into shared waterways, this could lead to major problems with erosion at higher-order streams, as well as with water quality. Smaller blue areas are more likely to correspond with private land holdings, since timber companies would be more likely to own large contiguous clumps of land and to have the equipment necessary to disturb the soil layer over those large scales.

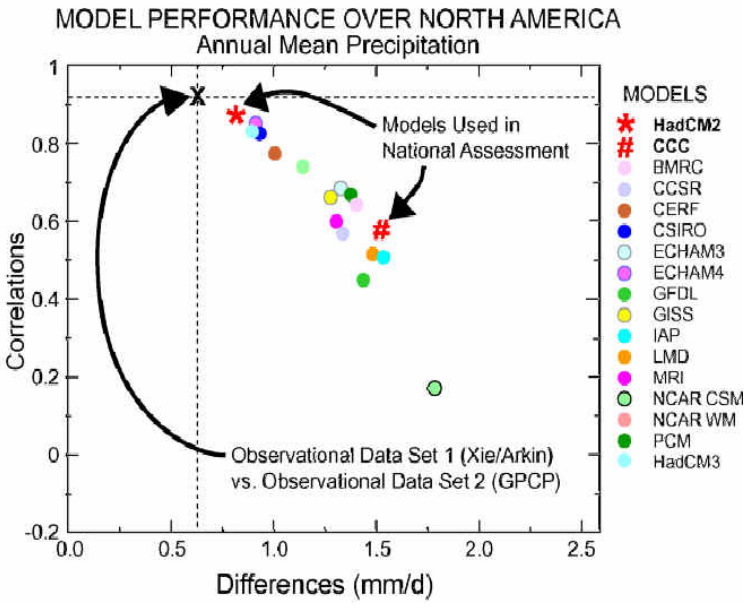
Areas with moderate to severe erosion are mostly restricted to the western part of the UNF. These can be found in two areas there: the Badin Lake area, and east of Morrow Mountain State Park. The heavy erosion near Badin Lake maps nicely onto the OHV trail network, and the moderate erosion just north of that follows a system of horse trails. The second area, east of Morrow Mountain State Park, is adjacent to a high-settlement area, judging from the tangle of streets next to Lake Tillery. The erosion in this area corresponds to the system of bike trails that are heavily used by nearby residents. Runoff resulting from the high erosion in these areas drains into both Badin Lake and Lake Tillery.

Climate Change Impacts on Forests

1. Temperature, Precipitation, and Drought

There is a great deal of uncertainty over how climate change might impact the Uwharrie area. The two most important elements of climate change that will affect plant communities are temperature and precipitation, with precipitation being the more important of the two. Drought stress has a much greater effect on survival than increased temperature (Loehle 1998). In transplant experiments (Wright 1976), many boreal trees can survive much farther south than their natural southern range limits if there is adequate rainfall. This indicates that increased temperature in the absence of drought stress has little effect on survival (Woodward 1987, 1988).

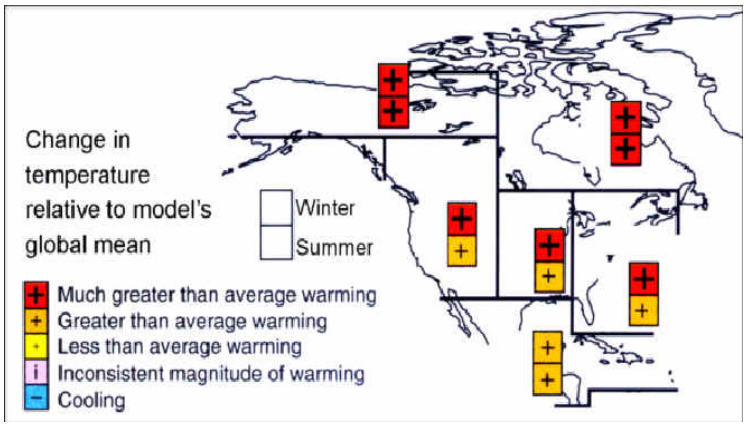
Much of the uncertainty over future precipitation in the Uwharrie area stems from how climate models handle their predictions of future precipitation. This is because climate models have difficulty in predicting future cloud cover and what the feedbacks might be between cloud cover, temperature, and precipitation. Researchers

