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*Local Ecology Research Papers*

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# Impact of Soil Quality by Long-term no-till Practices and Artificial Drainage Systems

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JONES, ANNIKA M. St. Olaf College, Northfield, MN, USA. **Impact on Soil Quality by Long-term no-till Practices and Artificial Drainage Systems.**

*Abstract* – Agricultural management systems can impact soil quality in several ways. I investigated the impacts that agricultural management systems have on the physical and chemical soil quality of corn-soybean fields near St. Olaf. Three research sites were chosen, all of which employ a no-till agriculture scheme on a two-year corn-soybean rotation. However, they differ by their classification as either long-term or short-term no-till practice and by their water drainage system. The soil quality of these fields was assessed by measuring their percent organic matter, percent moisture, soil bulk density, and their nitrate and phosphate concentrations. The results indicate that there was no significant difference in soil moisture, organic content or bulk density among the sites. The long-term no-till site had a significantly higher phosphate concentration than the short-term no-till site with natural drainage. Soil nitrate concentration significantly differed as well, the highest being in the short-term no-till site with natural drainage and the lowest in the short-term no-till site with artificial drainage. This study implies that these three fields are similar in soil quality regardless of their differences in water drainage systems and length of no-till practice.

*Introduction*

Soil vitality is an easily overlooked but crucially important aspect of our existence. In order to sustain a healthy population, our agricultural practices must support rather than degrade the land we depend on for food. Only recently, however, have we realized and explored this link between agricultural management systems and their impacts on soil quality. The growing awareness of this link has renewed interest in the study of agroecosystems. An agroecosystem can be defined as "a dynamic association of crops, pastures, livestock, other flora and fauna, atmosphere, soils and water" (U.S. EPA). Furthermore, they are parts of larger landscapes that include things such as urbanized land, drainage networks and wildlife (U.S. EPA). Keeping the concept of an agroecosystem in mind, my study explored the associations and possible causes of soil degradation in relation to no-till farming systems and water drainage mechanisms.

In an agricultural sense, soil is simply the medium in which most of our food is grown, as well as the food we provide for livestock. Biologically speaking, soil is the habitat of plant roots and of a diverse range of microscopic and macroscopic organisms that contribute to agroecosystem productivity and health (Giller et al. 1997)). Recent studies assert that the interactions between agricultural management practices and environmental conditions can significantly affect soil function (Varvel et al. 2006). This in turn affects the quality and yields of our food supply. Information gained from soil assessments can be used to encourage sustainable agricultural management practices, allowing the soil to support vital crop yields (Varvel et al. 2006). This information can also help to characterize the physical, chemical and biological aspects of soil and how they are affected by changes in management (Varvel et al. 2006).

Since many years are needed for certain soil characteristics to change in any measurable way (Varvel et al. 2006), long-term ecological studies are crucial in assessing the soil health of a particular agroecosystem. In addition, each agroecosystem varies due to differences in local topography, so it is important that agricultural management plans take these local differences into consideration (Strock et al. 2005).

Previous research has shown that no-till cropping systems affect soil's physical and chemical properties differently than conventionally tilled systems. Conventional soybean farming involves a multi-year corn and soybean rotation that is tilled by a chisel plow and disk ripper each year (Gregory et al, 2004). However, no-till practice leaves the previous year's crop residue on the surface of fields after harvest rather than plowing it under, affecting soil on a physical level by increasing the amount of soil organic matter and soil moisture (Gregory et al. 2004). This especially may hold true in the long-term with regards to soil moisture, as McCoy et al. (2006) have shown that the amount of soil water stored in a no-till system is significantly greater than in a conventionally tilled system as both systems aged over the course of the study. No-till agriculture has shown to control sediment losses and reduce negative impacts on water quality, as well as influence soil properties such as temperature, aeration and bulk density (Evans et al 1996). By helping to reduce wind and water erosion of topsoil, no-till practices lessen the negative impacts of excess phosphorous loading when sediment enters a waterway (Evans et al. 1996). Chemically and biologically speaking, it also has been shown to increase soil macroinvertebrate abundance, which in turn aids the decomposition and nutrient cycling processes (Gregory et al. 2004). Still, this relationship is highly variable depending on local climate and other contributing factors, thus underscoring the need for further studies in this area.

