# FIRE AND ALTERNATIVE FUEL TREATMENTS ON SOIL NITROGEN: A CASE STUDY OF MYAKKA RIVER STATE PARK

A MASTER'S THESIS

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**By**

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## DEDICATION

To my brother, Carlinton.

"Even the impossible is possible."

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## ABSTRACT

An appropriate balance between prescribed fire and mechanical fuel treatments can be used to reduce excessive fuel accumulation in Florida's Flatwoods. A study was conducted at Myakka River State Park in Sarasota Florida, to identify the effects of fire and fire treatments on soil nitrogen, during the period July 2000 to August 2001. A randomized complete block design, consisting of three blocks and five treatment plots represented the experimental layout. Soil samples were collected from randomly selected 50 m by 50 m grid points, before and after prescribed fire and/or mechanical fuel treatment was applied. The data obtained were analyzed, using Statistical Analytical System (SAS), Version 8.0. The results indicate that the soil moisture levels were below levels favorable for soil microbial activity. The overall rate of ammonia ($NH_4^+$) production was highest when the site was treated with prescribed fire. A combination of prescribed fire and mechanical fuel treatment (fire & mow) according to the results obtained was best suited for nitrate ($NO_3^-$) production. Myakka River State Park forest demonstrated relatively high C:N ratio in the range of 24:1 to 33:1. The best management practice that has the least negative effect on soil nitrogen is a prescribed fire.

# CHAPTER ONE

# INTRODUCTION

Human activities, including but not limited to fire suppression, past livestock grazing, timber harvesting or farming have resulted in most of the current forests in the United States, especially those in the south, having dense understory and spatially uniform overstory (Skinner and Chang, 1996; Weatherspoon and Skinner, 1996; Arno et al. 1997). That is, these forests have many more small trees and fewer large trees (Figure 1) (Bonnicken and Stone, 1982; Chang, 1996; Harrod et al., 1998). Natural Fires in these forests occur less frequently and cover much less area resulting in greater accumulation of forest fuels (Skinner and Chang, 1996; Weatherspoon and Skinner, 1996). To restore ecosystem integrity and sustainability appropriate restorative management practices are needed (Chang, 1996; Hardy and Arno, 1996). These practices should result in reduced excess fuel accumulation, while preventing or minimizing the negative effect on vegetation, soil minerals, wildlife and insects (Weatherspoon, 1996; Weatherspoon and Skinner, 1996).

Scientists have agreed that there is a need for restorative management practices, which will reduce excessive fuel accumulation and create a sustainable forest ecosystem (SNEP, 1996; Van Wagtendonk, 1996; Weatherspoon, 1996; Stephen, 1998). However, they have failed to agree on the appropriate balance among chopping, mechanical fuel treatments, and prescribed fire that would achieve this goal (SNEP, 1996; Van Wagtendonk, 1996; Weatherspoon, 1996; Stephen, 1998). More research information is needed on the consequences that each treatment or a combination of treatments will have

Figure 1. Dense Understory and Sparse Overstory at Myakka River State Park Forest

on the forest ecosystem. In determining the appropriate balance one of the markers that needs to be examined is the amount of the essential nutrient element nitrogen that is lost if mechanical treatments are used instead of prescribed fire or if they are used in combination with prescribed fire.

Nitrogen (N) is an integral component of many compounds, including chlorophyll, nucleic acids and enzymes, essential for plant growth processes (Brady, 2001). It is essential for carbohydrate use within plants and stimulates root growth and development (Brady, 2001). The amount of nitrogen that is in forms naturally available to plants in the soil is small in comparison to the quantity withdrawn annually by plants. In fact, nitrogen is one of the most deficient nutrients in forest soils (Brady, 2001). Nitrogen mineralization and nitrification in the forest are now generally recognized as the main input to pools of "available" nitrogen in forest systems (Wollum and Davey 1975; Plymale et. al., 1987).

Nitrogen mineralization is the release of organically bound nitrogen into inorganic mineral forms ($NH_4^+$ and $NO_3^-$) (Brady, 2001). Soil N mineralization potential has been suggested as a basis for predicting the amounts of soil N mineralized under field conditions (Stanford et al., 1974). Nitrification is the oxidation of ammonia to nitrates by microorganisms in the soil (Brady, 2001). Nitrification is important because it mobilizes soil nitrogen, making readily usable forms of nitrogen available to plants (Singer and Munns, 1996). Soil nitrification and mineralization has been studied by burying soil samples in polyethylene bags (Eno, 1960; Le Tacon, 1972; Plymale et al, 1987; Perez et al., 1998).

## 1.1 Objectives

This study has been undertaken, as part of a national effort by the United States Department of Agriculture and United States Development Interior (USDA/USDI) Joint Fire Science Program, to better understand the role of fire and alternative fuel treatments in the management of flatwoods forest ecosystem. The general objective of this study was to identify the initial effects of prescribed fire and alternative fuel management treatment on the essential element nitrogen in the flatwoods of South Florida. Three specific objectives are the focus of this study.

(1) To determine the rates of nitrogen mineralization and nitrification in undisturbed South Florida Flatwoods at Myakka River State Park.

(2) To determine the effect of soil moisture and soil pH on rates of mineralization and nitrification of soils in these flatwoods.

(3) To quantify the effects of prescribed fire and mechanical fuel treatment on nitrogen mineralization and nitrification with regards to fuel treatment load reduction in South Florida Flatwoods.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 The Flatwoods

The pine flatwoods are the most common type of terrestrial ecosystem in Florida (Abrahamson and Hartnett, 1990). They are dominated by long leaf pines (*Pinus palustris*), slash pines (*Pinus elliottii*), and low-growing saw palmettos (*Serenoa repens)* which in turn are interspersed with cypress, marshes, hardwood forests, and other natural communities (Abrahamson and Hartnett, 1990) (Figure 1). These forests are usually characterized by low, flat topography, and poorly drained, acidic sandy soils (Edmisten, 1963).

Many of the unique characteristics of Flatwoods ecosystems changed markedly, following human settlement (Abrahamson and Hartnett, 1990). The early settlers viewed the forests as a source of building materials, fuelwood and food (Stoddard and Stoddard, 1987). During the Civil War extensive areas of virgin pine were cleared (Abrahamson and Hartnett, 1990). Later, many roads and fire barriers were constructed as the population continued to increase. These constructions caused a concomitant decrease in the extent and frequency of natural fires (Abrahamson and Hartnett, 1990).

Flatwoods have now been diverted to numerous other land uses. In some areas non-native plant species have become established (Abrahamson and Hartnett, 1990). These changes have resulted in a departure from the characteristic of a “natural” presettlement Flatwoods ecosystem, with probably only a few stands closely resembling those of the past (Abrahamson and Hartnett, 1990). The present stands differ from presettlement stands by having lower fire frequencies, more even age structure, and a denser understory with greater shrub cover and less herb cover (Abrahamson and Hartnett, 1990).

**2.2 Fire in the Management of the Flatwoods**

Fire plays several roles in the ecosystem of the Flatwoods. These roles include reduction of hardwood competition; creation of soil conditions suitable for germination of seeds of some species; increased vigor of populations of some plant species; turnover of litter, humus, and nutrients; and reduction of fuel buildup (Abrahamson and Hartnett, 1990). The buildup of live and dead biomass over a long time leads to the accumulation of natural fuels (Wenger, 1984). Fuel accumulation can be modified by mechanical fuel treatment, prescribed fire or chemical herbicide use (Wenger, 1984). Prescribed fire is the most popular form of fuel management treatment used in Flatwoods ecosystems because of its low cost and efficiency. Plant species in the Flatwoods, such as wiregrass and saw palmetto, are highly flammable, thus promoting the spread of the fire (Abrahamson and Hartnett, 1990).

After a fire, many plants rapidly send up new shoots from underground stems and roots (Abrahamson 1984a, b). Fires increases nutrient cycling rates, raises soil pH, and stimulates nitrogen fixation (Gholz and Fisher, 1984). On the other hand, some loss of nitrogen occurs because of volatilization by fire. The amount varies with fire intensity (Gholz and Fisher, 1984). Fire can be grouped on the basis of maximum temperature into low to moderate-intensity surface fire (250° C), high-intensity brush fire or forest fire (700° C), and long-burning fuel accumulation fire (700+ ° C) (Wenger, 1984). Frequent low to moderate-intensity surface fires (250° C) release small pulses of nutrients and volatilizes only 20 to 40 percent of the forest floor nitrogen (Gholz and Fisher, 1984).

### 2.2.1 Prescribed Fire

Prescribed fire is an economical method of reducing fuel accumulation and disposing of undesirable species (Wenger, 1984). It can be done by broadcast burning or burning selected vegetation (Wenger, 1984). Periodic prescribed burn is one way of preventing high-intensity fires that are damaging to natural resources and property (Wenger, 1984). Nitrogen volatilizes at 200°C, which is easily exceeded in any type of forest fires (Wright and Bailey, 1982). Materials burning above the ground have the greatest chance of being volatilized compared to those retained in the soil compartments (Wright and Bailey, 1982).

Large quantities of nitrogen are readily made available during a fire, despite the rapid decomposition of organic material and nutrient losses that occur (Wright and Bailey, 1982). Burning is often used to establish new stands and to control disease and insect pests in existing stands (Wade, 1983; Abrahamson and Hartnett, 1990). Prescribed fire reduces the cover of woody understory species, reduces surface litter cover by as much as 50 percent, and increases biomass and the diversity of herbaceous species (Moore and Terry, 1980; Abrahamson and Hartnett, 1990).

### 2.2.2 Mechanical Treatments

Mechanical fuel treatment is the rearrangement of fuels by equipment or manpower (Wenger, 1984). This method is widely used with or without fire. Vegetation can be mechanically chopped, mowed or harvested to reduce competing vegetation, and to increase the availability of nutrients, through increased debris decomposition (Abrahamson and Hartnett, 1990). Intensive fuel management practices, involving the use of heavy equipment to chop, mow, or harvest sites mechanically, have a much greater positive impact on soil nutrients than fire (Abrahamson and Hartnett, 1990). Management practices, such as stump removal, windrowing, and harrowing, cause even greater disturbance to both soil and vegetation (Abrahamson and Hartnett, 1990). Mechanical fuel treatments have been accepted practices in southern pine forest management for over twenty five years (Abrahamson and Hartnett, 1990).

