

Table 1. Average fecal matter input by geese and ducks, per treatment field per day, LEISA and Conventional farms, Tallahatchie and Leflore County, Mississippi, November-March 2017-2018.

Average (\bar{x}) Fecal Inputs per Field Type per Day (g/ha)			
	(\bar{x}) fecal input	Standard Deviation	Standard Error
CN	258.51	282.72	89.40
CF	659.07	534.09	382.07
LN	677.67	98.24	49.12
LF	1924.62	1005.12	317.85

Descriptive statistics of dry fecal matter contributed to field treatment per day over the fallow season. Significantly higher ($p=0.0012$) inputs in LEISA Flooded (LF) fields than other treatment fields were observed.

Table 2. Results of individual based model statistics for influential soil health indicators (fecal matter, anaerobic, gram-neg HPC microbial activity, %TN, %OM, %C) on LEISA and Conventional farms, Mississippi, November-March 2017-2018.

Response Var.	Test Type	Test Statistic	R ²	Model	Fall Measurement	Fecal Matter Input	Treatment Group
	ANCOVA/Rank-Based	F-statistic/Drop in Dispersion Test	Adjusted/Robust	p-value	Covariate p-value	Predictor p-value	Predictor p-value
Fecal Matter	Rank-Based	11.99	0.54	0.001			< 0.05
Anaerobic Richness	ANCOVA	7.379	0.49	0.0001	0.12	0.36	< 0.05
Gram -	ANCOVA	0.28	-0.12	0.91	0.58	0.49	>0.05
Microbial Activity	Rank-Based	2.28	0.29	0.07*	0.003	0.14	< 0.05
%TN	Rank-Based	7.55	0.58	0.05	0.25	0.35	< 0.05
%OM	ANCOVA	43.113	0.25	0.02	0.13	0.20	< 0.05
%C	ANCOVA	5.06	0.38	0.00	0.33	0.19	< 0.05

Type of test performed on variable (parametric ANCOVA or nonparametric rank-based) and associated statistics: F-value (parametric) or Drop in Dispersion F (non-parametric) and Adjusted R² (parametric) or Robust R² (nonparametric listed. Model parameter significance also included (Fall measurement covariate, fecal matter input and treatment predictors). Bold type indicates significance at $p<0.05$. Asterisk represents significance at $p<0.10$ level

Table 3. Pairwise comparisons of treatment fields of influential soil health indicators between field types, Tallahatchie and Leflore County, Mississippi, November-March 2017-2018.

Soil Parameter	Treatment Comparison					
	CN--CF	LF--CF	LN--CF	LF--CN	LN--CN	LN--LF
Fecal Input	ns	>	ns	>	ns	<
Anaerobic Diversity	<	>	ns	>	>	ns
Gram - Activity	ns	ns	ns	ns	ns	ns
%TN	ns	>	ns	>	ns	ns
%OM	ns	ns	<*	ns	ns	ns
%C	ns	> *	ns	>	ns	ns

Tukey contrasts multiple comparisons of means for general linear hypothesis. Asterisk show significant difference at $p < 0.10$ level, $>/<$ show significant difference between comparison at $p < 0.5$ level, ns=no significance in treatment comparison.

Table 4. Tukey's *post hoc* model effect means and 95% confidence intervals for individual pathogens

Pathogen	Treatment											
	CF			CN			LF			LN		
	\bar{x}	95% CI		\bar{x}	95% CI		\bar{x}	95% CI		\bar{x}	95% CI	
		Lower	Upper		Lower	Upper		Lower	Upper		Lower	Upper
<i>E.coli</i>	2.87	0.767	10.739	4.808	1.082	21.428	1.782	0.891	10.116	2.488	0.310	19.998
<i>Enterococci</i>	1.667	0.087	2.792	0	N/A	N/A	0	N/A	N/A	0	N/A	N/A
<i>C. perfringens</i>	645.65	242.66	1713.95	501.18	186.21	1330.45	3162.27	1188.50	8394.59	1883.64	401.49	8810.48

Results reported in CFU/g dry soil. Bold indicates significant difference between groups.