Water drainage systems in agricultural fields have also been studied in the past, although not to the same extent that tillage has. One way of draining excess water from agricultural land is by installing a tile drainage system (Legvold 2006). This network of underground pipes drain excess water downhill and empty it into a nearby stream or ditch, which helps the soil become drier and more fertile for planting seeds (Legvold 2006). When agricultural fields cannot drain excess water from the soil, crop productivity tends to suffer and cause a decline in yields to farmers (Randall et al. 2003). While helpful in managing water in poorly drained soils, artificial drainage systems may increase nitrate loads to surface waters (Kladivko et al. 2004). Evans et al. (1996) have also found that poorly drained soils may require more tillage than well-drained soils due to differences in soil temperature. Tile water drainage could help this situation but still may not be enough to offset crop yield losses under no-till systems. Thus more long-term research on different soil types in different climates is needed in order to understand how to sustainably manage our food production (Kladivko et al. 2004).

My study investigated the impacts that agricultural management systems have on the physical and chemical soil quality of soybean fields near St. Olaf. More specifically, I tested the effects of two agricultural management practice variables on soil quality. The first variable was the length of time since conversion from conventional to no-till practice, and the second variable was the presence of a tile water drainage network on sloped agricultural land.

In light of what has been discovered by other agricultural studies over the past 15 years at St. Olaf, my research intends to continue adding new information on sustainable agricultural practices. Past research has established a solid base of information regarding the ecological comparisons between conventional, organic and no-till farming, whereas my study aims to narrow the focus on the differences among fields that are already under no-till, rotational cropping practices. These results are intended to add to the available information on soil conditions in fields with particular agricultural practices.

The specific purpose of my study is to compare soil quality in terms of its organic matter, moisture, bulk density, nitrates and phosphates within three corn-soybean fields near St. Olaf. My hypotheses are that soil quality, as measured by higher levels of organic matter, moisture, nitrates, phosphates and lower soil bulk density, improves with increased time since adopting no-till practices and that drainage tiling will decrease soil moisture levels.

*Methods*

Three sites in southern Dakota County were chosen for soil sampling, all of which are currently corn-soybean two-year rotation fields employing no-till practice. However, they differ by their classification as either long-term (15 years) or short-term (3 years) no-till agriculture and by their water drainage system as either natural or artificial. Sites 1 and 2 have a natural water drainage system, but site 1 has been under no-till management for 15 years while site 2 has been no-till for only 3 years. Site 3 has also been under no-till management for 3 years, but it differs from the other sites in that it is a sloped piece of land with a recently established drainage tile network to reduce soil erosion. St. Olaf College has owned and leased to farmers the land occupied by sites 2 and 3, but site 1 is a much smaller piece of agricultural land that is immediately adjacent to private residential property and not owned by the college. The soil in this area of these sites is classified as 'soil association #2' by the USDA Soil Conservation Service.

Soil organic matter, moisture, bulk density, phosphates and nitrates were measured by taking a series of random 15cm soil core samples from each site on two separate sampling dates. All sampling was done in mid-October through early November of 2006. A series of three random soil core samples were taken for the measurement of soil organic matter, moisture and bulk density on each sampling date for each of the three sites. They were placed in metal soil tins and labeled according to site, day and sample number. The samples for measuring nitrate and phosphate levels were taken from a series of six randomly chosen locations within each site on each sampling day. These six soil core samples were combined into one plastic bag and labeled according to site and day.

All physical and chemical analyses of soil characteristics were done according to the procedures described by Shea et al. (2004) in Methods for Soil Analysis at St. Olaf College. Phosphate and nitrate levels were converted from absorbance to concentration (ppm) through a standard phosphate and nitrate functional equation given by Methods of Soil Analysis at St. Olaf College (Shea et al. 2004). Data were statistically analyzed using STATA software (Statacorp 2004) to calculate means, standard deviations, and significance values with one-way ANOVAs of group means for percent moisture, percent organic matter, bulk density, and phosphate and nitrate concentrations.