### 2.3 Soil Texture and Nutrient Availability

In South Florida, the soils of the Flatwoods are typically quartz sands, poor in nutrients, and are level, deep, acidic, poorly drained, coarse textured throughout, or coarse textured in the upper part, and moderately coarse textured in the lower part (Mullahey et. al., 2000). These soils contain few weatherable minerals and have low nutrient levels in the surface soil. They also have low clay content and low retention capacity, which result in high degree of leaching, except in the areas where there are thick litter layers in long-unburned stands (Gholz and Fisher, 1984; Abrahamson and Hartnett, 1990).

Nutrients are effectively retained within managed Flatwoods forests (Gholz et al., 1985a). The retention is partly because woody plants quickly accumulate essential nutrients after a disturbance such as forest cutting (Golkin and Ewel, 1984; Gholz et al., 1985ab). Initially, the growth of slash pine is rapid, probably due to the accumulation of essential elements in the vegetation and litter, but it slows quickly. (Gholz et al., 1985a). The mineralization process and the small atmospheric inputs of nutrients are only sufficient to supply the annual nutrient requirement for maintenance of mature stands (Gholz and Fisher, 1982; Gholz et al., 1985a). When soil supplies of phosphorus and nitrogen decrease, the pines reallocate nutrients internally to sustain growth (Gholz and Fisher, 1984; Abrahamson and Hartnett, 1990).

Certain types of Flatwoods species, dry prairies, and scrubby Flatwoods play specific roles in the cycling of minerals (Abrahamson and Hartnett, 1990). For example, saw palmetto readily takes up calcium from the soil and returns it as litterfall. This litter calcium can then be taken up by surface feeder roots of other species (Edmisten, 1963; Snedaker and Lugo, 1972; Abrahamson and Hartnett, 1990). Nitrogen can be added to Flatwoods soil, through nitrogen fixation by wax myrtle symbiont (Edmisten, 1963; Glolz and Fisher, 1984).

## 2.4 Organic and Inorganic Nitrogen in Soil

Soil organic N consists of a heterogeneous mixture of components, including crop and animal residues, microbial biomass, and microbial metabolites adsorbed to colloids and stable humic substances (Campbell, 1978; Curtin and Wen, 1999). Microorganisms will attack the plant and animal residues and adsorb the inorganic N ions and convert them to organic compounds, where the nitrogen is immobilized (Brady, 2001). The organic N in their bodies may be converted into forms that make up the humus complex or may be released as $NO_3^-$and $NH_4^+$ ions at the death of the organism (Brady, 2001). At this time, the plant will be able to extract the released $NO_3^-$ from the soil (Brady, 2001).

Although most soils contain several thousand kilograms of N per hectare (Brady, 2001), only 1 to 3% of soil organic N mineralizes and becomes available to plants each year (Keeney, 1982; Curtin and Wen, 1999).

The inorganic N in soils occurs predominantly as $NH_4^+$ and $NO_3^-$, with the exception of soils receiving $NH_4^+$ or $NH_4^+$ producing fertilizers. Nitrate is seldom present in detectable amounts (Keeney and Nelson 1982). Within the past 40 years studies showing that soils containing significant amounts of fixed nonexchangeable $NH_4^+$ have led to a realization that inorganic N may represent more than a small fraction of the total N in soils (Rodrigues, 1954; Dhariwal and Stevenson, 1958; Bremner and Harada, 1959; Bremner, 1959; Keeney and Nelson 1982). Subsequently, *fixed* $NH_4^+$ has been defined as the $NH_4^+$ in soil that cannot be extracted by a neutral K salt solution (e.g., 1 *N* $K_2$ $SO_4$, 2*N*KCl). Exchangeable $NH_4^+$ is defined as $NH_4^+$ that is extractable at room temperature with natural K salts (Keeney and Nelson 1982). Nonexchangeable $NH_4^+$ is thought to be present in soil, primarily as $NH_4$ ions, in interlayer positions of 2:1 type clay minerals (Keeney and Nelson 1982). Research results indicate that nonexchangeable $NH_4^+$ may account for up to 10% of the total N in surface soils and more than 30% of the total N in subsoils (Keeney and Nelson, 1982).

### 2.4.1 Nitrogen in Forest Soils

Mineralization of N in the forest floor and turnover of small roots are now generally recognized as the main contribution to pools of "available" nitrogen in forest ecosystems (Wollum and Davey, 1975; Henderson and Harris 1975; Keeney, 1980). Atmospheric input via precipitation is often closely matched by leaching losses (Gessel et al., 1973; Henderson and Harris, 1975; Bormann et al., 1977; Keeney, 1980). Hence, N from the mineralized soil is often the apparent source of much of the net gain in nitrogen in the biomass (Heilman and Gessel, 1963; Stone and Will 1965; Switzer and Nelson 1972; Henderson and Harris, 1975; Wells and Jorgensen, 1975; Turner and Singer 1976). This again is approximately 19 to 25 kg N/ha/year, for the systems studied, thus far (Keeney, 1980). In most cases this nitrogen is sufficient for maximum growth. However the systems soon become nitrogen deficient as N is incorporated into the forest floor and plant biomass (Heilman and Gessel, 1963; Gessel et al., 1973; Miller et al., 1979; Keeney, 1980).

### 2.4.2 Nitrogen Mineralization and Immobilization

The carbon to nitrogen (C:N) ratio of the litter in most forest floors is relatively high, ranging from 40 to 60:1 (Roberge and Knowles, 1966; Williams, 1972; Gosz et al., 1973; Sowden and Ivarson, 1974; Ohta and Kumada, 1977; Keeney, 1980), corresponding to total nitrogen concentrations of 0.6 to 1.4%. Immobilization (the conversion of an element from the inorganic to the organic form in microbial tissues or in plant tissues, thus rendering the element not readily available to other organism or to plants (Brady, 2001)) dominates over mineralization during initial decomposition, and the total nitrogen concentration of the litter increases, while the C:N ratio decreases (Keeney, 1980).

Van Praag and Weissen (1973) attempted to relate nitrogen released on incubation to nitrogen available in the forest floor. Virtually no nitrogen was mineralized in the litter, but 1 to 5% of the organic nitrogen was mineralized in the more humified material and the soil immediately below this layer (Keeney, 1980). An aerobic incubation for 6 weeks was used (Van Praag and Weissen 1973; Keeney, 1980). In general, the net mineralization rates were related to the state of decomposition of the material (Van Praag and Weissen 1973; Keeney, 1980). An *in situ* plastic bag incubation gave results similar to those in the laboratory (Keeney, 1980). These results indicated sufficient nitrogen was released to supply tree needs in these soils (Van Praag and Weissen 1973; Keeney, 1980). Van Praag and Weissen (1973) concluded that in natural conditions there is no correlation between the quality of sites and the nitrogen mineralization rates.

### 2.4.3 Nitrification

The rate of mineralization and nitrification of nitrogen in the forest soils is key to the nitrogen status of forest ecosystems. However, due to the horizontal and vertical variability, particularly of the forest floor material, accurate assessment of net nitrogen release rates is difficult to determine (Keeney, 1980). Several researchers have noted little or no nitrification in incubated samples of non-nitrogen treated forest soil (Roberge and Knowles, 1966; Williams, 1972; Van Praag and Weissen, 1973; Heilman, 1974; Theobald and Smith, 1974; Geist, 1977; Keeney, 1980). Since the presence of nitrate may result in losses of nitrogen through denitrification and leaching, the low rate of nitrification is ecologically desirable (Henderson and Harris, 1975; Bormann et al., 1977; Keeney, 1980). It would appear that the low nitrification rate is due to the low population of nitrifiers. When favorable conditions are obtained by modifications such as liming, urea, or disturbance, nitrification will commence following a lag period (Otchere-Boateng and Ballard, 1978, Vitousek et al., 1979; Keeney, 1980).

## 2.5 Determination of Ammonium and Nitrate Nitrogen

Ammonium ($NH_4^+$), nitrate ($NO_3^-$), and nitrogen (N) have been determined, using field and laboratory methods. These approaches are based on the principles of soil incubation, to determine N mineralization and nitrification process.

### 2.5.1 The Polyethylene Bag Method

Eno (1960) successfully obtained nitrate production in polyethylene bags in the field, which compared with nitrate production under laboratory conditions. Since then, the polyethylene bag technique has been used successfully to determine N mineralization and nitrification under field conditions (Plymale et al., 1987; Le Tacon, 1972; Perez et al., 1998).

Generally, polyethylene is unaffected by moisture, soil, and most common chemicals (Eno, 1960). It is impermeable to nitrate and ammonia, slightly permeable to water vapor, while being highly permeable to oxygen and carbon dioxide (Eno, 1960; Smith et. al., 1976; Westermann and Crothers, 1980; Plymale et. al., 1987). A film 1 mil thick will transmit about 500 ml of oxygen and 2,900 ml of carbon dioxide per 645 $cm^2$ in 24 hours (Renfrew and Morgan, 1957; Eno, 1960). A study of the permeability of polyethylene bags to nitrate revealed that no nitrate diffused through the film, during a 24 week period (Eno, 1960).

Nitrate production in field soils can be assayed by incubating the soil in polyethylene bags (Eno, 1960; Smith et al., 1976; Westermann and Crothers, 1980; Plymale et al.; 1987). In the original study, thirty polyethylene bags containing 100 g of Arredondo fine sand treated with 200 μg/g of ammonium nitrogen and calcium carbonate equivalent to 574.29 kg per hectare, were closed and secured with rubber bands (Eno, 1960). A piece of sod, approximately 38 cm by 38 cm by 10 cm deep was removed, after which a thin layer of soil was removed (Eno, 1960). The bags were laid in the recessed area in one layer, flattened to approximately 2.54 cm, and covered with soil (Eno, 1960). Each week, during the six weeks of the study, 30 bags were buried in one location and 5 bags from each of the earlier weekly placements were removed and analyzed for nitrate and ammonium-nitrogen (Eno, 1960). As a result of this study the use of polyethylene bags for incubation studies is an efficient method of monitoring soil N when moisture loss needs to be minimized and where a degree of aeration must be maintained, without the loss of nitrate (Eno, 1960).

