SOIL RESILIENCE IN DISTURBED FORESTS AND ASSOCIATED WETLANDS FOLLOWING TIMBER HARVEST

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Abstract

This research focuses on quantifying the resilience of disturbed forested wetland habitats by studying the physical and biogeochemical properties of soil. The need for knowledge about ecosystem resilience following disturbance is becoming more critical for curbing the loss of natural resources. Using soil parameters as environmental indicators may lead to a better understanding of managing these resources. The aim of the study is to estimate resilience data from the study site and incorporate it with similar pre-existing studies to provide a wider perspective on soil processes occurring throughout the watershed (the Yazoo-Tallahatchie River Basin). Soil samples were taken from three disturbed sites of different ages (6 months, 7 years and 18 years since last harvest) and one undisturbed site (94 years since last harvest) from Northern Webster County, Mississippi. Six sampling points -three uphill and three streamside- were sampled in each of the sites. Soil samples were tested for concentrations of Total Soil Organic Matter (SOM), Total Carbon (TC), Total Nitrogen (TN), Total Phosphorous (TP), pH, Compaction, and Moisture Content. The TC and the Soil Compaction showed a decreasing trend with increasing age of the sites, with the 6 months site showing the highest values. The moisture content in the 7 year site was significantly lower than other sites, and 6 month streamside samples had significantly higher moisture content than uphill samples. TP was highest in the 6 month sites, followed by the uncut sites. There were no differences in SOM and TN levels among all sites, but a consistent trend of an initial decrease and a gradual increase can be observed in comparisons between pre-researched sites within the watershed. A Soil Perturbation Index (SPI), which incorporates these soil parameters and predicts the regeneration period needed for the disturbed areas with respect to the undisturbed reference sites, has further explained the biogeochemical dynamics of the study sites. Data from past sites within the watershed (in Calhoun, Issaquena, Leflore and Lafayette Counties, MS) where similar studies have been conducted have been compared to project a comprehensive picture of the biogeochemical processes taking place within the watershed's timber producing forests and associated wetlands. The results of this study will be beneficial for forest and wetland resource user groups in the region such as foresters, landowners, timber companies, farmers, conservation and government agencies, and the local stakeholders in utilizing and sustainably managing the available natural resources.

Introduction

The problem of diminishing natural resources is becoming more complex throughout the world (Mitsch 1993). Human activities have altered natural functions of ecosystems; humans are using more resources, resulting in stressed systems (Lubchenco et al. 1991). Wetlands are one of the most vulnerable systems prone to alteration and destruction, and more than 50 percent of the world's original wetlands have been lost (Dugan, 1993).

Recent focus on curbing the loss of natural resources has been placed on restoration of ecosystems that are sustainable (Mitsch 1993). Here, information about resilience, the ability of a system to respond to stress, is important. The need for knowledge about wetland resilience following disturbance is becoming more critical (Mitsch and Gosselink 2000), but it is often difficult to assess impacts on the system and predict the resilience (Holland 1996). It has been suggested that using soil parameters as environmental indicators may provide resilience information for sustainable resource management (Smith 1997).

A simple index to determine resilience of forested bottomland wetlands using multiple biogeochemical indicators, named the Soil Perturbation Index (SPI), was first developed and applied by Rebecca Smith Maul (Smith 1997, Maul et al. 1999). The SPI is based on soil nutrient contents such as total nitrogen (TN), total phosphorous (TP), total carbon (TC), and soil organic matter (SOM), and helps evaluate how different successional stages (=*time since harvest*) compare to mature uncut forested wetlands from a biogeochemical standpoint. It helps predict the time for the different stages to grow back to pre-disturbance conditions and shows the general trend in biogeochemical changes in disturbed systems.

The objective of this study is to examine the difference in biogeochemical and physical soil properties of forested wetlands which have been disturbed due to timber harvesting in Webster County, MS, and to predict the resilience of these systems. The study also focuses on comparing biogeochemical trends of wetland forests within the same watershed *(The Yazoo River Basin)* but with different topography and soil associations. There have been similar soil biogeochemical and resilience studies undertaken within the watershed in the past (Balducci et al. 1998), which makes the comparison possible. Balducci (1998) conducted soil resilience studies in the Mississippi Delta in Leflore County. A very similar study was done in the Agricultural Wetlands in the Delta in Issaquena County by Maul and Holland (2002). Recently, another soil study was completed in the Mississippi Hilly Coastal Plains (Calhoun and Lafayette counties) by Chambers-Strong (2003). All of these studies looked at the same soil parameters and followed similar research guidelines.

Site Description

The study area lies at the headwaters of the Yalobusha River and is located near the boundary of the Yazoo-Tallahatchie River Basin in Northern Webster County in Northern Mississippi (Figure 1). The area lies in the coastal plains of Mississippi with low rolling forested hills. Three timber harvested sites of different ages (six months,

seven years, and 18 years since cutting) and an uncut site (~90 years since cutting) were selected within the study area. All the different aged sites had been clear cut for timber harvesting, and had been allowed to regenerate naturally since clearcutting. The six month, seven year and uncut sites were located in lands owned and managed by the Weyerhaeuser Timber Company. The 18 year site was located in private lands owned by the family of Dr. Jim Anderson of the University of Mississippi Field Station. Each site was separated into an 'upland' section (pertaining to areas on ridges, highland, etc), and a 'lowland' section (pertaining to areas near streams, valleys, etc). The presence of rolling hills and streams nearby all the sampling sites made this classification of upland and lowland sites possible.