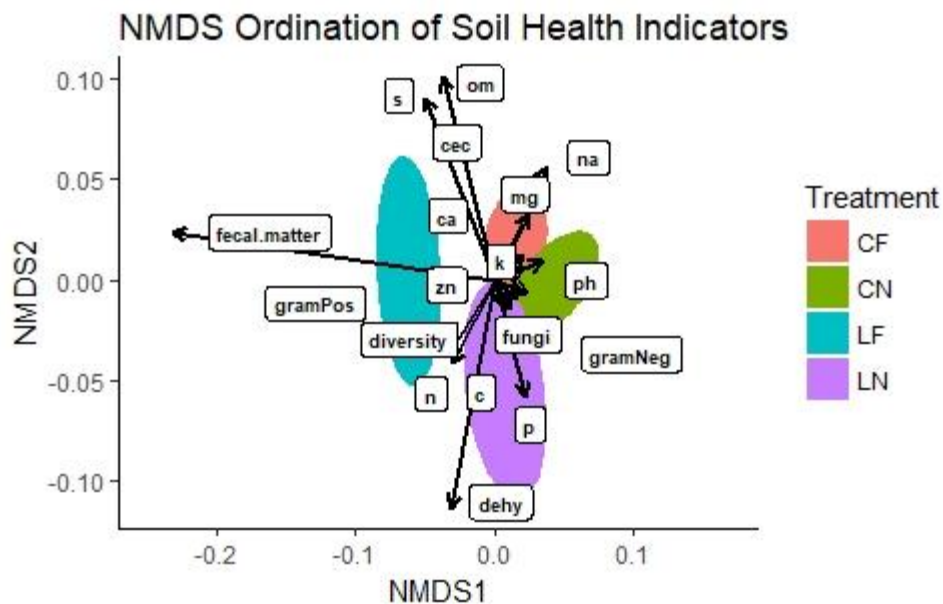


Figure 1. NMDS Ordination of Soil Health Indicators on LEISA and Conventional field treatments. Tallahatchie and Leflore County, Mississippi, November-March 2017-2018.

Nonmetric multidimensional scaling (NMDS) 95% confidence ellipse by field treatment samples. Vectors represent correlation of NMDS axes with soil health indicators ($p < 0.1$). Abbreviations: dehy=dehydrogenase assay/microbial activity, p=Phosphorus, c= %Carbon, n=% Total Nitrogen, gramNeg=Gram – bacteria diversity, fungi=Fungal diversity, diversity=anaerobic heterotrophic bacteria diversity, gramPos= Gram+ bacteria diversity, zn=Zinc, ph=pH, fecal.matter= Bird Fecal Matter inputs, k=Potassium, ca=Calcium, mg=Magnesium, na=Sodium, cec=Cation Exchange Capacity, om= % Soil Organic Matter, and s=Sulfur.

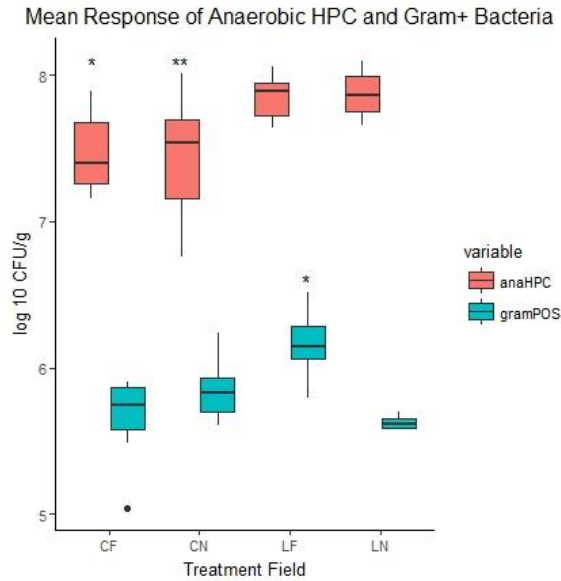


Figure 2. Mean Response of Anerobic HPC and Gram + Bacteria of LEISA and Conventional field treatments. Tallahatchie and Leflore County, Mississippi, November-March 2017-2018.

