Soil Manipulation by Leaf Cutter Ants at La Selva Biological Station, Puerto Viejo, Costa Rica

Malcolm Barnard, Harrison Brock, Patric Campbell, Jenna Peissig

University of Georgia

1. Introduction:

Soil conditions may be an easily overlooked issue related to anthropogenic land use change. Many species that depend on very specific soil properties could be altered if the surrounding environment were to be disturbed. Under human pressure, soil housing leaf cutter ants may become degraded to a degree that negatively impacts the ants' behavioral and colony cycle. Our group started our project with a simple objective: determine the effects leaf cutter ants have on the soil they nest in and the area around the soil in which they nest. The focus of this research was to explore anthropogenic effects on the soil, specifically analyzing the soil conditions and its effects on leaf cutter ant colonies. Thus, we analyze the anthropogenic effects on the soil. Leaf cutter ants share a mutualistic relationship with fungi. Leaf cutter ants cultivate a specific type of fungus that grows in their nests. The ants constantly bring fresh leaf cuttings to feed the fungus, and the fungus also gains protection from pests and other harmful molds. Leaf cutter ants benefit from this relationship by using the fungus as a reliable source of food. Gaining an understanding of the ants' earth manipulation habits will allow people to more accurately quantify the sensitivity of their environment and specific impacts of deforestation.

We hypothesized that leaf cutter ants influence the soil in which they nest to maintain certain physical and chemical characteristics that are more hospitable for their species. We believe that the pH of the soil will increase as distance from the ant nest increases because of secondary metabolites produced by the fungi that grow in the nests. We also predicted that the temperature of the soil would not be a significant factor on colony size determination, because ants do not produce their own body heat. Finally, we hypothesized that canopy coverage will not be significant for colony size determination, because canopy cover is independent from ants.

2. Methods:

We conducted our experiment at La Selva Biological Station at Puerto Viejo, Costa Rica. We travelled through various trails covering open field, secondary growth forest, and old growth forest areas. The average temperature at La Selva while we were conducting the experiment was around 33^{0}C. We selected three leaf cutter ant mounds in three different habitats: open field, secondary growth forest, and old growth forest. All nests used in the experiment were active.

We measured several factors including soil pH, internal and surface temperature of the soil, visible perimeter of the nests, and light penetration. We made a thirty-meter transect, starting at the center of each leaf cutter ant mound, and measured these factors every ten meters along each transect. Flags were placed at the end points of every perceivable location of ant activity and the distance between flags was taken in centimeters to determine the approximate circumference of each nest. Also, we used a soil pH probe and measured the pH of the soil at each location along each transect. An infrared temperature gun was used to measure the surface temperature of the soil, and a meat thermometer measured the internal temperature of the soil at a constant depth. A multimeter was used to measure light penetration at each site as an indication of canopy cover.

We made the assumption that ant colony size is proportional to the external perimeter of the ant mounds. We are also assuming that the matrix of ants below the surface has no impact on the surface soil.

We conducted an ANOVA test to determine which factors were statistically significant in determining the size of the different leaf cutter ant mounds. We also conducted multiple linear regression t-tests to compare the mounds within each of the different types of areas.

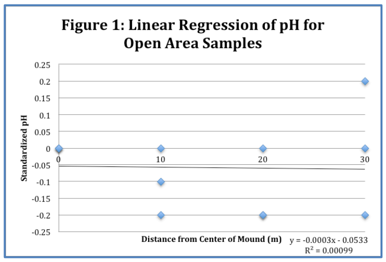
4. Results:

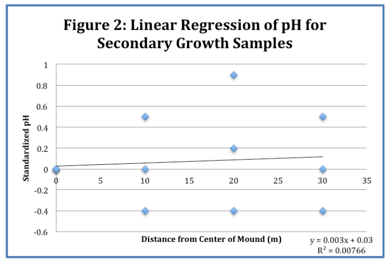
Table 1: General Site Data

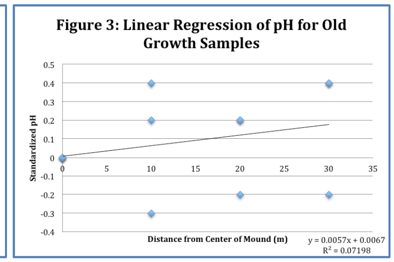
Sample Group	Site	Perimeter of Colony	Width of Ant Trail	Distance from Concrete Walkway	Direction of Ant Movement (Relative to Nest)	Direction of Sample (Relative to Nest)
Open Field	1	253 cm	144.8 mm	2500 cm	W	E
	2	2724 cm	27 mm	98 cm	NE	SW
	7	4700 cm	51.1 mm	60 cm	All	S
Secondary Forest	3	2821 cm	51.0 mm	n/a	NE	NW
	4	6100 cm	50.5 mm	50 cm	W	E
	8	5460 cm	90.6 mm	n/a	S	N
Old Growth Forest	5	2190 cm	n/a	0 cm	NW	SE
	6*	1275 cm	-----	-----	-----	-------
	9	2730 cm	327 mm	320 cm	N	S
	10	2040 cm	79.2 mm	335 cm	E	W

