

The influence of vegetation composition and soil quality on nitrogen cycling:

Implications for land cover choices and restoration efforts on Martha's Vineyard

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Abstract

Current restoration efforts on Martha's Vineyard include plans by the Nature Conservancy to burn oak forest areas and restore the landscape to a pre-European, native species mosaic. Two important considerations with such landscape changes are: (1) land cover changes can alter the nitrogen (N) cycle and increase rates of N loss from vegetation and soils into groundwater and the atmosphere and (2) alterations to species composition that can change internal soil N-cycling rates. I evaluated soil N cycling under different land covers and under the same land cover with different species composition. First, I compared soil properties (bulk density, pH, C:N ratios and nutrient pools) and N-cycling (net N mineralization, net nitrification, and potential nitrification) across a typical successional gradient on sand plain regions of the Island that included native grassland (*Schizachyrium scoparium* and *Carex pensylvanica*) to scrub oak (*Quercus ilicifolia*) forest bottom, and mature forest (*Q. alba* and *Q. velutina*). Second, I compared the same parameters between a native grassland and a species-rich grassland that included non-native species. Across the successional gradient, net N mineralization rates were similar, and net and potential nitrification rates decreased from grassland to forest. Between the grasslands, the non-native system had a lower net N mineralization rate and higher net and potential nitrification rates than the native system. Results indicated that changing a forest back to grassland will potentially increase N cycling, and the accelerated rates of NO_3^- production in the non-native grassland may be exacerbated by non-native and invasive species. As land values change and restoration and preservation of landscapes and species become more important, the full implications of ecosystem changes need to be carefully deliberated.

Key words: Nitrogen cycling, net N mineralization, net nitrification, potential nitrification, land cover change, Martha's Vineyard

Introduction

Historically, human influence has been a powerful force shaping vegetation changes on the Martha's Vineyard landscape. Native Americans maintained early successional areas by fire, colonists deforested selected areas, and now reforested and early successional areas are disappearing and are full of exotic species (Dunwiddie 1994). Although the non-native and exotic species integrated themselves to become part of the Vineyard landscape, local conservation groups are acting now to restore regions to their "native", early successional habitats. Presently, Nature Conservancy officials want to burn certain regions of the Island to eliminate the oak trees and invasive grasses that have

established themselves after management practices, such as fire control, were eliminated (Tom Chase and Bruce Hammond, *Personal communication* October 1999). Their hope is that these management activities will recreate a 'native species mosaic' on portions of the Island.

An important aspect of the Martha's Vineyard restoration project is the influence of vegetation cover on soil N-cycling and microbial activity (Scott and Binkley, 1997). Studies of grassland and woodland ecosystems by many researchers [Compton, et al. (1998), Scott (1998), Scott and Binkley (1997), Tilman et al. (1996), Wedin et al. (1990), and Zak et al. (1990)] indicate that these different vegetative communities have varying rates of soil net N mineralization and net nitrification rates (microbial activity under current soil conditions), as well as potential nitrification rates (microbial activity under optimal conditions for nitrification). These processes relate to the quality and quantity of the litter inputs to the system, and N use efficiency/demand of the microbial and vegetation communities. At sites with relatively similar climatic conditions and soil substrates, we can consider differences in N-cycling rates between sites. Such comparisons allow us to indicate which system is most likely to retain N, which has a store of N in the soil, and which may have a current N loss or shows the most potential for loss. N loss is particularly important to study on Cape Cod and the Islands since the nutrient-poor, coarse-textured sand plain is likely to leach nitrate (NO_3^-) out of soil and into coastal water bodies. NO_3^- loading has the potential to lower water quality, raise aquatic primary production rates, decrease the abundance of some species of fish and shellfish, and threaten N standards in drinking water (Valiela, 1995).

The questions surrounding my study are: 1) What are N cycling characteristics under different land covers? How has that changed historically? What will vegetation do to the regional pattern? and 2) What effect does invasion of exotic species have on N cycling? To address these questions, I compared soil C and N pools and N-cycling rates (net N mineralization, net nitrification, and potential nitrification) in different land covers that represent the dominant present and historic landscapes of Martha's Vineyard. In the first scenario, I compared three land covers that form a successional gradient: a grassland, a frost bottom scrub oak, and a mature oak stand. I used Katama Plains, a community of native grasses, and the Kohlberg Property, which has both a defined oak scrub frost bottom (KoFB) and a mature oak stand (KoF) (Table 1). I expected the mature oak stand to have the highest quality organic matter and the lowest N-cycling rates. Across such a successional gradient, it is important to study how much NO_3^- each system produces, how much each system can potentially produce, and if there might be a potential for N loss if the system is perturbed with fire or other management regimes. Such investigation leads to an indication of ecosystem efficiency and nutrient storage capacities.

In the second scenario, I compared a species-rich, non-native grassland to a native grassland: the Sheriff's Meadow Property (SMP) in West Tisbury and Katama Plains in Katama (Table 1). In this comparison, I expected the SMP to have higher rates of N-cycling than Katama due to a lower C:N ratio (lower substrate quality) and higher soil N-enrichment by non-native and invasive species (Zak et al. 1990). By comparing these two types of grasslands on the Island, I hoped to investigate the *possibility* that not non-native/invasive species create an N rich soil that is unsuitable for restoring native species that compete in a nutrient-poor soil (Chris Neill, *Personal communication* October 1999).