Asterisk denotes significance difference at $p < 0.05$ level. Points indicate outliers.

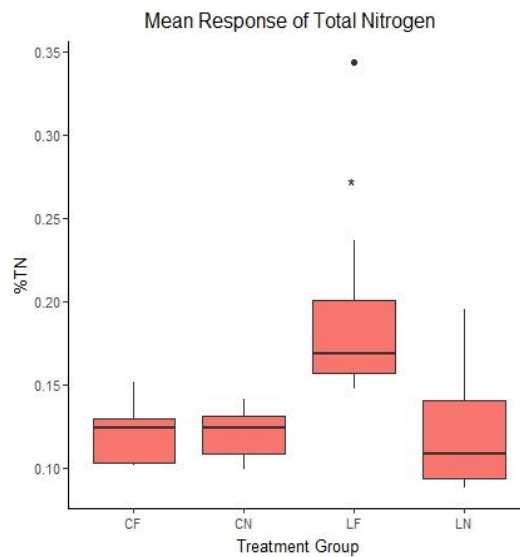


Figure 3. Mean Response of %N in LEISA and Conventional field treatments Tallahatchie and Leflore County, Mississippi, November-March 2017-2018.

Asterisk denotes significance difference at $p < 0.05$ level. Points indicate outliers.

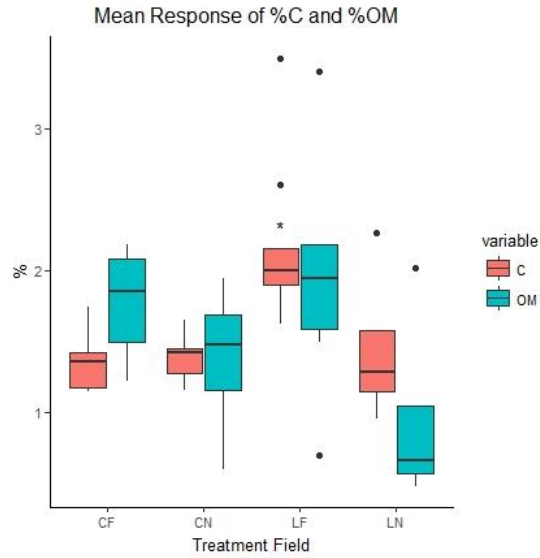


Figure 4. Mean Response of %C and %OM in LEISA and Conventional field treatments. Tallahatchie and Leflore County, Mississippi, November-March 2017-2018.

Asterisk denotes significance difference at $p < 0.05$ level. Points indicate outliers.

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Introduction

Rice is a staple food for more than half of the population and has the ability to support more people per unit of land area than wheat or corn. However, there are concerns about the sustainability of rice production practices pertaining to soil and water quality. Conventional farming practices (relying on external inputs) can affect nutrient cycling and availability in soils and subsequently the water quality. Using an alternative farming approach, Low external input sustainable agriculture (LEISA), which is a production approach that optimizes the use of locally available resources while minimizing the use of fertilizers or pesticides, has the potential to improve soil health and prevent soil degradation while improving water quality. This study using soils from four different fields, under four different management regimens in the Mississippi Alluvial Valley (MAV) measures these effects via a soil column experiment. Soils were kept at set temperatures to mimic winter weather, and ecologically relevant concentrations of phosphorus and nitrogen were added to each column. Water was tested for changes in nutrient concentration to assess soil-water interactions at specified intervals. It is hypothesized that LEISA soils will facilitate nutrient reduction in overlying water concentration than those from conventional rice production systems.

