Field-Based Learning for Secondary Students while Studying a Buried Soil M Horizon

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Overview

The goal of this technical paper is to provide the framework and philosophy for a dual credit secondary school environmental science curriculum. The course, designed for an urban school, will focus on soils and human impact on the environment. To establish the goal, this paper will examine teaching philosophies and how they relate to minority students and underprivileged students. Specifically, field-based and project based learning are discussed in relation to a soil research project that was undertaken at an urban high school. The school has a predominantly minority student population and is considered to be significantly underperforming by Kentucky Education Standards. Due to the dual nature of this paper, both a philosophy and outline for a secondary curriculum, and an attempt at original research, it is divided into two distinct parts.

Part one discusses the motivation for creating a field-based learning curriculum, and the framework for the curriculum itself. This includes student demographics, the course syllabus, my own classroom teaching philosophy, as well as my philosophy for the curriculum standards and the course framework. Within this framework, the research that was undertaken in part two will be incorporated into the curriculum, providing urban students with a genuine field-based learning experience. This field study portion of the class provides students with hands on experience and examines soil formation, soil classification, anthropedogenesis, nutrient cycles, localized climate change, and human impacts to the environment.

Part two could be considered as supplemental materials and provides a detailed research proposal that uses a plot of land provided by an urban school in Louisville, KY. The research proposal was designed to examine the relationship between soils, cover crops, and tilled and no-till agricultural soils. The goal was to use the help of student volunteers to undertake the research itself while building the foundation for the ongoing project-based portion of the dual credit curriculum. As will be discussed in part one, the research itself encountered a dilemma in the form of a buried soil M horizon. While this greatly affected the outcome of the research itself, it presented a tremendous opportunity for student learning and ongoing research of human impacted soils. Examining the original proposal and discussing future steps to modify this research is an important step to providing a more authentic learning experience to future students and may later provide important data about urban soils and how buried M horizons influence our ability to transition soils to agricultural use.

In his course, Environmental Pedology, I recall Dr. Allan Bacon saying something to the extent of, “Environmental science is a field that requires us to be outside to study effectively”. The following quote from myself builds upon this important statement. Environmental science is an area of study that requires us to be hands on and in the field. This importance cannot be overstated and becomes truer for our students that come from inner cities and urban populations. Many of these students have little to no life experiences outside of their urban environment. Additionally, in a world that is so heavily influenced by our actions, the subject of sustainable land use is often overlooked in secondary curriculums. One could easily imagine how sustainability might be an important topic for a student living in these urban city centers. Providing the means for our youth to examine this world and their place within it, in such a way that is engaging, meaningful, and relative to their own experiences, is imperative for ensuring a future generation that understands future consequences of today's actions, and that value the natural world as a dynamic system in which we are an integral part.

Part One

Incorporating Field-Based Learning and Soil Science into a Secondary Curriculum for Inner City and Urban Students

The necessity for field based and hands on education should be apparent, and even more obvious when the subject is related to environmental sciences. School-based gardens provide a means to this field learning experience. When the literature is considered, a clear pattern emerges that demonstrates a positive relationship between school-based gardens and student's academic achievement. Studies have shown that science, math, and language arts scores are improved in students that are involved in school gardening programs (Fisher-Maltese, et al, 2018;). A meta-analysis from Williams and Dixon (2013) that examined 48 separate studies found that 82% of the potential outcomes were positive with math and language arts academic outcomes being the greatest benefactors. This study concluded that mathematic concepts such as data analysis, measurements, and geometry are applied in school-based gardens, as well as scientific writing, which helps bolster both math and language arts skills.

Now consider for a moment, who has access to these curriculums and opportunities? There are numerous barriers of entry for teachers and schools interested in incorporating these field-based learning opportunities. Funding, teacher staffing, and available land are a few of the many barriers. For some groups of students, there are two other key barriers to these opportunities as well, race and socioeconomic status.

