# Does the Presence of *Malus spp.* Increase the Fertility of the Soil Surface in Pastures?


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## Abstract

Techniques to increase soil fertility in a pasture can benefit the system by combating soil degradation and increasing the health of vegetation. The use of apple trees *(Malus spp.)* may be particularly beneficial in achieving this due to reliable fruit yields, ease of management, and variety of suitable habitat. We hypothesized that soil directly under the canopy of apple trees would be higher in nutrients (C, Ca, K, Mg, N, & P) than soil in areas with no tree cover. Soil samples were taken from the top 15 cm of the soil surface under apple trees and in areas without trees at 14 sites in Massachusetts and New York. Samples were analyzed using spectrometry and color imagery to determine nutrient content. Potassium and magnesium concentrations were found to be significantly higher in under-canopy samples. Further research may expand these results and determine if the application of apple trees can be used to increase the health of pasture systems.

## Acknowledgements

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## Introduction

Raising livestock on a pasture has many benefits over the conventional feedlot system (Clancy, 2006). However, there are a number of short term and long term challenges that must be addressed. One major challenge is maintaining the fertility of the pasture. The conventional method of adding large amounts of commercial fertilizer to highly stocked, continuously grazed pastures has been linked with decreased pasture fertility and polluted water resources (Osei *et al.* 2003). When stocking rates are aligned with a pasture's natural carrying capacity, the livestock play an integral role in the cycling of nutrients throughout the pasture. However, if a pasture is supporting more livestock than natural inputs can compensate, soil fertility will be negatively affected and the practice is then unsustainable (Bouman *et al.* 1999). Fruit trees have the potential to increase pasture fertility by concentrating fertility in upper soil horizons and capturing nutrients from lower horizons.

Managing the flow of nutrients off farms is a challenge in many conventional farming systems. A phenomenon referred to as nutrient mining can be caused by processes such as erosion, leaching, or harvesting of crops, among others (Drechsel *et al.* 2001). When plants and animals are raised and then removed from a pasture, nutrients are lost and accumulate in waste systems (Drechsel *et al.* 2001).

Conversely, biogeochemical hotspots are areas with high nutrient concentrations and nutrient cycling due to intersections of nutrient and hydrologic flow (McClain *et al.* 2003), but biotic factors such as plants can also provide nutrient vectors (Wetzel *et al.* 2005). It has been found that among ecosystems plants can create "islands of fertility" characterized by increased soil fertility under the canopy of certain shrubs, trees, and grasses (Schlesinger *et al.* 1996). The nutrient hotspots are likely formed from biogeochemical cycling: roots from vegetation uptake the nutrients from the soil, fruit and leaf litter then decompose under the tree, thus enriching the soil (West & Skujins 1977). Soil fertility largely determines species composition and health (Ordoñez *et al.* 2009), so these nutrient hotspots can support healthier or different plants than the surrounding areas. Growing trees in an open space, such as a pasture, may create a small fertile zone around the base of the tree likely due to litter fall (Reis *et al.* 2010), however little research has been done on the specific mechanism in a pasture setting.

Trees can be used in a pasture to benefit the system in multiple ways. Trees provide shade to shelter livestock from heat stress, can expand sources of income both short and long term, and can aid in the cycling of nutrients (Klopfenstein *et al.* 1997). In a pasture with trees, the forage has access to higher quality soil based on their vicinity to the trees (Obrador *et al.* 2004), which results in higher quality forage available to the livestock. Additionally, trees benefit the forage by providing the topsoil with extra water from lower soil horizons (Horton & Hart 1998). This process is termed hydraulic lift, which begins by roots taking up water into the tree for use during photosynthesis. At night when trees are no longer photosynthesizing, water seeps back out of the roots into upper soil horizons (Horton & Hart 1998). This may benefit surrounding forage, especially during drought conditions.