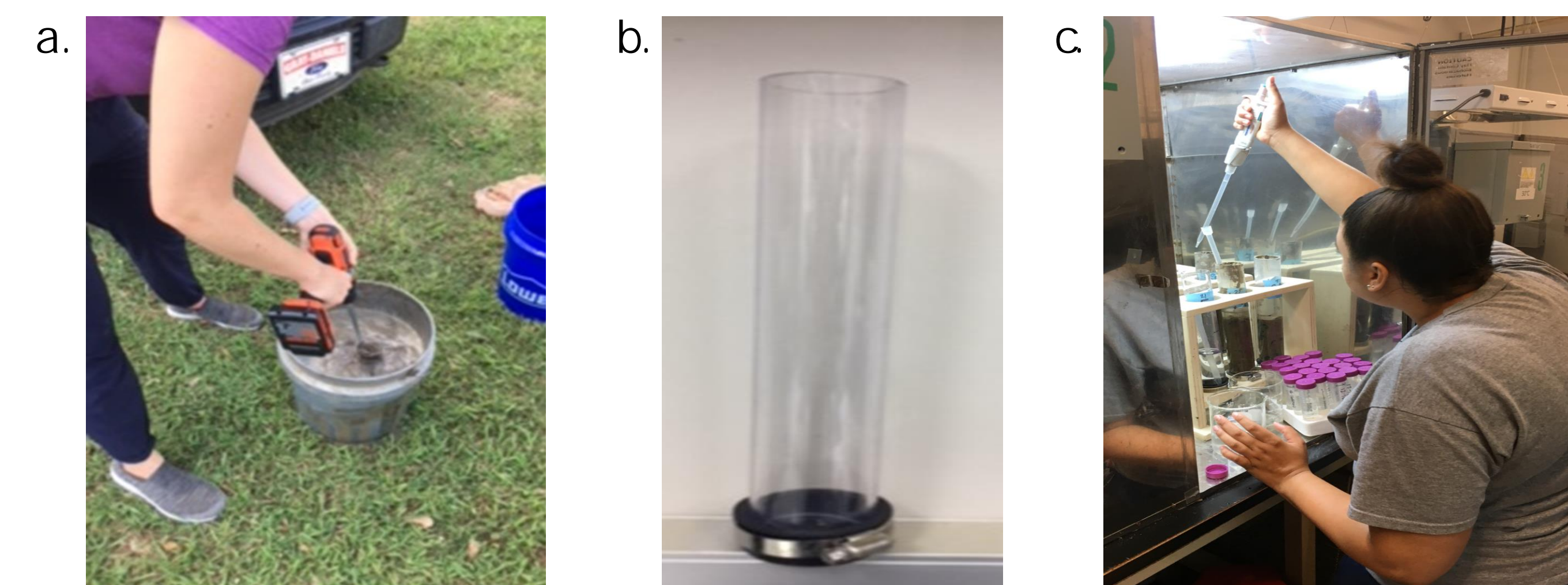


Figure 1. a) Soils being mixed into a pourable slurry using an electric drill; b) depicts cylindrical microcosm columns measuring 30.48 cm X 5.08 cm capped off with 3.81 cm (Econo) test caps, fastened with stainless steel clamps; c) shows water sampling from temperature controlled chambers.

Methods

Forty liters of topsoil (approximately 1 liter from each field) were collected from four study fields: LN, LF, CN, CF. Initial soil moisture content of each soil was determined by weighing 10 grams of moist soil, then placing it in a drying oven for 24 hours. Soils were weighed again, and percent moisture was calculated from the differences. Groundwater was added to each soil type until soil was homogenized to a pourable slurry state (Figure 1). The slurry soils were distributed by treatment into cylindrical microcosm containers (Figure 2), filled to approximately half of the containers volume. Microcosms were dried back to their original moisture content. Microcosms were then set up in a randomized block design: four liters of groundwater experimentally formulated into moderately hard reconstituted water, containing concentrations of N and P (5.67 mg/L and 6.37 mg/L, respectively) added to all experimental columns. The microcosms were then placed in environmental chambers with temperatures set to approximately 5°C high and a 4°C low. At predetermined intervals (24, 48, and 168 hours), 30 mL of water from each microcosm was tested for changes in nutrient concentrations. Samples were analyzed for TN in liquid samples using HACH TNT 880 kits. Total inorganic phosphorus (TIP) was also analyzed using HACH TNT 843 and 845 kits. Percent change in nutrient concentrations between time periods was calculated. Preliminary descriptive statistics indicated non-normality of data, which was confirmed with both Kolmogorov-Smirnov and Shapiro-Wilk tests. Because of that, non-parametric Analysis of Variance (ANOVAs) were used to assess nutrient reduction difference between farm treatments at each specified time interval. Post hoc analysis significant p-value was set at 0.05.

