# FOREST SUSTAINABILITY AND AGRICULTURAL BENEFITS FROM PINE STRAW MANAGEMENT PRACTICES

A Senior Thesis

By

Danielle Miller Scroggins

1996-97 University Undergraduate Research Fellow

Texas A&M University

Group: BIOLOGY II

# Forest Sustainability and Agricultural Benefits from Pine Straw Management Practices

**Danielle Miller Scroggins**
**University Undergraduate Fellow, 1996-1997**
**Texas A&M University**
**Department of Rangeland Ecology and Management**

**APPROVED**

**Fellows Advisor** Robert W Knight

**Honors Director** Suzanne Pursell

**Forest Sustainablility and Agricultural Benefits from Pine Straw Management Practices**,
Danielle Miller Scroggins (Dr. Robert Knight), Rangeland Ecology and Management, Texas A&M University

Research on pine straw (pine needles) harvesting has already begun because of its high demand by home owners and commercial industry. This high demand has forced increased straw removal on pine forests. Straw harvesting influences soil nutrient levels, infiltration rates, understory vegetation, and timber productivity of the forest ecosystem. The objectives of this project were to determine the effects of pine straw harvesting and fertilizer applications on water infiltration rates, runoff quality, and erodibility of the system. These hypotheses were tested using a series of rainfall simulators on the Palustris Experimental Forest in Rapides Parish, Louisiana. Four treatments were installed on three sites; these include: fertilizing, burning, straw harvesting, and an undisturbed control. Soil core samples, runoff water samples, vegetation samples, and cover estimates were taken to provide appropriate data to determine the environmental impacts of pine straw harvest on this ecosystem. Results showed that fertilizer had no significant impacts on the hydrologic parameters; therefore was excluded from the analysis. Additional results showed that infiltration rates decreased with increased harvest; soil erosion, as well as runoff quality decreased with increased harvest, which was supported by soil production, soil concentration, and nutrient production data. These results prove the hypotheses correct, with the exception of fertilizer as a significant factor. A treatment of yearly harvest straw harvest and burn defines the limits of this ecosystem, rendering it unproductive to commercial and private industry. Best management approaches would need to include a period of rest to prevent degradation of the system.

# INTRODUCTION

## Background and Definition

Pine straw (pine needles) is the litter that collects in the understory of a pine forest. This straw is an excellent mulch, in that it controls water and nutrient delivery into and out of the system. For these reasons, pine straw mulch is a highly valued resource used by homeowners, professional landscapers, and agriculture. To meet this increasing demand, pine straw is harvested annually from many forest lands. However, pine straw removal may adversely effect soil nutrition, vegetation, and timber productivity of these lands (Knight 1994). Since excessive litter removal may have these effects, removal would not be beneficial to the ecosystem in terms of long term health and sustainability. In the past, pine straw has been used more in landscaping, and less in the fruit and vegetable industry. With proper management, pine straw mulch could allow farmers to produce horticultural crops with less artificial input, such as plastic mulch and pesticides. This mulch would also allow for more efficient use of water, aiding in fresh water conservation. Currently, plastic mulches are used for many horticultural crops. These plastics are nonrenewable petroleum products, and, unless high quality products are used, degrade quickly in direct sunlight. Compared with the current plastic mulches, pine straw mulch is more durable in direct sunlight, and more cost efficient (Knight 1994). Being a natural renewable material, pine straw is aesthetically pleasing, easy to distribute, organic matter rich, and positive in building soil tilth.

To understand the scope of this research, one must understand key ecological concepts. Ecology is defined as the inter-relationships between organisms and their abiotc as well as biotic environments (Miller 1994). Fundamentally, ecology studies the connections between climate and soils to producers, consumers, and decomposers. Many components influence these interrelationships: evolutionary history, ecological succession, energy flow, energy efficiency, material cycling, and population interaction (Miller 1994). These components are assessed through a hierarchical organization which begins with organisms, and continues through populations, communities, ecosystems, and landscapes. Ecology is a broad field that has implications in both basic and applied science; some issues facing ecologists are natural resource management, conservation, environmental quality, biological diversity, desertification, deforestation, and global warming. An understanding of ecological concepts and principles can contribute to the proper management of intact natural systems, as well as contributing to the restoration of greatly altered systems. Ecosystem management is an attempt to strike a balance between using ecosystem products while conserving essential resources of the system; this aids in informative, sustainable management of the system.

**Subject and Purpose**

A sustainable ecosystem uses nature's resources without depleting them. A use is sustainable if it will allow the resource to regenerate without harm to the system. A sustainable system conserves the Earth's vitality and diversity by conserving life-support systems, biodiversity, and ensuring the sustainable use of natural resources (Miller 1994). These concepts are crucial to understanding the implications of the pine straw study conducted in Louisiana. Forested areas are sensitive to disturbance, so understanding the sustainable level of pine straw harvest is necessary to maintaining a healthy ecosystem. Considering these concepts, the objectives of this research project focused on infiltration rates, soil erodibility, and runoff quality as they pertain to pine straw harvest and the various treatments outlined earlier.

**Hypotheses**

Hypotheses to be tested involve negative correlations in pine straw harvest to water infiltration rates, erosion rates, and runoff quality, given conditions regarding pine straw harvest and fertilizer application.

- Infiltration rates are affected by pine straw harvest or fertilizer application.
- Runoff quality is affected by pine straw harvest or fertilizer application.
- Erosion is affected by pine straw harvest or fertilizer application.

