The Effects of Social Trails on Soil Compaction and Vegetative Cover in Forest and Prairie Ecotypes

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ABSTRACT

Social trails are a well documented phenomenon in many natural areas and national parks [1]. Created by foot traffic through natural areas by park patrons, these trails are not made by a park service or trail making organization. They are unplanned and usually unnecessary. This study examines the effects of such trails on soil compaction and plant performance. Two tests were used to determine the impact of different rates of trampling on plant performance and plant community structure. Soil bulk density measurements, (the mass of soil per unit volume) and vegetative percent cover were quantified in two different ecotypes with eight different rates of trampling, from 0 passes (control) to 100 passes per week. These effects were examined in a grass and sedge dominated prairie, and a deciduous forest. The experiment lasted four weeks and was carried out from mid-July to mid-August 2004. The results showed that trampling had no statistically significant effect on the compaction of soil in either ecotype. However trampling did have a significant effect on the plant community composition. Trampling significantly changed the percent cover of plots in both the forest and prairie. From comparison data, it was found that lower rates of trampling are less damaging in the forest than in the prairie, while high rates of trampling are less damaging in the prairie than the forest.

INTRODUCTION

Venturing into the outdoors can be a great way to take a break from city life. Taking a hike through a forest or prairie to see the seasonal wildlife and vegetation can be an excellent way to relax and enjoy nature. However there can be negative effects of recreational hiking, such as trail widening, soil erosion, and plant damage [1]. These effects not only alter community health, but also decrease the quality of experience for patrons [2]. One major cause of these effects is social trails. Social trails are unnecessary trails made inadvertently by recreational hikers. These trails are often started by hikers who are lost, chasing after wildlife, or shortcutting the main path. A study by Kutiel *et al.* (1999) demonstrated that indeed recreational impacts are more widespread on lower use trails than high use trails [3]. They postulate this is because low use trails are harder to follow, and as a result social trails are more frequent.

This study examines the effects of different rates of trampling on the health of two different ecotypes. The experiment tries to simulate the creation of social trails, by having plots trampled once a week, for four weeks. There were 10 sets of the seven treatments and one control treatment all replicated in each ecotype. Treatments ranged from 0 to 100 passes per week. A pass was counted as a walk once through the middle of the plot at a normal pace. The experiment took place during the summer of 2004 at Cedar Creek Natural History Area, a Long-Term-Ecological Research site in Bethel, Minnesota.

Detrimental impacts caused by trampling are increased soil compaction, and loss of vegetative cover (both live plant material and litter cover) [1]. Soil compaction is a loss of interstitial spaces in soil [4]. Interstitial spaces are essential to plant health. These soil pores hold water and nutrients which the plant is then able to exploit through root growth into these spaces. Plant life is critical for grassland ecosystem functioning because it releases oxygen into the atmosphere and provides both food and habitat for countless organisms. An important component of plant life in both the forest and grassland ecosystems is plant litter. Litter can take the form of dead roots or dead and decomposing leaves from prior years' growth. Litter provides organic material for microorganisms to decompose and can strongly influence nutrient inputs into the soil [5].

This study seeks to understand the impacts of trails that are unnecessary and often detrimental to the recreational experience. From the data collected in this experiment we can also make statements about the following questions: Are the first passes over an area more detrimental than the last? If given a choice in getting to one particular place, is there less impact on an ecosystem in walking through a forest or prairie?

Many studies have been done in the area of environmental recreational impacts. Observational studies have found greater amounts of vegetation degradation and soil change from high traffic trails than low-traffic trails [1,3,6,7]. A few experimental studies have varied the trampling intensity and found mostly asymptotic relationships between damage and trampling intensity [8,9]. I expected to find similar relationships between change and trampling rates in the plots set up at Cedar Creek. Previous research however has applied its trampling treatments all at once. This experiment applies trampling at a rate over a short period of time (1 month), and examines changes due to some very minimal amounts of trampling.

Methods

Eighty plots were placed in both the forest and prairie areas near Fish Lake. 0.5 x 0.5 meter plots were laid out linearly with at least 2 meters between each plot to ensure an even stride by tramplers. Plots were established along transects where no noticeable trail or trampling impacts were already present. The plots were placed so that they could later be used as an intentional trail for visitors to the natural lake, which was adjacent to the study plots. Treatments included 0 (the control plots), 1, 4, 8, 16, 28, 40, and 100 passes per week. Each treatment was replicated ten times per ecotype.