Results

Results of ANOVA for time period 0-24 hours showed no significant difference for TN ($P > 0.05$). Results for TIP showed significant differences between farms ($P = 0.01$). Post hoc pairwise comparison results for TIP showed LF to be significantly different from E ($p = 0.004$) and LN to also be significantly different from E ($p = 0.012$). Kruskal-Wallis test showed significant differences between both TN ($p = 0.001$) and TIP ($p = 0.004$) for time period 24-48 hours. Post hoc pairwise comparison result for TN showed LF to be significantly different from CF ($p = 0.036$) and E ($p = 0.001$). Pairwise comparison of TIP also showed LF to be significantly different from E ($p = 0.002$). No significant difference between farm treatments were found for time period 48-168 hours for TN or TIP ($P > 0.05$).

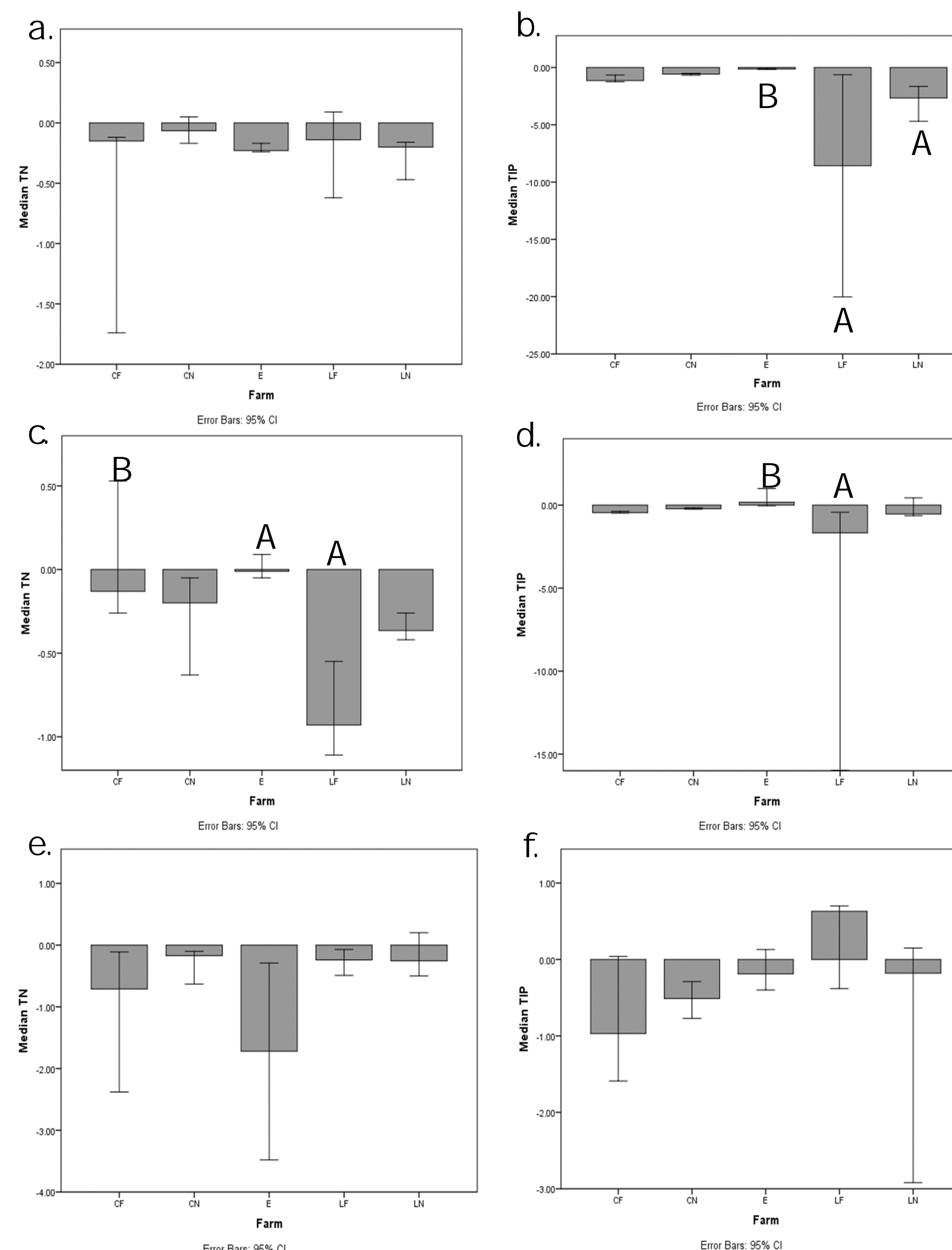


Figure 2. Nutrient concentration percent change are reflected on the y-axis. Figure a) 0-24 hour Median TN; b) 0-24 hour median TIP; c) 24-48 hour median TN; d) 24-48 hour TIP; e) 48-168 hour median TN; f) 48-168 hour median. *Units are indications of percent change, however they are not in percentage form.

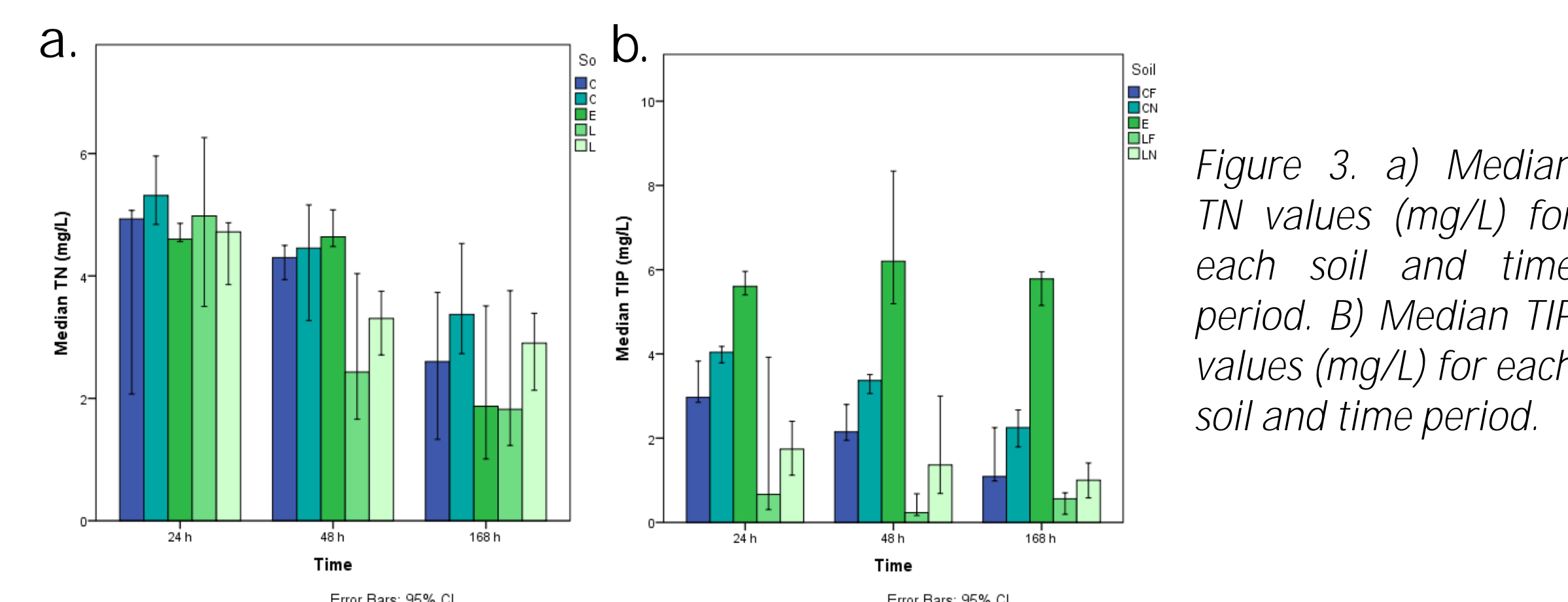


Figure 3. a) Median TN values (mg/L) for each soil and time period. b) Median TIP values (mg/L) for each soil and time period.

