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Establishing Agroforestry Silvopasture Systems in the Missouri Ozark Region

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ESTABLISHING AGROFORESTRY SILVOPASTURE SYSTEMS IN THE MISSOURI OZARK REGION

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Master of Science, Plant Science

By

Kara Lynn Powelson

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ABSTRACT

The Missouri Ozarks is located in the south-central part of Missouri, ranging from the very southwest corner of the state and east to St. Louis. This region is enriched with large dense populations of oak and hickory tree species, while also being occupied with prime forage pastures for livestock grazing. Missouri is ranked second in the nation for farming operations and hay production, while also third in the nation for beef cow number of head (MDA 2021). The objective of this study is to observe the establishment of two separate silvopasture systems: a planted walnut plantation and a converted silvopasture. In the summer of 2020, soil samples were collected, along with soil moisture and soil temperature from the two silvopasture sites located at the Missouri State University Journagan Ranch in Douglas County, Missouri. Plant species transects and tree canopy density were observed within the converted silvopasture stand located on the ranch. Bray I phosphorus (P) and soil pH were measured within the Missouri State University Agriculture lab. The plantation and converted silvopasture sites showed very low available Bray I P within their stands, but overall a suitable pH for forage production. The converted silvopasture was seeded with a tall fescue (*Festuca arundinacea*), and orchardgrass (Dactyliz glomerata) seed mix in April of 2020. The converted stand's forage plant species transects were taken September 22, 2020. The transects showed one-third bare soil, one-third grassy weeds and one-third desirable forage species throughout the converted silvopasture stand. These findings suggest that possible fertilizer application may be needed to allow for more available Bray I P lbs/ac and for the converted stand, another forage seeding should be applied along with a weed management plant. This observational study established the baseline data for soil properties and species densities for future studies that will be conducted within these silvopasture sites. The long-term goals are to observe multiple years of soil fertility and health under management intensive grazing (MiG), observe plant species diversity, provide best management practices to livestock producers regarding silvopasture establishment and provide data to USDA-NRCS on these site specific silvopasture establishment located in the Missouri Ozarks.

KEYWORDS: agroforestry; silvopasture; forage; grazing; soil health; beef cattle; management intensive grazing

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INTRODUCTION

Ozarks

The Missouri Ozarks is located in the south-central part of Missouri, ranging from the very southwest corner of the state and east to St. Louis. This region is enriched with large dense populations of oak and hickory tree species, while also being occupied with prime forage pastures for grazing livestock. Missouri is ranked second in the nation for farming operations and hay production, while also third in the nation for beef cow number of head (MDA 2021).

The Ozarks were once heavily populated in short-leaf pine forest, but in the later 1800's Missouri's Ozarks were exploited by eastern United States milling operations (Benac and Flader 2004 and Rafferty 1992). The Missouri Ozark region is predominantly filled with an acidic silt loam texture on the surface soil and containing more of a clay base on the lower subsoil. These soils are known to be highly erodible and have become very diverse on the upper portion of the soil profile due to erosion causing tree throw mass movement and or soil creep (USDA 1997). Nutrients within the soil impact diversity, competitiveness, and growth for plant species within the ecosystem. The Ozarks soils are known to be low in available Phosphorus. Phosphorus is an important macronutrient that assists with plant proteins, amino acids and is necessary for plant metabolism (Hammer 1997). The inventory of 1999 revealed that in Missouri, there is a total of 5.7 hectares of forestland; 1.85 hectares are located on farms, .92 hectares are pastured, and .94 hectares are not in pasture on the farm (MDA 2021).

A positive outlook on the adoption of implementing a silvopasture system into a producer's farming operation is not always easily accepted by producers. Research conveys this stems from cultural barriers from the older generation of farm families and their original

practices (Raedeke et al. 2003). Much research has been conducted on the short-term effects of agroforestry practices within production agriculture and have seen benefits of increased macroclimates, positives of soil fertility and cycling of nutrients, while also seeing results of reduced soil erosion and improved water quality (Lorenz and Lal 2014). There is a lack of knowledge in the Midwest on how hardwood forests can be best managed for optimal returns to the land and to the landowner. Agroforestry has gained interested because of the large amount of underground biomass that has the potential to store much carbon (Lorenz and Lal 2014). Long-term silvopasture research within the Midwest will help learn the effects of such a system on the land, while also spreading knowledge to Midwest landowners and farm operators on how they can best optimize their farming practices with livestock, forages and trees combined (Garrett et al. 2004).

Silvopasture

Silvopasture is a n intensively managed agroforestry system that integrates trees, forages, and grazing livestock for a production benefit. Silvopasture is also a management practice that is known to improve local water quality and positive climate stabilizing effects for livestock all through the use of implementing trees into an agricultural system (Garrett et al. 2004). There are two practices that can be used when establishing silvopasture; the practice of taking an already established pasture and planting trees into it or taking a tree stand and thinning it out to allow for adequate light to produce forage growth (Angima 2009). Silvopasture brings economic flexibility for the producer by providing multiple crops to harvest and different ways to market their crops. Silvopasture also adds additional protection for livestock and wildlife, while in return, lengthening the production season of forage through the benefits of trees. Silvopasture is a

practice that requires the knowledge of livestock maintenance, tree species, tree density and forage species. It requires a good grasp on the environment of the silvopasture system and all the components alone and in combination (Angima 2009).

Black Walnut

Black walnut (*Juglans nigra*) is Missouri's most valuable tree. It is suitable for well drained northern Missouri soils and southern Missouri's alluvial river-deposited soils. Black walnut is known for its valuable wood and its profitable nutmeats (Reid et al. 2009). Black walnuts are one of the last species to bud out in the spring and one of the first to lose their leaves in the fall (Garrett et al. 1996). This aids in cool season forage growth because it allows time for more sunlight during the spring and fall but produces shade for protection during the heat of the summer.

Forage

Forage is the ultimate component of a grazing system. It is essential to choose a forage that is suitable for the growing site and able to provide the nutritional needs to the livestock that are chosen to graze the site. Research has shown that cool season grasses such as tall fescue, perennial ryegrass (*Lolium perenne*) and orchardgrass can perform well under 50% tree canopy shade (Angima 2009). Pang et al. (2019a) tested the effect of shade from trees on growth and nutritional quality for 43 forage species. The study's results showed that annual forage yield under moderate to dense shade have higher yields than an open pasture. Cool season forage was also proved to be more tolerable to shade than warm season forage. A sister study was conducted by Pang et al. (2019b) and concluded that the relative feed value of the forages benefited from

shade by having quality or greater feed value when grown in a silvopasture system instead of an open pasture (Pang et al. 2019b). Many studies have found that trees within a forage system can increase the nutritive value of the forage without decreasing its digestibility (Orefice et al. 2019 Hill et al. 2016 Lin et al 2001). In Central Minnesota, a study's results concluded that forage within a silvopasture stand can withstand drought conditions better than forage in an open pasture (Ford et al. 2019).

Plant Diversity

Plant Diversity can influence many factors within the soil of a grazing system. Having a diversified plant community allows for a more active, abundant, and diverse soil microbial communities. Long term data from a grassland biodiversity experiment results showed that a more diverse plant species grassland, increases rhizosphere carbon inputs into the microbial community (Lange et al. 2015). An increase of carbon into the microbial community has a positive effect on microbial activity and carbon storage within the soil. Carbon storage is influenced by the activity of soil microbes, and a more diverse plant community produces greater amounts of root exudates, which then feeds and leads to more soil microbial activity. The more soil microbial activity, the greater amount of carbon storage. A diversified grazing system would allow for a denser vegetation ground cover due to different growth rates of plant species. A covered soil allows for less evaporation from the soil, which then leads to higher microbial activity and growth within the soil. Increased plant diversity can also lead to more root exudation compared to a low plant diverse grassland. Root exudation is linked to carbon storage by changing the activity and composition of the microbial community (Lange et al. 2015). A more diverse grassland will also increase the bacterial and fungal diversity, along with an increase of

different soil microbial communities causes an increase in soil microbial respiration (Lange et al. 2015). Lange's data on long term grasslands conveys the positive impacts on soil microorganisms for carbon storage when a diverse grassland is present on the land. "Plant diversity and associated soil microbial communities can significantly contribute to sequestration of atmospheric carbon dioxide" (Lange et al. 2015).