*Results*

The results indicate that there was no significant difference in soil moisture, organic content or bulk density among the sites. As shown in Figure 1, mean percentages of soil moisture ranged from 19.4% in Site 3 to 21.2% in Site 2, which was statistically insignificant in difference ($p = 0.52$).

Mean soil bulk densities, displayed in Figure 2, did not significantly differ among sites ($p = 0.27$), ranging from 0.318 g/cm$^3$ in Site 2 to 0.338 g/cm$^3$ in Site 3.

Figure 3 shows that the mean percentages of soil organic matter varied from 5.42% in Site 3 to 5.83% in Site 2, with strong evidence that this variation was due to natural statistical variation rather than environmental differences ($p = 0.82$).

In contrast to the similarities among sites in terms of physical soil qualities, the results indicate that there were significant differences among sites in their mean phosphate and nitrate concentrations. As seen in Figure 4, Site 1 had a significantly higher mean phosphate concentration than Site 2 ($p = 0.013$), ranging from 13.29 ppm to 10.02 ppm, respectively.

Mean soil nitrate concentration significantly differed between all three sites ($p = 0.010$), with Site 2 at 12.62 ppm being significantly higher concentration than that of Site 1, and Site 1's mean nitrate concentration of 12.62 ppm being significantly higher than Site 3 at 9.36 ppm (see Figure 5).

*Discussion*

*Moisture, Bulk Density and Organic Matter*

The similarity among sites in terms of their percent soil moisture did not support the study's hypothesis that length of no-till practice and the presence of an artificial drainage system would alter soil moisture levels. These unexpected data can be explained by several possible factors. First, all three of the sites had two major management practices in common, namely that they were no-till fields experiencing the same two year crop rotation of corn and soybeans. Since each of the sites cultivated the same two crops, they could be expected to produce not only similar amounts and types of plant residue on the field. This has important ramifications on soil characteristics because corn generates more residue than soybeans, and furthermore soybean residue is considered ‘fragile’ and easily decomposed in comparison with corn residue, which is ‘non-fragile’ and hardy (Evans et al. 1996). Given that all three study sites grew corn and soybeans on a two year rotational basis, they undergo the same cycle of decomposition of these two residue types and thus may have similar capabilities to trap moisture in the soil and maintain comparable soil densities and levels of organic matter.

Second, the time scale could be a key to understanding why these sites showed such similar physical soil qualities. The rate at which certain soil characteristics change in any substantial way is known to be fairly slow, as mentioned earlier (Varvel et al. 2006). This means that what my study classified as a ‘long-term no-till’ field (15 years) could in fact still be considered ‘short-term no-till’ since many years are needed in order to measure changes in particular soil properties, and that the sites chosen to be studied may all be representative of the earlier stages of field conversion from conventional to no-till agriculture. Given the opportunity in a future study to compare agricultural fields with a greater variation in the amount of time since adopting no-till practices, more significant differences in soil moisture, density and organic matter might be revealed.

Finally, the physical soil property similarities among the three sites may be partially explained by the nature of the tile drainage system itself. The artificial water drainage system present in Site 3 was designed to target the subsoil rather than the top 15cm of soil from which core samples were taken in this study. Thus the hypothesis that Site 3 would show significantly lower mean percent moisture than the other 3-year no-till field (Site 2) was based on the assumption that the improved water drainage system would impact soil moisture within the top layer. Another possible explanation for the similarities observed is that the soil sampled in Site 3 had undergone a mixing of soil layers to a certain extent during the process of tile installation in 2005.

The results did not support the hypothesis that an artificial water drainage network would decrease soil moisture levels on a no-till field. This hypothesis implies that a no-till field with drainage tile would have no significant difference in soil moisture than a tilled field with natural drainage, since these two management practices could counteract each other in this regard. However, since soil moisture levels in the tile-drained field remained the same as in the fields with natural water drainage, these results imply that the artificial drainage system affects only deep subsurface soil rather than upper A horizon soil.