Table 1. Site description			
Site	Ecosystem	Geologic form	Vegetation
Sheriff's Meadow Property (SMP)	grassland	moraine	Diverse community of native, non-native, and invasive species
Katama	grassland	outwash sand plain	Primarily <i>Schizachyrium scoparium</i> , <i>Carex pensylvanica</i> ; species native to Martha's Vineyard
Kohlberg Frost Bottom (KoFB)	forest	outwash sand plain	<i>Quercus ilicifolia</i>
Kohlberg Forest (KoF)	forest	outwash sand plain	<i>Q. alba</i> (white oak) <i>Q. velutina</i> (black oak)

Table 1. Site description of the four sites used in the gradient and grassland comparisons. Information was from Bruce Hammond (*Personal communication*, October 1999) and Deborah Swanson (*Personal communication*, 1999).

I hypothesized also that across the grassland to forest gradient, net N mineralization and net and potential nitrification rates would decrease. The older trees of the Kohlberg oak stand are less likely to have high rates of N cycling, due in part to higher C:N ratios, a more acidic substrate (Aber and Melillo 1991), and the physiological differences that alter the way in which grasslands and forests cycle N. I hypothesized also that net N mineralization and net and potential nitrification rates would be higher in the SMP than the Katama grassland, due to a lower substrate quality and more N enrichment of the system by fixation (Zak et al. 1990). While I could not clearly test the parts of my hypotheses that relate to ecosystem manipulation by changing land cover types and the effects of individual species on the N cycle, I hoped to indicate that these areas should have consideration in future research, as well as in the plans for the Martha's Vineyard restoration project in the spring of 2000.

Materials and Methods

Field work

On October 13-14, 1999, I sampled from the SMP and Katama grasslands, KoFB scrub oak, and KoF oak stand. At each of the four sites, I took 8 mineral soil cores along a 100 m transect. Each core was extracted to 10 cm depth using a stainless steel and PVC pipe corer (5.3 cm diameter) or a tulip bulb corer. At KoFB and KoF, I used a 10 cm x 10 cm template to take a sample of the organic horizon. Grasslands did not have an organic horizon. I took two separate samples of the organic (forests) and mineral horizons at each site for bulk density analysis. Each sample was stored in a polyethylene bag kept in a refrigerator at 5°C.

Soil properties

In preparation for all analyses, I homogenized each soil sample, removing large roots and rocks, and used a 1 mm sieve to remove fine root material. To characterize soil properties at each site, I estimated C and N pools and soil organic matter quality with bulk density, pH measurements, and CHN analysis. For bulk density, I multiplied the dry weight of each organic and mineral sample (two per site) by the volume of the organic horizon template or the corer to obtain a g/cm³ value. For pH measurements, I used one organic horizon (forests) and one mineral horizon sample from each site. Ten grams of organic soil and 15 grams of mineral soil were mixed with 100 and 75 mL of deionized water, respectively, and read by a glass electrode pH meter. For CHN analysis, I packed 5 samples from each depth at each site with 3-5 mg of organic soil (forests) and 0-2 cm

mineral soil (grasslands) and 20 mg mineral soil (0-10 cm in forests, 2-10 cm in grasslands). A CHN analyzer was used to obtain percent C and N values.

Net N mineralization and net nitrification

To get dry weight values for each soil sample, I calculated a dry:wet ratio by weighing each bag of soil when I brought it to the lab (wet weight) and a dried subsample of known weight from each soil core. For net N mineralization and net nitrification analyses, I did an initial 1 M KCl extraction of 5 g organic soil and 10 g mineral soil (wet weights) for each organic sample and soil core from each site. Each soil subsample was placed in a 100 mL specimen cup with 50 mL KCl, and shaken for 1 hour on a low-speed shaker table. After shaking, the samples were filtered through Whatman No. 42 filter paper into 20 mL scintillation vials. The vials were frozen until NH_4^+ and NO_3^- analyses could be done. Another set of soil subsamples was incubated at 15 °C for eight days. Seven and 15 g organic and mineral soil were used to minimize surface area and soil moisture loss. Every two days during the incubation, samples were weighed and watered with deionized water to bring them to their original volumes. After eight days, each sample was extracted with 1 M KCl, using the same protocol as the initial set of samples (Hart et al. 1994).

To analyze each sample for NH_4^+ concentrations (net N mineralization), I diluted each sample 1:5 and used a Shimadzu UV-VIS Spectrophotometer (Soloranzo, 1969). The absorbances of the samples were converted to μM concentrations per gram of soil using a standard curve. To analyze each sample for NO_3^- concentrations (net N mineralization and net nitrification), $\frac{3}{4}$ of a test tube was filled with sample and run through the Lachat AutoAnalyzer (cadmium reduction to nitrite, followed by color development with sulfanilamide and naphthylethylenediamine) to obtain μM concentrations per gram of soil (Wood et al. 1967). Net N mineralization was calculated as the difference between incubated and initial $\text{NH}_4^+ + \text{NO}_3^-$ concentrations, and net nitrification was calculated as the difference between incubated and initial NO_3^- concentrations.

Potential nitrification

I put 15 g mineral and 10 g organic field-moist soil in 250 mL Erlenmeyer flasks for each of eight mineral cores and eight organic samples (forests) per site. I added 100 mL of a 1.5 mM NH_4^+ and 1 mM PO_4^{3-} solution (pH 7.2) to each flask (Hart et al. 1994). All flasks shook on an orbital shaker at 180 rpm for 24 hours. To evaluate the amount of NO_3^- produced throughout the 24-hour period, I used Whatman No. 42 filter paper to gravity-filter 25 mL of the soil slurry at 2, 4, 22, and 24 hours. These samples were frozen in scintillation vials until Lachat analysis could be done. I expressed the rate of NO_3^- production over time (hours) with a logarithmic curve fit to the data points.