Apple trees *(Malus spp.)* are an attractive choice for use in a pasture setting. Apple trees can grow in a wide variety of soil types and climates, but generally thrive in cool temperate zones with deep, well-drained soil (Collett 2011). A benefit to using apple trees over other tree options in a pasture is that the apples are not wind dispersed. Unless animals are allowed to consume or remove the fruit, they will stay where they fall and decompose. Apple trees are considered alternate bearing fruit trees, describing the way individual trees alternate between heavy mast years and years with low fruit production (Smith and Samach, 2013). Much research has been done to quantify nutrient levels in the leaves and fruit throughout the growing season. Total amounts of nutrients (including Ca, K, P, N and Mg) in fruit and leaves have been shown to increase gradually with fruit maturation, regardless of variety (Nachtigall & Dechen 2006). Microfauna within the soil can aid in the decomposition of organic material and cycling of nutrients (Bonkowski *et al.* 2000). If concentrations of decomposing apples increase soil fertility, the soil may have the ability to support more abundant populations of microfauna and other plants such as forages, which will capture those nutrients.

Our study aims to determine if apple trees can be a valuable option for increasing soil fertility in the upper soil horizon in pastoral settings. We hypothesize that soil samples taken under the crowns of apple trees will be higher in nutrients (Ca, K, P, N, Mg and C) than samples taken from a nearby areas with no tree cover.

## Methods

*Study Site*

Our study was conducted in northern New York and in central Massachusetts. Northern New York has a mean annual temperature of 4.44°C with 100-120 frost-free days per year and over 127 centimeters of precipitation (NCDC, 2011). Central Massachusetts has a mean annual temperature of 9.44°C with 140-160 frost-free days per year and 102-127 inches of precipitation (NCDC, 2011). Soils in these areas are either inceptisols or spodosols formed through glaciation and have a sandy loam texture (Ciolkosz *et al.* 1989). Specific soil types and site descriptions can be found in Table 1.

Table 1. Geographical location and land use type and soil type of study sites. (Coc= Conroe loamy fine sand, ScB=Scio very fine sandy loam, NbB=Narragansett very stony slit loam).

| Site | Coordinates | Description | Soil Type |
|---|---|---|---|
| 1 | 44.5908674 N, 73.893507 W | Silvopasture | CoC |
| 2 | 44.4352070 N, 74.2593778 W | Mowed Lawn | No Data |
| 3 | 42.4172828 N, 71.5114979 W | Mowed Lawn | No Data |
| 4 | 42.4185808 N, 71.5121349 W | Mowed Lawn | No Data |
| 5 | 42.4951481 N, 71.5681689 W | Mowed Field | No Data |
| 6 | 42.4327926 N, 71.3034686 W | Mowed Field | No Data |
| 7 | 44.4261645 N, 74.1744191 W | Mowed Field | Scb |
| 8 | 44.4161685 N, 74.1746216 W | Mowed Lawn | Scb |
| 9 | 44.4159769 N, 74.1746377 W | Mowed Field | Scb |
| 10 | 44.4306217 N, 74.1776364 W | Mowed Lawn | No Data |
| 11 | 44.4276512 N, 74.0516058 W | Mowed Lawn | Nbb |
| 12 | 44.4286405 N, 74.0524641 W | Mowed Lawn | Nbb |
| 13 | 44.4216048 N, 74.0703370 W | Unmaintained Field | No Data |
| 14 | 44.4292688 N, 73.9480712 W | Unmaintained Field | No Data |

*Site Requirements*

Sampling sites met the following criteria: (1) three or more fruit producing *Malus* present; (2) trees were not individually fertilized; (3) trees were treated organically for at least three years; and (4) each *Malus* had adjacent open area that is treated equally.

*Data Collection*

Soil samples were collected, using a soil corer, from the top 15 centimeters of soil. At each site, five samples were collected halfway between the trunk and edge of crown under three *Malus* (see Fig. 1) and aggregated into one sample. Five samples were then taken from open area 3 meters from the edge of the crown at equidistant intervals in a ring at each tree and aggregated into one sample. Any surface vegetation was removed before using corer. Samples were stored in open plastic zip-top bags until air dry.

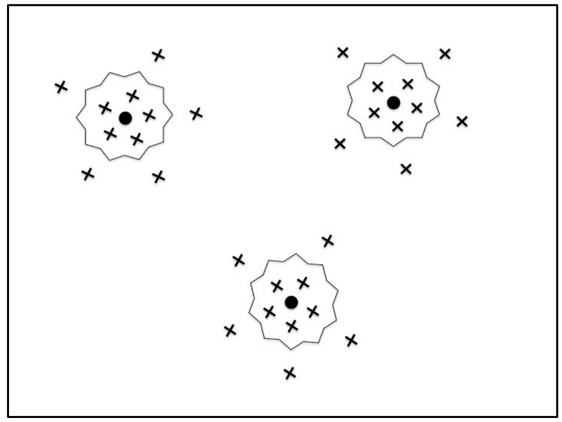

Figure 1. Sampling design used for soil collection. Five samples were collected halfway between the trunk and edge of crown under three *Malus* and aggregated into one sample. Five samples were then taken from open area 3 meters from the edge of the crown at equidistant intervals in a ring at each tree and aggregated into one sample.