### *Phosphate and Nitrate Concentration*

A significant difference was found among sites in terms of soil phosphate concentrations, as seen in Figure 4, with the long-term no-till site (Site 1) having a significantly higher phosphate concentration than the short-term no-till site with natural drainage (Site 2). There was also a significant difference found in terms of soil nitrate concentration, shown in Figure 5, with Site 2 showing a significantly higher concentration and the short-term no-till site with artificial drainage (Site 3) showing a significantly lower nitrate concentration than the other two sites. These differences among sites can be explained by several possible factors.

First, the drainage tile in Site 3 may also be draining nutrients from the soil along with excess water. This could explain why the mean nitrate concentration in Site 3 was found to be significantly lower than those of the other two sites. These fields with natural water drainage systems are less likely to lose soil nutrients than the field with drainage tile since the purpose of the artificial water drainage system is to help manage water in poorly drained soils, and nutrients such as $NO_3$ can dissolve in subsurface water and be drained along with it. As mentioned before in Kladivko et al.'s study (2004), artificial drainage systems may increase nitrate loads to surface waters, thus supporting the data found by this study that the field using an artificial drainage system showed significantly lower nitrate concentrations within the soil.

Second, the amount and type of fertilizer applied to crops may be greater in some fields than in others. Since these three fields have been farmed by two different farmers, it is possible that their choices about fertilizer application to the soybean fields may differ depending on the characteristics of each field. For instance, the significantly higher mean soil nitrate concentration in Site 2 could be partially due to the fact that it is farmed by a different person than Sites 1 and 3. Given that fertilizer is a costly commodity, however, it is unlikely that either farmer chooses to apply a greater quantity of fertilizer to their field than what is necessary. Rather, it is more likely that any differences in fertilizers applied to these fields would be due to their particular blends of Phosphorous and Nitrogen.

Finally, differences observed in chemical soil qualities among sites may be attributed in part to their qualitative soil differences and proximity to non-agricultural property. As samples were taken from each field, it became apparent that Site 1 had a noticeably greater proportion of ground covered by weedy species such as dandelion, whereas Sites 2 and 3 had virtually bare soil aside from the decomposing crop residue. This could contribute to Site 1's significantly higher mean concentration of soil phosphates since the vegetation composition of the fields differed. Sites 2 and 3 were also much larger than Site 1 and were not within such close proximity of non-agricultural land the way that Site 1 was. This could mean that animals from nearby patches of forest or from the private residential property next to Site 1 may be leaving scat or dispersing other plant species into the field, thereby impacting soil nutrient levels.

## *Conclusions*

This study implies that these three fields are similar in physical soil quality regardless of their differences in water drainage systems and length of no-till practice. The results of this study neither supported nor rejected the hypothesis that as fields had been under no-till management for a greater amount of time, the quality of the soil would increase, as measured by higher percent moisture, organic matter, phosphates and nitrates and lower bulk density. However this study did imply that the presence of an artificial water drainage system on its own does not affect soil moisture levels, but future studies would have to be done in order to discern the multi-year time scale necessary to observe and measure potential changes in soil characteristics due to the length of no-till practice and the use of artificial drainage systems on agricultural fields.