“Yet, there is only one group that has historically and continuously experienced ghettoization— Blacks in America. Despite some common assertions, Blacks did not develop these ghettos or voluntarily choose to live in them. Instead, through coordinated institutional acts of discrimination and uncoordinated individual acts of discrimination, Blacks were denied access to certain housing markets, thereby creating spatial segregation.” (Fisher-Maltese, et al, 2016)

Research from Maltese-Fisher, et, al (2016) examined 5th grade classes in Washington DC, which is considered at the forefront of curriculums using school-based gardens. Due to numerous grant opportunities for Washington DC public schools, 48% of schools have school-based gardens. Student demographics in Washington DC show that 70% of students in public schools are Black, 15% Hispanic, and 11% white. Despite these numbers, Black students made up 91% of the population in schools without gardens, while white students made up just 1% of students in schools without school-based gardens. Maltese-Fisher, et al (2016) also examined data around free and reduced lunch programs and found similar results. Students on free and reduced lunch programs represented 95% of the total number of students without access to gardens at schools. A study from Santa Clara, California conducted by Stewart, et al (2013) found similar results. Schools situated in high income and racially less diverse areas had greater access to school-based gardens. Again, highlighting the inequality that minority and low-income students face when it comes to field-based learning opportunities.

The goal of this paper is not to examine racial outcomes in education, despite the matter being of the utmost importance, there is already a wealth of literature on the topic that warrants further reading if that is the reader's interest. However, this baseline is important to establish due to the demographics in which I teach and have begun to incorporate the groundwork for this curriculum.

Jefferson County Public Schools (JCPS) is in Jefferson County, Kentucky, with the predominant city, Louisville being the center of the county. JCPS is the largest school district in the state and is a sanctuary city for numerous refugees from around the world. According to JCPS's student data, as of November 2022, the district serves 96,148 students, there are 139 languages spoken by students, and 66.6% are on free and reduced lunch programs. JCPS data from 2012-1013 shows that 47.2% are white, 35.9 are Black, 9.25% are Hispanic, and 3.65% are Asian. According to the Kentucky Department of Education School Report Card, the individual school in which this curriculum and field-based research site is intended is 50.4% Black, 25.6% White, 16.4% Hispanic, and 7.6% Other. Additionally, 81.7% of the student population is considered Economically disadvantaged, and more than 25 different languages are represented.

When considering the demographics of this school paired with the benefits of Field Based Inquiry and Learning, this school presents a prime opportunity to provide students with an exceptional learning tool. Not only does it give inner city and urban students a field-based experience and potential to see academic improvements in other courses, but it does so by using a soil that is highly impacted by human activity. As humans, we continue to rapidly spread our footsteps across this world. Often doing so in ways that are unsustainable and destructive. By studying urban soils with a gradient of soil depth covering a buried M horizon containing layers of gravel, asphalt, and concrete, this field learning experience is highly relevant to these students' own lives and could also provide valuable data in the future about how we might better utilize these shallow root limiting soils.

My personal teaching philosophy

My teaching philosophy begins with providing my students a clean, well-organized, and safe environment for each one to grow and learn. Students should feel welcomed by both me and by their peers. Diversity is positive and helps all of us grow and develop to be better people. To assess this concept, research based, and data driven instruction is necessitated. Nationality, race, sex, or gender diversity should not influence the ability of students to succeed in my classroom. Documenting student progress and utilizing objective measures of assessment will help achieve this goal. Project based learning will take place with diverse groups of students to promote these ideas. Learning objectives will vary from task to task, as science embodies both writing and mathematics standards while working to understand the mechanics of the world around us. Results will be measurable by incorporating objective, and unbiased rubrics to assess students.

Well-reasoned discussion, presented respectfully, is to be encouraged. We should be receptive to actively listening to others and attempting to understand their views, even when those views differ from our own. We do not have to share common goals or interests to treat each other with respect and dignity. My actions in creating a space that is open to discussion and sharing of differing ideas builds professional rapport. An environment as such is welcoming to students and peers because they know that are free from judgment and open to being themselves. These decisions and actions will apply when dealing with students, colleagues, and parents. This will ensure that those relationships develop trust and mutual respect in a professional environment.

I will seek to find the truth regarding the world around me. I will always be willing to reexamine my own knowledge and beliefs based on new information. This is imperative in ensuring that, as an educator, I never stop learning. It would be a disservice to my students if I did not continue to adapt. The importance of adult learning cannot be overstated and the use of continuing education to benefit my students should shine in their results. Use and development of research-based learning strategies will be a cornerstone in my lesson planning.

We live in an ever-changing world of technology. Technology is rapidly changing due to the needs within the workforce. It is our duty to prepare each student for success in that future workforce. In order to do so, we must be knowledgeable in regard to those future needs and must be capable and willing to provide access to hands-on, differentiated instruction that prepares them accordingly. Education serves a much grander purpose in today’s society than many realize. Throughout history, education was a right allotted purely to the wealthy and privileged. Not only is that concept antiquated and discriminatory, but it has the effect of holding back advancements and increasing the necessity of welfare.