Livestock

Cattle and sheep are predominantly the livestock species that are managed within a silvopasture system. Silvopasture aids in animal performance by reducing heat stress, provides greater forage availability and improves nutritional quality (Angima 2009). Silvopasture systems with uniformity in tree canopy shade help increase the grazing time of livestock and manure distribution. An increase in grazing results in an increase in improved weight gains in livestock. Shade is a huge benefit, but properly positioned trees will also allow for weather protection from wind and winter weather. These are important factors for livestock producers who calve in the winter and early spring months (Angima 2009).

Management Intensive Grazing

Management Intensive grazing (MiG) is a way that producers can control the grazing pressure that their livestock will put on a forage pasture. MiG is a way to conserve forage, promote diversity within a grass stand and better the environment. A MiG producer would observe their forage often and judge by the forage when they should rotate their livestock into a new area. A well-managed grazing system allows for more ground cover, less soil nutrient and water run-off, more organic matter, and a net in greenhouse gas emissions (Franzluebbers et al.

2012). Rotating through a paddock or grid system, allows for less grazing pressure and gives forage and trees a longer recovery time and increases root development (Angima 2009). MiG is a concept that is for the next generation of livestock producers. It can be considered a risk to producers to start a MiG system, but it is with local extensions and USDA-NRCS providers educating local producers at a community, state and federal level where producers will be able to see the benefits to their land, families, communities, and pocketbooks (Franzluebbers et al. 2012).

Soil Health

Healthy soil is such an important factor for agriculture ecosystems. Defined by Doran et al. (1996) "the continued capacity of soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain biological productivity, maintain the quality of air and water environments, and promote plant animal, and human health." USDA defines soil health as "the continued capacity of the soil to function as a vital living ecosystem that sustains plants, animals and humans" (USDA-NRCS 2018). Silvopasture systems can enhance soil organic carbon, soil nutrient availability and the soil biota. Soil organic carbon is enhanced by adding trees into a silvopasture system. An addition of trees will incorporate litter above and below ground that then turns into organic matter. Organic matter will then feed the soil organisms and influence the soil biodiversity and function (Jose and Dollinger 2018). Adding trees into a forage environment provides a new nutrient supply pathway through litter decomposition and nutrient leaching from leaves. "The process of litter decomposition and mineralization supplies abundant nutrient stock in agroforestry systems and consequently improves crop yields" (Jose and Dollinger 2018).The overall study goals and objectives are to 1) observe the establishment of a plantation silvopasture

and a converted silvopasture stand and 2) provide a baseline of data for the plantation silvopasture and the converted silvopasture for future studies to come. Based on the goals and objectives, struggles and success of the two silvopasture establishments will be monitored and specific environmental, soil and plant species data will be obtained.

MATERIALS AND METHODS

Experimental Design

Missouri State's Journagan Ranch is where the silvopasture establishment study site resides. Leo Journagan gifted the Missouri State University with the Journagan Ranch. This ranch resides on 3,300 acres in Douglas County, Missouri. Journagan Ranch runs one of the largest Herford herds by a University, while also owning the fifth largest herd of registered Polled Herford cattle in the United States (Rose 2010). Observations and measurements of forage and soil were collected through the spring and fall of 2020 on two separate types of silvopasture establishments.

The first type of silvopasture is a black walnut plantation, referred to as the walnut plantation. The walnut plantation was planted on a predominantly tall fescue cool season forage pasture (Roberts and Gerrish 2001) located on a Razort silt loam, 0 to 2 percent slopes, a fine-loamy, mixed, active, mesic Mollic Hapludalfs (USDA-NRCS 2002). The site measures 219.45 meters by 73.15 meters. Two types of black walnut cultivars, football and kwikrop, were planted on December 19, 2019. Bare root walnut seedlings were grown in raised beds at the Missouri State University Shealy Farm in Fair Grove, Missouri. Seedling were collected the day before planting and planted into 12 rows, each row 18 meters apart, with six trees planted within each row 12 meters apart. Spacing accounted for ease of passing equipment through the pasture in future forage and nut harvests (Figure 1).

The second type of silvopasture is a thinned timber stand, referred to as the converted silvopasture. The converted silvopasture is about two hectares and is composed of mixed oak and hickory tree species. It resides on an Ocie-Gatewood complex, 3 to 15 percent slopes, a loamy-skeletal over clayey, mixed, semiactive, mesic Oxyaquic Hapludalfs and a Gatewood-Moko

complex, 3 to 15 percent slopes, a very fine, mixed, active, mesic Oxyaquic Hapludalfs (USDA-NRCS 2012). A forest inventory was taken to mark the dominate and codominant tree species to keep for health and vigor of the converted silvopasture tree stand. The converted silvopasture tree stand was thinned to about a 50% canopy cover in November 2019 to allow for adequate light through the canopy to assist with cool season forage growth (Gardner 1985). A fescue and orchardgrass seed mix was broadcasted over the converted silvopasture in April 2020. Eighteen 0.04-hectare fixed plots were delineated for future referencing and data collection (Figure 2). Within each fixed plot, a center point was established with a t-post and four stakes were driven into the ground 7.62 meters away from the center in each cardinal direction.

Environmental Data

Weather data for years 2010 through 2020 were obtained from the University of Missouri Extension weather station located in Mountain Grove, Missouri. Weather data included average maximum temperature, minimum temperature, monthly rainfall, and yearly rainfall. The Mountain Grove weather station is located about 15 kilometers north of the silvopasture study sites. In the late summer of 2020, two weather stations were installed at each silvopasture study site location at Journagan Ranch. These weather stations will provide accurate precipitation rates at each specific site along with other valuable environmental data. Environmental data will be obtained from these silvopasture study site weather stations to aid in precise environmental data collection.

Soil Sample Collection

Twenty-seven composite soil samples were collected on July 22, 2020. Within the walnut plantation, three composite soil samples were taken from each of the three blocks (Figure 3). Within the converted silvopasture stand, nine composite soil samples were collected within both blocks of the converted silvopasture within the subplot structure (Figure 2).

At each composite sample location, an average of 15-20 soil probe cores were randomly taken by using an AMS 33" Soil Probe Sampler (Forestry Supplier, Jackson, MS, USA). Cores were taken to a maximum of 7.5 cm depth, sometimes limited by the shallower depth of the collectable soil across the site. Each soil core was subdivided into the depths of 0-2.5 (A), 2.5-5 (B), and 5-7.5 (C) centimeters (Figure 4). Soil from each depth was combined from the different cores at one location into one composite sample for each depth and stored in plastic bags. Soil samples were transported to the lab in Karls Hall (Missouri State University, Springfield, Missouri) opened and allowed to air dry at room temperature. Dry samples were then sieved through a 2mm screen, ground with a mortar and pestle, and stored in plastic bags at room temperature.

Each soil sample was analyzed for salt pH (pHs) and Bray I phosphorus. Soil pHs was measured as outlined by Nathan et al. (2012) by weighing 10 grams (± 0.1grams) of air-dried soil and placing into a labeled 50 milliliter beaker along with 10 milliliters of 0.01 M $CaCl_2$ solution. Each sample was then stirred with a glass stir rod and then placed on a (FisherBrand™ Multi-Platform Shaker.) The shaker table was set at a speed of 450rpm and shook the samples for 30 minutes. Samples were then measured with an OHAUS (W.W. Grainger, Inc., Lake Forest, IL, USA) Starter300, model ST300 calibrated pH meter and recorded to the hundredth decimal.

Bray I soil phosphorus (P) (Bray and Kurtz 1945) was determined colorimetrically by weighing out 0.5 grams (± 0.1 grams) dried soil sample and adding it into a plastic beaker with 5 milliliters Bray I extractant (Nathan et al. 2012). Samples were vortexed periodically over 5 minutes and centrifuged for five minutes at 4500rpm. Supernatants were then pipetted into the duplicated labeled tubes, with 4 milliliters of working solution as followed by Nathan et al. (2012), vortexed and then allowed to sit for 20 minutes for color development. Samples were placed in plastic cuvettes and read for absorbance of 660nm light using a Thermo Scientific Genesis 30 visible spectrophotometer (Thermo Scientific, Waltham, Massachusetts, USA) Solution P concentration (ppm) were then converted to pounds per acre Bray I P (Nathan et al. 2012).