The major advantages of the polyethylene buried bag incubation method are that it is inexpensive and is easy (Eno, 1960). The main disadvantage of the polyethylene buried bag incubation method is that, because the bags are impermeable to water, the soil in the bags must remain at the initial moisture level throughout the incubation (Plymale et al., 1987). In addition, the removal of live roots may also influence minerialization rates (Pastor et al., 1984). To minimize the possibility of denitrification, samples should be taken a minimum of 48 hours after a significant rain in sand textured soils. Sandy soil allows for rapid percolation of water and lower moisture percentages (Plymale et al., 1987).

### 2.5.2 The Laboratory Method

Nitrate production in polyethylene bags was compared to that in ventilated pint milk bottles and sealed 125 ml Erlenmeyer flasks in the laboratory (Eno, 1960). In the study, 100 g of Arredondo fine sand, treated with 200 µg/g of ammonium nitrogen and calcium carbonate equivalent to 0.8 tons per hectare were placed in each of the following containers; polyethylene bags, ventilated pint milk bottles and 125 ml. Erlenmeyer flasks (Eno, 1960). The ventilated pint milk bottles were covered with aluminum foil, which had a 0.6 cm ventilated hole. The polyethylene bags were tightly closed and folded over and wrapped with a small rubber band at the top (Eno, 1960). The 125 ml. Erlenmeyer flasks were sealed with rubber stoppers covered with paraffin. Each treatment was replicated 30 times and the study was conducted for 6 week (Eno, 1960).

The rate of nitrification in soil contained in the bags was equal to that contained in ventilated bottles. Slight losses in soil moisture occurred in the polyethylene bag treatment during a 6 week period of incubation, since polyethylene is permeable to oxygen and carbon dioxide. No nitrate diffused through the polyethylene bags during the six weeks period. Although a small amount of nitrate was produced during the first week, the net result was a loss of nitrate over the 6-week period for soil in the Erlenmeyer flasks. The loss in nitrate production indicates that there was a need for aerobic conditions in the sealed Erlenmeyer flasks (Eno, 1960).

### 2.6 Factors Affecting Soil Nitrogen Mineralization and Nitrification

Soil nitrogen mineralization and nitrification are dependent on a number of factors, which include, soil moisture, soil pH, soil temperature, and soil microbial processes (Stanford and Smith, 1972). Field and laboratory studies of N mineralization have demonstrated that temperature and moisture are strong rate controllers and they have an effect on nitrogen mineralization and nitrification (Plymale et al., 1987). The optimum range of water potential (a measure of the difference between the free energy state of soil water) (Brady, 2001) for organic matter decay is –10 to –50 Kpa. When the overall moisture content is low the rate of nitrogen mineralization might be affected by the distribution of soil water (Singer and Munns, 1986). Decay of forest floor organic matter will gradually reduce, as moisture content deviates in either direction from this optimal range (Singer and Munns, 1986).

Temperature conditions that are favorable for plant growth closely resemble optimal conditions for microbial decay (Myrold, 1987). In the standard temperature range of forest soils, nitrogen mineralization increases as the mean summer soil temperature rises (Powers, 1980). Soil moisture and soil temperature have been found to be higher in the clearcut forests than in undisturbed forest canopies (Plymale et al., 1987). Microbial activities increase at higher temperature resulting in higher N mineralization rates (Powers, 1980; Plymale et al., 1987).

Most Flatwoods forests in Florida have acidic soils (Abrahamson and Hartnett, 1990). Nitrification rates are tied to the specific pH range of the sites studied (Plymale et al., 1987). In a study by Plymale and others (1987), soils with pH ranging from 4.7 to 5.8 nitrified over 90% of newly mineralized ammonia, whereas soils with pH ranging from 3.1- 3.8 nitrified less than 10% of mineralized N.

Microbial decay of organic matter is the main process by which biologically stored N is released (Singer and Munns, 1986). Nitrogen is released in the form of ammonium ($NH_4^+$), which can also be immobilized by microbes, as they take up nitrate and ammonium to satisfy their own requirements (Singer and Munns, 1986). The mobilization or immobilization of nitrogen is dependent upon the amount of N the decomposing material itself provides (Singer and Munns, 1986). An excess of N will satisfy the requirements of the microbes and provide a surplus to be released into the soil for use by the plants, but insufficient nitrogen released from decaying organic matter will result in the absorption of ammonium and nitrate by the microbes (Singer and Munns, 1986).

# CHAPTER THREE

# MATERIALS AND METHODS

## 3.1 Study area

This study was conducted in the Myakka River State Park located in South Central Florida (Figure 2). It is Florida's largest state park, consisting of 28,876 acres of land and is named for the Myakka River, which flows 12 miles through the park (FWC, 1999). The area is characterized by sub-tropical climate with a strong oceanic influence, temperature ranges from an average of 92.1° F to an average of 47.6° F, and an annual average precipitation of 57.13 inches (Southeast Regional Climate Center, 2000) (Appendix 1). During the rainy season, usually from June through September, this site may have water on or near the soil surface.

The predominant soil is the Myakka Fine Sand, which is unique to Florida and occurs in more than 1.5 million acres of Flatwoods, making it the single most extensive soil type in the state of Florida (FDOS, 2000). Myakka soil is nearly level, deep, acidic, and poorly to somewhat poorly drained. The surface layer is gray fine sand while the subsurface layer is light gray fine sand. It has high permeability in the A-horizon and moderate or moderately high permeability in the Bh horizon (USDA, 1998). The pH of this soil is usually low, ranging from pH 3 to 5 (Edmisten, 1963).

## 3.2 Experimental Design and Layout

The experimental design used was a Randomized Complete Block Design with three replicated blocks. All blocks had five treatment plots with 36 grid points on a 50 m

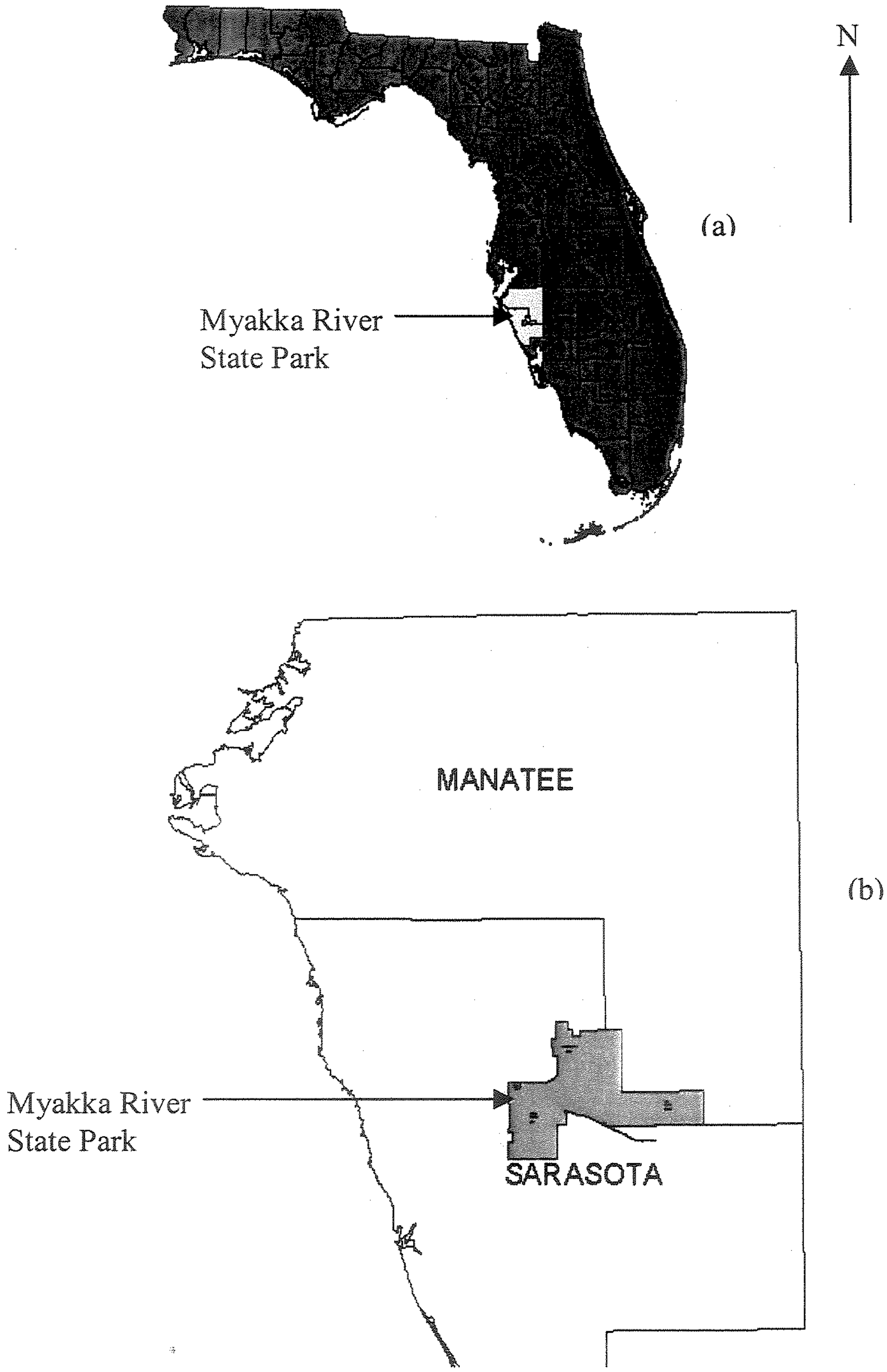


Figure 2. Maps showing the location of the Myakka River State Park.
(a) Map of Florida (b) Map of Manatee and Sarasota Counties in which the Myakka River State Park is located.

by 50 m spacing. The grid lines all ran north and south in all treatment plots. Blocks were used to represent site location, with each block selection based on the level of soil water at that particular site. Block I site location was selected for its dry soils. Block II was selected for its slightly moist soil and Block III site location was selected for its wet soils (Figure 3).