A businessman and philanthropist from Orlando, Florida, Harris Rosen, founded a program in an underprivileged neighborhood in Orlando, Florida. His program provides guaranteed college scholarships, job training, and free community run childcare for residents. This program has led to graduation rates and GPAs that are now among the highest in the state of Florida. (https://www.tangeloparkprogram.com/our-results/) Graduation rates are above 90%, 12 points higher than the state average. GPAs average 0.5 points higher than the state average. There has also been a clear correlation with a decreased crime rate in the neighborhood since the program's inception. Most intriguing is the return on investment. The total 24-year investment for this project has been $12,807,800. As Lance Lochner from the University of Ontario states in his research, the return on investment as of 2016 is $89,654,600; a return of 7 dollars for every one dollar spent. He is currently expanding his program to other communities as well. His dedication to funding educational opportunities in the local community of Tangelo Park is not only inspirational but testament to the positive effects that an accessible education has on society.

I of course do not fathom that I will have the opportunity to reach as many students' lives as Mr. Rosen. I do, however, believe with great conviction that a single teacher can inspire students to want to better themselves. Ultimately, I feel that is my primary goal in working as an educator, not simply teaching rote memorization, but to inspire my students to want to explore and think critically about the world around them.

Project-based learning approaches (PBL)

The origins of the term PBL or project based learning dates to 1960's Canada. The medical school at McMaster's University devised the approach for med students to learn using a realistic and hands on approach. It is not too much of a stretch to realize that a hands approach to learning was not new to the 1960’s (Doles, 2012). This approach to learning is nearly as old as life on Earth. Our ancestors would have learned primitive hunting with early weapons by repeatedly throwing a stone or stick until they become proficient enough to use the skill for survival. Modern education has in some ways regressed from this idea of hands on learning. However, modern interpretations of the PBL approach are attempting to bring education back in line with this more primitive, yet genuine approach to learning.

A PBL model developed by New Technology Academy in Napa Valley California eventually grew and has spread to more than 175 schools across the US and Australia. (The New Tech Network Story). This public school, which was funded by private entrepreneurs and has become the basis for which many educators across the United States base their own PBL approach. A few of the key characteristics of the New Tech approach as well as other PBL approaches include: a driving question, realistic problems, student autonomy, and collaborative work. When facilitated well, students take almost complete control of their own learning. (Kokotsaki, 2016)

Research has shown that PBL approaches to learning have provided positive outcomes in student academic achievement, social and emotional development, college acceptance, self-management skills (Kokotsaki, 2016, Alacapinar F. 2008). A literature review by Barak and Asad from 2012, showed strong potential for PBL models in STEM fields to increase females attitudes towards pursuing STEM education. This is important as a gap for females in STEM education and careers is prominent across the globe. According to data from the National Science Foundation shows that as of 2020 woman earned just 26% of the bachelor’s degrees earned in mathematics and computer science and 25% of the bachelor's degrees earned in engineering fields. An important finding from Doppelt (2003), linked project based models used with low-achieving students to increase their self-image and self-motivation. By allowing groups of students that are often left behind by traditional instruction an outlet to experience relevant and measurable results to problem solving, these students were better able to find motivation in themselves to continue education and growth.

Outcomes of a field-based learning and research project

Beginning August of 2021, I presented a research proposal (see Part 2: supplemental materials section) to the administrative staff at Doss High School, in Louisville, KY. After discussions with school administrators, I was provided with a field, approximately 50 m * 32 m in size (approximately 1600 sq m). I was told at the time that this had not been used for anything other than overflow parking in previous years. The field was surveyed in August of 2021 using a 1 inch soil probe and examined to 30 cm in depth. Some shallow resistance was noted in the southern portion of the field. This was assumed to be attributed to compacted soils from vehicle use. In October of 2021, myself and 7 students who voluntarily signed up for an after school environmental science club undertook the first stages of the proposed research project.