Four different women, weighing between 50 and 60 kilograms each, performed trampling. One quarter of each plot's total trampling, and trampling per week was carried out by each person. Tramplers wore the same hiking boots each week and were instructed to walk across each plot (using the extra 2 meters between plots) once at a normal pace to count one pass.

Data was taken on each plot twice: once before any trampling occurred, and once after the four week period of trampling was over. Percent cover was taken over the entire plot, although trampling only occurred through the middle of each plot. Percent cover was fitted into the categories of bare ground, litter and live plants and always totaled 100%. The live plant category was also then broken up into categories of five vegetative functional groups that added to the total live plant percent coverage. The five functional groups used were: forb, grass, sedge, legume and woody plants.

Measurements of soil bulk-density were taken at depths of 0-10 and 10-20 centimeters. Bulk density is the mass of dry soil per unit volume. This number is obtained by taking uniform cores in each plot, one from the top 10 centimeters of soil, and the second from the next 10 centimeters, drying this soil, and weighing it. The cores were taken from the middle of the plot in an area where the tramplers had walked. Cores were dried and weighed to get a measure of bulk density, the mass per unit volume of the soil sampled in each plot.

Table 1: **Bulk Density Statistics.** This table shows the results of statistical analysis of the bulk density data. Linear regressions were fitted to the data which yielded no statistically significant relationships between rate of trampling and bulk density.

Bulk Density p-values*		
Depth (cm)	**Prairie**	**Forest**
0-10	0.7009	0.2616
10-20	0.8275	0.4237
0-20	0.7019	0.8402
*obtained from linear bi-variate analysis		

Results

Bi-variate analyses were performed on all data sets using passes per week as the explanatory variable. Trampling had no significant effect on soil bulk density as compared to the control plots at either depth (Table 1). From this it can be inferred that trampling had no substantial effect on the compaction of the soil after four weeks. This may be because the trampling was not intense enough to see a change in the density of the soil. But it must also be noted that there were some difficulties with the sampling technique. It was often hard to get cores pounded down to precisely the appropriate level. Cores often fell apart and had gaps of missing soil. Thus, even though there was no statistical evidence in the soil bulk density analysis, from walking on the different plots, a qualitative difference in compaction could be felt by the tramplers.

Percent cover measurements, however did yield significant results. The change in percent of cover (final percent cover minus initial percent cover) for each category was used as the response variable in analyses. The rate of trampling, in passes per week was used as the explanatory variable. Significant trends were found for bare ground, litter, and the functional group of woody plants in the forest. Significant trends were found for bare ground, litter, live plants, and the functional group, grass in the prairie (Table 2). Linear bi-variate analyses were performed on the forest data, while the data from the prairie plots were fitted with a natural logarithmic curve.

The plot of change in percent cover versus passes per week of the forest plots shows three different trend lines for the three major categories of cover (Figure 1). As trampling increases the amount of litter decreases while the amount of bare ground increases. The live plant trend line is insignificant ($p = 0.0886$). There were only a small number of data points for this percent cover analysis. Only a few plots had live plants in them at the beginning of the experiment. The forest used in the experiment had very little understory vegetative

Table 2: **Percent Cover Statistics.** This table is the result of statistical analysis of the percent cover data. Each category was plotted against rate of trampling to obtain p-values from a bi-variate analysis. The prairie data followed logarithmic trends, while the forest trends were linear in nature.