### 3.2.1 Block I:

Painted trees along the south boundary marked the plot boundaries. The outside corners had a corner with the plot number in it and adjoining plots had an upside down T, with the plot numbers on each side. Within each treatment plot, the gridline number painted on a tree along the south boundary road marked North-South gridlines. Grid points were numbered and sampling was done at these points (Figure 4).

### 3.2.2 Block II:

A painted tree along the central east to west road marked plot boundaries for plot 1 - 4. The outside corner had a corner with the plot number in it, and adjoining plots had an upside down T, with the plot numbers on each side (Figure 5). Plot 5 boundary was marked by a metal tag on a 5 ft piece of conduit along the western boundary road. Grid lines 1-4 in plot 4 were marked by numbers painted on trees along the central road.

### 3.2.3 Block III

The plots in this block were not contiguous, but were situated along the south boundary line in zones 12A and 13A (Figure 6). Plot 1 was at the southeast corner and plot 2 was near the midpoint. Plot 3 was north of plot 2, plot 4 was

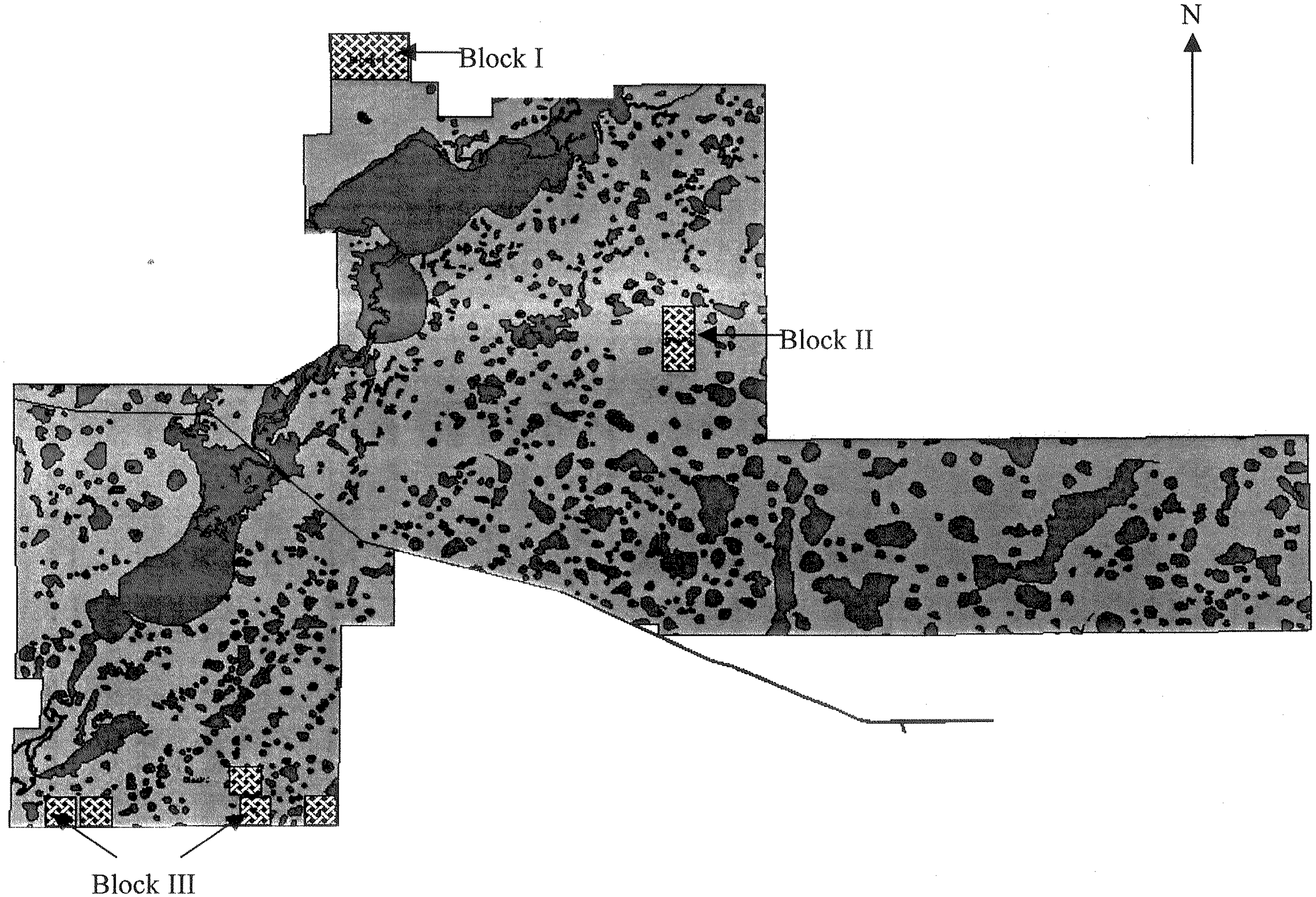


Figure 3. Location of the Blocks I, II and III, within the Myakka River State Park

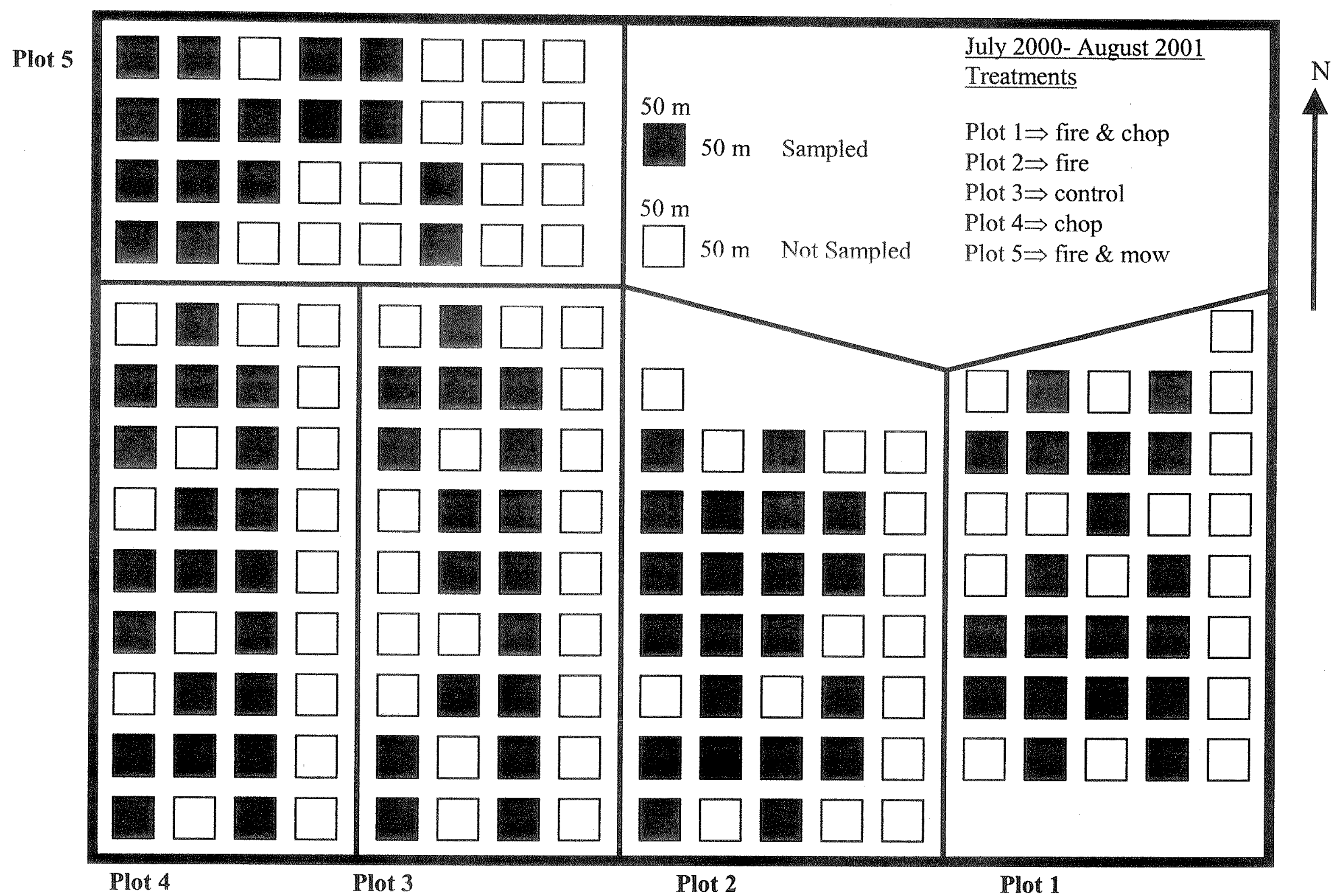


Figure 4. Location of plots within block I and the grid point within each plot. Areas sampled were randomly selected and are represented by solid squares