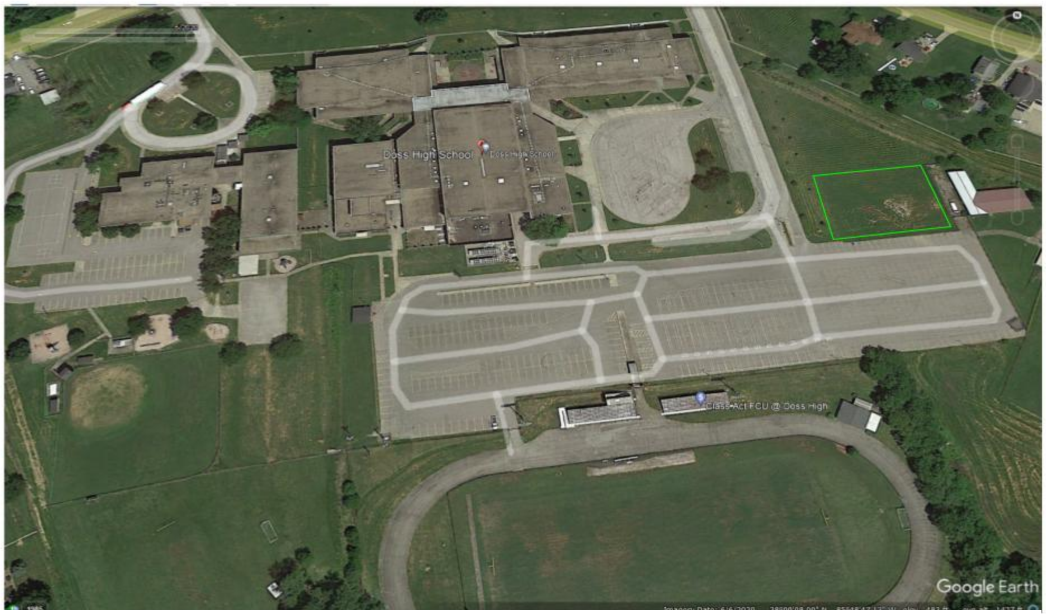

Figure 1: Aerial View of Doss High School. Captured from Google Earth: 6/6/2020.

The first step was to collect base line soil samples of the research plots. Students were divided into 2 groups and tasked with collecting integrated samples from 6 sub plots within the field. Within minutes our team of students encountered resistance while attempting to auger past the first several inches of soil in many parts of the research field.

After struggling to reach depths past 20-30 cm we decided to use a shovel to dig several random soil pits to gain a better view of the profile. What we found surprised us. We came to impenetrable layers of fill gravel first. The initial interpretation was that this was likely a gravel parking lot at some point in the past. At the time, I had worked for this school for 3 years and had seen this location used for overflow parking when needed. We discovered the top layer of a buried human manufactured soil horizon (Soil M horizon).

As we continued to probe into this profile, we discovered large pieces of black asphalt covered by a thick black landscaping fabric. Several shallow pits were dug randomly throughout the field. These ranged in depth from about 10-12 cm towards the southern edge of the field up to about 50-60 cm along the northern edge of the field. We were unable to collect samples from every depth/plot that was originally planned, we collected what we could. This amounted to 11 out of the expected 18 samples. I decided to continue with the project as intended with an understanding that the results were likely going to be skewed by these root limiting horizons.

Figure 3: Left: Photo of an M horizon with concrete and black landscaping fabric; taken from near the center of the research field, approximately 20 cm.

Figure 2: Right: Photograph taken from the Northern edge of the field that shows the M horizon at about 10 cm, and strong gleying at 40 cm.

Further research and use of Historical satellite imagery found that there was a tennis court in this location previously. Using historical images, it was discovered that between 2016 and 2017 the tennis court was “removed”. The term here is used quite loosely. From our sample profiles and probing attempts, it seems that the asphalt was broken into smaller pieces and all of it left in place, covered with landscaping fabric, and then covered with gravel, fill soil and sod. The layer of top fill ranged in depth from 10 cm on the southern edge to approximately 60 cm along the northern edge.

Figure 4: Historical satellite image from Google Earth; June 2016

Field Growth Experiment

The original intent of this project was to study tilled and no-tilled (NT) soils using cover crops and sunflowers. The entire field was cover-cropped over winter with a cereal ryegrass and hairy vetch. For the study it was subdivided into 6 smaller plots with three being tilled and the remaining 3 using a roller-crimper to terminate the cover crops and leave the plant matter in place. The goal was for me and the seven student volunteers to examine the differences in the distribution of SOC, nutrients, and microbial abundance throughout soil profiles and compare them between NT and tilled soils. It was hypothesized that the NT fields would see a greater concentration of SOC, and nutrients in the upper 10 cm of soil and that the tilled plots would see a more even distribution throughout the soil profile. We also hypothesized that due to the lack of herbicides allowed, the NT field would experience greater overall growth due to less competition from weeds, attributed to the remaining cover crops that were roller crimped and left in place.