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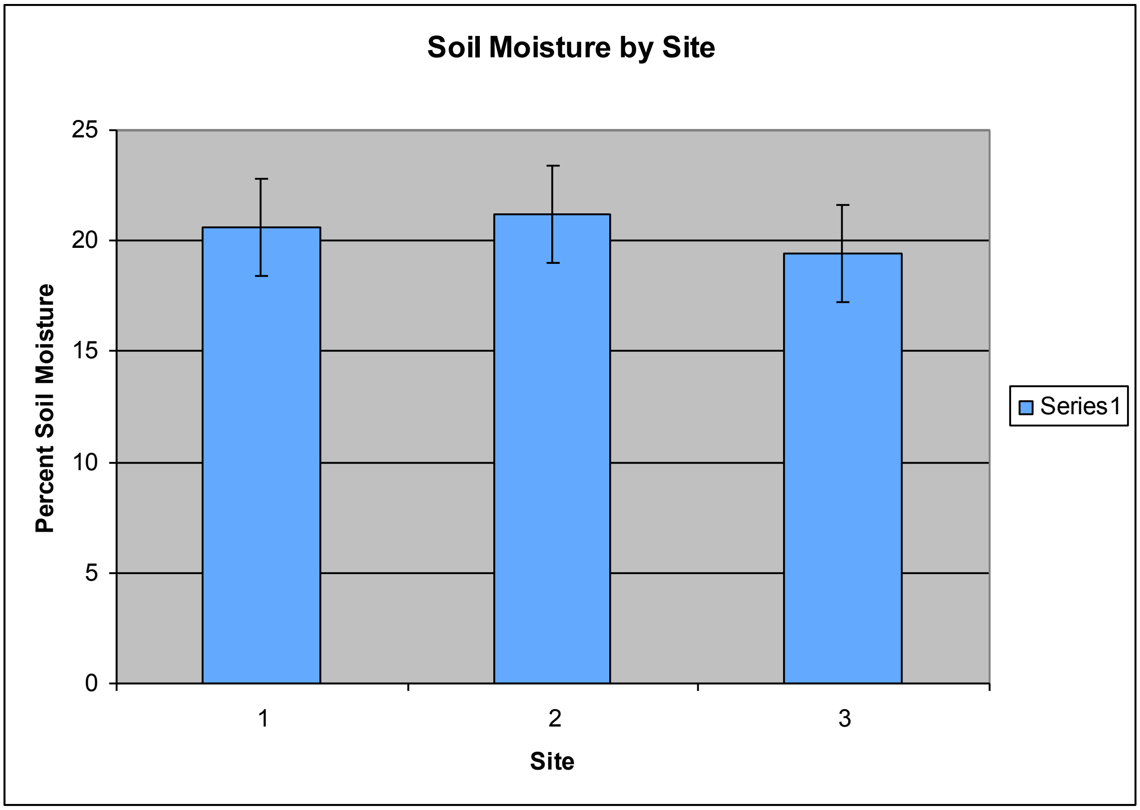


Figure 1: Mean percent soil moisture found in each site, with no significant difference shown between sites (p=0.52).