Field Measurements

Soil temperature and soil moisture were measured on June 1, July 8, July 22, and August 10 of 2020 and light levels were measured on June 1, July 8 and August 10 of 2020. Four measurements, one at each sub plot structure (Figure 3), were taken in every fixed plot in the converted silvopasture and at each seedling in the walnut plantation. Soil temperature was recorded using a SpotOn® temperature probe (Forestry Suppliers, Jackson, MS, USA) by inserting the probe rods into the soil to a 7.5-centimeter depth. Sunlight was measured waist high with an Apogee MQ-306: Line quantum six sensor handheld meter (Forever Green Indoors, Spokane, WA, USA) that measures a spatial average of PAR (Photosynthetically Active Radiation). Soil moisture was measured by a Campbell Scientific Hydrosense II meter (Campbell Scientific, INC. Logan, UT, USA). The Hydrosense II meter was inputted into the

soil to about 7.5 centimeters and measured the average soil moisture to the depth of the probe in percent moisture by volume.

Canopy Density

Overstory tree canopy density was measured on July 8, 2020, with a modified spherical densiometer (Forestry Suppliers, Jackson, MS USA). The spherical densiometer consists of a small wooden box with a convex or concave mirror, engraved with 24 squares, placed in it. The densiometer is used by holding it at breast height so that the observer's head is reflected from the edge of the mirror just outside the graticule (Lemon 1956). Four readings from a reference tree are taken in each cardinal direction and follow Lemmon, Paul E., (1956) to create percent canopy density.

Species Transects

A total of 100 plant species observations were taken within all 18 fixed converted silvopasture plots on September 18, 2020. Each plot was sub-divided by subplot structures (Figure 3). Plant species observations started within the center of the plot and went 7.62 meters in each cardinal direction to the subplot structures. An observation was collected at each 30.48 centimeter by writing down what plant species was growing from the soil in that location. Bare soil was observed along with grassy weed species: southern crabgrass (*Digitaria ciliaris*), shortawn foxtail (*Alopecurus aequalis*) and yellow nutsedge (*Cyperus esculentus*). Bermudagrass (*Cynodon dactylon*), Kentucky bluegrass (*Poa pratensis*), tall fescue, orchardgrass, little bluestem (*Schizachyrium scoparium*), legumes (white clover Trifolium repens) and woody broadleaves (*Hickory Carya* spp.) were all observed.

RESULTS

Environmental Data

Monthly precipitation for the observation year of 2020 was similar in all growing months compared to the past 10-year average besides August and September. The past ten-year average precipitation for August was 11.4 centimeters and for September was 8.31 centimeters. For the observation year 2020 August and September both had less than half the ten-year average of precipitation with August having 3.78 centimeters and September having 3.38 centimeters (Figure 5). Minimum and Maximum temperature for 2020 was on average lower than the past ten years (Figure 6).

Soil Chemistry

Soil pHs within the walnut plantation ranges from 6 to 7.18 in pHs value within the 9 composite soil sample sites. Plot 4 has the highest pHs value of 7.18 and plot 3 has the lowest pHs value at 6 (Figure 7 & 8). Soil pH within the converted silvopasture ranges from pH value of 5.56 in plot 10 to 7.12 pH value in plot 15 (Figure 9). Soil pHs follows a trend of being more acidic on the north side of the converted silvopasture site and gradually becomes more alkaline and neutral as elevation increased to the south side of the study site (Figure 10).

Phosphorus values for the Walnut Plantation at depth A, ranged from 15.98 lb/ac P in plot 7 to 9.36 lb/ac P in plots 5 and 9. Plots 5 and 9 have the lowest values and have the same value of 9.36 lb/ac P. Plot 3 had the highest available P at depth B, with 11.5lb/ac P and Plot 6 had the lowest available Phosphorus value at 4.08 lb/ac P of available P. Plot 9 had the lowest available P at depth C, with 4.43 lb/ac P and plot 3 had the highest available P value of 14.82

lb/ac P. At depths B and C, the same values were observed within Plots 1, 7 and 9. Plot 3 had the same available P value for depth A and depth B (Figure 11). The average drop in available P from depth A to depth B is 6.05 lb/acc P. The average drop in available P from B to depth C is 0. All information is referenced in figures 11 and 12.

Available Phosphorus (P) values for the converted silvopasture at depth A range from the lowest available P recorded in plot 15 at 16.39 lb/ac P and the highest recorded in plot 51.08 lb/ac P. Available P within the converted silvopasture for depth B was recorded the lowest in plot 12 at 8.94 lb/ac P and the highest at 26.32 lb/ac P. For depth C, the lowest available P was in plot 15 at 3.58 lb/ac P and the highest was in plot 10 with a value of 27.84. Plot 8 shares the same values of available P in depth B and C. Plots 1, 3, 10, 16, and 17 all have available P values greater in-depth C, than in depth B. The average drop in available P from depth A to depth B is 13.96 lb/ac P. The average drop in available P from depth B to depth C was 2.54 lb/ac P. For detailed results, reference figures 13 and 14.

Canopy Density

In the converted silvopasture stand, 13 of the 18 plots have a mean canopy density higher than 50%. Plots 2, 13, 14, 15 and 18 have a canopy density lower than 50%. Plot 8 has the highest canopy density at 78% canopy coverage and plot 15 has the least dense canopy coverage at 30% density (Figure 15).

Species Transects

Within the converted silvopasture, plots 9, 12 & 15 had over 50% bare soil counted within their species transects. Plot 15 had the highest amount of bare soil counted within its

species count with 80% counted bare soil. All plots had a count of grassy weeds, but plots 1, 3, 4, 10, 13, and 14 had over a 40% weed species count. Legumes were observed in plots 1, 3, 4, 7, 8 and 9 but most significant in plot 1 with 19% and plot 7 with 7% legumes. Plot 17 is the only plot with bermudagrass present that was counted at 3%. Plots 2, 7 and 8 were observed with around 30% tall fescue species within the plots species transects. Plot 16 had a significant amount of Bluegrass with 22% counted in species transects. Orchardgrass was observed in all plots, but in plots 2, 6 and 16 there was a significant amount of biomass of 15%. Little Bluestem was observed in plots 12, 13, 14, 15 and 17 with plots having the most significant amount at 13%. Woody broad leaf species were observed in plots 1 and 6, with plot 6 having the most observations at 3% (Figure 8).

DISCUSSION

Environmental Data

Weather data does not convey the severity of the short drought like conditions in the late summer of 2020 at the silvopasture study sites. Weather data indicated that we had above average precipitation for the month of July, but this precipitation came in between two weeks of no precipitation. For 2020, the months of August and September were excessively dry at the silvopasture sites (Figure 5). Precipitation was recorded 15 kilometers north of the silvopasture study sites. There were dates where precipitation fell in Mountain Grove, Missouri at the weather station and not at the Journagan Ranch silvopasture study sites.

Soil Chemistry

Available Bray I Phosphorus results for the plantation study site are very low (Buchholz, 1983). Phosphorus application of fertilizer should be suggested to help with forage growth on both silvopasture sites. Results display that available Bray I P for plots three and six have more available P at depth C than at depth B (Figure 11). No conclusions determined besides sampler error. There were many students assisting with soil sampling and possibly could affect results. Available Bray I P amount was higher overall for the converted silvopasture. The higher amounts of Bray I P were located in plots 1,2,4,5, and 10 (Figure 13 & 14). All these plots reside at the bottom of a natural drainage way. These plots may have higher P values compared to the other parts of the converted silvopasture due to having a concentrated area of soil and nutrient runoff. Typically, the most concentrated amounts of plant available Bray I P is within the top of the soil surface. Plots 1,10,16 and 17 have higher values of Bray I P at depth C than the depth B. Much ground disturbance happened to the converted silvopasture through the thinning process.

Trees were thinned by heavy machinery and much soil was turned over. Soil disturbance has not had enough time to settle down, thus leading to a higher content of available Bray I P deeper in the soil profile. Between the top depth A to depth B, is on average the largest decline in available Bray I P (lbs/A) value. The average Bray I available P from depth A to depth B is 13.96lbs/A P. Thus, showing that the most plant available Bray I P resides within the top depth A of the soil. Reference figure 15 for P results.