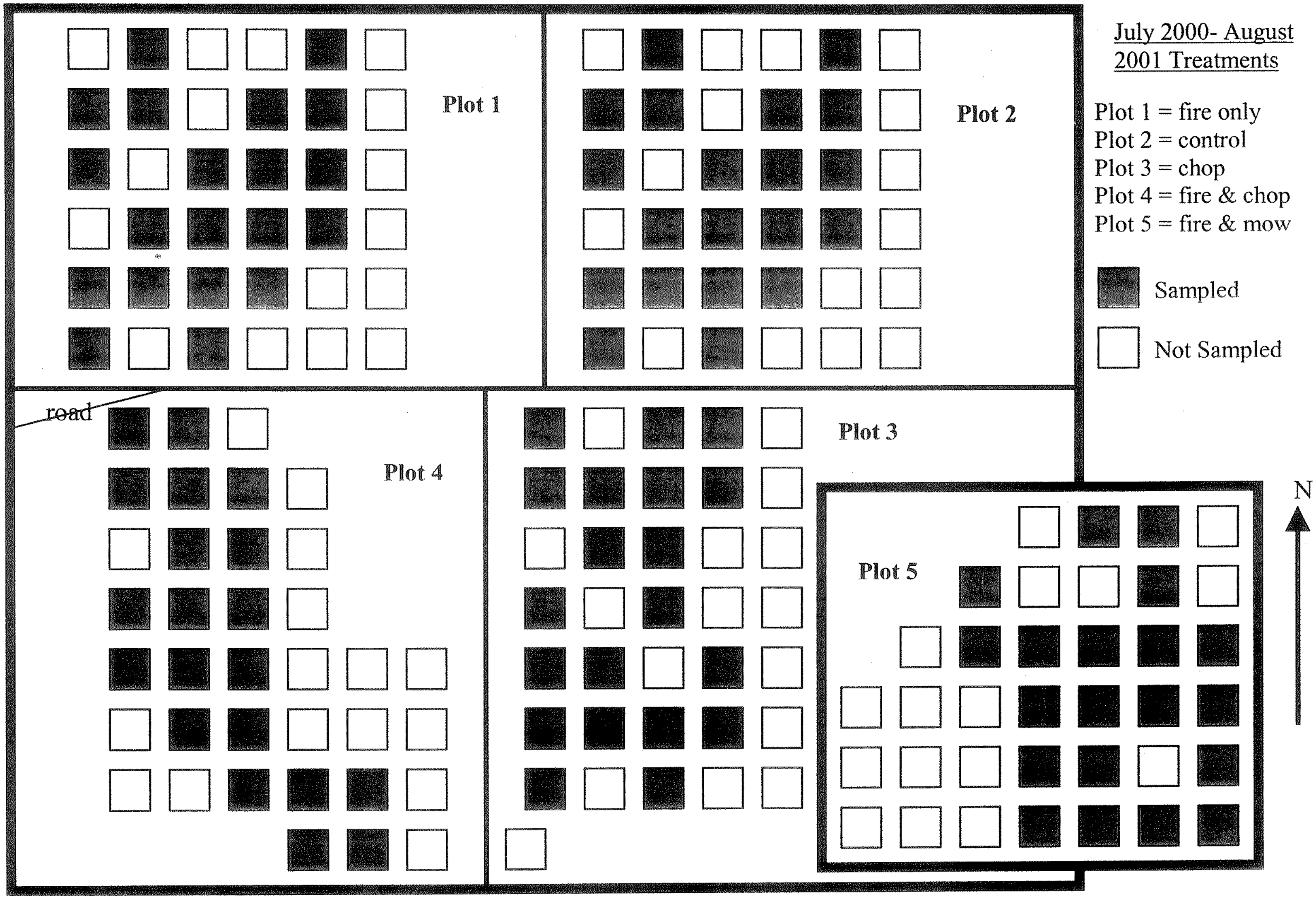


Figure 5. Location of plots within block II and the grid point within each plot. Areas sampled were randomly selected and are represented by solid squares

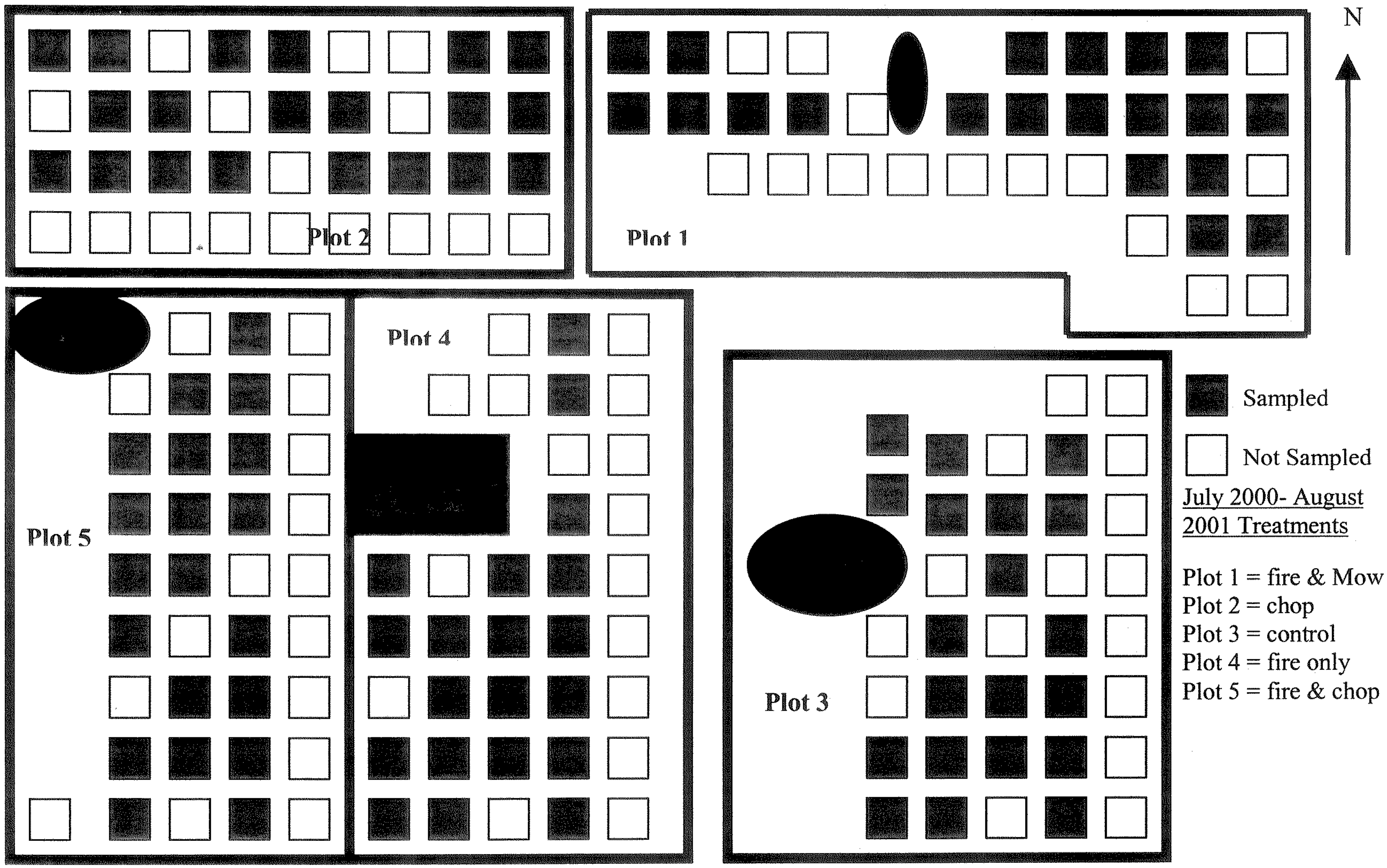


Figure 6. Location of plots within block III and the grid point within each plot. Areas sampled were randomly selected and are represented by solid squares

at the intersection of the south boundary and old fence line road, and plot 5 was just west of plot 4. The corners of plots 1, 2, 4, and 5 were marked by painted trees, with a corner and plot number along the south boundary road. A number painted on a tree, if one was available, was used to mark gridlines within each plot. Like all other plots, the gridlines run north and south.

### 3.3 Experimental Treatments

Five experimental treatments implemented in this study were: (1) untreated control, (2) prescribed fire only, (3) prescribed fire & mow, (4) chopping only, and (5) prescribed fire & chop. The untreated control received no prescribed fire or mechanical fuel treatment. It remained undisturbed excepted for periodic sampling throughout the study period. Before prescribed fire treatments were applied to each block, firelines approximately 1.2 m deep were constructed around the plot to be treated. The fire was ignited using a drip torch to start a solid line of fire. The intensity of the fire at each prescribed fire treated plot was not measured. A Brown Tree Mower (bush hog), approximately 1.8 m wide, was used to cut the understory of the fire & mow plots to a height of about 10 cm. In the treatment plots that were chopped, a metal tooth chopper was attached to the back of a tractor and used to cut the understory only. The resultant cut to approximately 10 cm in height. All plots that were treated with a combination of fire and fuel management treatments (fire & chop or fire & mow) were chopped or mowed after they were burned.

Each treatment was replicated three times. Each block covered approximately 80 hectares. Each plot covered approximately 14 hectares, with varying dimension, based on the arrangement of the 50 m by 50 m grid point within each plot. The five treatments were chosen for restorative management and anticipated reduced ecological effect.

**3.4 Field Methods**

Mineralization and nitrification of Myakka River State soils were measured from June to August 2000 and from July to September 2001, using the polyethylene buried-bag incubation method (Eno, 1960; Smith et al., 1976; Westermann and Crothers, 1980; Perez et al., 1998). The experiment was limited to the OA horizon (0 to10 cm depth).

Two sets of two soil samples were collected from randomly selected 50 m by 50 m grid point within each plot, from June to August 2000, and placed in polyethylene bags (Figure 7). The points of collection were flagged at sampling. One set of samples per grid point was taken to Florida A&M University Forestry Laboratory, to determine the soil moisture content, soil pH, soil particle size, and the initial amounts of exchangeable $NH_4^+$and $NO_3^-$. The remaining set of samples per grid point were buried and referred to as incubated samples from this point at the flagged site for 20 to 30 days. Two samples were incubated to minimize the possibility of samples being damaged by native animals. After 20 to 30 days, the incubated samples were retrieved and taken to the laboratory. A composite of the two incubated samples per grid point was made if the polyethylene bags containing the samples were not damaged. If any of the bags were damaged, then the demaged samples were discarded. The production of $NH_4^+$ and $NO_3^-$ during incubation was determined from these samples.