Results

Grassland to scrub oak to forest gradient

The bulk density of the forest floor soil was $\frac{1}{4}$ and $\frac{1}{3}$ that of the mineral soil in KoFB and KoF, respectively. In KoFB, this layer ranged in depth from 3-7.5 cm, and in

KoF it ranged from 4-6.2 cm. The bulk density increased from grassland to forest (Figure 1).

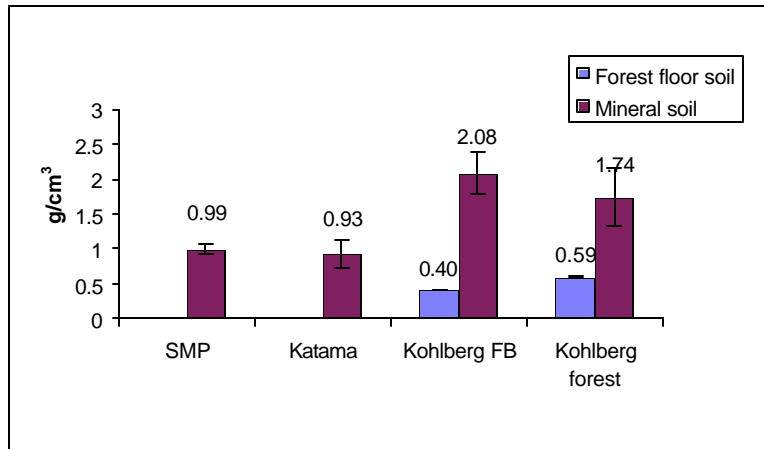


Figure 1. Average bulk densities in four land cover types. Bulk density was calculated by multiplying the dry weight of the core (all mineral soil) or the 10 x 10 cm template (forest floor soil) by the volume of the corer.

The pH of the soil decreased from grassland to forest. Within the forest soils, the mineral horizons had a higher pH than the forest floor (Figure 2). There was a two-fold difference in C stock between the forest soils and Katama (Figure 3). Most of this soil C was located in the forest floor. The N stock was higher in Katama than KoFB, but lower in Katama than KoF (Figure 4). Like C, the majority of the N was located in the forest floor soil. The two forest soils had an equal C:N ratio that was higher than that of the Katama soil (Figure 5).

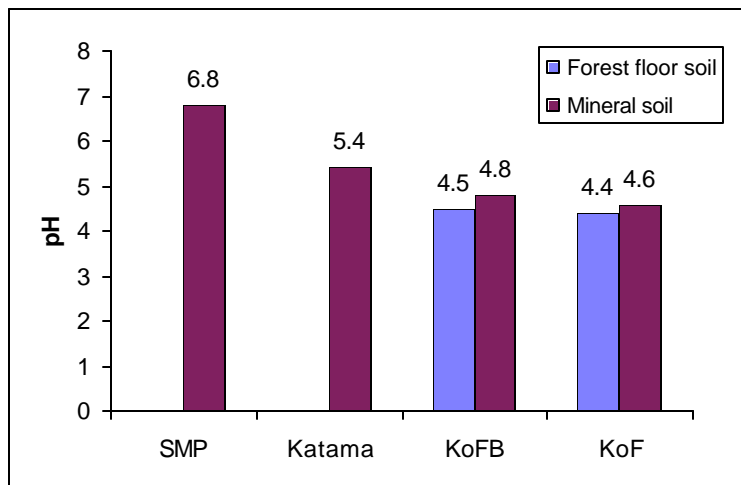


Figure 2. pH in the mineral and forest floor soil of the four sites.

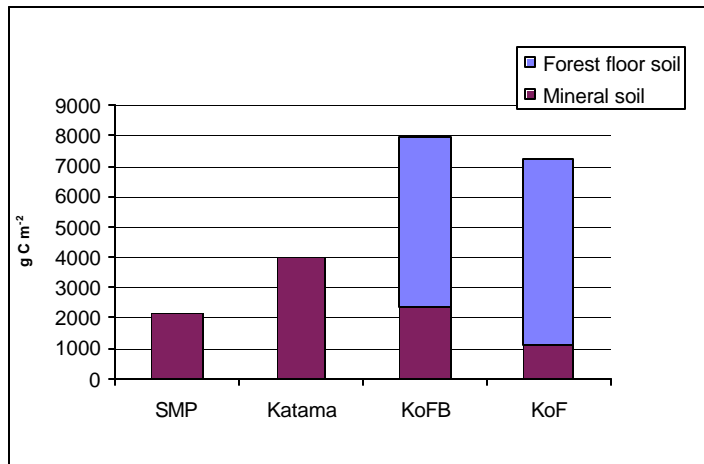


Figure 3. Carbon stock in 0-10 cm soil. These values were calculated with the equation: bulk density*2*%C (from CHN analysis).