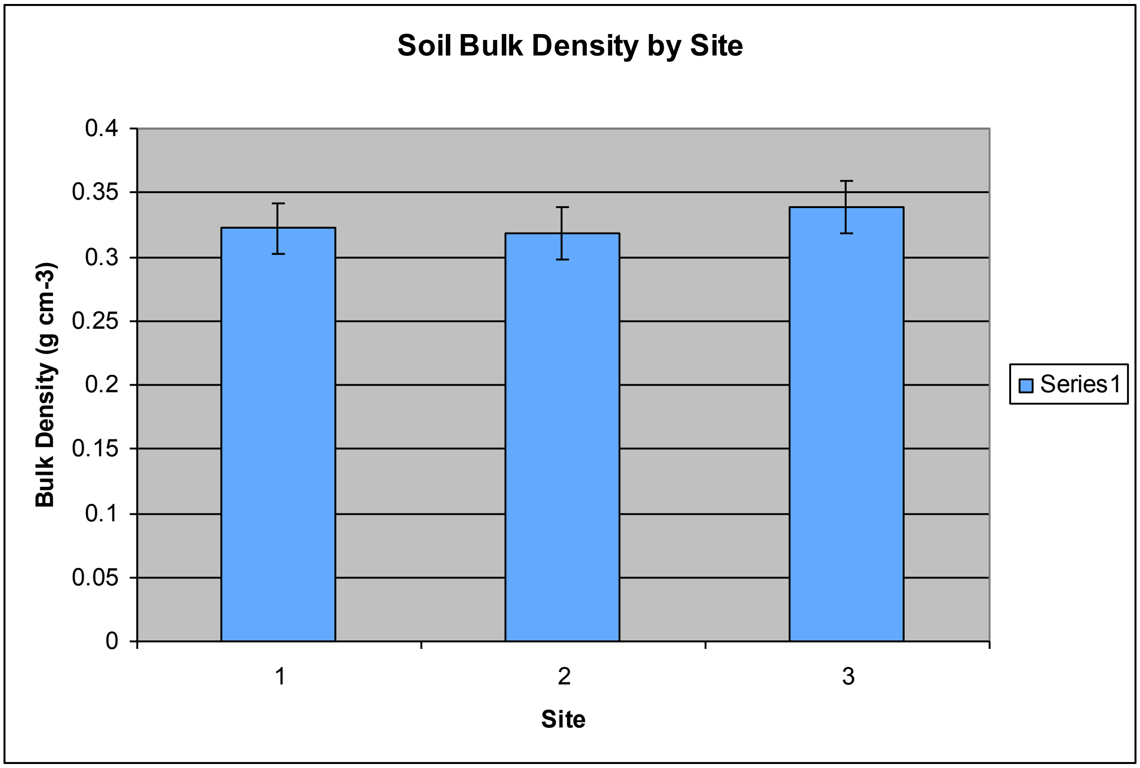


Figure 2: Mean soil bulk densities (g/cm$^3$) in each site, showing no significant difference among sites ($p=0.27$).