**Significance and Importance**

The significance of this study lies in the areas of horticulture and agriculture. Many homeowners as well as farmers foresee pine straw as the new mulch replacement. In addition, timber owners benefit from pine straw harvest off their lands. These timber producers receive cash income every 2-3 years for pine straw, as opposed to once every 20-40 years for timber production. If harvesting the forests of the ground cover (pine straw) proves to be detrimental to the ecosystem, many will need to reassess their priorities. Although pine straw is more appealing than any other current manufactured mulches, preserving nature's tight cycles need to be considered in agriculture convience.

**MATERIALS AND METHODS**

**Site Description**

The study site in Louisiana is a gently rolling with 45 year old direct seeded longleaf pine forest on the Palustris Experimental Forest in Rapides Parish, Louisiana. Associated plant species include poison oak, poison ivy, yaupon, blackjack oak, bluestem, Eragrostis, and Panicum grasses. To study several management practices associated with straw harvesting, various treatments were completed on the area. The site was divided into eight partitions including a variation of fertilizer, straw harvest, and burning treatments. Three blocks were installed in 1990, in a randomized complete split block design. The two primary plot treatments within each block are: 1) fertilizer applied as diammonium phosphate at 250 kg/acre, which includes 20 kg nitrogen and 25 kg phosphorus per acre, broadcast evenly over the entire unit on April 23, 1991; or 2) no fertilizer applied. Four subplot management treatments were imposed within the main plots: 1) control: the untreated check longleaf pine stand now developing an understory cover, 2) triennial winter burning, 3) triennial winter burn, annual mow, and winter pine straw harvest for two years, rest one year, and 4) yearly mow, yearly summer burn, and yearly winter pine straw harvest. The codes outlined in the table below were assigned to the appropriate areas (Table 1).

***Table 1: Codes for plot treatments in Palustris Experimental Forest pine straw study.***

| Plot Number | Fertilize | Burn Treatment | Straw Harvest |
|---|---|---|---|
| 01 | no | none | none |
| 02 | no | winter triennially | none |
| 03 | no | winter triennially | 2 years-fallow 1 |
| 04 | no | summer annually | annually |
| 11 | yes | none | none |
| 12 | yes | winter triennially | none |
| 13 | yes | winter triennially | 2 years-fallow 1 |
| 14 | yes | summer annually | annually |

Measurements were taken in October 1994, May and October 1995, and May 1996. Data from these four sample collections were analyzed to determine treatment effects on infiltration, erosion factors, and runoff quality.

**Experimental Design and Organization**

Materials for Field Work

- 4 mobile infiltrometers as described by W.H. Blackburn et al. (1974)
- 4 (20 liter) polyethylene bottles
- 10+ water hoses
- 1200 liter water holding tank
- 4 spring scales and 4 (12-volt) pony water pumps
- 4 (3X3) plot frames, plexi-glass cover sheets, and collectors
- 60 sediment bottles and whirl packs
- core soil sample kit
- paper bags, clippers, coolers, burlap sacks, and seals
- data sheets estimating cover of a $0.25m^2$ area, and runoff
- flags, stopwatch, permanent markers, and pencils

Methods for Field Work

*Rainfall Simulator:* A rainfall simulator was used to determine water infiltration and sedimentation rates from about $.35m^2$ plots. A simulator, or mobile infiltrometer, similar to the one described by W.H. Blackburn, et al. (1974) was used. This infiltrometer is a portable drip-type infiltrometer; water is pumped from a 1200-liter tank into 20-liter bottles. This water flows with gravity through filters to raindrop producing modules, suspended two meters above the soil surface; simulated raindrops reach about 70% of terminal velocity. The modules must be leveled for uniform raindrop distribution on the plot. The raindrop modules are composed of two 2-meter sheets of 0.6 cm plexi-glass spaced 1.2 cm apart, sealed by caulking, and bolted to aluminum on the supporting legs (Blackburn 322). Each module contains 2,209 tubes at 2.5 cm spacing that project 0.6 cm above and below the lower level plexi-glass sheet (Blackburn 322). These tubes are composed of 23 gauge stainless steel; theses tubes are 1.8 cm long with a 0.0476 cm inside diameter (Blackburn 1974).

*Plot Selection:* The plots were spaced at selected intervals within the treated areas. A plot frame was driven 3 cm into the soil to form an area of about 0.35 $m^2$. (Blackburn 323). A collector trough was placed downslope in the plot, with a sheet of plexi-glass over it to protect it from simulated rain falling directly into the trough.

*Operation:* The plots were covered with polyethylene plastic to maintain dryness while the simulators were being set up and adjusted to a 12.7 cm/hr rainfall rate. After alterations were made, the plastic was removed; two plots were monitored in each treatment plot for a total of 48 plots for each measurement date. Before the simulations began, two soil cores were taken adjacent to the plot at 0-30 mm depth. These samples were taken by the core method; this method samples soil vertically in one area to ensure a uniform sample. These samples were weighed and oven-dried to calculate soil moisture and bulk density. Vegetation cover and plot shape were also estimated with reference to data sheets (Refer to Appendix for example). During each rainfall event, runoff was collected in a 20 liter bottle, and weighed at five minute intervals for a total of fifty minutes. "Time runoff begins" was also recorded to acknowledge infiltration rates and percent moisture capacity, already in the soil. Infiltration rates were calculated by determining the difference between applied rainfall and the quantity of runoff. A pooled one liter subsample of runoff was collected and used for analysis of settleable and filterable solids, which determined erosion indicators (sediment production and concentration). Four 400 ml subsamples of runoff water were collected and used for chemical analysis; the samples were temporarily stored at 4°C to avoid bacterial or fungal growth in the sample. These 400 ml subsamples were placed in whirlpacks for easy access. Plots were clipped after they were allowed to dry. The plots were clipped according to vegetation category: grasses, forbs, vines, woody, and litter. Each of these categories were placed into separate bags for future analysis.