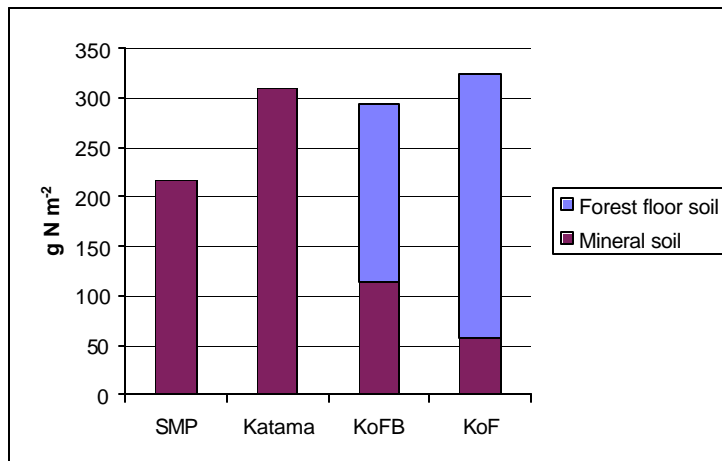


Figure 4. Nitrogen stock in 0-10 cm soil. These values were calculated with the equation: bulk density*2*%N (from CHN analysis).

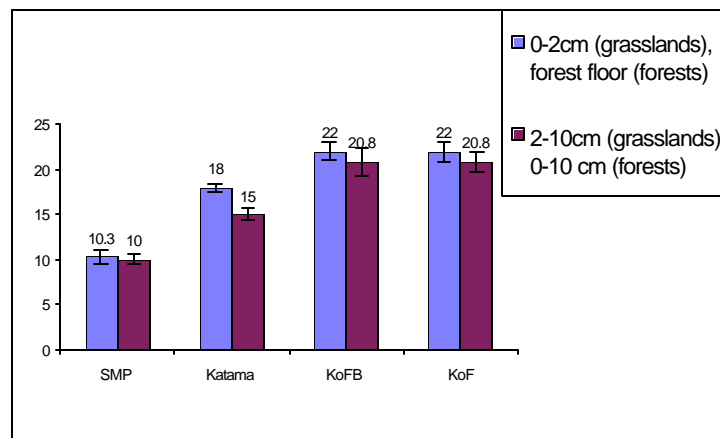


Figure 5. Average C:N ratios in the forest floor and mineral soils of each site. The top 2 cm of the grassland soils was measured separately to show that this part of the grassland soils is slightly more enriched than its lower depths. Values were obtained from the CHN analyzer.

NH_4^+ pools decreased from Katama to KoFB to KoF (Figure 6). In all three sites along the successional gradient, NO_3^- is a very small proportion of the total N (Figure 7). There was not a clear trend in net N mineralization rates from Katama to KoFB to KoF. The KoFB had the highest rate of net N mineralization, which was nearly equal to that of Katama.

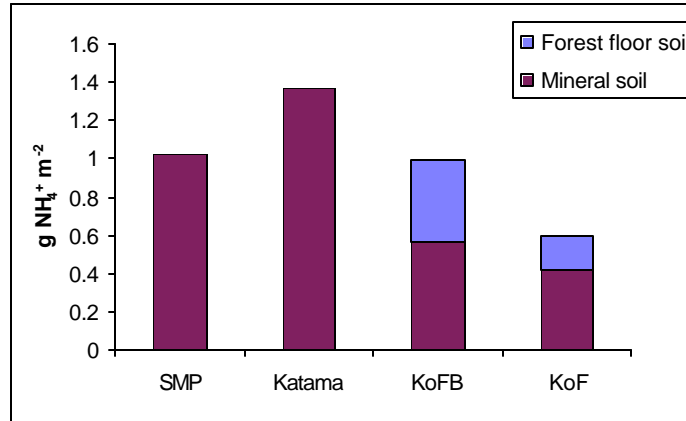


Figure 6. NH_4^+ pools in 0-10 cm soil. These values were calculated from the extractable NH_4^+ in the initial and incubated soil samples from each site.

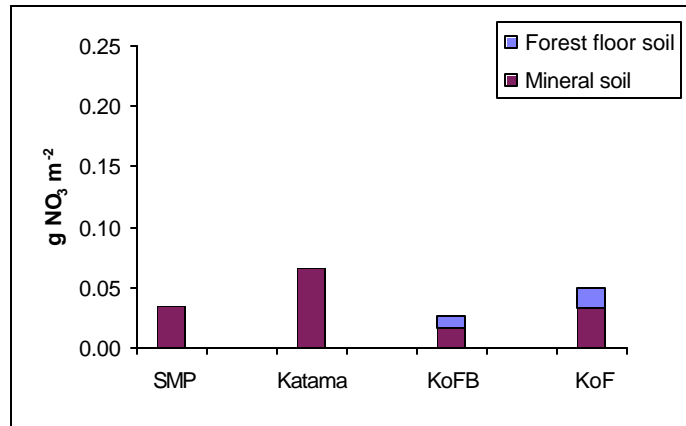


Figure 7. NO_3^- pools in 0-10 cm soil. These values were obtained from Lachat AutoAnalyzer analysis of samples extracted with 1 M KCl. When comparing values to the g NH_4^+ m^{-2} , note that y-axes are different.