*Laboratory Analysis*

Soils samples were dried and sieved before testing for nutrient content. Calcium, magnesium, and potassium levels were determined using an inductively coupled plasma optical emission spectrometer (ICPOES) on ammonium chloride extractions following the U.S. Environmental Protection Agency's cation exchange capacity method (Schumacher *et al.* 1995). Phosphorous was determined using the phosphorous soluble in dilute hydrochloric acid and sulfuric acid method by the American Society of Agronomy (Olsen *et al.* 1982). Nitrogen amounts were determined using anaerobic incubation and color imagery following the American Society of Agronomy chemical methods for nitrogen availability indices (Keeney, 1982). Organic matter content was determined by loss on ignition using a muffle furnace (Roberston, 2011). Additionally, pH was determined using a pH-meter.

*Data Analysis*

Descriptive statistics for each nutrient were determined first. Data were then analyzed using a general linear model (ANOVA) for each nutrient or characteristic using XLSTAT. Nutrient levels under and outside the canopy were compared at each site.

## Results

Results of nutrient analyses are summarized in Table 2. Potassium and magnesium were found to be the only nutrients with a significant increase in under-canopy samples compared to open areas.

Cation concentrations averages were higher in under-canopy samples for potassium and magnesium but slightly lower for calcium (Fig. 2). Both potassium (p=0.0023) and magnesium (p=0.0371) were significantly higher for concentrations under the canopy than in open areas. Magnesium was found to have the highest concentration of any nutrient tested at 21.40 mg/kg under-canopy. Potassium concentrations showed the greatest difference with an average of 7.1 mg/kg higher concentrations in under-canopy sites.

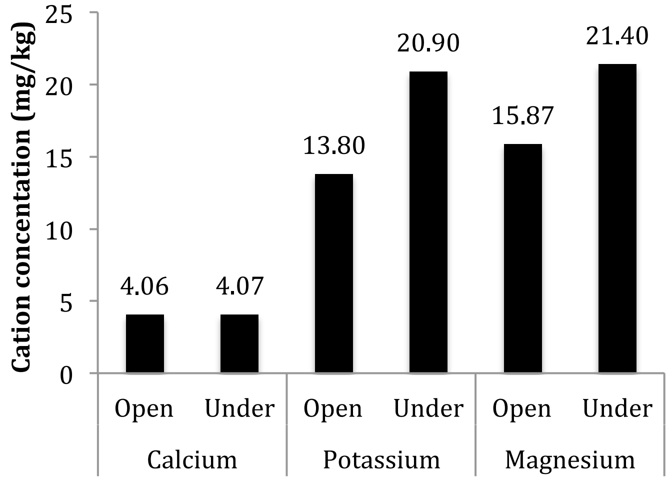


Figure 2. Average nutrient concentrations of cations (mg/kg) in open areas and under the canopy of *Malus* at sites in New York and Massachusetts (n=14).

Table 2. Summary of descriptive statistics for soil nutrient analyses under the canopy of *Malus* and in corresponding open areas at sites in New York and Massachusetts (n=14).

| Nutrient | | Minimum | Maximum | Mean | Standard Deviation |
|---|---|---|---|---|---|
| Calcium (mg/kg) | Open | 3.830 | 4.270 | 4.057 | 0.141 |
| | Under | 3.840 | 4.280 | 4.066 | 0.131 |
| Potassium (mg/kg) | Open | 0.674 | 40.743 | 13.804 | 11.382 |
| | Under | 1.101 | 39.021 | 20.904 | 9.536 |
| Magnesium (mg/kg) | Open | 6.147 | 47.300 | 15.872 | 11.972 |
| | Under | 5.249 | 40.400 | 21.402 | 9.511 |
| Nitrogen (mg/L) | Open | 0.830 | 8.700 | 4.971 | 2.264 |
| | Under | 0.824 | 9.030 | 5.190 | 2.319 |
| Phosphorous (mg/kg) | Open | 0.202 | 3.688 | 1.448 | 1.101 |
| | Under | 0.319 | 5.242 | 1.604 | 1.458 |
| Carbon (%) | Open | 2.689 | 10.744 | 7.880 | 1.928 |
| | Under | 2.213 | 13.231 | 8.353 | 3.004 |

Nitrogen was found to be slightly higher under-canopy at an average of 5.19 mg/L than in open areas at 4.97 mg/L (Fig. 3). However, this was not shown to be significant (p=0.6783).