Within the walnut plantation, plots 4, 5, 8 and 9 have a close to neutral pHs or alkaline pHs (Figure 9). For figure 10 to be improved, more soil samples need to be taken across the study site to add more data points to be used within creating the map. Overall, soil pHs is desirable within this site. Soil pHs for the converted silvopasture has an alkaline to neutral soil pH on the southern side of the stand, especially within plots 15 and 12. This is the location of the site's soil change from an Ocie-Gatewood complex to a Gatewood-Moko complex. Located in plot 15 is rock outcrop and the start of a glade. Limestone and dolomite glades are common within the Ozarks area. They cause calcium, magnesium, and lime to leach out into the soil, thus raising the pHs value of plots 12 and 15 (Figure 9). Soil pHs is lower within plots 1, 4 and 10, but overall, soil pH is desirable within all other converted stand plots (Figure 9 & 10).

Canopy Density

Canopy density for the converted silvopasture was an average of 55.57% canopy density (Figure 15). The goal of the thin was to obtain a 50% canopy coverage to allow for adequate sunlight through to optimize cool season forage growth (Gardner et al. 1985). Fifty five percent canopy density conveys that the tree thinning was successful is staying close to the 50% canopy density goal. Management is still needed to maintain the canopy and observe the density over

time so that the converted silvopasture canopy does not become too dense and have a negative impact on cool season forage growth. Light intensity (PAR) and canopy density did correlate when looking at plot 15. Plot 15 had a low tree canopy density of 29.8% and had 74.2% PAR light intensity reading (Figure 16). Though plot 15 displays how the canopy density correlates with light intensity, not all plots present this correlation. This may be concluded from light intensity readings taken at different times of the day at different times of the year. The sun is located at different points and shifts through the sky all through the day and year, this effects the light intensity rates. Canopy density is measuring from a the bottom of a base tree by looking through a densiometer to observe what is directly above that specific tree, thus light was measured right above the tree. PAR light intensity will have different rates when compared to canopy density. They can be correlated too, but there are also many errors within comparing the two with each other.

Species Transects of Converted Silvopasture

Species transects from the converted silvopasture were lumped into three groups of observations (bare soil, grassy weeds, and desirable forage). Plot two is the only plot with over 50% desirable forage species present within the plot. The average cover of desirable plant species for all 18 plots is 34% (Figure 8.) Plot 15 is predominantly bare due to much of the stand being consumed with exposed limestone. The biggest concern for the converted stand is that over 50% of the soil is bare or resides in weedy plant species. Forage management practices such as flash grazing or chemical herbicide spraying will help reduce the weed population and provide more room for desirable forage species to grow. Another forage seeding should take place in the

fall of 2021 and spring of 2022. Observations convey that it may take the converted silvopasture two to three years to develop adequate forage to graze livestock on.

CONCLUSION

This study was strictly an observation study to establish a baseline of data for years to come at the Missouri State's Journagan Ranch silvopasture study sites. Struggles and successes were monitored within the walnut plantation and converted silvopasture study sites. The silvopasture study sites were built to help provide info to local livestock producers and the USDA for best management practices that livestock producers can utilize for their Ozark lands.

The walnut plantation had an overall very-low plant available phosphorus lbs/ac and a relatively good soil pH. The First year of the converted silvopasture tree thinning, canopy density was close to the 50% tree canopy density goal. Much soil disturbance was noticed through soil chemical readings along with much bare soil and weed species present in the ground species.

The walnut plantation silvopasture needs time to establish walnut trees and the converted silvopasture needs a brush and weed management plan, along with at least one more forage seeding. The converted stand also needs a few more years for the disturbed soil to settle down to allow for accurate soil chemical readings from the study site. Many years of observation and study are needed to conclude results from establishment and management of a plantation silvopasture and converted silvopasture. This observation study will allow for future years to assess plant species development and management within the converted silvopasture site. Expanded soil nutrient analysis is needed to assess soil parameters such as soil organic matter, nitrogen, microbial activity, soil water infiltration, soil compaction and many more soil parameters to help assess soil health

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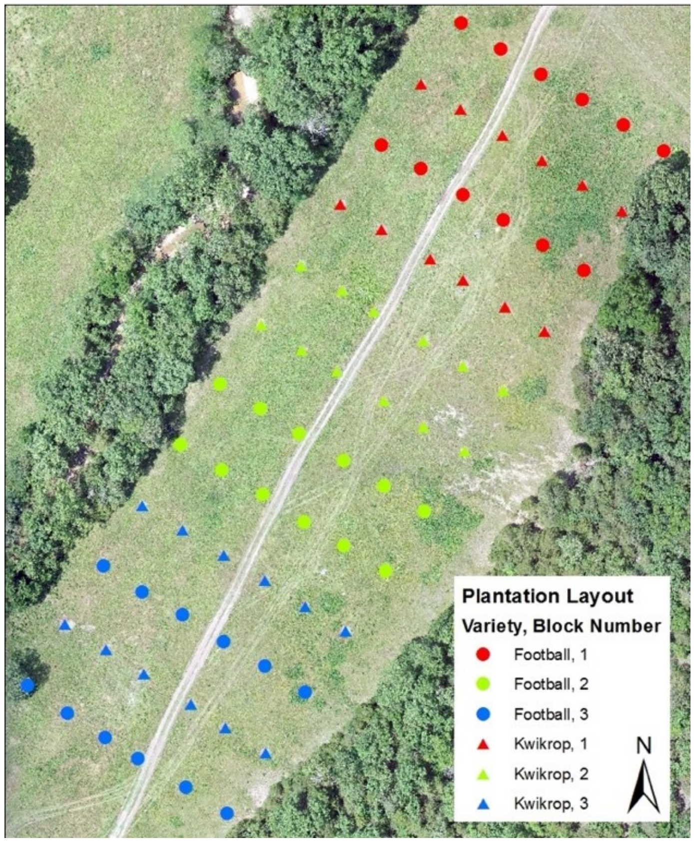

Figure 1. Aerial view of the walnut plantation located at MSU Journagan Ranch Douglas County. The system was divided into three replicate blocks. Each block containing four rows randomly assigned to each walnut cultivar football or kwikrop.

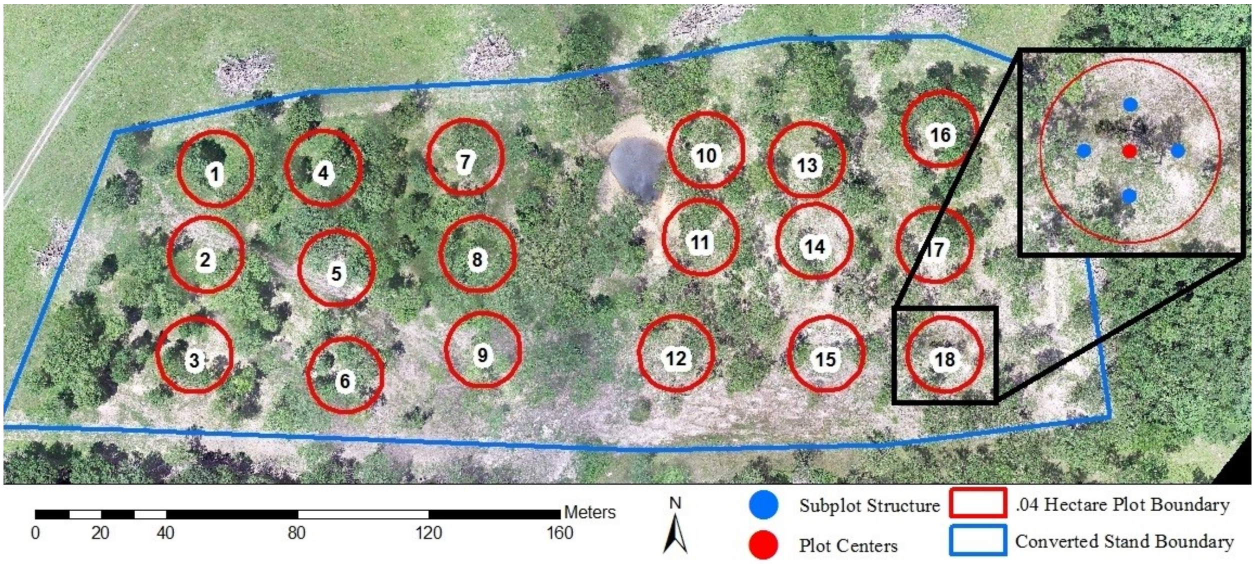

Figure 2. Aerial view of the converted silvopasture system. Areas represented by the red circles (1-18) indicate plots (1327.7 m^2) for soil sampling and species transects. Blue dots within each plot represent permanent subplot structures.