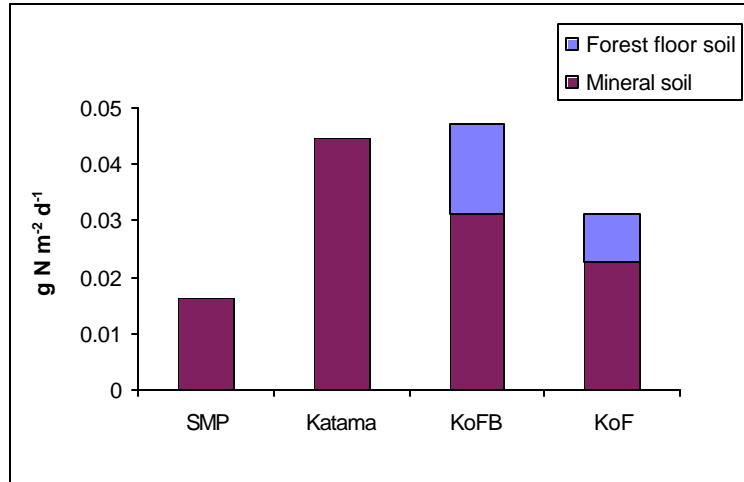


Figure 8. Rates of net N mineralization in 0-10 cm soil. The amount of N produced per g per m² per day was calculated from the initial and 8-day incubation N values (1 M KCl extraction).

There was a strong decrease in the rate of net nitrification across the grassland to forest gradient (Figure 9). Per g of soil organic matter (after incubation), Katama released the highest amounts of N per gram of soil organic matter, while the mineral soils of the forests were lower than the forest floor soils (Figure 10).

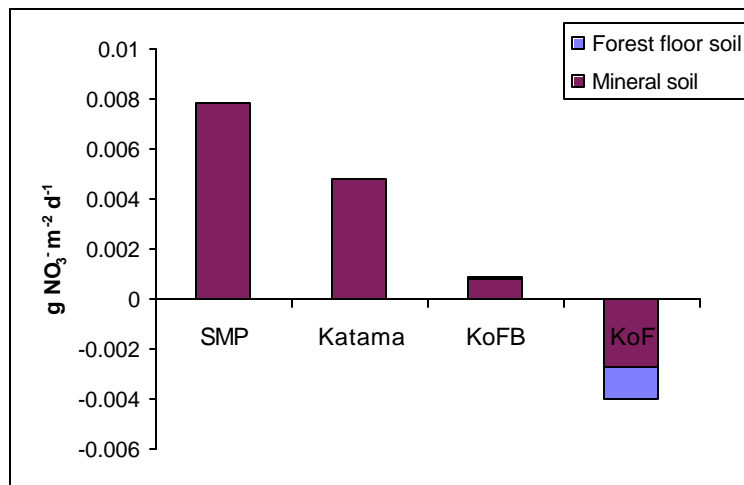


Figure 9. Rates of net nitrification in the four sites. Rates were calculated by subtracting the final from the initial NO₃⁻ concentrations (1 M KCl extraction).

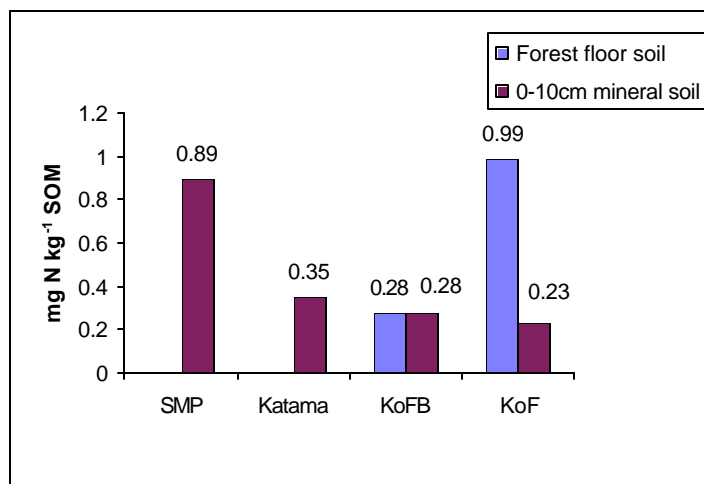


Figure 10. Mg N released per kg soil organic matter. These values were calculated from the amount of N per g of dry soil (soil incubation extraction). SOM was calculated from the percent C values (CHN analysis).

Expressing net nitrification as a percent of net N mineralization showed that there is a five-fold difference between the amount of N that Katama and KoFB nitrify (Figure 11). KoF did not accumulate NO_3^- .