Materials for use in Water Quality Lab

- 400 ml whirlpacks, permanent markers, and pencils
- sample bottles, racks tweezers, petri dishes
- 54 test tubes with rubber stoppers
- 108 100 ml flasks
- 54 50 ml beakers
- petri dishes, 45 micron filter paper
- filtering station with 200 ml flask
- 200 ml graduated cylinder
- 1 ml, 5 ml measuring device
- lab equipment for safe use with hazardous chemicals: hood, lab coats, goggles, gloves
- oven
- atomic absorption spectophometer
- automated analyzer

Methods for use in the Water Quality Lab

*Soil Samples:* The soil samples were oven dried and weighed to determine soil characteristics and soil type. Bulk density refers to the compactness of the soil, and soil moisture refers to the amount of water currently suspended in the soil.

*Vegetation Samples:* After the samples were bagged according to category, they were oven dried and weighed. From this weight, exact vegetation production was calculated.

*1 Liter Sample Bottle:* The pooled one liter subsample measured filterable solids. These filterable solids were measured by filtering the sample through 45 micron filter paper; the filter paper was oven dried and weighed to determine the weight of the filter paper and sediment. Sediment weight was determined by subtracting the weight of the pre-weighed filter paper from the total weight. From this, total sediment loss per hectare was calculated, and used as an index of erosion.

*400 ml Subsample Whirlpacks:* Two of the four samples were treated with a 1:1 mixture of nitric acid to reduce the pH to less than 2.0, while the other two samples were kept cool, at 4°C. The acid-treated samples were analyzed for calcium, magnesium, potassium, and sodium on an atomic absorption spectrophotometer following standard methods (APHA 1976). The cooled sample was analyzed for ortho-phosphorus, total phosphorus, total kjeldhal nitrogen, ammonia, nitrites, and nitrates using standard methods (APHA 1976).

<u>Data Analysis</u>

The soil samples provided bulk density, soil moisture, and organic matter data for calculations to determine current health of soil conditions. The treated 400 ml samples provided data concerning runoff quality and nutrient analysis. The untreated samples concentrated on water quality of runoff and sediment loss (soil production), indicating erosion characteristics of the site. These qualities as well as the amount and time of the runoff determine water infiltration rates into the soil profile

All data was first entered into the Quattro Pro Spreadsheet package, and means were determined for familiarization. After all data was consolidated, it was adapted to the SAS (Statistical Analysis System) program for statistical analysis. The following table (Table 2) shows the data transformations needed to normalize the data before being analyzed using the analysis of variance procedure.

***Table 2: Transformations for data entered into SAS for Palustris Experimental Forest, and pine straw study.***

| Data | Code | Transformation |
|---|---|---|
| Infiltration | INFIL | none |
| Sediment Concentration | SQSEDG | SQUARE ROOT |
| Sediment Production | LSEDKG | natural LOG |
| Nitrite (NO2) | LNO2 | LOG 10 |
| Nitrate (NO3) | LNO3 | LOG 10 |
| Ammonia (NH4) | NH4 | LOG 10 |
| Filtered TKN | LFTKN | LOG 10 |
| Unfiltered TKN | LUTKN | LOG 10 |
| Filtered OP | LUFP | LOG 10 |
| Unfiltered OP | LUOP | LOG 10 |
| Unfiltered TP | LUTP | LOG 10 |

The Duncan Multiple Range Test was used to test for significant differences between treatments, with all significant differences at $P \leq 0.05$. Fertilizer was not a significant factor in any of the tests run; therefore, it was not included in the final model. Data was only analyzed by date, not across dates.

Parameters analyzed in the SAS system included: calcium, magnesium, nitrate, nitrite, ammonia, unfiltered total kjedhal nitrogen, filtered total kjedhal nitrogen, unfiltered total phosphorus, unfiltered ortho-phosphorus, and filtered ortho-phosphorus. Sodium and potassium showed no significant differences on any test run; therefore, those nutrients are excluded from this report. Results are reported as untransformed means, but tests were conducted on normalized data (Table 2).

## RESULTS AND DISCUSSION

### Soil and Vegetation

Soil texture is defined as the size and distribution of particles in the matrix. Soil texture is a primary factor in considering infiltration rates. Sandy soils allow water to infiltrate at a higher rate, but lose water quickly to the underlying water table. Clay soils have a slower infiltration rate, but retain water for a longer period of time. The soil in the Louisiana Palustris Experimental Forest is primarily sandy loam, allowing for a relatively fast infiltration rate, and moderate retention periods. Infiltration rates are also effected by bulk density, which is defined as the dry weight of the soil divided by the volume. The higher the bulk density, the lower the infiltration rate, because of less available pore space for water movement in the soil profile.

Vegetation cover and production influence infiltration rate, and thus other factors, such as bulk density, percent organic matter, soil production, and soil concentration. The following two tables (Tables 3 & 4) illustrate the changes in vegetation cover through the course of the study.

***Table 3: Comparative averages of vegetation cover % for the Palustris Experimental Forest for October 1994 across four treatments.***

| Treatment | Cover Type | | | |
|---|---|---|---|---|
| | Litter | Grass | Forb | Bare Ground |
| Control | 79.583[1] | 15.083 | 5.250 | 0.083 |
| Burn triannually | 38.250 | 27.000 | 17.833 | 16.333 |
| Burn triannually & harvest 2 years-fallow 1 | 32.000 | 29.667 | 7.000 | 22.167 |
| Burn & Harvest Annually | 48.250 | 10.417 | 4.917 | 36.417 |

[1]Averages encompass fertilized and unfertilized sites.