Methods

Soil samples were collected from 24 sampling plots of various ages within Webster County. Six plots were established at each of the uncut (reference), six months, seven years and 18 year old sites - three sampling plots for upland and three plots for lowland areas for all four sites. Each plot was divided into four quadrants (NW, NE, SE, and SW) and a random soil sample was taken from each quadrant. Soil cores were collected using a stainless steel split core sampler 5cm in diameter x 30 cm in length. Soil samples were taken to a depth of five centimeters, including the litter layer. Soil compaction and Soil Moisture Content were measured on site using a DICKEY–John Soil Compaction Tester® and a Hydrosense® Water Content Meter respectively. Samples were kept in a cooler during transport from the site to the laboratory and were frozen in the lab until analyses could be conducted. Samples were homogenized before analyses. All field sampling was conducted within the month of June in 2004.

Total soil organic matter (SOM) was determined through loss on ignition (LOI) in a muffle furnace at 550ºC for 5 hours. Total carbon (TC) and total nitrogen (TN) were determined using the standard procedure for a COSTECH Elemental Analyzer (COSTECH Analytical Technologies, Inc. 2002). Total phosphorous (TP) was determined by performing an aquaregia digestion and analyzing samples via an Optical Emission Inductively Coupled Plasma Spectrometer (ICP-OES) (EPA Method 200.7 1994). Soil pH was measured by creating an aqueous solution of the soil sample and taking the pH of the solution. All soil analyses were performed in the Analytical lab at the University of Mississippi Field Station.

A Soil Perturbation Index (SPI) was developed using SOM, TC, TN and TP values from the sites as calculated by R.L. Smith (1997). The mean for each parameter per site was converted to a unit-less value using the following equation:

$$[(u - c) / u] \times 100 = \text{perturbation index number}$$

where, u = mean value of the 0 (mature) successional stage wetlands, and

c = mean value of the cut wetland in question.

The SPI numbers were compiled for all parameters for all sites and then plotted on a graph according to successional stage (=time since harvest). A second degree polynomial best fit line was drawn to illustrate the overall pattern of biogeochemical change among different aged sites (see Smith 1997, Maul et al. 1999).

Results

There was no difference in soil pH among different sites (Figure 2). Soil Compaction showed a decreasing trend among sites with the six month site showing the highest compaction and the uncut site showing the lowest (Figure 3). The seven year site had significantly lower moisture content than any other site. Also, the six month upland site had significantly lower moisture content than six month lowland sites (Figure 4). TC showed a decreasing trend with age with the six month site having the highest concentration and the uncut site having the lowest (Figure 5). SOM was higher in lowland sites than upland sites except for the seven year site where lowland concentrations were lower than upland sites (Figure 6). TN was also higher in lowland sites than upland sites except for the six month site where upland concentrations were higher than lowland concentrations (Figure 7). TP was highest in the six month sites and then decreased in the seven year and 18 year sites (Figure 8). The uncut site had higher phosphorous concentrations than the seven year and 18 year sites.

The Soil Perturbation Index derived from the formula mentioned above suggested that it would take 19-20 years for the soil biogeochemical properties of the three disturbed forests to return to preharvest conditions (Figure 9). It also suggested that the changes in the biogeochemical functions will be greatest (~90%) from the uncut conditions at nine to ten years after harvest. The SPI derived from only upland sites suggests the regeneration period to be around 22-24 years (Figure 10). The SPI derived from only lowland sites also suggests a very similar time frame (Figure 10). The upland SPI shows the maximum change from uncut to be around 90% while the lowland SPI shows the change to be nearly 200%.

Implications

The soil pH for all sites were not significantly different and were all found to be slightly acidic with pH values ranging from 4 to 6. Increased soil compaction in the six month site can be attributed to absence of vegetation and pressure form heavy machinery during timber harvest. A decreasing compaction shows that as plant communities start to grow, the soil is loosened by plant roots and other microbiological activities occurring in the rhizosphere. The seven year site soil was visibly sandier than other sites and could be the reason for its significantly lower moisture content. The six month lowland sites were inundated by water in most cases and the upland sites were very dry with no vegetation cover which explains the difference in moisture content between the two sites.

The results from the analyses of individual soil nutrients show that there is not a distinct linear pattern to biogeochemical changes and most may not be significant from a statistical viewpoint. The SPI helps incorporate these soil parameters into a single, efficient index and gives a clearer picture of all the different biogeochemical processes occurring within the study sites. Looking at previous study sites and their SPI results within the watershed, the upland SPI regeneration time is quicker than neighboring Calhoun and Lafayette county sites (~ 60 years; in the Mississippi Hilly Coastal Plains),

similar to the lowland Issaquena county site (~ 24 years; agricultural wetlands in the Delta), and slower than lowland Leflore county site (~ 12 years; in the Mississippi Delta).

The SPI helps indicate a regeneration period and the overall resilience of forested habitats disturbed by timber harvesting. This index helps project long term biogeochemical trends which may not be apparent when looking at each of the soil parameters separately. This study helps establish a background data set for the greater Yazoo River Basin and the study can be utilized as a reference for future studies within the watershed or in similar ecotypes around the Southeastern region. The results of this study will be beneficial for forest and wetland resource user groups in the region such as foresters, landowners, timber companies, farmers, conservation and government agencies, and the local stakeholders in utilizing and sustainably managing the available soil and forest resources.

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