Percent Cover p-values		
Cover Category	**Prairie****	**Forest*****
Bare Ground	0.0286	<0.0001
Litter	0.0159	<0.0001
Live Plant	0.0004	0.0886
Forb	0.6558	0.1141
Sedge	0.0529	0.4542
Grass	0.0057	0.3551
Legume	0.6559	0.1788
Woody Plants	--------	0.0021
** values obtained from ln(x) bi-variate analysis		
*** values obtained from linear bi-variate analysis		

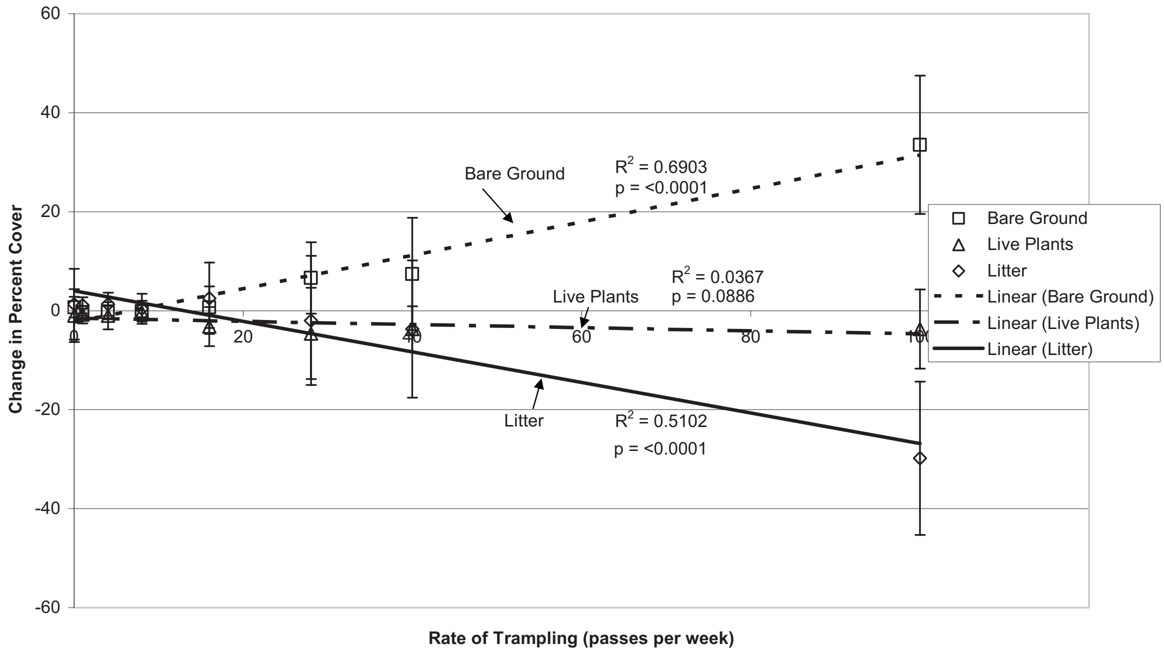

***Figure 1*. Forest - Change in Percent Cover.** This graph shoes the three different trends for change in percent cover of bare ground, live plants, and litter, as trampling rate increases in the forest. Each point represents the average change of all plots with the same treatment for that measurement. Error bars represent one standard deviation from the mean. As the rate of trampling increases amount of litter decreases and the amount of bare ground coverage on plots increases linearly.