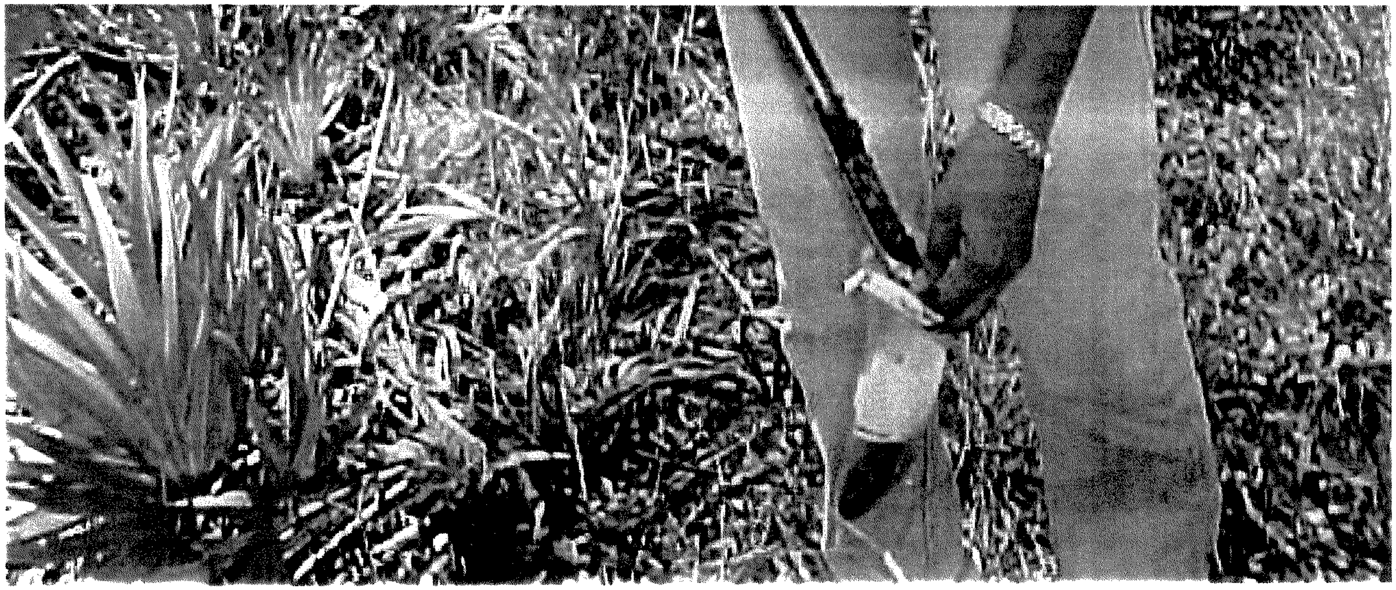

Figure 7. Soil sampling by removal of a 10 cm in length and 1.9 cm in diameter soil plug, which was then inserted into a polyethylene bag.

Twelve composite soil samples within each block were collected randomly from the first 10 cm of the forest floor during September 2000. A total of 36 composite samples were collected over the three blocks. All soil samples were placed in polyethylene bags and transported to the laboratory, where they were analyzed for total carbon and total nitrogen content.

Between July 2000 and August 2001 each of the five plots within each Block was subjected to a different fire or fuel management treatment. A second set of soil samples was collected after each block received its fire and fuel management treatments. Three soil samples were collected from the same randomly selected 50 m by 50 m grid point within each plot, as in the previous year. The samples were placed in polyethylene bags and the points of collection were again flagged at sampling. One sample per grid point was taken to the Forestry Laboratory for the determination of soil moisture content, soil pH, and the initial amounts of exchangeable $NH_4^+$ and $NO_3^-$ available to plants after each fire and fuel management treatment. The remaining two samples per grid point were incubated at the flagged site for 20 to 30 days. After 20 to 30 days, the incubated samples were retrieved and taken to the laboratory to determine the production of $NH_4^+$ and $NO_3^-$ after each treatment.

### 3.5 Laboratory Methods

All soil samples were stored in a refrigerator at –5° C. Soil samples were analyzed to determine soil moisture content, soil pH, soil particle size, and soil $NH_4^+$ and $NO_3^-$ content.

### 3.5.1 Soil Moisture Content

The percentage (%) moisture content of the soil on a wet weight basis was determined in order to calculate the influence of soil moisture content on nitrogen mineralization and nitrification. A 10 g sub-sample of each sample was weighed (wet weight) in preweighed Daigger 43 mm aluminum dish (tin weight). The identification number of each sample was recorded on the aluminum dish. The 10 g sub-samples were oven-dried at 105° C for 24 hours in a Fisher Isotemp Gravity-flow Convection Oven. After oven drying, each sample was weighed and its weight recorded. The moisture content of each sample, on a wet weight basis, was calculated using the % moisture content formula on a wet weight basis.

$$\% \text{ Moisture Content} = \frac{(\text{wet weight} - \text{dry weight})}{(\text{wet weight} - \text{tin weight})} * 100 \qquad (1)$$

### 3. 5.2 Soil pH Content

The soil pH of each sample was determined by using a 1:1 (weight by volume) soil:water paste. A 10 g sub-sample of each sample was weighed and 10 ml of deionized distilled water was added to each 10 g sub-sample and it was mixed into a paste. An Oakton Benchtop pH meter, with a glass electrode was calibrated, using buffer solutions of pH 4 and 7. The glass electrode of the pH meter was inserted into each soil:water paste and the readings were recorded.

### 3.5.3 Nitrogen Extraction

Exchangeable nitrate and ammonia were extracted from initial and incubated soil samples in a 1:10 ratio of soil solution of 1 M KCl (Keeney and Nelson, 1982). Soil samples were first removed from the freezer and allowed to thaw and then the soil samples were mixed within polyethylene bags. A 10 g sub-sample of each sample (initial and incubated) was then weighed and placed into a previously labeled 250 ml Erlenmeyer flask. To each flask, 100 ml of 1 M KCl was added. Using a mechanical rotary shaker the soil and KCl mixture was shaken for 1 hour at 230 rpm. After shaking, the KCl extract (liquid and soil) was poured through a funnel containing Whatman # 42 filter paper. For each sample, the clean filtrate was poured into individual sample cups, for analysis with an Alp-chem Auto analyzer. The net nitrogen mineralization was calculated as the difference in total inorganic nitrogen ($NH^{+}_{4}$ and $NO_3^-$ ) between the initial samples and those incubated *in situ* for 20 to 30 days. Net nitrification was calculated as the difference between $NO_3^-$ in the initial samples and the incubated samples.

### 3.5.4 Soil Carbon/Nitrogen Ratio

Each of the 36 composite samples for carbon to nitrogen (C:N) was sieved using a 2 mm metal sieve and ground into a powder using a mortar and pestle. A 35 mg subsample of each sample was weighed and placed in a labeled capsule tin. The sample was then placed into a free well on a 96 well plate of a Carlo-Erba C:N Analyzer (Carlo Erba Instrument), which then analyzed the sample for total organic carbon and total organic nitrogen.

### 3.5.5 Soil Particle Size Analysis

Particle size distribution was determined by the hydrometer method of G. J. Bouyoucos (VanScoyc et al., 1974). A composite of soil samples from each treatment plot within each block (total of 15 composite, five for each block) was oven dried in a Fisher Isotemp Gravity-flow Convention Oven at 105° C for 24 h. Sub-samples of 50 g of each oven dried composite sample were weighed and sieved in a 2 mm metal sieve. The resulting sieved sample was then placed in a 400 ml breaker. Enough water was added to each oven dried sub-sample to cover the soil, followed by 10 ml of 30% $H_2O_2$ to oxidize the organic matter present. After the reaction subsided, an additional 10 ml aliquot of $H_2O_2$ was added to each sub-sample, then the sub-sample was heated on a hot plate until the fizzing action stopped or oxidation was complete. If there was any visual indication that oxidation was not completed, the procedure was repeated. To each sub-sample, 5 ml of 1 N sodium hexametaphosphate was added to disperse the soil particles, then the beakers were filled to within two inches of the top with deionized water and the soil stirred for 15 minutes. The contents of the beakers was transferred to a labeled 2 liter measuring cylinder and a hydrometer was carefully placed in each cylinder and filled with deionized water to 1130 ml. The hydrometer was then removed and all the soil materials in the cylinders were brought into suspension by placing a rubber stopper in the cylinder and vigorously shaking it end over end. The time at the instant each cylinder was set down was recorded, then the hydrometers replaced into each cylinder and read at 40 seconds. The hydrometer was then removed and the temperature determined using a glass mercury thermometer. The hydrometer was then placed into each cylinder for two hours and another hydrometer and temperature reading was recorded. The following calculation, described by Bouyoucos in 1962, was used to determine % sand, % silt, and % clay.

$$\% \text{ Sand} = \frac{\text{corrected 40 second reading}}{\text{dry weight of sample}} \times 100 \quad (1)$$

$$\% \text{ Clay} = \frac{\text{corrected 2 hour reading}}{\text{dry weight of sample}} \times 100 \quad (2)$$

$$\% \text{ Silt} = 100 (\% \text{ sand} + \% \text{ clay}) = 100 \quad (3)$$

### 3.6 Data Analysis

Data analysis was performed using the Statistical Analytical System (SAS), Version 8.0. Analysis of variance was used to determine differences between treatments and among blocks. To show the relationship between rates of N mineralization and net nitrification, a multiple regression analysis was performed. The parameters that were considered were nitrate and ammonium nitrogen, soil moisture, soil pH, soil organic carbon and soil carbon to nitrogen ratios (C:N). The dependent variables were nitrate and ammonium nitrogen and organic carbon to nitrogen ratio, while the independent variables were soil moisture and soil pH.

# CHAPTER FOUR

# RESULTS

## 4.1 Soil Moisture Content

Over the first sampling period, June to August 2000, block III, which was selected for its wet soil, showed significantly higher soil moisture content than the other two blocks (Table 1). Soil moisture content ranged from a high of 29.3% to a low of 16.6 % in block III, while in block I, which was selected for its dry soils, moisture content ranged from a high of 16.8% to a low of 8.3% (Table 1). Block II, which was selected for its moist soil, had the lowest moisture level of all three blocks.

Soil moisture content in the second sampling period (July to August 2001) was consistently lower than the first year in every block except block I, which showed an increased moisture levels over the previous years (Table 1). An analysis of variance of the results for soil moisture content indicated that there was no significant difference in moisture content between the plot treated with prescribed fire and the untreated control in block I and II. In block III however, significant differences in moisture content was shown between prescribed fire and the untreated control.

## 4.2 Soil pH

The soil pH results obtained from both years were relatively stable, but they were consistently lower in the fire and fuel management treated second year (Table 1). In year one, mean pH values ranged from a low of 4.3 to a high of 5.2. In year two, which was sampled after a particular fire or fuel management treatment was applied, mean pH values ranged from a low of 3.9 to high of 4.7. These values indicate that the soil at Myakka River State Park is an acidic soil.