***Table 4: Comparative averages of vegetation cover % for the Palustris Experimental Forest for May 1996 across four treatments.***

| **Treatment** | **Cover Type** | | | |
|---|---|---|---|---|
| | Litter | Grass | Forb | Bare Ground |
| Control (1) | 84.167[1] | 3.667 | 2.333 | 0.167 |
| Burn triannually (2) | 74.000 | 13.083 | 5.750 | 0.667 |
| Burn triannually & harvest 2 years-fallow 1 (3) | 69.917 | 12.108 | 10.417 | 0.417 |
| Burn & Harvest Annually (4) | 16.667 | 9.583 | 5.000 | 52.000 |

[1]Averages encompass fertilized and unfertilized sites.

As the tables show, bare ground increasingly dominated the annually burned and harvested treatment (treatment 4), while litter cover dominated the control treatment (treatment 1), with the successive two treatments (treatments 2 and 3) falling between the two extremes.

In conjunction with vegetation cover data, vegetation production also affects the system either positively or negatively. Extreme increased production in the understory leads to dense understory vegetation, decreased nutrient efficiency, diversity, and pine tree production. Extreme decreased vegetation production leads to decreased infiltration rates, increased bulk density, increased runoff, increased soil loss, and overall degradation of the system. Both situations would be detrimental to pine straw and timber productivity, thus the agriculture and timber industry. The following two tables (Tables 5 & 6) illustrate comparisons between vegetation production through the course of the study in Louisiana.

***Table 5: Comparative averages of vegetation production (g/plot) for the Palustris Experimental Forest for October 1994 across four treatments.***

| **Treatment** | **Vegetation** | **Type** | |
|---|---|---|---|
| | Litter | Grass | Forb |
| Control (1) | 350.883[1] | 16.792 | 7.200 |
| Burn triannually (2) | 108.650 | 22.700 | 13.633 |
| Burn triannually & harvest 2 years-fallow 1 (3) | 80.717 | 31.192 | 13.700 |
| Burn & Harvest Annually (4) | 112.692 | 10.083 | 2.667 |

[1]Averages encompass fertilized and unfertilized sites.

***Table 6: Comparative averages of vegetation production (g/plot) for the Palustris Experimental Forest for May 1996 across four treatments.***

| **Treatment** | **Vegetation** | **Type** | |
|---|---|---|---|
| | Litter | Grass | Forb |
| Control (1) | 561.167[1] | 3.808 | 2.175 |
| Burn triennually (2) | 300.742 | 23.775 | 2.067 |
| Burn triennually & harvest 2 years-fallow 1 (3) | 284.100 | 29.592 | 4.858 |
| Burn & Harvest Annually (4) | 128.108 | 6.950 | 2.458 |

[1]Averages encompass fertilized and unfertilized sites.

Litter production is the primary concern in considering vegetation production and percent cover. Litter (pine straw) collects in the understory of the forest, and affects infiltration rate, organic matter, and erosion of the system. Increased litter positively impacts the system, while increased bare ground negatively affects the system in terms of the parameters outlined above. Within each date set, treatment data relative to eachother shows the impacts on increased disturbance to the system. October 1994 showed treatment 1 to have ample litter, and treatments 2, 3, and 4 to have equal amounts, as compared to eachother(Table 5). May 1996 showed increased differences within each treatment. The control treatment (1), has a significant amount of litter in the understory, while understory development in treatment 4 produced much less litter (Table 6). Grass and forb production are not as important in this forested ecosystem. Bare ground percentages were in similar ranges between treatments in October 1994 (Table 3); however, May 1996 shows an increased range between treatments 1, 2, and 3, as compared to treatment 4 (Table 4).

**Infiltration**

Organic matter increases infiltration rates by allowing more available pore space to the water. The following table (Table 7) shows the differences in organic matter percentages in October 1994 and May 1996.

***Table 7: Comparative averages of organic matter % for the Palustris Experimental Forest for October 1994 and May 1996 across four treatments.***

| **Treatment** | **Collection** | **Dates** |
|---|---|---|
| | October 1994 | May 1996 |
| Control (1) | 2.838[1] | 3.406 |
| Burn triannually (2) | 2.691 | 4.147 |
| Burn triannually & harvest 2 years-fallow 1 (3) | 3.659 | 4.853 |
| Burn & Harvest Annually (4) | 3.074 | 3.183 |

[1]Averages encompass fertilized and unfertilized sites.

These percentages show the adverse effects of increased disturbance on the system in reference to organic matter. The change is much lower in treatment 4, as compared to treatment 1, which allowed all litter and other organic matter to accumulate.

As outlined and discussed above, many ecological aspects affect all components of a succinct, productive, and healthy ecosystem, in particular, a healthy pine forest. The following table (Table 8) shows changes in infiltration rates throughout the course of study. Again, these rates were influenced by soil texture, bulk density, organic matter content, vegetation cover, and vegetation production.

***Table 8: Mean (n=12) infiltration rates (cm/hr) for the Palustris Experimental Forest for four sample collection dates in four landscape treatments.***

| Treatment | Collection Dates | | | |
|---|---|---|---|---|
| | October 1994 | May 1995 | October 1995 | May 1996 |
| Control (1) | 11.967a[1] | 9.479a | 13.611a | 13.070a |
| Burn triannually (2) | 8.713b | 9.599a | 11.205b | 9.672b |
| Burn triannually & harvest 2 years-fallow 1 (3) | 7.455b | 5.453b | 7.834c | 7.140c |
| Burn & Harvest Annually (4) | 7.159b | 3.704b | 5.966d | 2.981d |

[1]Means in a column followed by the same letter are not significantly different at $P \leq 0.05$.