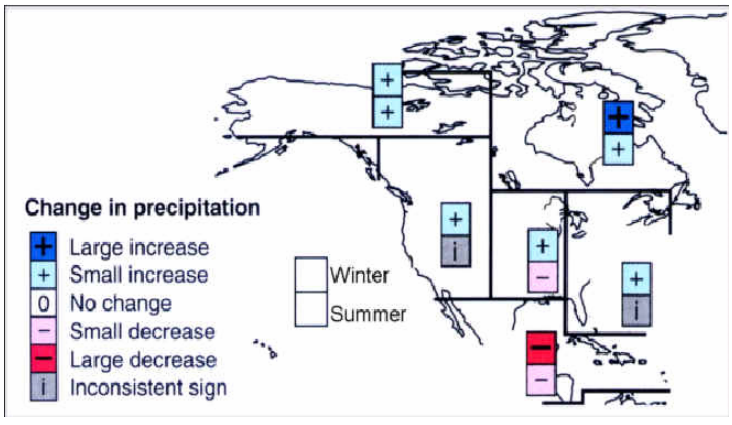


Less precipitation fell than was predicted by all 17 models used in a national assessment (Karl 2002).

wanting to understand the future impacts of climate change will generally analyze different scenarios from several climate models, in hope that their results will include the whole range of scientific uncertainty (US EPA 2000). However, in the plot **(previous page)** of climate models available in 2002, we see that all of the models gave higher predictions for the annual mean precipitation than was actually observed (Karl 2002).

The HadCM3 climate change model, which has had the best predictive success for temperatures in North America thus far, suggests that precipitation in the Uwharrie region will increase over the next 50 years (Nearing 2001). However, instead of more precipitation, the entire Central Piedmont area has actually been experiencing drought conditions since 1998 (USDA Forest Service 2003b). Although NC might be receiving more precipitation, warmer summer temperatures create more evapotranspiration. Thus, rainfall would have to increase just to maintain current water levels. If there is not enough of a rainfall increase to balance evapotranspiration caused by warmer temperatures, then this can result in drought. The figures below show that in the southeastern United States, multiple models agree there will be a strong warming trend but only a weak increase or even decrease in precipitation. Thus, it is more likely that drought conditions will occur more often in the Uwharrie area than in the past, with consequences for the health of its forests.





Analysis of inter-model consistency in regional temperature and precipitation changes. From Karl (2002).

2. Changes in Forest Productivity

More conversion of sunlight into forest biomass doesn't seem like a bad thing, especially for forest restoration and harvesting. However, it can be if a few species are able to take advantage of the

increased CO_2 at the expense of others—this can quickly lead to a loss of biodiversity. Increased tree densities would further help to foster the spread of diseases and insect outbreaks. Also, increased plant growth from increased CO_2 requires that there aren't other limits to plant growth, such as nutrients, diseases, fire, and droughts, which alone would increase disease susceptibility and increase the risk of damaging fires in areas having an already high fuel load due to fire suppression.

3. Altered Fire Regimes

Fire regimes have already been considerably altered in the area since pre-European times. Humans have also altered the fire regime not only spatially due to different land uses and road/trail construction, but also temporally. The historical fire regime in the Uwharrie area consisted of small fires that burned over large areas, but because of the fragmented fire compartments with heavy understory fuels that now exist, fires can cause high mortality in the fragments that manage to get ignited. The seasonality of fires has also changed—Native Americans once practiced cool season burns prior to heavy European settlement in the area (Barden 1997), but today, private landowners may decide to burn their land any time of year.