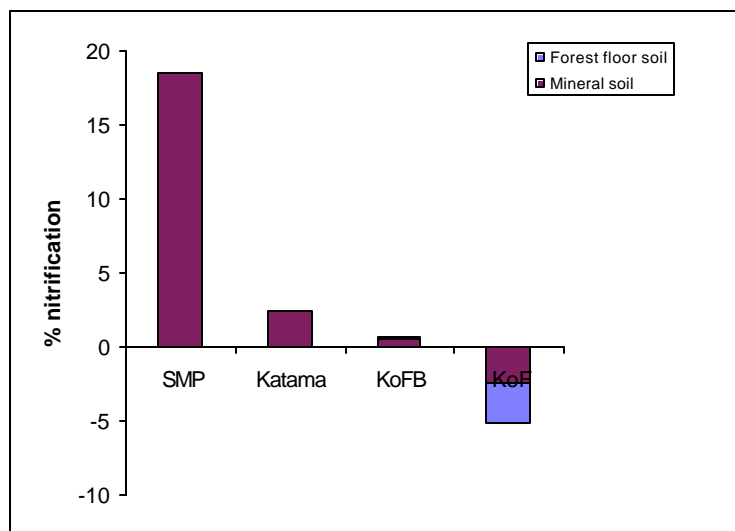
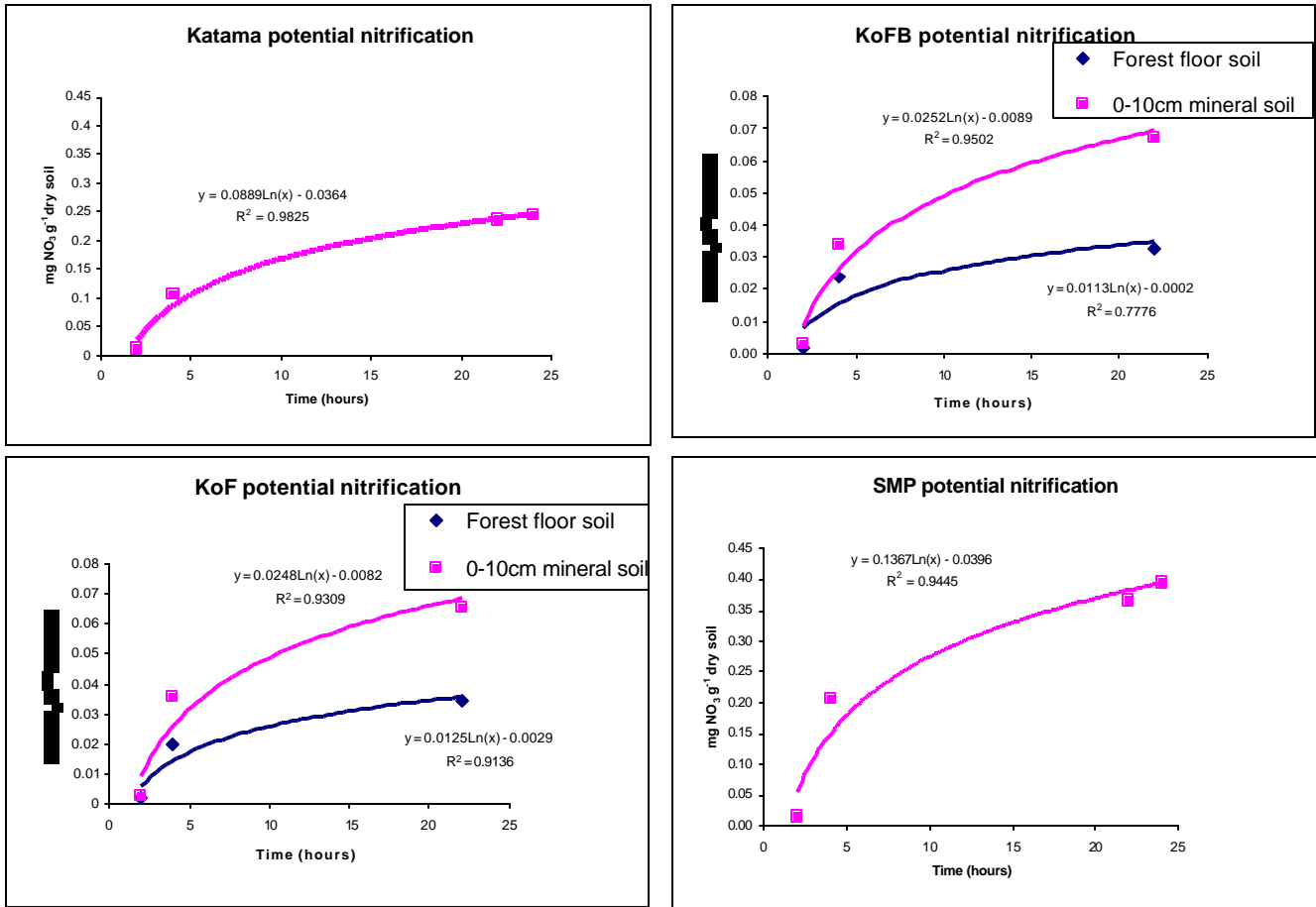


Figure 11. Net nitrification as a percent of net N mineralization.

Results of the potential nitrification assays were consistent with the net N mineralization and net nitrification measurements: more NO_3^- was produced in the grassland than the forest systems (Figures 12a-c). In the forest soils, the amount of NO_3^- produced was much greater in the mineral horizons than the forest floor. In all systems, the largest jump in NO_3^- production was from the 2-4 hour time points, then there was a much slower rate of increase to T=24 hours. The amount of NO_3^- produced was highest in the Katama soil, and decreased in the KoFB and KoF soils. KoFB and KoF began to

consume NO_3^- , as indicated by the drop in NO_3^- concentration after the $T=22$ hours time point (Hart et al. 1994).



Figures 12a-d. Potential nitrification at each of four sites. Sample points $T=2, 4, 22,$ and 24 hours are represented on the graphs of the grasslands, and $T=2, 4,$ and 22 hours are represented on the graphs of the forest soils. At $T=24$, the concentration of NO_3^- in the KoFB soil was 0.02 (forest floor) and 0.03 (mineral) $\text{mg NO}_3^- \text{g}^{-1}$ dry soil, and in the KoF soil, 0.03 (forest floor) and 0.04 (mineral) $\text{mg NO}_3^- \text{g}^{-1}$ dry soil. I did not measure NO_3^- concentration at $T=0$ hours. The concentration at $T=2$ was very close to this amount. When comparing potential nitrification rates, note that the scale is different on the grassland and forest graphs.

Native versus non-native, invaded grassland

Bulk density was nearly equal in value between the two grasslands (Figure 1). The SMP soil had a slightly higher pH than Katama (Figure 2). C stock was twice as high in Katama as in the SMP soil and N stock was higher in Katama than SMP soil (Figures 3 and 4). The C:N ratio of the SMP was 56% and 66% that of Katama in the 0-2 cm and 2-10 cm soil (Figure 5).