The treatments were significantly different between the control group as compared to the treated groups in October 1994. May 1995 showed treatment 2 and treatment 1 being similar to eachother, as well as treatments 3 and 4 being similar to eachother. October 1995 and May 1996 showed significant differences between all four treatments (Table 8). Highest infiltration rates occurred in the control group (treatment 1), and the lowest in treatment 4. As shown in Table 8, infiltration improved over time in treatment 1, and lowered over time in treatment 4. This data shows the impacts of severe over harvesting of pine straw and the detrimental effects this has on the ecosystem with time. With lower infiltration rates, runoff increases, carrying topsoil off site, and decreases productivity.

**Erosion Indicators**

Sediment Loss

As with infiltration rate, sediment loss (erosion rate) relies heavily on soil texture, bulk density, organic matter, vegetation cover, and vegetation production, as discussed above. The higher the bare ground, the greater the raindrop impact, and the higher the erosion rate. Table 9 illustrates the changes and increases in sediment loss over time.

***Table 9: Mean (n=12) sediment loss (kg/ha) for the Palustris Experimental Forest for four sample collection dates in four landscape treatments.***

| **Treatment** | **Collection Date** | | | |
|---|---|---|---|---|
| | October 1994 | May 1995 | October 1995 | May 1996 |
| Control (1) | 16.096b[1] | 64.131c | 10.137c | 58.992c |
| Burn triannually (2) | 35.292a | 89.829c | 40.168b | 23.025b |
| Burn triannually & harvest 2 years-fallow 1 (3) | 91.619a | 147.439b | 70.026a | 38.739a |
| Burn & Harvest Annually (4) | 101.509a | 610.631a | 219.161a | 2274.73a |

[1]Means in a column followed by the same letter are not significantly different at $P \leq 0.05$.

According to the Duncan Multiple Range Test, treatment 1 differentiated from treatments 2,3, and 4 in October 1994; May 1995 shows treatments 1 and 2 significantly different from treatments 3 and 4, respectively. Again, in October 1995 and May 1996, treatments 1 and 2 were different from treatments 3 and 4. Treatments 3 and 4 were not significantly different from eachother at the end of the study. Sediment loss increased over time as a result of increased disturbance to the system, and the increasing impact of the treatments on the soils and vegetation. Treatment 1 lost a generally low amount of soil; this effect is the result of no disturbance to the site. Soil accumulates on the forest floor as the result of increased organic matter, litter, and vegetation; without disturbance, the positive effects of rest climax, and then begin decreasing. Treatments 2 and 3 fluctuated in sediment loss, as the result of management practices and treatments, showing the effects of intermittent disturbance. These two treatments are standard treatments across the agriculture industry; they are used to maintain the production of pine needles needed to promote pine straw harvesting. Therefore, one explanation of the fluctuations is that these two treatments tend to vary more with yearly weather patterns; another explanation discusses the options included in aspects of site disturbance, which encompasses maintaining the current system and qualitative management of the system. Treatment 4 maintained the highest sediment loss, succinct with previous data as to the effects of this management regime. This data is also used as an erosion indicator. The higher the sediment loss, the higher the erosion off the system; the lower the sediment loss, the lower the erosion rate. Using this relationship, treatment 1 would have a low erodibility index, and treatment 4 would have a high erodibility index, thus proving its disadvantages in sustaining the system.

Sediment Concentration

Sediment concentration is defined as the amount of sediment suspended in a given amount of water. This measurement gives indications of soil erosion off the site. The higher the sediment concentration, the higher the erodibility of the site; the lower the sediment concentration, the lower the erodibility of the site. This measurement also influences infiltration and runoff quality. Table 10 illustrates the sediment concentration values as they progressed through the study.

*Table 10: Mean (n=12) sediment concentration (g/l) for the Palustris Experimental Forest for four sample collection dates in four landscape treatments.*

| Treatment | Collection Date | | | |
|---|---|---|---|---|
| | October 1994 | May 1995 | October 1995 | May 1996 |
| Control (1) | 0.045b[1] | 0.136b | 0.033c | 0.204b |
| Burn triannually (2) | 0.086a | 0.142b | 0.095bc | 0.082b |
| Burn triannually & harvest 2 years-fallow 1 (3) | 0.130a | 0.162b | 0.131ab | 0.069b |
| Burn & Harvest Annually (4) | 0.138a | 0.613a | 0.265a | 2.020a |

[1]Means in a column followed by the same letter are not significantly different at $P \leq 0.05$.

Sediment concentration increased in treatment 4 as the study progressed. Significant differences occurred between treatment 1 as compared to treatments 2, 3, and 4 in October 1994. These differences showed little sediment concentration in the control group (treatment 1), with increasing sediment concentration levels through each treatment. These differences persist in May 1995, as treatment 4 steadily progresses in erodibility. October 1995 and May 1996 repeat the same pattern. This data shows how over-harvesting and over-treatment of the ecosystem has detrimental effects.

**Runoff Quality**

Nutrient Production

As discussed earlier, nutrients analyzed by SAS include: unfiltered total phosphorus (UTP), unfiltered ortho-phosphorus (UOP), filtered ortho-phosphorus (FOP), unfiltered total kjedhal nitrogen (UTKN), filtered total kjedhal nitrogen (FTKN), nitrate, nitrite, and ammonia. These nutrients occur in the soil naturally, and are necessary for plant survival. These nutrients are also affected by management treatments such as those outlined in the study. Nutrient loss values are outlined in the following tables.