Table 2: Transect Data

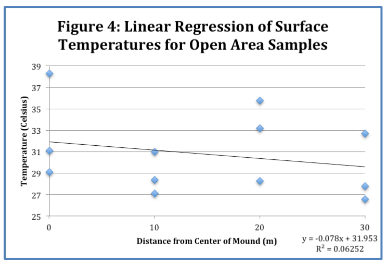
Sample Group	Site	Sample Distance from Colony	pH	Temperature (Celsius)			Light Penetration
				Surface	Subsurface	Difference	
Open Field	1	0 m	6.2	38.3	20.5	17.8	6402 lux
		10 m	6.0	27.1	18.0	9.1	808 lux
		20 m	6.0	28.3	19.0	9.3	651 lux
		30 m	6.0	27.8	19.0	8.8	530 lux
	2	0 m	6.2	29.1	21.0	8.1	2020 lux
		10 m	6.3	31.0	20.5	10.5	7600 lux
		20 m	6.8	33.2	20.5	12.7	12600 lux
		30 m	6.3	32.7	21.0	11.7	14500 lux
	7	0 m	5.8	31.1	20.0	11.1	1325 lux
		10 m	5.7	28.4	19.0	9.4	895 lux
		20 m	5.6	35.8	20.5	15.3	1650 lux
		30 m	6.0	26.6	19.5	7.1	92 lux
Secondary Forest	3	0 m	5.5	28.1	19.0	9.1	1300 lux
		10 m	6.0	27.9	20.0	7.9	700 lux
		20 m	6.4	28.5	20.0	8.5	3200 lux
		30 m	6.0	27.8	18.0	9.8	1650 lux
	4	0 m	5.6	27.6	18.0	9.6	853 lux
		10 m	5.6	27.4	18.0	9.4	1600 lux
		20 m	5.8	27.4	19.0	8.4	1045 lux
		30 m	5.6	27.3	19.0	8.3	930 lux
	8	0 m	6.4	26.5	18.0	8.5	134 lux
		10 m	6.0	26.5	19.0	7.5	106 lux
		20 m	6.0	26.6	19.0	7.6	52 lux
		30 m	6.0	26.9	20.0	6.9	209 lux
Old Growth Forest	5	0 m	5.8	28.3	19.0	9.3	870 lux
		10 m	5.5	26.6	19.5	7.1	1315 lux
		20 m	6.0	26.6	19.5	7.1	673 lux
		30 m	6.2	26.9	22.0	4.9	1111 lux
	6*	0 m	5.8	----	----	----	280 lux
		10 m	5.8	---	----	-----	369 lux
		20 m	5.6	---	-----	------	160 lux
		30 m	5.5	-----	-----	------	142 lux
	9	0 m	5.2	25.7	18.0	7.7	61 lux
		10 m	5.6	25.8	19.0	6.8	25 lux
		20 m	5.0	25.6	18.0	7.6	89 lux
		30 m	5.6	26.3	17.0	9.3	180 lux
	10	0 m	6.0	27.3	18.0	9.3	32 lux
		10 m	6.2	26.6	17.0	9.6	80 lux
		20 m	6.2	26.8	17.0	9.8	43 lux
		30 m	5.8	26.6	19.0	7.6	24 lux