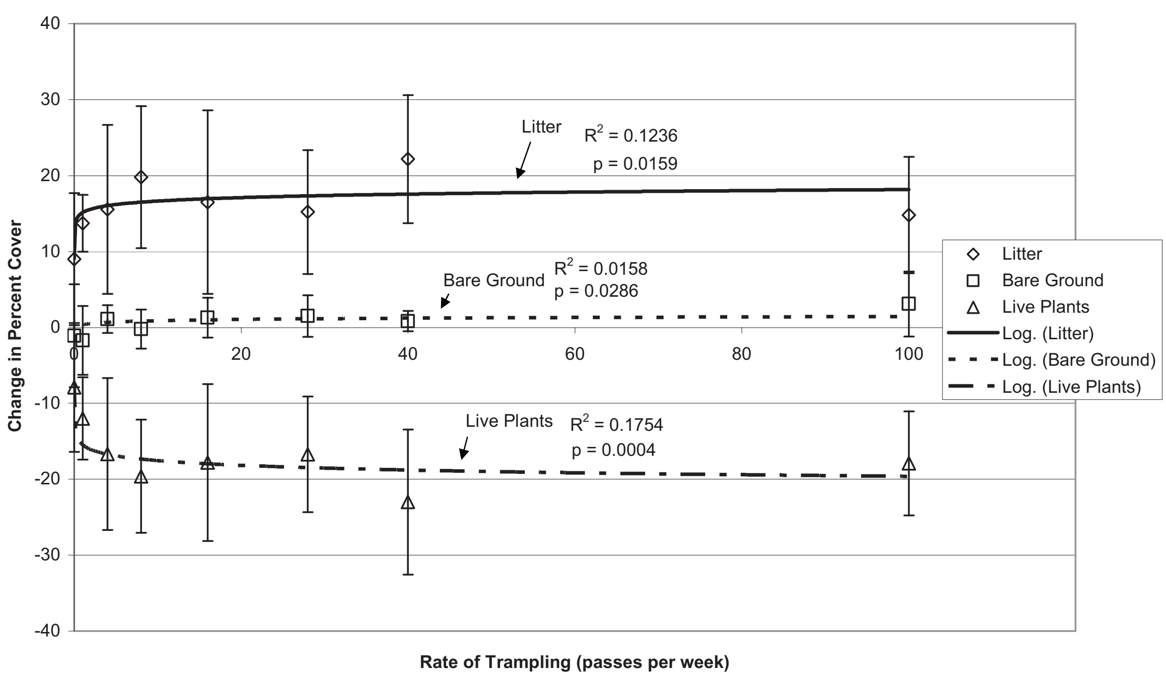

***Figure 2*. Prairie - Change in Percent Cover.** This graph shoes the three different trends for change in percent cover of bare ground, live plants, and litter, as trampling rate increases in the prairie. Each point represents the average change in of all plots with the same treatment for that measurement. Error bars represent one standard deviation from the mean. As the rate of trampling increases the rate of change in change in percent cover decreases for the litter and live plant cover categories; this is a logarithmic (or asymptotic) trend.

cover. Logarithmic trends were not used in this data set as they were with the prairie data, because such trends did not fit the data as effectively. Adjusted R^2's were compared to come to this conclusion.

Trends for the prairie data all had better fits with logarithmic trend lines than linear trend lines. Significant trends were found for the change in live plants and litter, but not the bare ground (see Table 2). Bare ground in the prairie was rare. The intensity of trampling did not generally reach the point of removal of litter to expose bare ground. The live plant and litter trends lines look like mirror images of each other (see Figure 2). As trampling rate increases the amount of live plants decreases and litter increases, logarithmically.

***Table 3*: Differences Between Ecotypes.** This table is a comparison between the two different ecotypes. At each treatment level, one way ANOVA tests were done between the aggregate change of each ecotype. Aggregate change is the sum of the absolute values of all the changes in percent cover for each plot.

Differences Between Ecotypes	
Treatment	**p-value**
0	0.0145
1	<0.0001
4	0.0003
8	<0.0001
16	0.0052
28	0.0920
40	0.0266
100	0.0057

Some plots were excluded from percent cover analysis. None of the forest plots were omitted from analysis, but prairie plots: 2, 3, 39, 47, 55, 63, 18, 43, and 58 were disregarded. Plots 2, and 3 were thrown out because they were incorrectly placed in an area that had been previously subjected to trampling. Plots 39, 47, 55, and 63 were placed on more uneven terrain than the rest of the plots and gained much greater amounts of bare ground than any of the other plots, making them large outliers in the data set. From these plots it is interesting to note that unevenness in terrain can greatly increase the amount of change in percent coverage composition. And finally, plots 18, 43, and 58 were lost because of gopher mounds created in them in the middle of the experiment.

The forest and prairie plots were compared, by using a measure of aggregate change. Aggregate change is defined as the sum of all the absolute values of each change in percent cover value (aggregate change = |change in bare ground| + |change in litter| + |change in live plants|). Aggregate changes for the prairie and forest were compared at each rate of trampling. Analysis of Variance (ANOVA) t-tests were performed to obtain p-values for this data. Significant differences were found at all rates of trampling except for the rate of 28 passes per week (Table 3). These t-tests show that there is a statistically significant difference between the amount of change experienced by the forest and prairie due to the same amount of trampling that was performed on the same days and by the same people. Rates of trampling below approximately 60 passes per week contributed to more change in the prairie than the forest, rates above approximately 60 passes per week contributed to more change in the forest than the prairie.