Figure 3. Aerial view of the walnut plantation for composite soil sampling. Areas represented by the numbered rectangles (1-9) indicate three benchmark soil sampling sites (731.5 m^2) for each block.

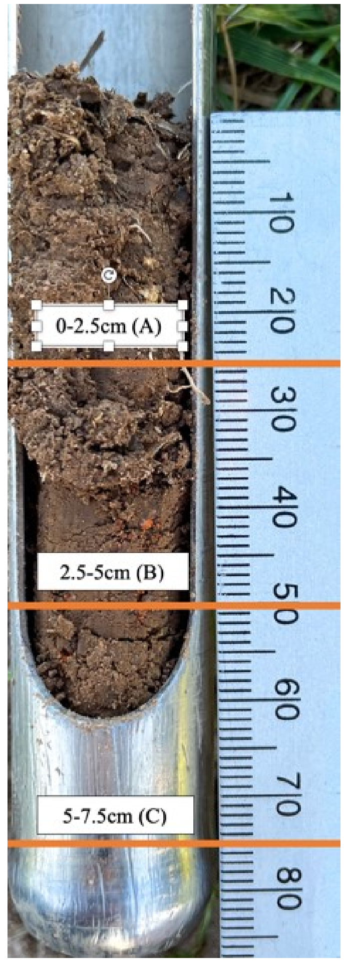

Figure 4. Individual soil cores were divided into depths of 0-2.5cm (A), 2.5-5cm (B) and 5-7.5cm (C).

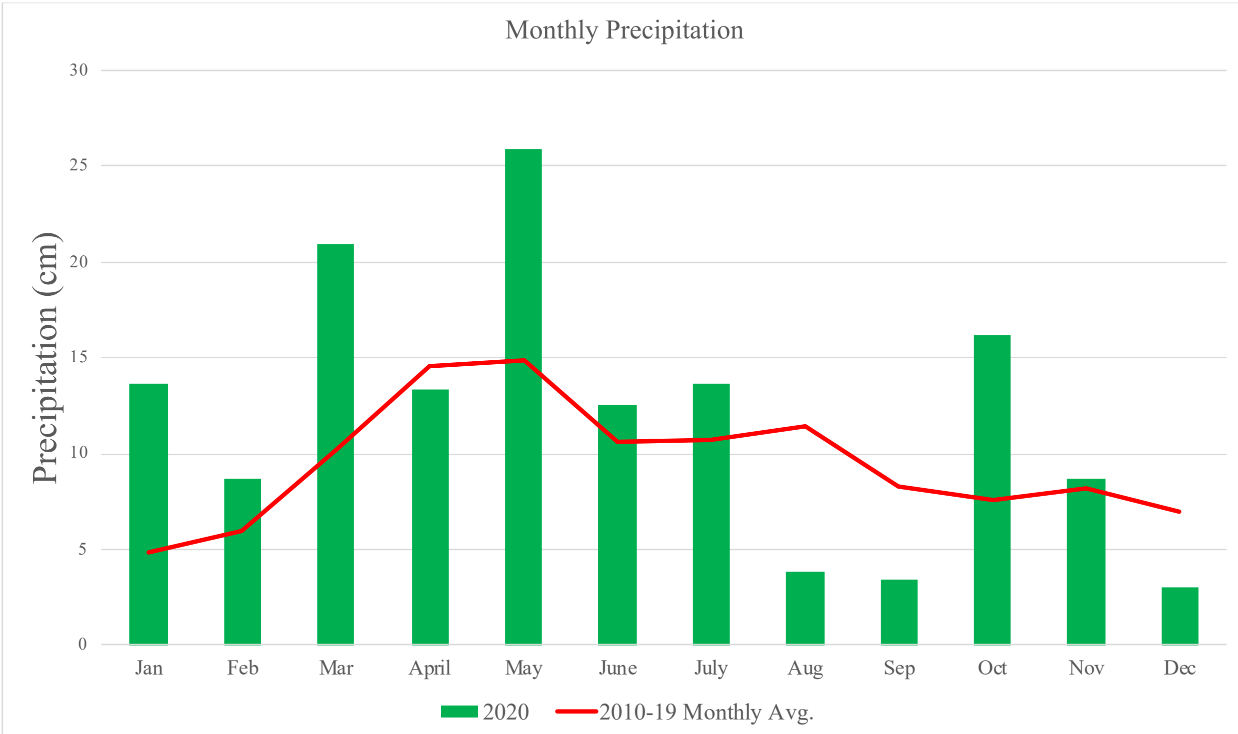

Figure 5. Monthly precipitation total for 2020, and a 10-year (2010-2019) monthly precipitation average for Mountain Grove, Missouri.

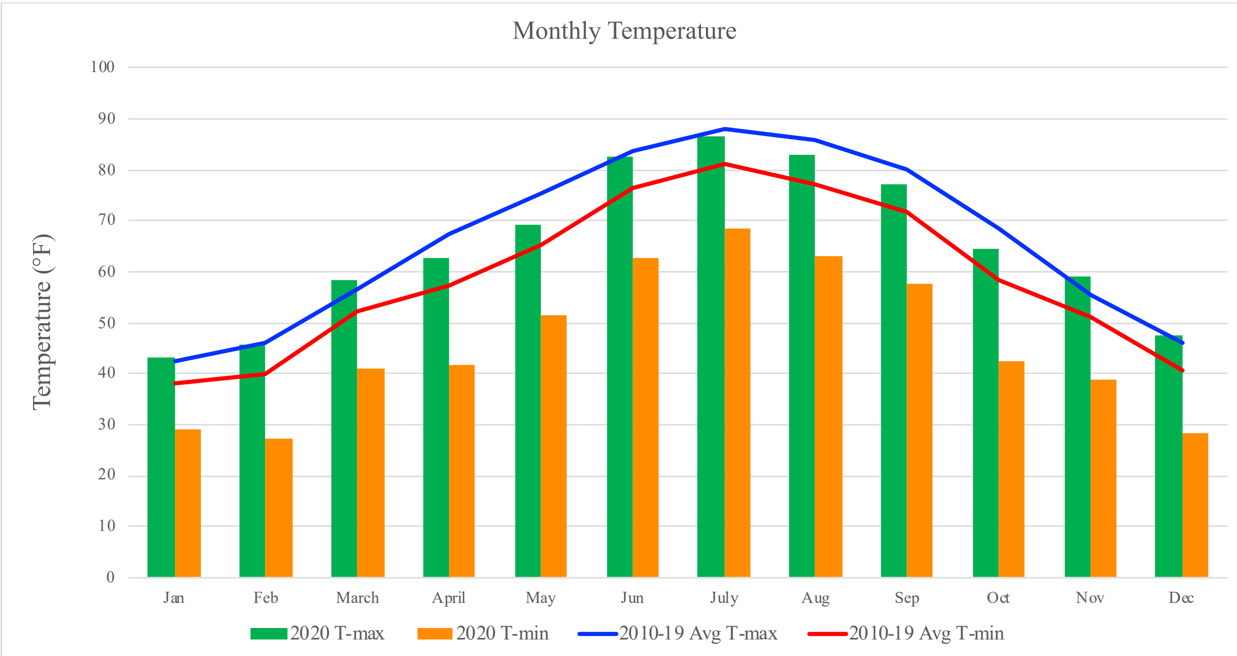

Figure 6. Monthly maximum (2020 T-max) and minimum (2020 T-min) temperatures for the 2020 growing season and the 10-year (2010-2019) average maximum (2010-19 Avg T-max) and minimum (2010-19 Avg T-min) for Mountain Grove, Missouri.