*Phosphorus:* UOP tests show phosphorus elements which are insoluble in water, thus attached to soil particles; therefore, by decreasing erosion, phosphorus levels increase on site. Phosphorus levels on site are significant in plant growth, productivity, and photosynthesis operation; phosphorus levels taken off site produce eutrophication problems in streams and lakes.

***Table 11: Mean (n=12) UOP loss (kg/ha) for the Palustris Experimental Forest for four sample collection dates in four landscape treatments.***

| Treatment | Collection Date | | | |
|---|---|---|---|---|
| | October 1994 | May 1995 | October 1995 | May 1996 |
| Control (1) | 12.807b[1] | 32.799b | 40.843c | 9.977c |
| Burn triannually (2) | 27.779a | 23.958b | 26.620b | 28.467b |
| Burn triannually & harvest 2 years-fallow 1 (3) | 37.606a | 52.052a | 14.713a | 44.766b |
| Burn & Harvest Annually (4) | 38.490a | 60.118a | 5.368a | 75.017a |

[1]Means in a column followed by the same letter are not significantly different at $P \leq 0.05$.

As shown in Table 11, significant differences for UOP appeared in treatment 1, as compared to the other treatments in October 1994, showing stability on the control site. May 1995 showed significant differences in treatments 1 and 2, as compared to treatments 3 and 4. Disturbance to the site is apparent in that the control treatment increasingly differentiates from the other treatments throughout the study by maintaining low levels of phosphorus loss.

FOP measures phosphorus levels which are soluble in water; these levels flow with water through the system, and thus are more difficult maintain or increase with different management regimes. Filtering ortho-phosphorus secludes these elements because of their chemical bond with water.

***Table 12: Mean (n=12) FOP loss (kg/ha) for the Palustris Experimental Forest for four sample collection dates in four landscape treatments.***

| **Treatment** | | **Collection Date** | | |
|---|---|---|---|---|
| | October 1994 | May 1995 | October 1995 | May 1996 |
| Control (1) | 7.337b[1] | 29.729b | 5.418c | 9.329c |
| Burn triannually (2) | 21.630a | 20.333b | 14.657b | 25.401b |
| Burn triannually & harvest 2 years-fallow 1 (3) | 21.669a | 44.084a | 26.485a | 41.091b |
| Burn & Harvest Annually (4) | 28.880a | 54.310a | 39.800a | 76.972a |

[1]Means in a column followed by the same letter are not significantly different at $P \leq 0.05$.

Table 12 shows significant differences occurring in October 1994 between treatment 1 and treatments 2, 3, and 4. Through the course of the study, treatment 4 became increasingly different than the previous three treatments. May 1996 data shows the extreme significant differences between treatment 1 and treatment 4.

UTP (unfiltered total phosphorus) data shows total potential phosphorus loading to the system. UTP is insoluble in water, chemically bonding itself to the soil and soil particles.

***Table 13: Mean (n=12) UTP loss (kg/ha) for the Palustris Experimental Forest for four sample collection dates in four landscape treatments.***

| **Treatment** | | **Collection Date** | | |
|---|---|---|---|---|
| | October 1994 | May 1995 | October 1995 | May 1996 |
| Control (1) | 22.700b[1] | 57.216b | 11.064c | 20.391c |
| Burn triannually (2) | 43.300a | 40.680b | 28.463b | 59.028b |
| Burn triannually & harvest 2 years-fallow 1 (3) | 60.332a | 79.561a | 45.688a | 44.766b |
| Burn & Harvest Annually (4) | 68.182a | 124.881a | 74.573a | 269.917a |

[1]Means in a column followed by the same letter are not significantly different at $P \leq 0.05$.

Table 13 illustrates the significant differences in October 1994 between treatment 1, as compared to treatments 2, 3, and 4. The differences between treatments 1 and 4 double every collection date, with May 1996 having the most significant difference between these two treatments.

*Nitrogen:* Nitrogen levels on site are significant in photosynthesis, respiration, growth, and health of vegetation. Off site nitrogen levels contribute to eutrophication problems in freshwater areas. UTKN measures insoluble nitrogen tied up in organic matter. With time, UTKN degrades to nitrite, and is taken up by vegetation. Table 14 shows the change in UTKN values over the course of the study.

***Table 14: Mean (n=12) UTKN loss (kg/ha) for the Palustris Experimental Forest for four sample collection dates in four landscape treatments.***

| Treatment | Collection Date | | | |
|---|---|---|---|---|
| | October 1994 | May 1995 | October 1995 | May 1996 |
| Control (1) | 146.354b[1] | 370.983b | 60.731c | 158.475c |
| Burn triannually (2) | 258.593a | 320.848b | 152.568b | 371.818b |
| Burn triannually & harvest 2 years-fallow 1 (3) | 427.307a | 534.587b | 215.132a | 544.924b |
| Burn & Harvest Annually (4) | 446.949a | 1168.040a | 296.713a | 4229.700a |

[1]Means in a column followed by the same letter are not significantly different at $P \leq 0.05$.

Treatments 1, 2, and 3 maintain fairly constant levels of UTKN throughout the study. Treatment 4 shows significant differences in nitrogen loss over time. Significant differences also arise between treatment 1, as compared with treatments 2, 3, and 4 throughout the study. May 1996 data shows the most significant difference in UTKN loss by comparison of treatment 1 and treatment 4.