All 6 plots were tilled or mowed and then seeded with hairy vetch and winter rye. Cover crops grew acceptably in 5 of the 6 plots. The northern 3 plots experienced the greatest growth from cover crops and the southern 3 plots experienced less overall growth. Plot 6 located in the Southeastern corner experienced very little overall growth from the cover crops. However, the plot located on the southeastern edge of the field, experienced very low growth from the hairy vetch and low to moderate growth from the winter rye grass. The cover crops were terminated as planned at the start of April 2022 and sunflowers were seeded into all 6 plots during the last week of April. Sunflowers were seeded in rows spaced 3 feet apart and each plant seeded about 2 feet apart within each row.

Figure 6: Six weeks of cover crop growth taken from Southwestern corner of the field; Nov. 2021

Figure 5: Six weeks of growth taken from Southeastern edge of the plot; Nov. 2021

According to The National Weather Service and NOAA, the average temperature for April 2022 was 57.1 degrees F and no days fell below the frost point with the lowest temp after seeding reaching 43 degrees F and the high reaching 87 degrees F. Total precipitation for April was 4.44 inches. Regular waterings took place twice per week for the first 6 weeks after seeding. Sunflowers require a location with full sun, well drained soils, and prefer soils that are slightly acidic (6.0 -6.8) (University of Minnesota Extension, Sunflowers). No unexpected frosts and clear, warm days provided for reasonable growing conditions for sunflowers in this region.

Around the first week of June, six and half weeks after seeding. Of the more than 2800 sunflowers that were seeded, only 24 plants were found to have emerged from the soil. By August 12 sunflowers plants survived. The surviving plants were all tightly grouped in the Northwest corner of the field in what was a conventionally tilled plot labelled as plot 1. It seems that the conditions in one small corner were acceptable for the long-term survival of the plants that did grow. The northwest corner of this Plot 1 reached a depth of 60 cm, and it seems to have provided ample depth for root growth. A germination test was not conducted on the seeds prior to planting. Poor seed quality could have been a cause for the low growth rate. Another issue is likely a high pH in much of the research plot. From integrated samples, the pH in the Southeastern subplot was 8.1 with a depth to refusal of less than 10 cm. The Northwester most plot was able to be sampled to lower depths. The integrated sample in the upper 0-20 cm was 7.9 and the sample from 20-40 cm was 7.5. Given the growth of sunflowers was constrained to a small corner along the Northeastern edge of the plot, it seems possible that soil in that specific was slightly lower than the integrated samples average. Both of these considerations will need to be considered as research of this site continues.