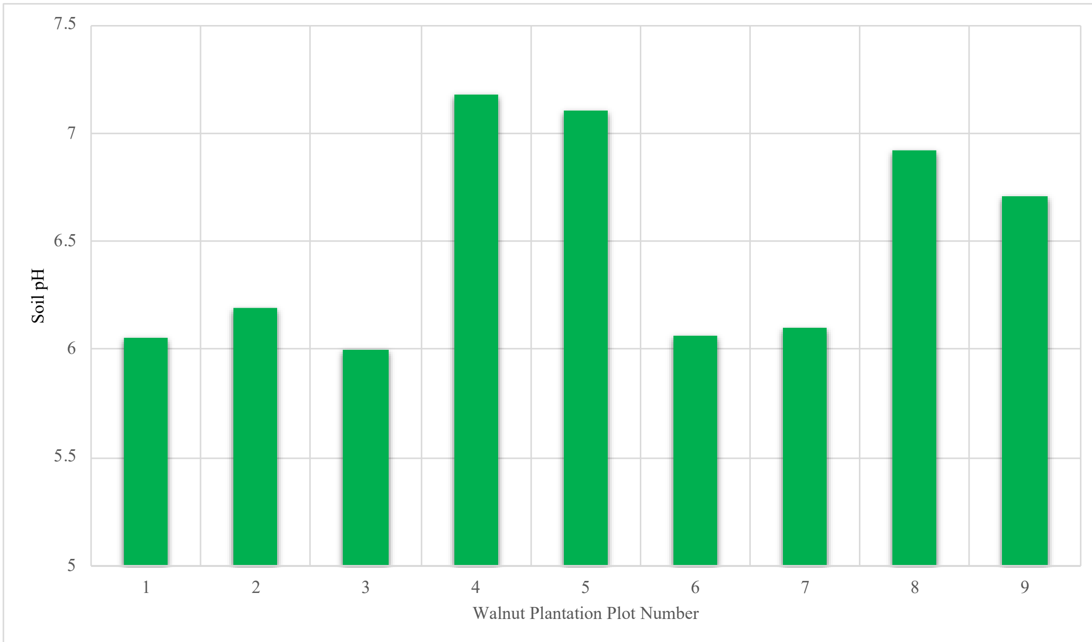

Figure 7. Soil pHs values from composite soil samples for each of the 9 benchmark soil sampling sites in the walnut plantation.

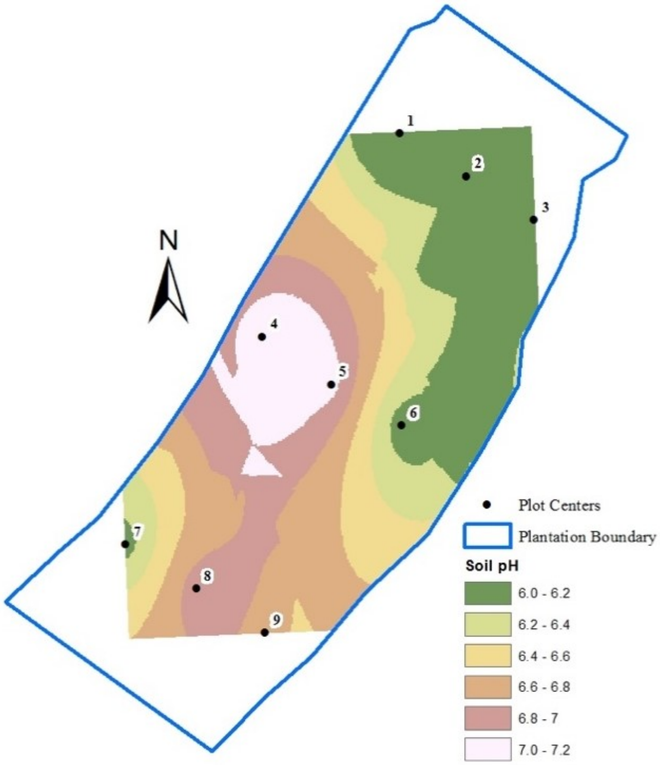

Figure 8. Spatial representation of soil pHs values for walnut plantation. Dots 1-9 represent the benchmark soil sampling sites.

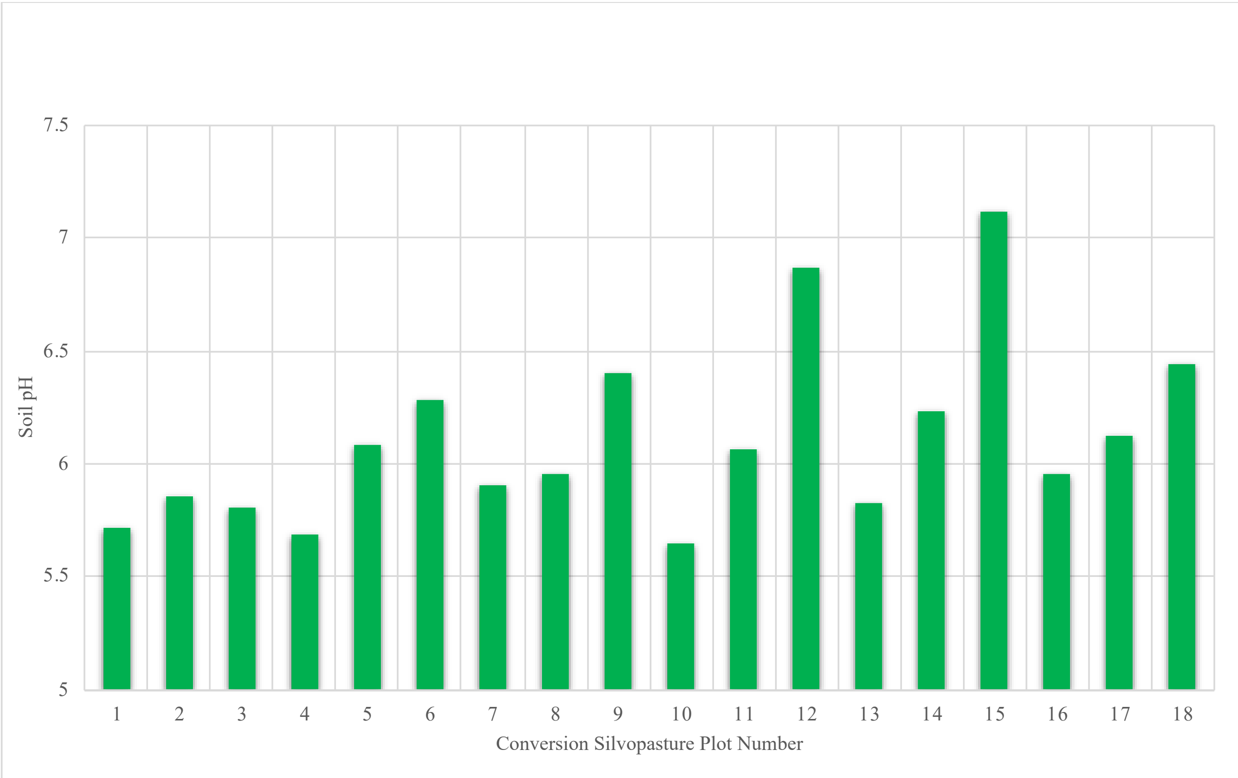

Figure 9. Soil pHs values from composite soil samples for each of the 18 plots in the converted silvopasture site.

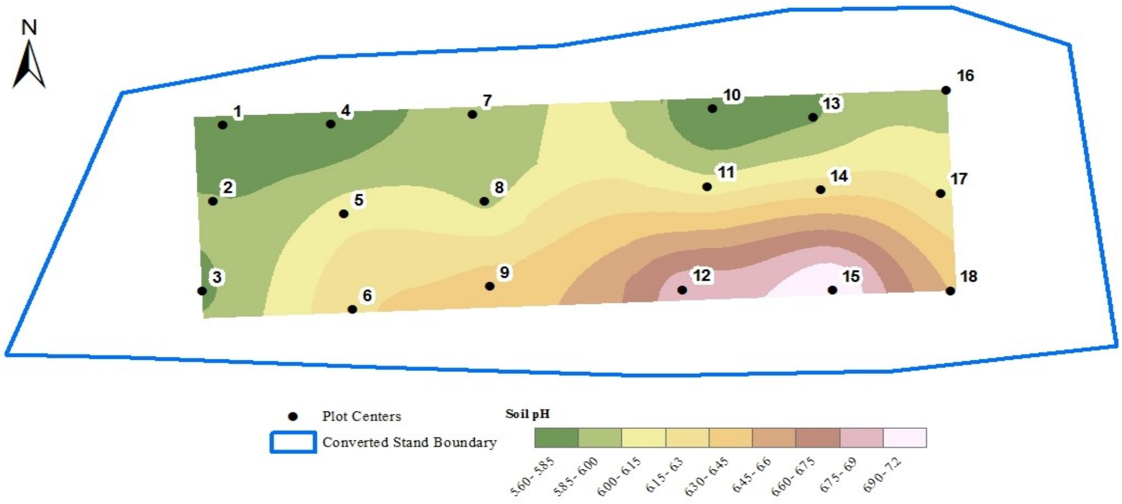

Figure 10. Spatial representation of soil pHs values for converted silvopasture. Dots 1-18 represent the plots for soil sampling