FTKN measures water soluble total nitrogen; this nitrogen does not cohere to soil particles, and flows with water through the system. Water soluble elements are more difficult in controlling through management practices, for both maintenance and production. Through the filtering process, TKN materials insoluble in water are removed, leaving soluble TKN materials for analysis.

***Table 15: Mean (n=12) FTKN loss (kg/ha) for the Palustris Experimental Forest for four sample collection dates in four landscape treatments.***

| Treatment | Collection Date | | | |
|---|---|---|---|---|
| | October 1994 | May 1995 | October 1995 | May 1996 |
| Control (1) | 99.678b[1] | 248.027a | 40.192b | 80.910c |
| Burn triannually (2) | 158.846a | 181.103a | 87.843a | 221.740b |
| Burn triannually & harvest 2 years-fallow 1 (3) | 194.682a | 269.336a | 109.468a | 285.227b |
| Burn & Harvest Annually (4) | 193.182a | 357.999a | 6.533a | 700.733a |

[1]Means in a column followed by the same letter are not significantly different at $P \leq 0.05$.

As shown in Table 15, October 1994 and May 1995 do not show very significant differences between treatments; however, significant differences are dominant in May 1996 between treatments 1 and 4. Significantly more nitrogen is lost to the system in the more disturbed (annually burned and harvested) site than the control site.

NH4 is the first stage of nitrogen as it is exposed to the ecosystem; nitrogen is unavailable to plants in this form, and must be broken down into nitrate, then to nitrite for plant uptake through the nitrification process. High amounts of NH4 as compared to nitrites would indicate microbe deficiencies, as these organisms are the primary factors in NH4 breakdown. Loss of NH4 to the system would render it nitrogen deficient, and thus unproductive. Table 16 shows change in NH4 over the course of the Louisiana study,

***Table 16: Mean (n=12) NH4 loss (kg/ha) for the Palustris Experimental Forest for four sample collection dates in four landscape treatments.***

| **Treatment** | **Collection Date** | | | |
|---|---|---|---|---|
| | October 1994 | May 1995 | October 1995 | May 1996 |
| Control (1) | 17.564b[1] | 23.526a | 1.723c | 9.252c |
| Burn triannually (2) | 36.659ab | 26.635a | 5.420b | 13.612b |
| Burn triannually & harvest 2 years-fallow 1 (3) | 30.305a | 24.403a | 9.893a | 18.348b |
| Burn & Harvest Annually (4) | 23.847ab | 37.203a | 6.533ab | 129.003a |

[1]Means in a column followed by the same letter are not significantly different at $P \leq 0.05$.

October 1994 and May 1995 show average levels across treatments, while October 1995 and May 1996 show significant differences between treatments (Table 16). October 1994 and 1995 show the most significant difference to occur between treatment 1 and treatment 3, while May 1995 and 1996 show the highest degree of significance between treatment 1 and 4, illustrating that pine litter collects mostly during the winter, as treatment four is harvested and burned in the summer.

Nitrate is the intermediate stage of the nitrification process, as nitrogen moves through the nitrogen cycle from NH4 to nitrite (nitrification). This form of nitrogen will decompose to nitrite, and thus is important on site for plant production purposes, such as fruit and vegetative production. Off site, nitrate causes health problems in pregnant women, and thus should be monitored carefully. Refer to Table 17 for nitrate values.

***Table 17 Mean (n=12) Nitrate (NO3) loss (kg/ha) for the Palustris Experimental Forest for four sample collection dates in four landscape treatments.***

| **Treatment** | | **Collection Date** | | |
|---|---|---|---|---|
| | October 1994 | May 1995 | October 1995 | May 1996 |
| Control (1) | 0.749b[1] | 4.687b | 2.111c | 2.943c |
| Burn triannually (2) | 3.753a | 8.259a | 4.707b | 6.583b |
| Burn triannually & harvest 2 years-fallow 1 (3) | 9.619a | 10.383a | 8.528a | 8.780b |
| Burn & Harvest Annually (4) | 5.918a | 12.263a | 12.200a | 19.842a |

[1]Means in a column followed by the same letter are not significantly different at $P \leq 0.05$.

Levels of nitrate on the study site are well within safety standards. According to Table 17, significant differences arise immediately in October 1994 between treatment 1, compared to treatments 2, 3, and 4. These differences escalate through May and October 1995. May 1996 shows the most extreme significant differences between treatment 1 and treatment 4, as compared the prior three less disturbed treatments.

Nitrite is nitrogen available to vegetation; these numbers should not be very large, in that most nitrogen of this type is tied up in vegetative plant components. This form of nitrogen also volatizes out of the system in the form of NH4 through ammonification.

***Table 18 Mean (n=12) Nitrite (NO2) loss (kg/ha) for the Palustris Experimental Forest for four sample collection dates in four landscape treatments.***

| **Treatment** | | **Collection Date** | | |
|---|---|---|---|---|
| | October 1994 | May 1995 | October 1995 | May 1996 |
| Control (1) | 1.788c[1] | 0.965b | 0.264b | 0.261c |
| Burn triannually (2) | 5.628b | 0.773b | 0.494ab | 0.583b |
| Burn triannually & harvest 2 years-fallow 1 (3) | 8.607a | 2.033a | 0.593a | 0.811b |
| Burn & Harvest Annually (4) | 7.039b | 2.378a | 0.768a | 1.669a |

[1]Means in a column followed by the same letter are not significantly different at $P \leq 0.05$.

Table 18 demonstrates the similarities between nitrate and nitrate production means, and thus plant use of nitrogen. Significant differences immediately in October 1994 between treatment 1 and 3. Treatments 2 and 4 are also significantly different from treatment 1. These differences stabilized through May and October 1995; May 1996 data shows increasingly significant differences between treatment 1 and 4, illustrating the degree of degradation treatment 4 has on the system.