**Table 1**

**Mean values for percentage soil moisture and soil pH of the various treatments over two sampling periods at the Myakka River State Park. Year 1 represent baseline values while year 2 was after the treatments were applied.**

| | Soil Moisture (%) | | | | Soil pH values | | | |
|---|---|---|---|---|---|---|---|---|
| **Block/Treatment** | **Year 1** | **CV** | **Year 2** | **CV** | **Year 1** | **CV** | **Year 2** | **CV** |
| I | | | | | | | | |
| Prescribed Fire only | 16.8c* | 0.31 | 19.3a | 0.31 | 4.3a | 0.04 | 4.0a | 0.07 |
| Chop only | 13.4d | 0.24 | 15.0b | 0.15 | 4.5b | 0.06 | 3.9a | 0.04 |
| Fire & Chop | 8.3e | 0.33 | 12.3b | 0.47 | 4.6b | 0.07 | 4.1b | 0.10 |
| Fire & Mow | 12.6d | 0.47 | 18.5a | 0.27 | 4.5b | 0.04 | 4.2b | 0.06 |
| Untreated Control | 12.6d | 0.36 | 19.4a | 0.23 | 4.5b | 0.05 | 4.2b | 0.06 |
| II | | | | | | | | |
| Prescribed Fire only | 12.8d | 0.31 | 13.5b | 0.19 | 4.8b | 0.08 | 4.1a | 0.06 |
| Chop only | 9.5e | 0.60 | 8.5c | 0.36 | 4.7b | 0.07 | 4.0a | 0.06 |
| Fire & Chop | 13.3d | 0.22 | 4.8d | 0.29 | 5.1c | 0.05 | 4.7c | 0.05 |
| Fire & Mow | 11.8d | 0.15 | 8.7c | 0.20 | 4.9c | 0.04 | 4.1a | 0.04 |
| Untreated Control | 12.2d | 0.32 | 11.7b | 0.23 | 4.9c | 0.07 | 4.0a | 0.04 |
| III | | | | | | | | |
| Prescribed Fire only | 21.6b | 0.20 | 9.2c | 0.17 | 4.9c | 0.07 | 4.0a | 0.04 |
| Chop only | 17.7c | 0.25 | 11.1b | 0.16 | 4.7b | 0.06 | 4.2b | 0.05 |
| Fire & Chop | 29.3a | 0.21 | 15.8a | 0.22 | 4.6b | 0.07 | 4.2b | 0.07 |
| Fire & Mow | 26.2a | 0.12 | -----† | ----- | 4.4a | 0.04 | ----- | ----- |
| Untreated Control | 16.6c | 0.26 | 11.0b | 0.18 | 5.2d | 0.09 | 4.4b | 0.05 |

***Means with the same letters within columns are not significantly different at p = 0.05 (Duncan's Multiple Range Test). N = 80 per treatment per block per year, except in block I treatment mow & fire where N = 64 per year.**
**† No samples for this treatment were evaluated due to lack of burning in accordance with Myakka River State Park regulations.**
**CV = coefficient of variation**

There was a significant difference in soil pH values between treatments of prescribed fire and the control, but there was no significant difference between the control values and the fire & chop values in block I and block III in year 2. In block II however, there was a significant difference between the control values and fire & chop values. There was no significant difference between prescribed fire values and the control values in block II. The results indicated that the pH values were significantly lowered after the prescribed fire treatment in block II and III.

### 4.3 Soil Nitrogen

Total change in $NH_4^+$ values over each incubation period was significantly higher than total change in $NO_3^-$ over the same incubation period (Table 2). The production of $NH_4^+$ in the first year ranged from a low of 7.0 μg/g to a high of 23.5μg/g over the three blocks. In the second year the $NH_4^+$ content decreased over the first year, ranging from a low of 4.0μg/g to a high of 14.0 μg/g, with the lowest and highest rates of total change in $NH_4^+$ both recorded in block III.

The rates of mineralization, as measured by the total change in $NH_4^+ + NO_3^-$ over each of the 20 to 30 day incubation period, were significantly higher in block I, in year 1 and block III in year 2 when compared to the other blocks in the same year. Rates of mineralization for block II were higher in the untreated control (10.5μg/g). Significant differences in $NH_4^+$ production were observed between prescribed fire only and chop only treatments in blocks I and III. However, in block II there was no significant difference between prescribed fire only and chop only treatments. The overall rates of mineralization were highest after the study site was treated with prescribed fire and lowest after it was treated with chop only. The treatments that were combined with fire had slightly higher levels of total mineralization than chop only treatments (Figure 8).

**Table 2**

**Mean increase values for change in nitrate, ammonia and total mineralization over two sampling periods in soil samples buried in polyethylene bags. Year 1 represent baseline values while year 2 was after the treatments were applied**

| Blocks/Treatments | $NH_4^+$ (µg/g) | | | | $NO_3^-$ (µg/g) | | | | Total Mineralization (µg/g) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Year 1 | CV | Year 2 | CV | Year 1 | CV | Year 2 | CV | Year 1 | Year 2 |
| I | | | | | | | | | | |
| Prescribed Fire only | 23.5a* | 0.39 | 8.3a | 0.64 | 0.94d | 0.24 | 0.87b | 0.56 | 24.4 | 9.2 |
| Chop only | 13.2b | 0.59 | 4.9b | 0.61 | 1.33a | 0.41 | 0.76b | 0.39 | 14.5 | 5.3 |
| Fire & Chop | 14.3b | 0.53 | 4.7b | 0.78 | 0.66e | 0.18 | 0.76b | 0.64 | 15.0 | 5.3 |
| Fire & Mow | 16.4b | 0.62 | 5.7b | 0.70 | 1.28b | 0.29 | 1.67a | 0.25 | 17.7 | 6.0 |
| Untreated Control | 16.3b | 0.52 | 4.2b | 1.05 | 1.10c | 0.27 | 0.69b | 0.49 | 17.4 | 4.7 |
| II | | | | | | | | | | |
| Prescribed Fire only | 9.9a | 0.61 | 5.3b | 0.55 | 0.93d | 0.21 | 0.81b | 0.78 | 10.8 | 6.1 |
| Chop only | 12.4a | 0.51 | 7.4b | 0.28 | 0.91d | 0.29 | 0.85b | 0.92 | 13.3 | 8.2 |
| Fire & Chop | 15.2a | 0.42 | 5.2b | 0.60 | 0.98c | 0.09 | 1.50a | 0.24 | 16.2 | 6.7 |
| Fire & Mow | 15.2a | 0.69 | 5.4b | 0.84 | 1.12c | 0.13 | 1.50a | 0.16 | 16.3 | 6.9 |
| Untreated Control | 12.5a | 0.63 | 9.7a | 0.46 | 0.90d | 0.20 | 0.70b | 0.64 | 13.4 | 10.4 |
| III | | | | | | | | | | |
| Prescribed Fire only | 7.0c | 0.84 | 14.0a | 0.70 | 1.10c | 0.44 | 1.60b | 0.30 | 8.1 | 15.6 |
| Chop only | 7.8c | 0.67 | 4.0c | 0.62 | 0.90d | 0.39 | 0.50c | 0.64 | 8.7 | 4.5 |
| Fire & Chop | 7.1c | 1.05 | 10.1b | 0.47 | 1.40a | 0.13 | 1.80a | 0.34 | 8.5 | 11.9 |
| Fire & Mow | 20.4a | 0.70 | -----† | ----- | 1.41a | 0.18 | ------ | ----- | 21.8 | ----- |
| Untreated Control | 7.7c | 0.93 | 10.0b | 0.37 | 1.12c | 0.27 | 0.50c | 0.49 | 8.8 | 10.5 |

***Means with the same letters within columns are not significantly different at p = 0.05 according to Duncans Multiple Range Test. N= 80 per treatment per block per year except in block I treatment mow & fire where N= 64 per year.**
**† No samples for this treatment were evaluated due to lack of burning in accordance with Myakka River State Park regulation.**
**CV = coefficient of variation**

For both years of sampling, nitrification (measured as total change in $NO_3^-$) over each 20 to 30 day incubation period was relatively low (Table 2). Significant differences in nitrification were observed between fire & mow and all other treatments in block I. In block II, no significant difference was observed between fire and mow and fire & chop, while in block III, all treatments were significantly different from all other treatments,

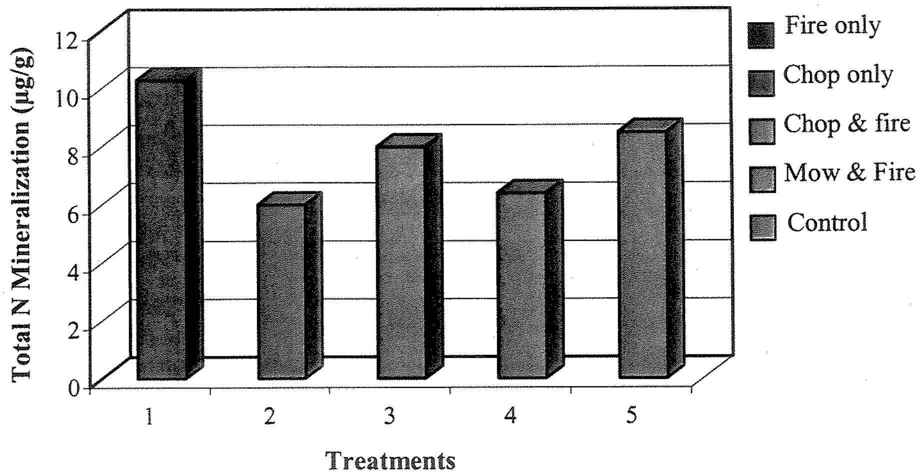


**Figure 8. Effect of prescribed fire and mechanical fuel treatments on mineralization over 20 to 30 days incubation, conducted from July to September 2001.**

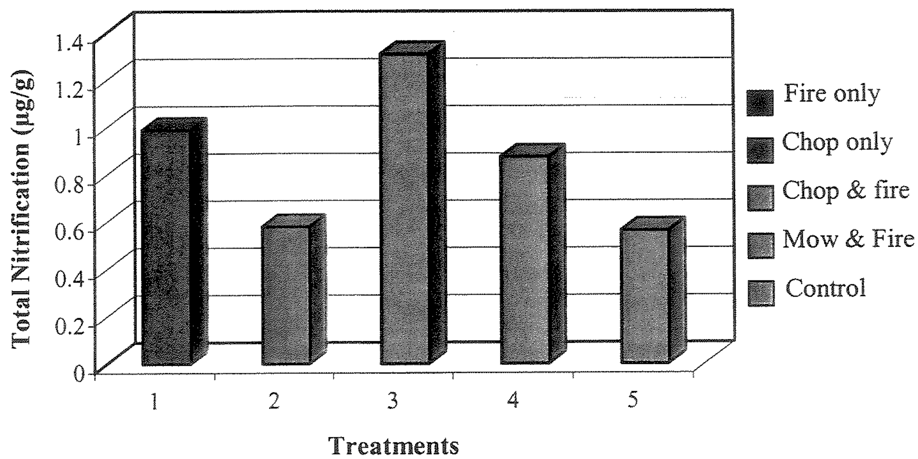


**Figure 9. Effect of prescribed fire and mechanical fuel treatments on nitrification over 20 to 30 days incubation, conducted from July to September 2001.**

except in the case of chop only and the control (Table 2). The highest rate of soil nitrification was produced after the study site was treated with prescribed fire & chop.