Climate change is expected to alter fire regimes by affecting the frequency and intensity of fire disturbance. Many papers have suggested that warmer temperatures and less precipitation would lead to more fires. This seems to be occurring recently in places such as California, Arizona, New Mexico, and Oklahoma that already have heavy fuel loads due to fire suppression, as well as in boreal forests, which are just as sensitive to fire and insect outbreaks as forests in the southeastern United States but have experienced greater magnitudes of climate change in recent years. Among some of these papers are that of Lynch (2003), which points out a strong correlation between fire size/severity and temperature/precipitation, suggesting that weather is a strong factor affecting fire disturbance. Overpeck et al (1990) also indicated that wildfires would generally increase with climatic warming because warmer temperatures often give rise to drier conditions.

4. Insect Outbreaks and Disease

The southern pine beetle has been a major biological disturbance agent in North Carolina and throughout the southeastern US, attacking loblolly, shortleaf, and in epidemic years, longleaf pine which is the least susceptible species. According to records collected by the US Department of Agriculture, the total county area of the southeastern US in southern pine beetle outbreak status for at least one year was 837,075 km^2 (Williams and Liebhold 2002). The value of timber and pulpwood lost to the SPB has reached $237 million dollars/year in the recent past (Price et al 1997).

It is predicted that climate change will cause the southern pine beetle and other insects and pathogens to have a stronger negative impact on both timber production and restoration of longleaf pine forests. This is because increases in summer temperatures generally accelerates the development rate of insects, and increases their reproductive potential (Ayres 2000, Porter et al 1991). Thus with warmer temperatures, there will be a greater abundance of insects to cause outbreaks.

Of the approximately 50,000 acres within the Uwharrie National Forest area, 24,554 or approximately 49% of those acres are susceptible to the southern pine beetle. Focusing only on the total land suitable for timber production, approximately 39,200 of the ~50,000 acres are suitable, and 20,900 (53%) of those are susceptible to SPB (USDA Forest Service 2003b).

District	Uwharrie
Forest Type	Acres
Loblolly Pine and Loblolly Pine /Hardwood	10,388
Longleaf Pine	1,718
Shortleaf Pine and Shortleaf Pine /Hardwood	7,969
Virginia Pine, Virginia Pine /Hardwood, and Hardwood /Pine Types	4,480
Total	24,554

Susceptible acres by forest type in the UNF (USDA Forest Service 2003b).

Infestations become epidemics when pine forests become stressed. This can happen when stressed by crowded growing conditions, or drought, because of damage from ice or wind, or because pines have matured. Beetle populations are able to increase exponentially due to the increase in susceptible trees. During epidemics, natural enemies of the southern pine beetle have little effect, and SPB populations become large enough that they can successfully attack healthy trees and cause widespread mortality (USDA Forest Service 2003b). If a spot has 25-30 infested trees, there exists a high probability that the infested area will triple within 90 days. Therefore,

infestations must be treated to prevent great losses to the dominant pines within the area, which can result in economic losses as well as reductions in the recreational and tourism value of forests. The treatment usually consists of cutting infested trees with heavy equipment, which necessitates good access from roads. Of the 24,554 susceptible acres, cut trees are generally either removed (19,603 suitable acres for this treatment), chipped (7,277 suitable acres), or left where they fell (6,627 suitable acres). Another treatment is to cut and burn infested trees, but there are only ~1,000 suitable areas.

Suggestions for Future Forest Management

Consider the impact of climate change on fire management, conservation, and forest restoration efforts

If droughts in the Uwharrie area continue in future years as predicted, what might be the impact of this on the different plant communities in the UNF? Areas may be more prone to fire but because of forest fragmentation, fires may not spread. There may be more insect outbreaks and diseases amongst trees. Forest productivity may actually decline, meaning less food resources for wildlife. More frequent storms may create more gaps throughout the forest, opening up new possibilities for longleaf pine restoration. The possible impact of climate change in the future should be taken into consideration in the next plan revision cycle.