Phosphorous was found to be slightly higher under-canopy at an average of 1.604 mg/kg than open areas at 1.448 mg/kg (Fig. 4). This was not shown to be significant (p=0.6543).

Average carbon percentages were found to be slightly higher under-canopy at 8.35% than in open areas at 7.88% (Fig. 5), however this was not significant (p=0.3051).

Average pH values (Fig. 6) were determined to slightly higher under-canopy (4.73) and in open areas (4.64).

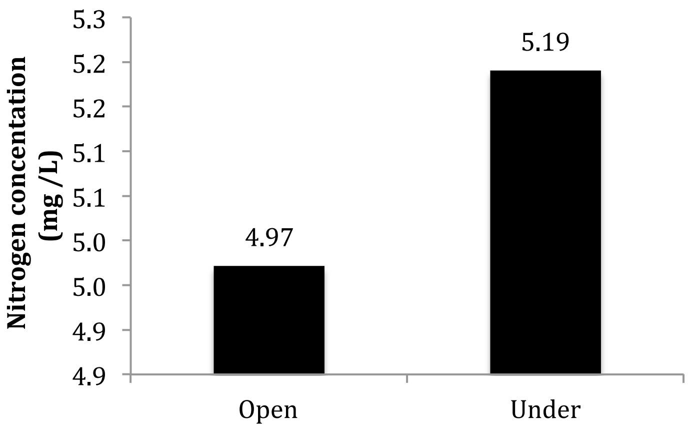


Figure 3. Average nitrogen concentrations (mg/L) in open areas and under the canopy of *Malus* at sites in New York and Massachusetts (n=14).

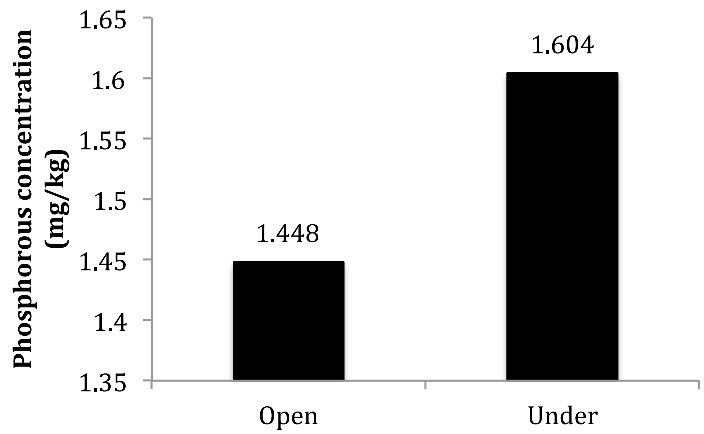


Figure 4. Average phosphorous concentrations (mg/kg) in open areas and areas under the canopy of *Malus* at sites in New York and Massachusetts (n=14).

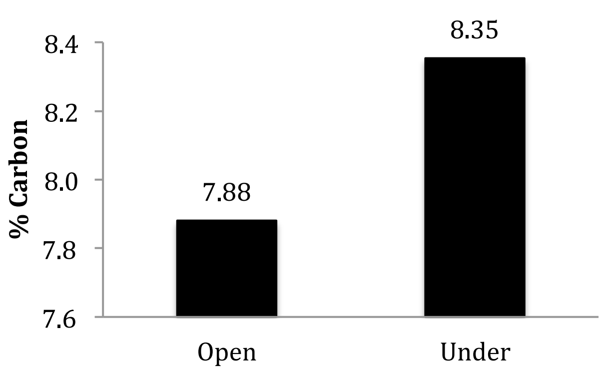


Figure 5. Average % carbon in open areas and areas under the canopy of *Malus* at sites in New York and Massachusetts (n=14).