Across area, Katama had a greater amount of NH_4^+ and NO_3^- per m^2 than did the SMP (Figures 6 and 7). The rate of net mineralization in Katama was more than double that of the SMP soil (Figure 8). There was a 36% decrease from the rate of nitrification in the SMP to Katama. Between the grasslands, the SMP had twice the amount of N per

g of soil organic matter that Katama had present. Between the SMP and Katama, there was also a five-fold difference in the percent of nitrification. The results of the potential nitrification data were consistent with the net N mineralization and net nitrification assays: more NO_3^- was produced at a faster rate in the SMP than the Katama soil (Figure 12 a and 12d).

Discussion

The sites I used in the successional gradient from grassland to scrub oak to mature oak forest are all representative of present Martha's Vineyard land covers that were dominant in the past. The bunched *S. scoparium* and *C. pensylvanica* grasses of Katama used to prevail as dominant species in the grasslands on the Island, due to the constant salt spray and wind of the shore and periodic fires and windstorms inland that allowed only these hearty natives to grow (Dunwiddie 1994, Dunwiddie et al. 1996); the low gnarled growth of scrub oak at the KoFB has remained a dominant land cover, especially in the natural frost bottom formations that are scattered over the island (Bruce Hammond, *Personal communication* October 1999); and the oak forest is representative of those areas of the Island where there used to be fire suppression and disturbance that maintained grasslands, and now forests have matured (Abrams 1992). The comparison of the non-native, invaded grassland on the Sheriff's Meadow property to the native grassland of Katama is a pertinent consideration for the grasslands of Martha's Vineyard today. According to Vitousek et al. (1996), invasive species threaten native grasslands across the globe, especially on islands. As non-native and invasive species colonize grasslands, they gain an edge over native species through physiological adaptations that go beyond N cycling to include shading competition, reproductive strategies, and symbiotic relationships (such as seed dispersal by birds) (Dunwiddie 1994).

The results of my study showed that there are clear differences in soil properties and N cycling rates across the grassland to scrub oak to forest gradient. All of the soil properties I measured increased from grassland to forest, except for pH. Conversely, net N mineralization stayed similar across the gradient, but net nitrification, and potential nitrification decreased from grassland to forest. The reason for these trends may be that various soil properties act as controls on N cycling rates. One difference between grassland and forest is the presence of a thick organic layer in the Mor soils of the forests, and the absence of one in the grasslands. Most soil C and N are contained in this forest floor: in both KoFB and KoF, nearly 75% of the C and 70% of the N are contained in this spongy upper layer (Figures 3 and 4). These percentages are high, compared with those of Katama, because the forest floor layer accumulates organic matter over time, but the grassland does not. However, one reason to explain why these top forest soils do not have higher rates of N cycling than their mineral layers or the Katama grassland is that the pH of the forest floor layer was slightly lower than that of the forest mineral horizons and the Katama soil. According to Aber and Melillo (1991), a more acidic pH lowers N-cycling rates.

The similarity in net N mineralization rates across the gradient suggests that these systems may be N-limited and have pH values that are alike enough to make them behave similarly. The decrease in net nitrification rates across the gradient from positive in grassland to negative in forest indicates that 1) most of the NO_3^- produced is consumed so

that it does not accumulate in the soil, or 2) microbes immobilize NH_4^+ so that it is not available for nitrification (Hart et al. 1994). Katama's potential nitrification was 4 times that of KoFB and KoF (Figures 12a-c). As in the net N mineralization and net nitrification assays, it is possible that the low pH and high C:N ratio of the organic material prevent nitrification rates in forest systems from reaching those of grasslands.

In the context of other forests, however, outwash sandplains with *Q. velutina* and *Q. alba* have relatively high rates of nitrification (Zak et al. 1989). Like the grassland, the forests had a substantial leap in NO_3^- production from 2-4 hours in the potential nitrification assay. This activity is explained by Hart et al. (1994), who asserted it is possible for up to 90% of NH_4^+ available to disappear in the first two hours of the trial, if the population of nitrifying bacteria is significant. In N-limited systems, the rate of N use is likely to be greatest as soon as the microbes are exposed to the excess nutrient. Both KoFB and KoF dropped their nitrification production from the 22-hour time point to the 24-hour time point. Again, it is likely that the microbes were consuming NO_3^- , making the determination of their true potential nitrification impossible. An addition of NH_4^+ to the slurry would have remedied this problem, and rendered the point of V_{max} determinable.

These land cover differences in the grassland to scrub oak to oak forest gradient have consequences for N cycling on a landscape scale. The trends indicate that grasslands cycle N more quickly, and they produce greater NO_3^- concentrations that remain in the soil solution (for an undetermined amount of time). Thus, reversing succession to change a forested area back to grassland may act to speed up the N cycle and leave more of a potential for N loss, if all of the NO_3^- is not reabsorbed. The next step in this study would be to use lysimetry to measure if there is N loss from the system.