Manage forests for biodiversity

Forests might be managed sustainably right now, but they could be managed for more biodiversity (Lamb 1998). Monocultures or plant communities with low species diversity have been shown to have greater invisibility, while invasive species have a much more difficult time getting established in high-diversity areas (Kennedy et al 2002, Knops et al 1999). Instead of monoculture pine plantations, other economically important trees could be planted alongside the pines, creating more of a mixed-wood forest. Then, instead of doing clearcuts which would increase erosion and runoff during harvest and leave the land looking unsightly, only certain species would be cut at certain times. This would open up more natural gaps to accelerate tree growth beneath. However, if logging is done commercially with heavy equipment, it may not be easy to selectively cut and remove trees. This management method would be better suited for private landowners opening up their lands for firewood harvesting using chainsaws.

Increase cooperation between the US Forest Service, timber companies, and private landowners

The US Forest Service has opened up opportunities for more cooperation by allowing public input to be received during its planning meetings. However, more could be done to facilitate interactions within the mixed-use, mixed-ownership landscape of the Uwharrie area to make broader fire management and restoration activities possible. Perhaps subsidies could somehow be provided for timber companies to thin hardwood trees on private lands, while passing along some of the revenue to the landowner. This would allow faster restoration of longleaf pine in areas of the Uwharrie where private landowners lack the time or equipment to thin their own forests. Also, perhaps timber companies and private landowners could be encouraged to swap lands with those held by the US Forest Service. Those parties owning rocky land unsuitable for agriculture or logging with heavy equipment, but are located adjacent to areas of prime conservation importance, should be identified and presented with the possibility of doing a land swap. This would help consolidate land for conservation, at no loss to the timber company's holdings or to private landowners.

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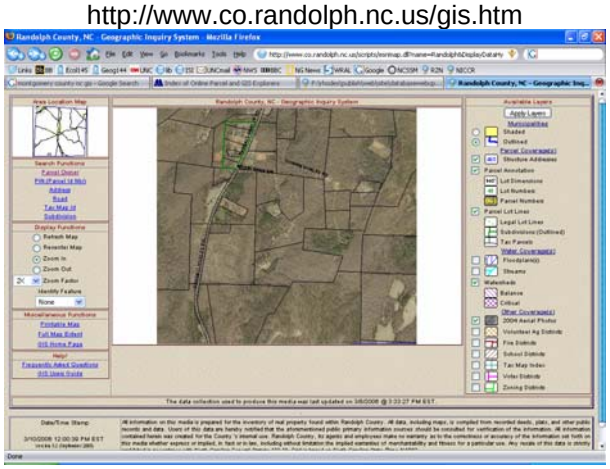
Fig. 1: Forest Fragmentation Within the Uwharrie Proclamation Boundary and Outside the UNF

Unfortunately, Montgomery County does not have an online GIS or easily accessible source of aerial photos, to provide a view of forest fragmentation in areas within and immediately adjacent to UNF lands.

Randolph County GIS Website
http://www.co.randolph.nc.us/gis.htm



Davidson County GIS Website
http://arcims2.webgis.net/davidson/default.asp

Above: a typical view of lands between the National Forest and Proclamation Boundaries. Private landowners largely determine the vegetation composition of these lands; parcel boundaries largely correlate with sharp boundaries between forests and cleared fields. This view was taken in the southern portion of Randolph County.

Above: a larger-scale view of another area within the Uwharrie Proclamation Boundary but outside the UNF. This view was taken at the southeastern corner of Davidson County where it meets with Randolph (right) and Montgomery (bottom) counties. Forest fragmentation is once again very obvious, and the smallest fragments appear very closely correlated with proximity to roads.

Fig. 2: Overlay map showing soil erosion, forest fragmented by roads and trails, and National Forest land (green).