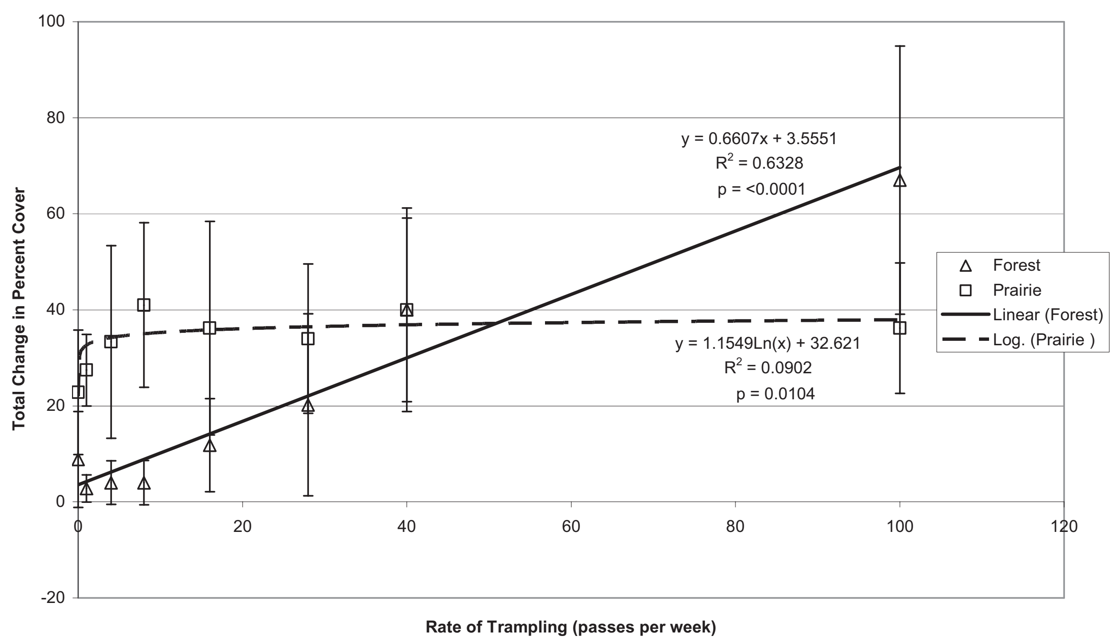

***Figure 3*. Aggregate Change - Percent Cover**. Each point on this graph represents the sum of the absolute values of each of the plots' changes in the three main coverage categories (litter, bare ground, and live plants). This graph demonstrates the difference in trends between the forest and prairie. The two trends cross near a rate of sixty passes per week, indicating that before that point the prairie experienced more change, while after that point the forest experienced more change.

Conclusion

Aggregate change was higher in the prairie for rates less than approximately 60 passes per week, and higher in the forest for rates higher than approximately 60 passes per week (for a graphical representation, see Figure 3). Because trampling at a rate of more than sixty passes per week is greater than what one would call accidental wanderings, social trails may have less of an impact in the forest, but the prairie can withstand heavy use trails better.

When comparing the effects of trampling in prairie to the effects of trampling in forest, we can easily observe two differences. The trends in the prairie are logarithmic, while trends in the forest are linear. The average changes are significantly greater in the forest, at the highest rate tested, and show no sign of slowing down. Because of the linear nature of the trend, the rate of change is constant. In the prairie, on the other hand the trend is not linear. The prairie data fits a logarithmic curve. This is a curve for which as the rate of trampling increases, the rate of change in percent cover decreases. In general, the data shows that the first passes over the plots had more of an impact than the last passes.

It would be advisable for Cedar Creek to allow visitors to walk on an established trail through the prairie to see Fish Lake, because the data of this experiment shows that this particular area sustains fewer impacts due to large amounts of trampling. Additionally, Cedar Creek should be warned that social trails in this ecotype can incur a significant impact on plant community, and that they should be discouraged. The experiment showed that this area experiences a great amount of change with only minimal amounts of trampling (around 1-8 passes per week).

Additional research on this subject could be done in still more ecotypes. It would also be interesting to take more specific percent cover measurements, to find out which species in the grassland are most affected by trampling. This would have implications for the field of conservation biology if such species were currently declining in numbers.

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