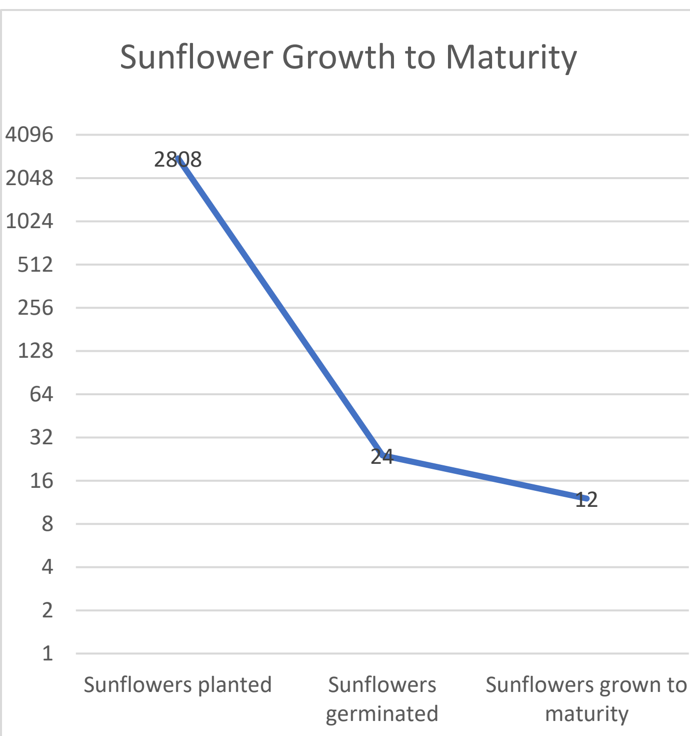

Figure 8: Rate of sunflower growth to maturity

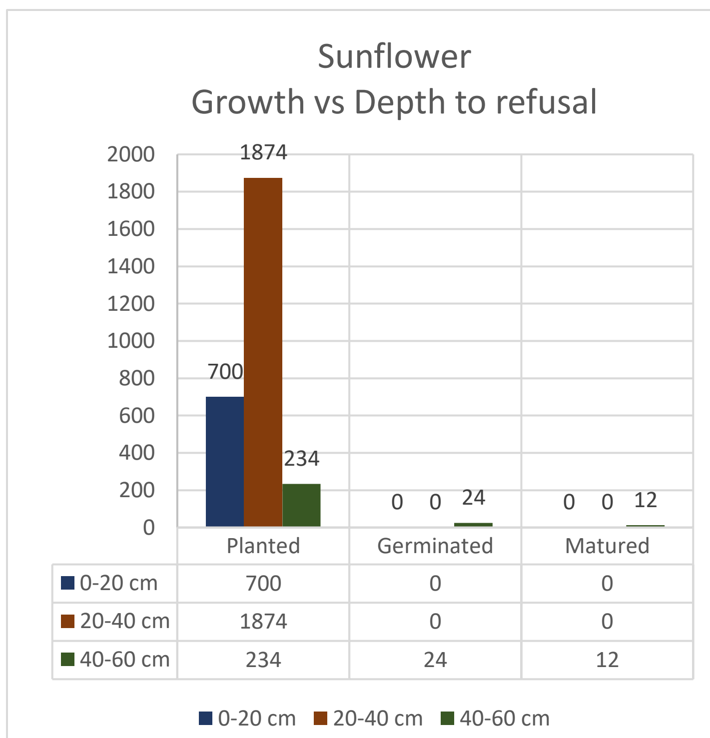

Figure 7: Sunflower growth vs depth to refusal

Manual weed maintenance took place, but the lack of herbicides meant that complete termination of the cover crops was not totally successful. Once it was apparent that the sunflower crop had failed, weed maintenance ceased and the hairy vetch and rye that did survive was encouraged to grow and reseed. In October of 2022, the field was reseeded with hairy vetch and winter rye at a rate of half of the previous year. Due to the environmental science club not taking place this year, a cash crop is not being planted. The cover crops will remain in place without termination and allowed to naturally reseed. Beginning again next Fall, students enrolled in my class will be using the field again to continue this research.

Despite the outcome of this research not turning out as originally intended, it does present a unique educational opportunity. One of the goals of this research proposal was to incorporate this site into a long-term research site for high school students. In this regard, the findings are a huge success. Adjusting the research to focus on the effects of human impacted soils, student will have an opportunity to learn firsthand how an ever growing human population affects our environment and impacts soils. By continuing to maintain cover crops, we can monitor the impact to the M horizon found in this field. The gradient in soil depth to the buried M horizon also presents a fascinating opportunity to examine agricultural outcomes within varying soil depths to a root limiting horizon. Additional research will need to be completed moving forward on how to best adjust the management of this site to focus on the impacts to the M horizon. With time, patience, and ongoing student efforts to expand learning, this site might one day be suitable for sustained agricultural growth. Continued collection and analysis of data, such as soil organic carbon, soil nutrients, and pH will help direct how this site managed in the future.

Feedback from student volunteers.

Combining a PBL approach with field-based learning provided students with all of the criteria to approach their learning in a meaningful way. The research project that was undertaken with the help of student volunteers was an attempt to lay the groundwork for just this sort of curriculum in the future. Incorporating student feedback is an important step for any educator that is seeking to better themselves and their curriculum. As I work to develop this field-based learning site into a functional curriculum for future classes a consideration of feedback from students is necessary. The following feedback came directly from students involved in the original project.

Much of the work performed took place outside within the research plot itself and involved seven students that volunteered for an environmental science club after school hours. The goal of the club was to undertake a number of projects around the school ranging from beautification projects, such as planting trees and flowers, and undertaking a major research project as proposed in part 2 of this paper. Students commented that a significant amount more physical labor was involved than expected. They seemed surprised by this originally, despite discussing the research plan for the field as well as other side projects around the school grounds. It was evident that they were tired and weary from the effort while we worked outside. Despite this, each of the student volunteers worked hard and put in significant effort to make the projects that we attempted a success.