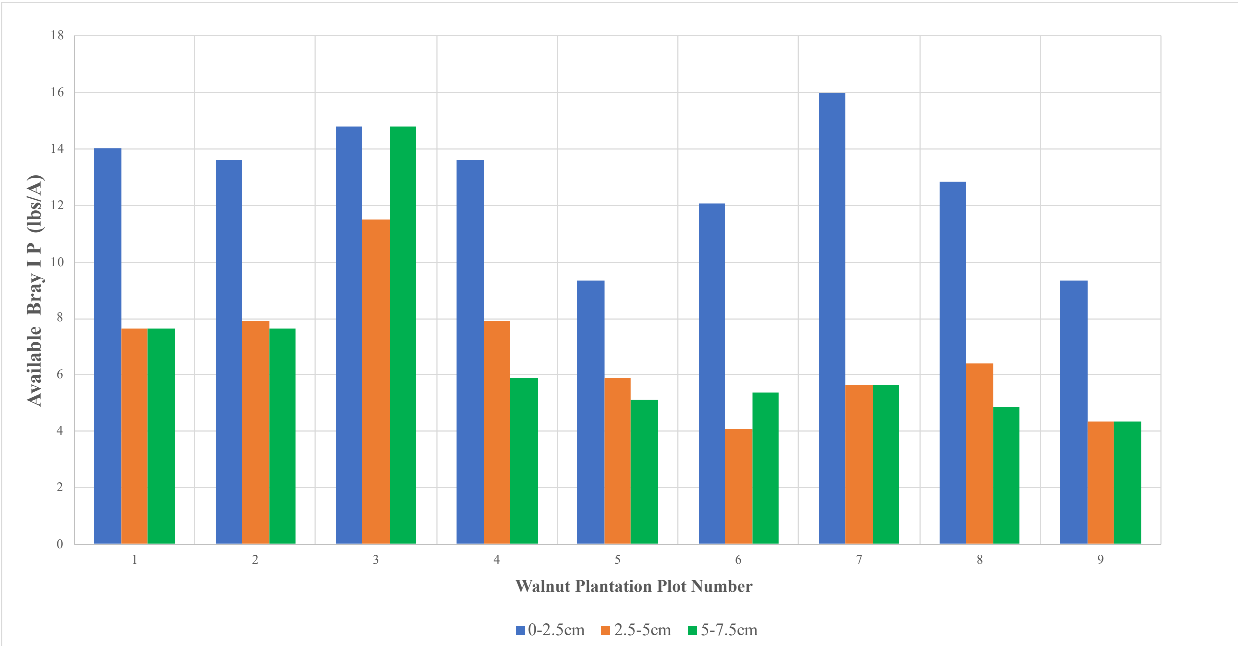

Figure 11. Available Bray I Phosphorus (lbs/ac) values by depth for each of the 9 benchmark soil sampling sites in the walnut plantation.

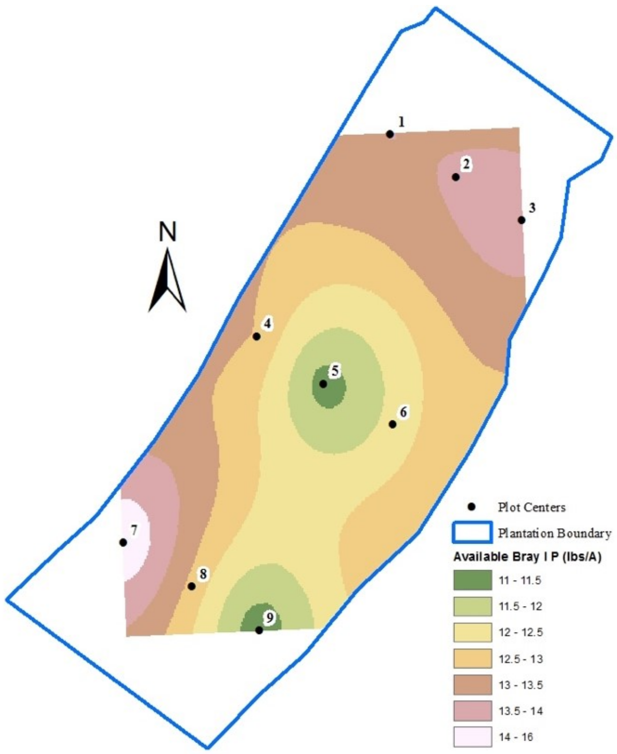

Figure 12. Spatial representation of available Bray I Phosphorus (lbs/ac) for the walnut plantation at the soil depth of 0-2.5 centimeters.

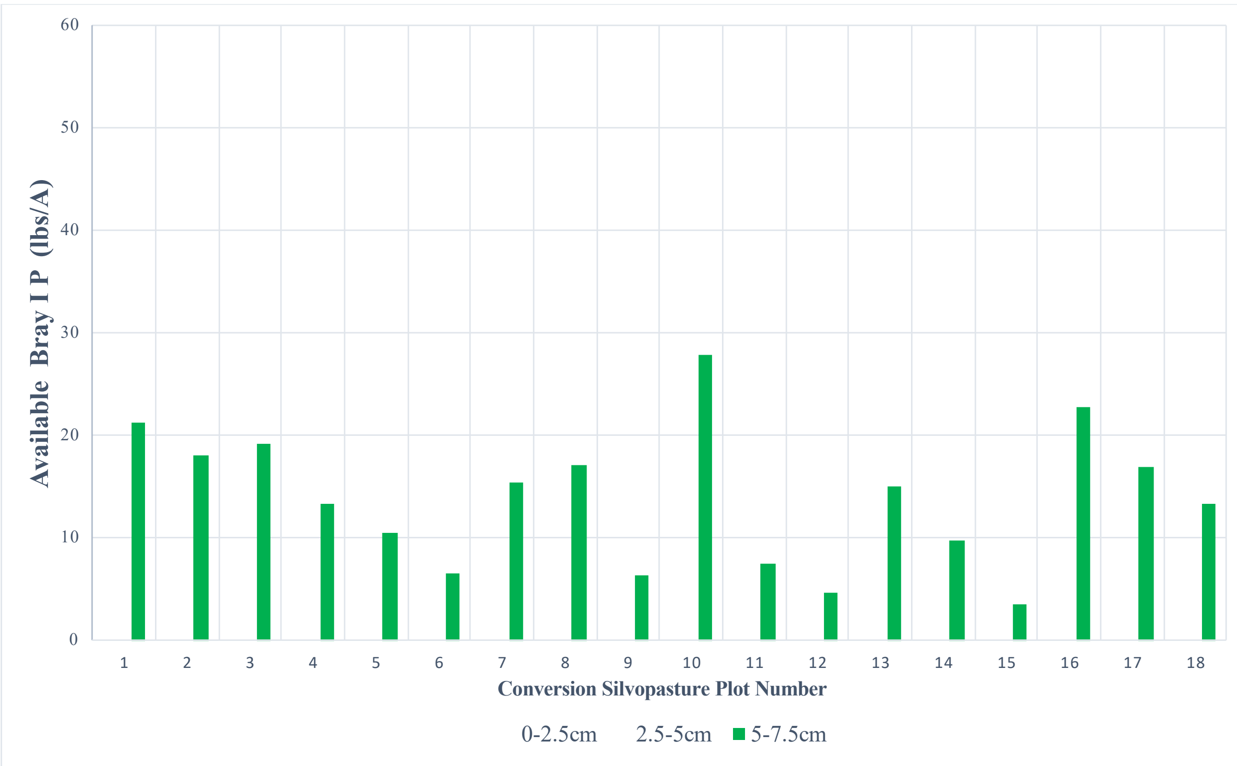

Figure 13. Available Bray I Phosphorus (lbs/ac) values by depth for each of the 18 plots in the converted silvopasture site.