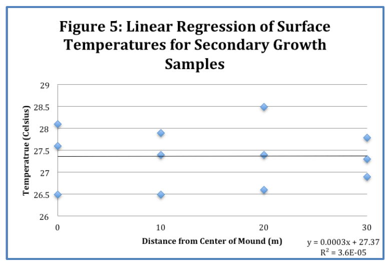


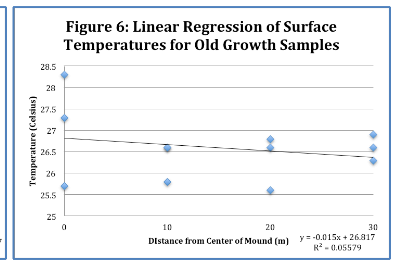




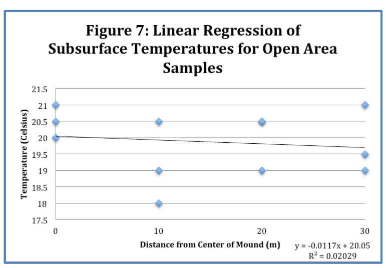
Figures 1-3: Linear regression t-test on the pH data collected from each site by area type. (Open Area: p = 0.716, t = 0.375, df = 10; Secondary Growth: t = 0.278, p = 0.787, df = 10; Old Growth: t = -0.197, p = 0.847, df = 10).

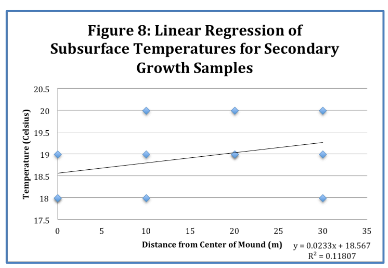


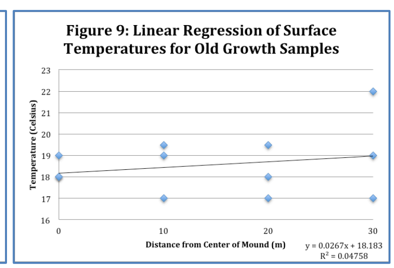




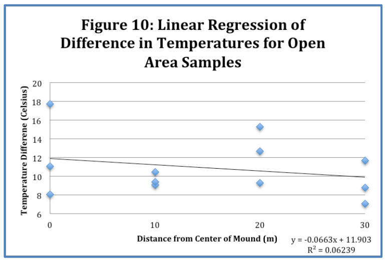
Figures 4-6: We ran a linear regression t-test on the surface temperature data we collected from each site by type of area. (Open Area: t = -0.504, p = 0.625, df = 10; Secondary Growth: t = -0.473, p = 0.365, df = 10; Old Growth: t = -0.789, p = 0.448, df = 10).

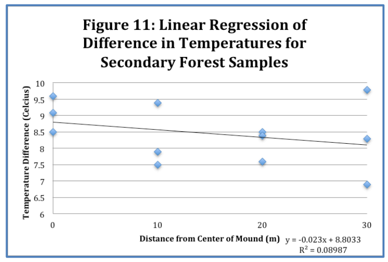


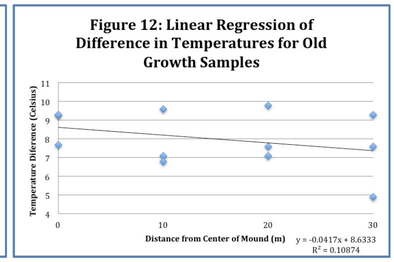




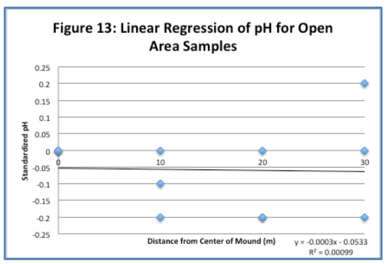
Figures 7-9: We ran a linear regression t-test on the subsurface temperature data we collected from each site by type of area. (Open Area: p = 0.716, t = 0.375, df = 10; Secondary Growth: t=1.030, p= 0.326, df = 10; Old Growth: t= 0.818, p= 0.432, df = 10).

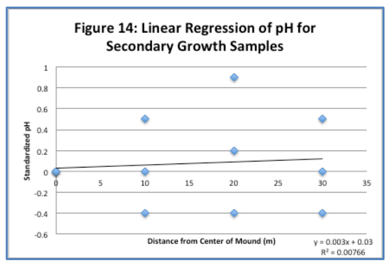


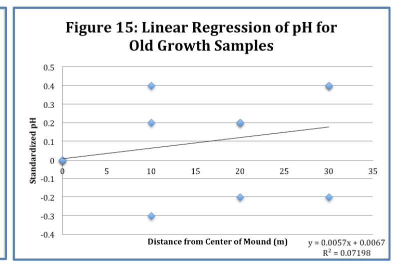




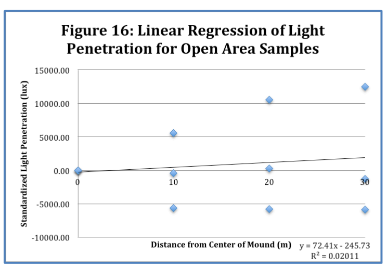
Figures 10-12: We ran a linear regression t-test on the difference between surface and subsurface temperature data we collected from each site by type of area. (Open Area: t = -0.816, p = 0.434, df =10; Secondary Growth t = -0.994, p = 0.344, df = 10; Old Growth: t = -0.11, p = 0.295, df = 10).