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Table 1 Summary statistics of percent change in water nutrient concentrations for each treatment for 24 hours.

Farm	Total Nitrogen (TN)				Total Inorganic Phosphorus (TIP)			
	Mean	Median	Min.	Max.	Mean	Median	Min.	Max.
CF	-48%	-15%	-174%	-12%	-105%	-114%	-124%	-66%
CN	-6%	-7%	-17%	5%	-59%	-58%	-68%	-52%
E	-22%	-23%	-24%	-17%	-13%	-14%	-18%	-7%
LF	-24%	-14%	-62%	9%	-919%	-858%	-2002%	-63%
LN	-27%	-20%	-47%	-16%	-272%	-266%	-469%	-165%

Table 2 Summary statistics of percent change in water nutrient concentrations for each treatment for 24-48 hours.

Farm	Total Nitrogen (TN)				Total Inorganic Phosphorus (TIP)			
	Mean	Median	Min.	Max.	Mean	Median	Min.	Max.
CF	-2%	-13%	-26%	53%	-43%	-45%	-48%	-37%
CN	-27%	-20%	-63%	-5%	-21%	-22%	-24%	-16%
E	2%	-1%	-5%	9%	28%	18%	-4%	100%
LF	-86%	-93%	-111%	-55%	-413%	-167%	-1597%	-43%
LN	-35%	-37%	-42%	-26%	-32%	-54%	-64%	44%

Table 3 Summary statistics of percent change in water nutrient concentrations for each treatment for 48-168 hours.

Farm	Total Nitrogen (TN)				Total Inorganic Phosphorus (TIP)			
	Mean	Median	Min.	Max.	Mean	Median	Min.	Max.
CF	-85%	-71%	-238%	-11%	-83%	-97%	-159%	4%
CN	-27%	-17%	-63%	-10%	-52%	-51%	-77%	-29%
E	-154%	-172%	-348%	-29%	-12%	-19%	-40%	13%
LF	-26%	-24%	-49%	-7%	26%	63%	-38%	70%
LN	-21%	-26%	-50%	20%	-78%	-18%	-292%	15%

Discussion

Results moderately supported hypotheses that LEISA soils (LF and LN) would improve nutrient removal from overlying water as significant differences between LF and the control (E) were observed after 24 hours for TIP, and significant differences were observed after 48 hours between LF and E and CF for TN and between LF and E for TIP. Summary statistics also indicate greater mean and median nutrient reduction after 48 hours for LF and LN. Results indicate that, in LEISA soils, most nutrient removal occurred between 0 and 48 hours, whereas nutrient reduction in conventional soils increased during the 48-168 time interval. We would expect the LEISA soils (LF and LN) to impact nutrient concentrations differently due to the minimal tillage practices and addition of organic wastes via animal defecation that have been applied to these soils, in addition to inorganic fertilizers during their life history. The conventional soils (CF and CN) on the other hand did receive inputs of fertilizer. The use of fertilizer may be fundamental to maintain yields, however, the risk of overfertilization that can cause imbalance of nutrients in soil (Sass 2012). Unlike LEISA soils, the conventional soils (CF and CN) have a life history of regular tillage. Intensive tillage practices fracture the soil, disturb soil structure, and can accelerate surface runoff and soil erosion (Al-Kaisi, Hanna, Tidman). According to the United States Department of Agriculture and Natural Resource Conservation Services, Tilling the soil is the equivalent of an earthquake, hurricane, tornado, and forest fire occurring simultaneously to the world of soil. Nutrient cyclings facilitated by soil organisms, which require adequate environmental conditions to thrive. Increases in TIP in certain samples are likely a result of anaerobic conditions causing dissolution of P from soil back into the overlying water. In general, the results moderately support the hypothesis, however, there were soils from two farms and replication was limited to 5 replicates of each treatment. Potential future research may consider utilizing intact soil cores, considering different time intervals, and investigating more complex modeling of the data.

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