The result showed nitrification was highest in plots treated with prescribed fire or a combination of prescribed fire and mechanical treatments than in the non burn plots (chop and control) (Figure 9).

### 4.4 Soil Carbon to Nitrogen Ratio

The data analyzed for total organic carbon and total organic nitrogen in each block showed that there was a significant difference in total nitrogen but no significant difference in total carbon between blocks I and II (Table 3). Block I had the highest C: N ratio, while block III had the lowest C: N ratio.

Table 3.

**Mean values for total carbon, total nitrogen and C/N ratio over two sampling period at the Myakka River State Park.**

| **Blocks** | **Total Carbon (%)** | **CV** | **Total Nitrogen (%)** | **CV** | **C: N ratio** |
|---|---|---|---|---|---|
| I | 1.0a* | 0.63 | 0.03b | 0.81 | 33:1 |
| II | 1.8a | 0.70 | 0.06a | 0.77 | 30:1 |
| III | 1.9a | 0.63 | 0.08a | 0.64 | 24:1 |

***Means with the same letters within columns are not significantly different at p = 0.05 according to Duncans Multiple Range Test. N= 12 per block. CV = coefficient of variation**

### 4.5 Soil Particle Size

Block III had the lowest percentage of sand (86%) when compared to the other blocks (Table 4). According to the soil classification table blocks I and II are classified as sandy soils while block III is classified as a sandy loam. The clay content in block III was higher when compared to the other two blocks.

Table 4.

**Soil particle size analyses for the Myakka River State Park**

| **Block** | **Sand (%)** | **Silt (%)** | **Clay (%)** |
|---|---|---|---|
| I | 93 | 2 | 5 |
| II | 93 | 1 | 6 |
| III | 86 | 0 | 14 |

# CHAPTER FIVE

# DISCUSSION

All soil samples in this experiment were collected in the upper 10 cm of the forest soil, as pervious studies have indicated that the first 10 cm of the soil profile is where fine-root biomass is concentrated (Plymale et al., 1987). This suggests that microbial activity and plant uptake of nitrogen occur mostly in the first 10 cm of the forest soil profile (Plymale et al., 1987).

## 5.1 Soil Moisture Content

Block III was shown to have significantly higher levels of moisture than the other two blocks in this study, but these levels were observed to still be below that which were needed for favorable microbial activity, as the rates of nitrification were consistently low. The results of this study confirmed the findings of Plymale et. Al. (1987) who suggested that soil moisture is a strong rate controller of nitrogen mineralization. On an average the highest rate of mineralization and nitrification were observed in Block III, which over the combined two sampling periods had the highest averaged moisture levels. Block I averaged the lowest levels of moisture, as well as the lowest rate of soil mineralization and nitrification. The results indicated that nitrifying microbes were relatively inactive in this forest soil due to a low moisture levels.

## 5.2 Soil pH

The low rate of nitrification could be related to soil pH, soil moisture content, differences in soil organic N levels, microbial activity, prescribed fire and/or the mechanical fuel treatment applied. The pH of the study site was acidic and according to Keeney (1980), the acidity of the organic layer and the underlying soils associated with most forests provide conditions that are not conducive to nitrification. Rates of nitrification are tied to the specific pH range with pH ranging from 4.7 to 5.8 being the best range for nitrifiers in acidic soils (Plymale et al., 1987). This is consistent with the findings of this study, which showed higher rates of nitrification over the first sampling period when the mean pH ranged between 4.3 to 5.2 than over the second sampling period, when the mean pH ranged from 3.9 to 4.7.

The results obtained indicated that pH values were significantly lower after being treated with fire. This was not consistent with the findings of Gholz and Fisher's (1984) in which soil pH was raised after the forest floor was treated with fire. The chemical, physical, and biological characteristics of a soil are altered by fire (Wenger, 1984). The degree of alteration depends on the intensity and duration of the fire (Wenger, 1984). Therefore, the relative intensity of fire (not recorded in this study) may have been responsible for the lowered pH and subsequently lowered nitrification rates.

**5.3 Soil Nitrogen**

Low rates of mineralization and nitrification were found during the two sample periods. Nitrogen has always been one of the most deficient nutrients in forest soil, hence it was not surprising that nitrogen mineralization and nitrification, the main contributions to pools of 'available' nitrogen in forest systems, produced low rates of nitrate and ammonia (Plymale et. al., 1987; Wollum and Davey 1975). The results also indicated that the soils had significantly more ammonia than nitrate, although most forest plants take up nitrogen in the form of nitrate, not ammonia.

The overall rate of mineralization was highest when the site was treated with prescribed fire. Fire has always been an important factor to the forest ecosystem. Studies have shown that during natural or prescribed forest fire, large quantities of nitrogen are made readily available to forest plants (Wright and Bailey, 1982). Fires reduce the cover of woody understory species, as well as the surface litter cover (Moore and Terry, 1980), thus creating a more favorable environment for microbial activities. Nitrogen volatilizes during the forest fires, but the material burned above ground has the greatest chance of been volatized (Wright and Bailey, 1982) and not the nitrogen that is retained within the soil compartment.

A combination of prescribed fire and the mechanical fuel treatment chop was best suited for nitrification. Matson and Vitousek (1981) compared N mineralization and nitrification in soils of clearcut forest with undisturbed neighboring forest stands. They found that soil moisture and temperature were higher in the clearcuts than undisturbed forest canopies and as a result, N mineralization and nitrification rates were always higher in the clearcut forest soils. Plymale et al. (1987) later demonstrated that increased soil temperature has a positive effect on microbial activities and thus mineralization. Removal of the heavy plant litter and understory whether by fire and/or mechanical fuel management treatment will result in increased sunlight reaching the forest floor, which in turn will result in increase soil temperature. Nitrification rates are low in most forests in Florida because of the acidic pH level of these forests.

The treatment that is best suited for reducing fuel load and thereby wildfire hazard is prescribed fire. This treatment caused no drastic reduction in the level of mineralization, which could affect plant growth. There was also no drastic increase in nitrate level after the study site was treated with prescribed fire. This is important since drastic increase in nitrate production could cause leaching from the soil into underground water and surface water bodies leading to depletion of soil nitrogen reserves.

**5.4 Soil Carbon to Nitrogen Ratio**

The rate of nitrification and mineralization was higher in block III compared to the other two blocks. This difference was associated with the slightly higher moisture levels and/or the relatively lower C:N ratio of the first 10 cm of the AO horizon. According to Brady (1990), a keen competition develops among microorganisms when the C:N ratio is high in soil, resulting in the decrease of available nitrogen for plant growth. The rates of mineralization and nitrification of this site was negatively related to C:N ratio and positively associated with moisture levels (Table 3).

The Myakka River State Park forest demonstrated relatively high total carbon and a high C/N ratio in the range of 24 to 33:1. Many studies have suggested that most forest floors are characterized by high content of total carbon and relatively high C:N ratio (Keeney, 1980; Roberge and Knowles, 1966). In most forests, the total carbon to nitrogen ratio range from 40:1 to 60:1 corresponding to total N concentration of 0.6 to 1.4 percent (Keeney, 1980; Roberge and Knowles, 1966). This site has lower C:N ratio than most forests. However, the decrease in available N resulting from high C:N ratio still applies, as indicated by the results obtained.

# CHAPTER SIX

# CONCLUSION

The best management practice, as determined by this study, to reduce fuel accumulation and successfully minimize the negative effect of fire and mechanical fuel management treatment on nitrogen mineralization and nitrification is the prescribed fire treatment. This treatment did not cause a large decrease in mineralization, which could affect plant growth, nor did it cause a large increase in nitrate production, which could cause leaching. Important factors to consider when applying a restorative management practice are soil pH, soil moisture, soil temperature, soil carbon to nitrogen ratio, and soil microbial activities. According to the study mean soil pH values were reduced when the Flatwoods were treated with prescribed fire. Low soil ph, and soil moisture will had a negative effect on nitrogen mineralization and nitrification. When C:N ratio is high (40:1 to 60:1) less nitrogen is readily available for plant growth.

## APPENDIX 1

Climatological Normals (1961-90)
MYAKKA RIVER STATE PARK, FL

| | MinTemp(F) | MaxTemp(F) | AvgTemp(F) | AvgPrcp(in) |
|---|---|---|---|---|
| Jan | 47.6 | 73.2 | 60.4 | 2.50 |
| Feb | 49.1 | 75.4 | 62.2 | 3.03 |
| Mar | 54.2 | 80.4 | 67.3 | 3.24 |
| Apr | 57.3 | 85.4 | 71.3 | 1.62 |
| May | 62.9 | 90.2 | 76.6 | 3.60 |
| Jun | 68.7 | 91.4 | 80.0 | 8.68 |
| Jul | 70.6 | 92.1 | 81.4 | 9.17 |
| Aug | 71.6 | 92.1 | 81.8 | 10.05 |
| Sep | 70.9 | 90.9 | 80.9 | 8.20 |
| Oct | 64.1 | 86.4 | 75.2 | 2.66 |
| Nov | 56.4 | 80.3 | 68.3 | 2.21 |
| Dec | 50.0 | 74.8 | 62.4 | 2.16 |
| **Annual** | **60.3** | **84.4** | **72.3** | **57.13** |

Adapted from: Southeast Regional Climate Center

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