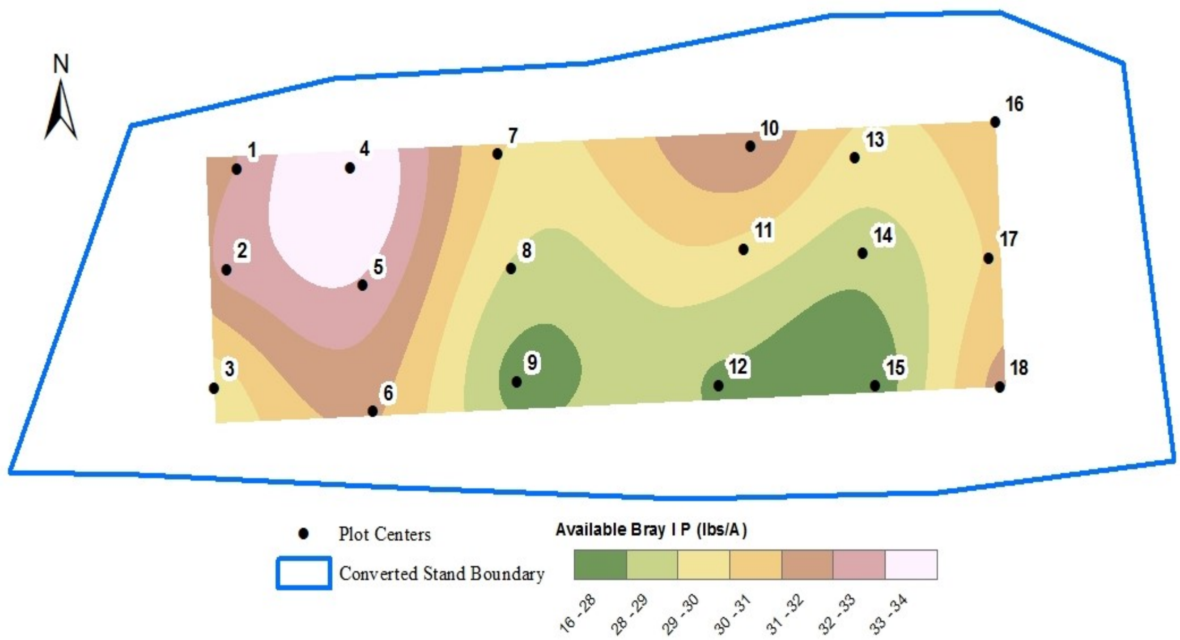

Figure 14. Spatial representation of available Bray I Phosphorus (lbs/ac) for the converted silvopasture site at the soil depth of 0-2.5 centimeters.

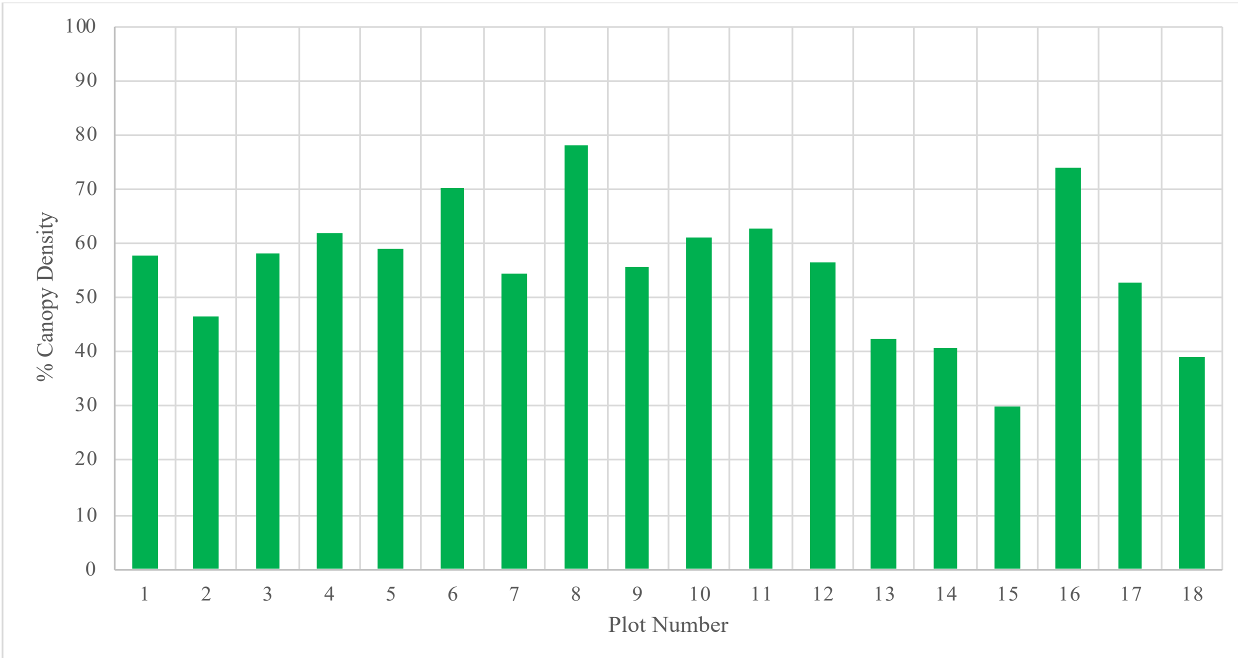

Figure 15. Converted silvopasture tree canopy density observations taken for each plot July 8, 2020.

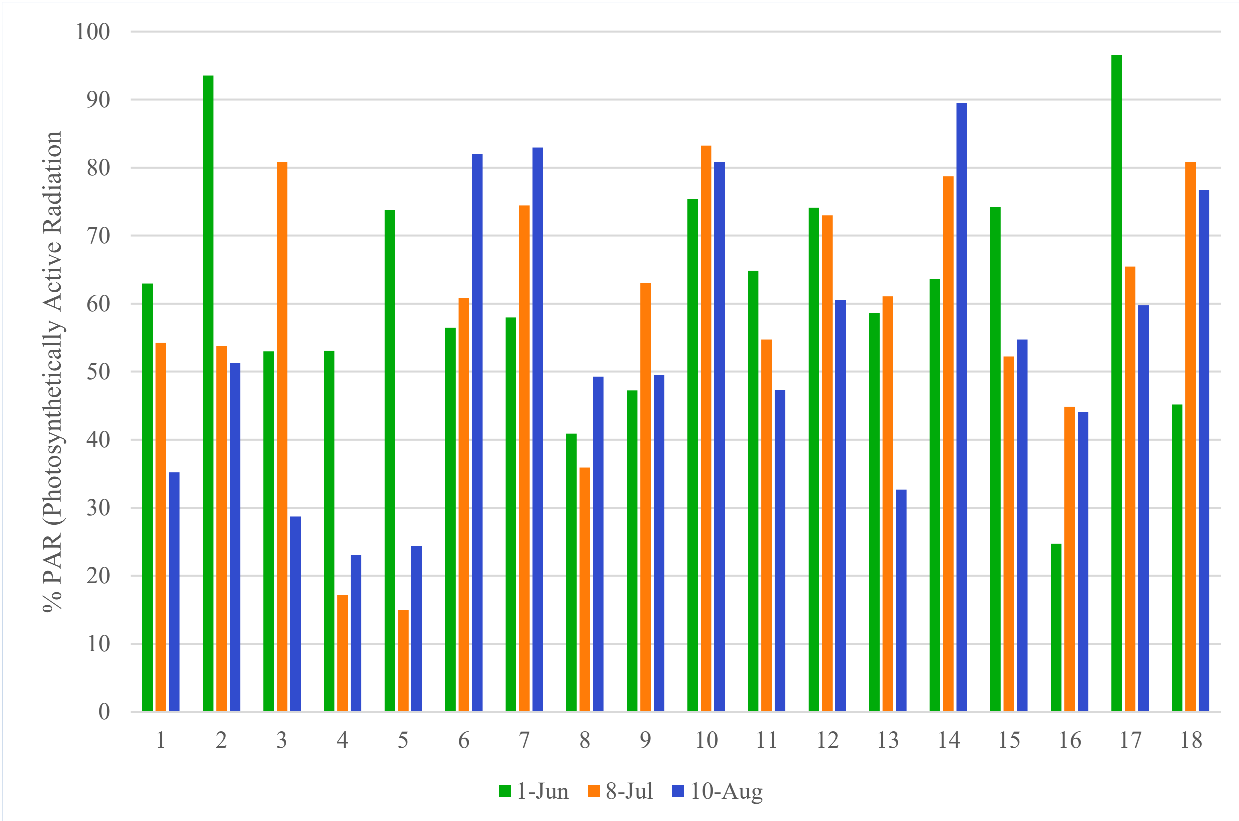

Figure 16. Photosynthetically Active Radiation (%) values in the converted silvopasture site for the dates of June 1, July 8 and August 10, 2020.