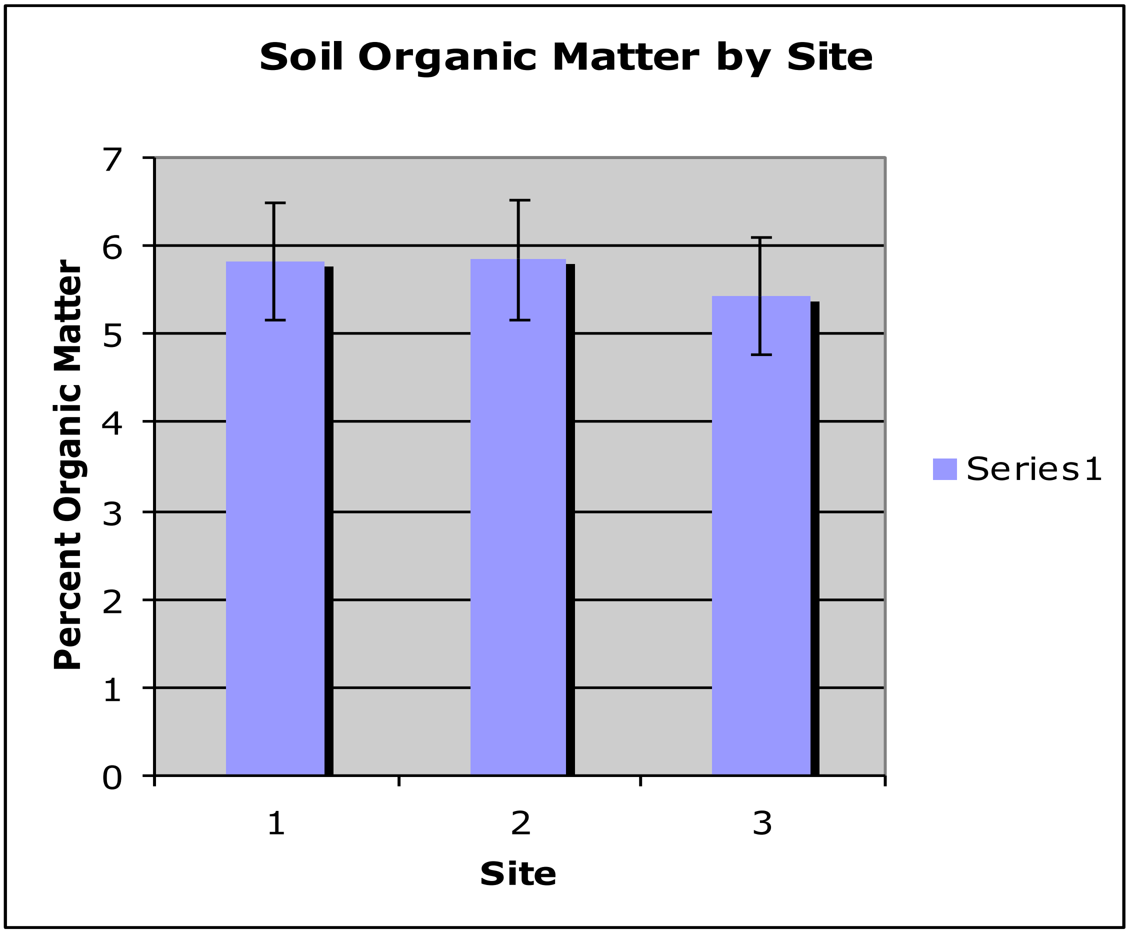


Figure 3: Mean percent soil organic matter found in each site, with no significant difference observed between sites (p=0.82).

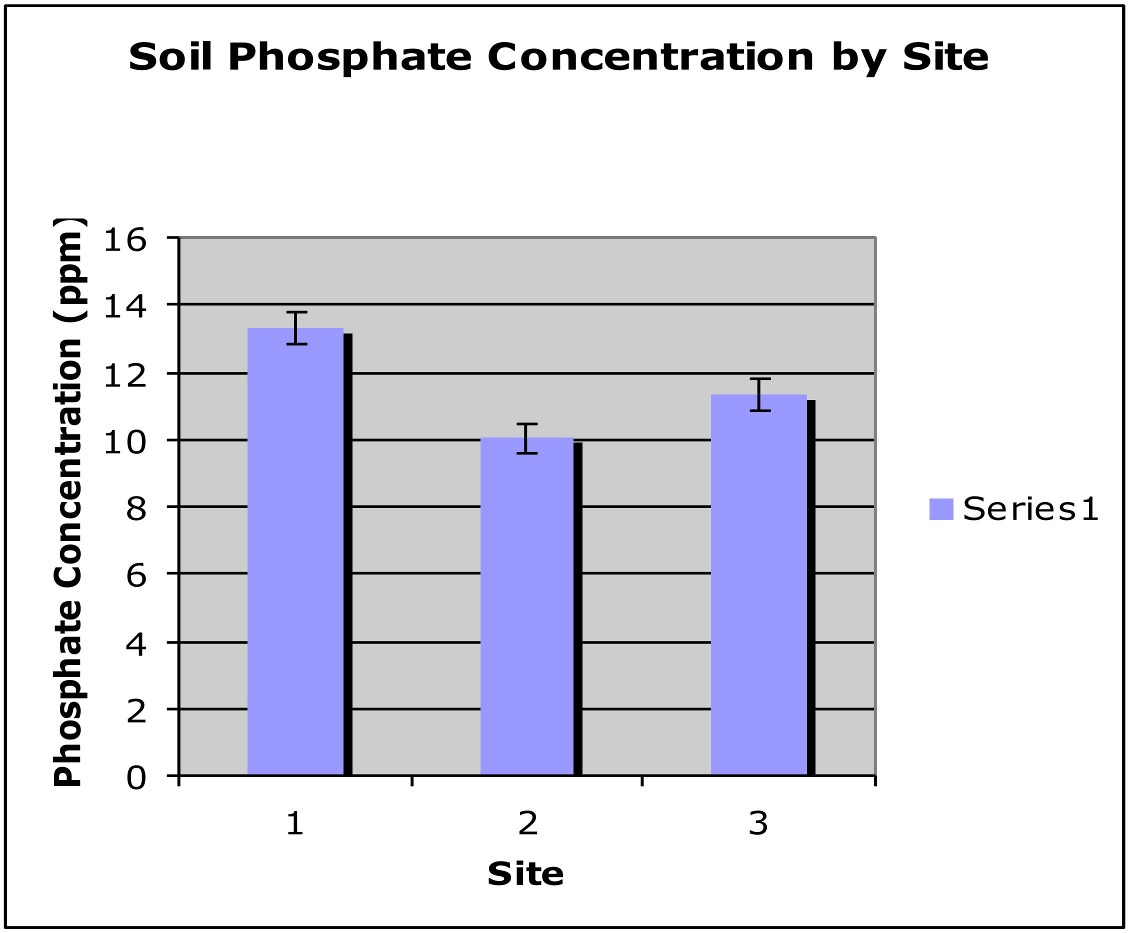


Figure 4: Mean concentration (ppm) of soil phosphates in each site, with Site 1 having a significantly higher concentration than Site 2 (p=0.013).