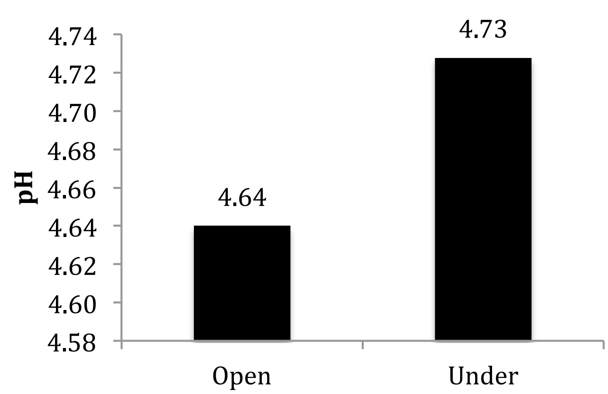


Figure 6. Average pH in open areas and areas under the canopy of *Malus* at sites in New York and New England (n=14).

# Discussion

We partially accept our hypothesis that nutrients (Ca, K, Mg, N, P, & C) would be higher in samples under the canopy of apple trees than in corresponding open areas. The average concentrations of each nutrient tested were higher under-canopy, however only potassium and magnesium were statistically significant. Factors that may have affected nutrient values include tree age, wildlife removing/eating a portion of the fruit, and the quality/quantity of fruit that was left to decompose under the trees.

Our results are likely due to biogeochemical cycling as described by West and Skujins (1977): roots from vegetation (in our case, apple trees) uptake the nutrients from the soil, and then throughfall, leaf litter, and fruit decompose under the tree, enriching the soil. Although no studies have yet been published regarding this effect in the northeastern United States, this effect has been documented in desert ecosystems with shrubs (Schlesinger *et al.* 1996) and tree islands in the Florida Everglades (Wetzel *et al.* 2005*)*. Schlesinger *et al.* (1996) found that local accumulations of nitrogen and potassium were present under the cover of a bunchgrass species in the deserts of the southwestern United States. Our study mirrors this in terms of significantly higher potassium concentrations under-canopy and a lesser increase in nitrogen. Additionally, islands of fertility in desert ecosystems have been found to be more developed in areas where individual plants have been established longer (Vasek & Lund 1980).

While most of our sites contained mature trees, in future studies it may be valuable to age the trees to determine if a correlation exists. Tree islands in the Florida Everglades have also been documented as important islands of fertility and biogeochemical hotspots. The Florida Everglades is a unique ecosystem that is limited by phosphorous. Ogram *et al.* found that tree islands contain six to 100 times greater concentrations of phosphorous than the surrounding areas. However, our results do not show a significant increase in the phosphorous concentration of soil directly surrounding apple trees and soil in open areas. This difference may be due to differing nutrient cycling processes in the species that Ogram *et al.* studied and apples. While the Everglades are dominated by much different climatic, geologic, and hydrologic regimes, this provides an example of the potential of trees to concentrate certain nutrients.

Our data suggest that the presence of *Malus* spp. may increase the fertility of the of the soil surface in pastures. This may carry implications that could be beneficial to various agricultural systems. The productivity of a pasture is largely dependent on soil fertility (Vlek *et* *al.* 1997). Using *Malus* to increase the fertility could yield a more productive pasture. Sims *et al.* (1998) emphasized a need for soil and water conservation practices to minimize phosphorous subsurface runoff. According to Nair *et al.* (2007) trees have the ability to reduce nutrient loss from drainage. The presence of *Malus* spp. could potentially reduce the need for phosphorous fertilization inputs as well as other soil amendments and capture nutrient loss.

Erosion is a force that diminishes soil fertility as well as disrupts water-holding capacity, organic matter content and soil biota populations (Pimental *et al.* 1995). Pimental *et al.* (1995) determined that 80% of the world's agricultural land suffers moderate to severe erosion and 10% suffers slight to moderate erosion. *Malus* spp. may aid in mitigating erosion due to its root structure and has the potential to reduce the associated negative effects of erosion. *Malus* spp. can easily be integrated into most pastoral systems and can have several benefits for the soil.

We suggest that further research into the ability of trees to create nutrient hotspots be performed in order to gain a broader understanding of the process. A larger dataset, as well as comparisons between different species of trees, may provide valuable insight to soil fertility management.

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