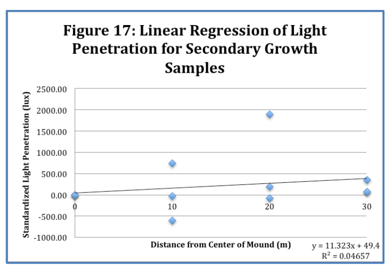


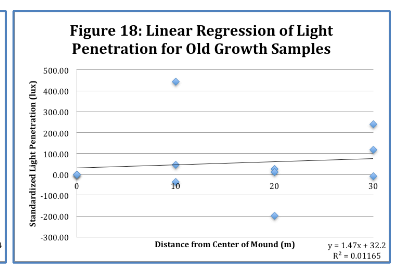




Figures 13-15: We ran a linear regression t-test on the pH data we collected from each site by type of area. (Open Area: p = -0.099, t = 0.923, df = 10; Secondary Growth: t = 0.278, p = 0.787, df = 10; Old Growth: t = 0.881, p = 0.399, df = 10).







Figures 16-18: We ran a linear regression t-test on the light penetration data we collected from each site by type of area. (Open Area: p = 0.716, t = 0.375, df = 10; Secondary Growth: t= 0.670, p= 0.518, df = 10; Old Growth: t=0.343, p=0.739, df = 10).

The ANOVA test gave p-values as follows: p=0.05268 for pH, p=0.17935 for light difference, p=0.01365 for light penetration, and p=0.01280 for trail width.

The regression analysis shows very weak connections between the factors we tested and leaf cutter ants. However, the ANOVA test shows that pH, light penetration, ant trail width were significant factors in determining the size of the ant colonies. Despite the lack of correlation in the regression analysis, we still believe that there exists some form of behavioral pattern between leaf cutter ants and their environmental conditions that affect them.

5. Discussion:

ANOVA test show that there is a significant affect of the variables studied and that some of these variables have a profound effect on leaf cutter ant colony size. In other words, larger ant nests produce narrower trails and tended to be in areas that had less light penetration. Low light penetration correlates with heavily forested areas, therefore our group believes that ants disperse more evenly from their nests in densely forest areas than in open areas. This pattern in dispersal is likely due to the reason that there is more availability of food resources in the densely forested areas compared with the open areas. In addition, compared to forested ants, ants in open areas are most likely more exposed to predation and, for protection, feed in a single, organized, and linear direction. We can say with security that deforestation will negatively impact ant mound size and may cause the ants to feed in a more concentrated manner.

While conducting the experiment, we faced several limitations. For instance, weather conditions were not ideal for taking several of our measurements. Variances in cloud coverage most likely altered the relative light readings, which is why they all had to be standardized. Furthermore measurements of the perimeter of the ant mounts were taken to the best of our ability, but do to irregular shapes and equipment restraints our measurements were still estimates. We did not have the ability to measure internal matrix of the ant mounds so the surface perimeter of the mound was our only indication of size. Lastly, we did not have the proper equipment to gain a more accurate internal temperature reading.

For future studies, we would like to compare surface size of ant mounds with internal expanse of the nests and then proceed to contrasts the size differences of the mounds between open, secondary growth, and old growth areas. It could be that ants in open areas have deceptively large colonies that are all submerged beneath the soil for protection. In addition to this study, we would like to research the connection of varying levels of predation between ant colonies living in the three habitats and the ratio of soldier ants to worker ants in the three environments. Another topic of interest would be to study varying food availabilities in relation to the manner in which leaf cutter ants disperse around the nest. This study could help explain the size differences in the ant trails.

We indicated in our results that leaf cutter ants do alter soil conditions in the areas that they inhabit. The implications of our findings suggest that human land use change could dramatically impact leaf cutter ant populations because leaf cutter ants require specific environmental conditions to thrive. Habitat fragmentation could alter these ideal conditions for leaf cutter ants. As leaf cutter ant populations decline, certain fungi species that depend on the ants will also decline due to the fact that they will be prone to certain pests that will consume them.