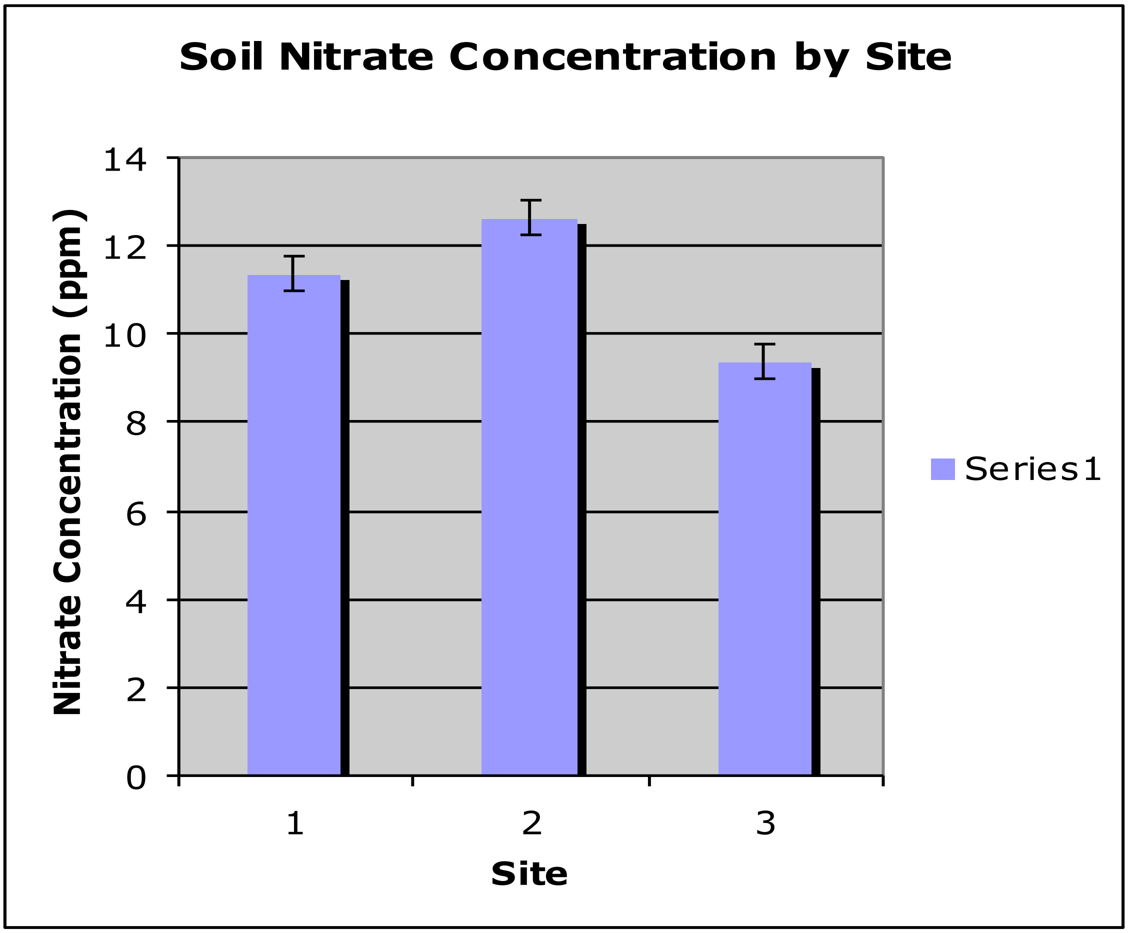


Figure 5: Mean concentration (ppm) of soil nitrates found in each site, with Site 2 having significantly higher concentration than Site 1 and Site 1 significantly higher than Site 3 ($p=0.010$).