Nutrient Concentration

Nutrient concentration data did not demonstrate significantly different results than nutrient production data. For this reason, nutrient concentration is excluded from this discussion and analysis.

## CONCLUSIONS

The research contained in this report benefits a diverse population, from commercial to private agricultural industry. As this project has proceeded, it has become more apparent that more research in these areas needs to be conducted to ensure proper and sustainable use of the system.

Many aspects of the environment affect infiltration rates, sediment production, sediment concentration, and nutrient production. The most significant elements include bulk density of the soil, soil texture, organic matter content, vegetation cover, and vegetation production. These vital components of the system determine the productivity of agricultural benefits on a site like the Palustris Experimental Forest studied in this paper. Highest infiltration rates occurred in treatment 1 of the study, but this group does not benefit agricultural uses by any productive means; however, treatment 4 obtained the lowest infiltration rates, indicating annual burning and harvesting are not productive means of sustainable agriculture in this ecosystem. Sediment loss was also highest in treatment 4, again emphasizing the importance of moderation in management regimes. Treatment 1, the control group, maintained highest amounts of all nutrients across all dates, with treatment 4 having the most detrimental amounts.

Based on this data, conclusions can be made as to the best management regime for the study area (Palustris Experimental Forest in Rapides Parish, Louisiana). Current agricultural management regimes include triennial burn, and a combination triennial burn and harvest 2 years-rest 1. The triennial burn is used to promote timber production by reducing understory competition, and the triennial burn, straw harvest and rest management regime is to gain the amount of pine straw production needed to support the current demand on the agriculture industry for these products. Though not as extreme as annual harvesting and burning, treatments 2 and 3 could eventually degrade the site. Due to decreased infiltration, a downward trend begins to operate including: increased bulk density, increased runoff, decreased vegetation establishment, decreasing organic matter content, and the trend continues downward.

This study proved the hypotheses correct in that infiltration rates were affected by pine straw harvest; runoff quality is affected by pine straw harvest, and erosion is affected by pine straw harvest. Fertilizer application has no significant impact on infiltration rates, runoff quality, or erosion. The limits for use of this ecosystem lie within the boundaries of treatments 1,2 or 3; treatment 4 puts too much stress on the system, rendering it unproductive. Key management implementations include regular moderate disturbance and resting of a system to assure proper understory management as well as overall production and sustainability. An unproductive system does not serve agriculture for pine straw harvest, or timber producers for timber production. Further studies and discussion on this topic need to be assessed to assure proper management of all ecosystems.

# LITERATURE CITED


American Public Health Association. 1976. Standard Methods for the Examination of Water and Wastewater. New York: APHA.

Blackburn, W.H., R.O. Meeuwing and C.M. Skau. 1974. A mobile infilrometer for use on rangelands. Journal of Range Management 27(a): 322-323.

Hays, Kelley Ann. 1993. Strip Mining Impacts on Plant Diversity. University Undergraduate Fellow Thesis. Texas A&M University,

Hester, Justin Wayne. 1996. Influence of Woody Dominated Rangelands on Site Hydrology and Herbaceous Production, Edwards Plateau. Thesis. Texas A&M University.

Klinkenborg, Verlyn. 1995. A Farming Revolution: Sustainable Agriculture. National Geographic 107 (6):61-89.

Knight, Robert W. Associate Professor, Rangeland Ecology and Management, Dep. Rangeland Ecology and Management, Texas A&M University, College Station, TX. 1994 Ecosystem Management Preproposal.

Losensky, Karen Mae. 1986. Runoff Water Quality and Vegetation Production on Reclaimed Mine Spoil in the Post Oak Savannah of Texas. Thesis. Texas A&M University,.

Miller, Tyler G. 1994. Sustaining the Earth. California: Wadsworth Publishing Company.

Pluhar, J.J., R.W. Knight and R.R. Heitschmidt. 1987. Infiltration rates and sediment production as influenced by grazing systems in the Texas rolling plains. Journal of Range Management 40 (3): 240-243.

# APPENDIX

INFILTROMETER DATA SHEET I

Plot I.D. Number ____________________ Date ____________

Treatment ____________________ Observers ____________________

Time runoff began (min.) __________ Sediment sample bottle # __________

Bulk density can #: Depth 1 ____________ Depth 2 ____________

Infiltration Data

| Time(min.) | Runoff lbs | Runoff liters | Infiltration cm/hr |
|---|---|---|---|
| 5 | | | |
| 10 | | | |
| 15 | | | |
| 20 | | | |
| 25 | | | |
| 30 | | | |
| 35 | | | |
| 40 | | | |
| 45 | | | |
| 50 | | | |
| 55 | | | |
| 60 | | | |

Vegetation Data

| Cover Class | Cover(%) |
|---|---|
| Bare ground | |
| Rock | |
| Litter | |
| Forb | |
| Midgrass | |
| Shortgrass | |
| | |
| | |
| | |
| | |
| | |
| | |

Microrelief (cm)

| Pin # | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | sd |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Rep 1 | | | | | | | | | | | |
| Rep 2 | | | | | | | | | | | |
| Rep 3 | | | | | | | | | | | |
| | | | | | | | | | | X sd | |

# INFILTROMETER DATA SHEET II

Plot I.D. Number____________________ Date____________________

Treatment____________________ Observers____________________

**Plot Layout (1/2 inch = 0.10 meter)**

**Area ($m^2$)**__________

**Comments:** ________________________________________