The results of my study also indicate that there is a difference in the soil properties and N cycling rates of native and non-native grasslands. The set of values and rates for the grasslands was consistent with those of Zak et al. (1990). As in the grassland to forest gradient, the soil properties I identified (especially a lower pH and a higher C:N ratio) may act as controls on nitrification rates in Katama soil. Yet, there is also the component of species richness and invasion in this grassland comparison, which may be more of an influence on N cycling rates. According to Deborah Swanson (*Personal communication*, October 1999), the SMP contains invasive, N-fixing species such as *Myrica pensylvanica*. Not only does this plant bring more N into the system, but it is also a successful competitor over other species. In addition to *M. pensylvanica*, there are 29 native species and 13 other non-native species (8 of which are invasive). While such a species-rich system has the potential to utilize its N efficiently and to buffer the system against disturbance (Tilman 1996), the greater the amount of species, the greater the likelihood that there will be an invasive N-fixer that might alter the system's N cycling rates. In contrast, Katama's *S. scoparium* has allelopathic inhibition on nitrifying bacteria (Wedin and Tilman 1990). This physiological characteristic of the species creates a more NH_4^+ dominated soil system that is less likely to produce NO_3^- at the same concentration levels and rate as the SMP.

I found that the SMP had a net N mineralization rate that was 25% lower than Katama, but net nitrification and potential nitrification rates that were higher than those of Katama. This evidence indicates that the SMP produces more NO_3^- per cycle of net N mineralization than Katama. If this NO_3^- is not recycled into plant or microbial tissue, it

will remain stored in the soil system and increase its N content, or it will leach from the system and into groundwater. According to Zak et al. (1989), another factor may explain why the SMP has higher rates of nitrification than Katama. Moraine soils have higher potential for nitrification, therefore the geologic forms of Martha's Vineyard may impact N cycling, as well. Combined with N enrichment by the vegetation cover, this geologic component intensifies the possibility of problems in non-native, invaded grasslands where these natural deposits persist. To test this factor, one would have to compare non-native grasslands of identical composition on an outwash sandplain and on a moraine.

A curious twist in the N cycling data from the grassland comparison is the greater concentration of $\text{NO}_3^- \text{ m}^{-2}$ in the Katama soil. With the higher rate of nitrification and potential nitrification concentrations in the SMP soil, one would expect the SMP to have the greater concentration of $\text{NO}_3^- \text{ m}^{-2}$. Perhaps there is a store of NO_3^- in the Katama soil, such that it does not move back into tissue or leave the system as fast as the SMP, or that the native grasses are not very efficient at using the NO_3^- produced. An explanation for the greater rates of net nitrification and potential nitrification in the SMP may be that nitrification rates are controlled by a product of the particular vegetation types, like litter quality. Another possible explanation is that the presence of one or more N fixers (like *M. pennsylvanica*) enrich the system. To test this possibility, one would have to examine N cycling in a non-native system with the same invasive species present, and the same invasive species removed.

The difference between net N mineralization and net nitrification rates in the grassland soils may have been more extreme than my results indicate. According to Wedin and Tilman (1990), a small fraction of net N mineralization and net nitrification occurs in fall and winter. I sampled in mid-October, so it is possible that my estimates of net N mineralization and net nitrification are lower than they should be (Belser et al. 1979). Low net nitrification rates can be explained also by competition between heterotrophs and nitrifiers for phosphorus or other limiting nutrients (Purchase 1974) and by moisture stress during lab incubation (Alexander 1976). I had difficulty maintaining moisture balance throughout the incubation period, so the latter explanation may be applicable to this data set.

These differences in land cover between the native and non-native grasslands have consequences for N cycling on a landscape scale. As time moves on, more and more non-native and invasive species colonize grasslands creating communities that are more complex. If degrees of N cycling and other components of soil quality such as C:N ratios change in response to invasion, it is possible that the system will become enriched with N to a point where native species cannot compete. According to Knapp et al. (1998), burning encourages the growth of *S. scoparium*. Perhaps a burn regime that takes into account the control of invasive species would be the best management plan for restoring native cover and for giving native species the ability to dominate over non-natives and invasives in a grassland system.

Conclusion

In the case of the Nature Conservancy on Martha's Vineyard, the current restoration effort is to manage a early successional native species mosaic with fire control (Tom Chase and Bruce Hammond, *Personal communication* October 1999). To do this, the Nature Conservancy will have to burn down the oak forests on the Island, and mow or

burn the grasslands periodically. In the case of the oak forests, there is a potential to alter the N-cycle by altering the C-cycle first. It is possible that burning the forest floor layer will decrease its depth and increase the potential for N-loss from the system. In these oak systems that have had time to mature and develop closed canopies, a thicker organic mat has developed, which will be lost from the system when burned (Abrams 1992). With the KoF property, which has never been a grassland, this course of events is quite possible. As these forests experience reverse succession from trees to grasses, it is likely that the vegetation cover will increase N-cycling rates. Humans, then, will be speeding up the N-cycle due to the land cover choices they make.

Another component to this issue of land cover choice is species composition and diversity. This aspect has not been a large part of the Martha's Vineyard restoration project plan. The primary intent is to change the forests into native grassland and low shrub regions, yet non-native and invasive species still will have the potential to colonize and monopolize the landscape. As I indicated, with a more species-rich system, there is a greater probability that species of N fixing plants, strong N competitors, and other types of invasives will be present. Due to their high nitrification rates, low organic quality, and possible N enrichment capabilities, these organisms could change N cycling to an even greater degree than the change in ecosystem type. Written into the management plan, then, should be some consideration of species; it might be in the best interest of Nature Conservancy officials to ensure that their burning regime (and other management strategies) minimize non-native and invasive species colonization. Such consideration may bring them even closer to their original goal.

Clearly, both of these considerations – ecosystem type and species composition – impact for the already human-altered N-cycle. When the Martha's Vineyard restoration effort begins in the spring of 2000, the implications of land cover choices need to be considered carefully. The goal behind the restoration plan shows that species have inherent value, but science shows that they also have the potential to affect the entire balance of the ecosystem.

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