There were several points of interest in the field-based work that stood out to these students. Discussions and in person observations about the soil profiles and soil horizons that we discovered were of particular interest. While the depth of this lesson was limited, each student actively engaged in discussions about how different soil horizons differed and what could cause these differences. Next, students enjoyed the examination of our cover crops and how they could potentially affect the soil structure and the buried M horizon that we discovered.

A portion of the work for this school club took place inside and involved project based learning opportunities using school lab equipment. Of particular interest was the lab work surrounding our attempts at titrating soil samples to monitor cellular respiration and microbial respiration. Soil was moistened in an airtight container and NaOH was used as a CO2 trap. Phenolphthalein and 50% BaCL2 were added to the trap after removing the trap from the soil samples. 1 M HCl was used to titrate the samples. Titration tests were attempted on two separate occasions in an attempt to measure soil microbial abundance. Both attempts appeared to have turned up wildly inaccurate results. The first attempt failed to provide any result, with the samples turning pink after the addition of the phenolphthalein and then immediately turning back clear. Our control sample experienced similar results. This was potentially due to older or out of date NaOH or HCl. The second attempt did manage to dramatically change color as the samples were titrated and this interested students. Additionally, they enjoyed working through math involved with the titration sample to quantify soil microbial respiration. Finally, the soil data results from our sampling were a point of interest. We reviewed these results as a group and had several discussions about the meaning of the results.

Students were engaged and intrigued how the buried M horizon and soil depth could drastically influence soil nutrients in a relatively small space.

This feedback is only qualitative, but it provides a valuable insight into the mindset of the students involved. This qualitative feedback is important in shaping the design of this field-based learning project for future students. As this work is converted into an actual curriculum formative and summative assessments of student academic achievement is necessary. PBL and field-based learning, as well as lab-based work were all used for the project. This multi-faceted approach to learning advocates for students to approach real world problems and work to develop solutions. It also allows take place in multiple stages and includes identification of a problem that they want to address, research related to their chosen problem, design and development of a solution or research experiment, implementation of their proposal, and presentation of the results.

Students enrolled in this proposed course will only have the option of participating in the course one school year, a Fall and Spring semester. This does limit each individual's potential for independent long-term research. Despite this limitation, there will undoubtedly be much crossover year after year. Students will ideally have the opportunity to explore and use portions of the study site in ways that interest them, however, ongoing experiments would allow for students to develop or build upon previous research. This will provide for long term research opportunities within the field of urban soils and buried M horizons.

In a PBL model students should have few limits as to how they explore their problem so long as it relates back to the course standards. This creates numerous opportunities for unforeseen, unexpected, and unique research topics. This field sits atop a shallow buried M soil horizon with varying depths at a relatively consistent gradient. Obvious areas of research include remediation of buried M horizons, effects on agricultural and cash crop within various depths of soil as well as rooting depths, effects on the M horizon with use of common cover crops, and of course the effects on soil measurements. This short list of ideas is far from all encompassing and the core idea to the curriculum allows for near endless possibilities for students to explore in a way that is relevant and interesting to themselves.

This project was originally self-funded out of my own pocket. In future, as this study site is incorporated into a curriculum I plan to seek outside funding as well to maintain the project for both research and a field lab site for students to use in the course of their studies. My goal is for this course to become part of a dual credit secondary school curriculum. Meaning that high school students will be taking a college level course and earning college credits from a partnering university. This connection, combined with the unique nature of the study site itself should be enticing when outside funding is sought.

Course standards and syllabus for the proposed dual credit course

Soils, the Environment, and Human Impact

Standards/Learning Outcomes

- Standard 1: Identify and differentiate the functions of Earth's subsystems.
- Standard 2: Identify and analyze the five classical soil forming factors. Apply scientific reasoning of human impacts to form an argument that includes humans as a sixth soil forming factor.
- Standard 3: Differentiate between soil properties and physical characteristics, including, color, texture, aggregates, density, and porosity. Apply scientific reasoning for how these characteristics affect the properties of soils.
- Standard 4: Model Nutrient cycles including Carbon, Nitrogen, and Phosphorus, and the water cycle through Earth's subsystems.
- Standard 5: Describe soils as living and dynamic systems and examine the role of soils in key nutrient cycles and the water cycle. Model nutrient cycles and the water cycle in a way that demonstrates the ecological role that soils play in these cycles.
- Standard 6: With the use of NRCS Soil Field Book and the NRCS Web Soil Survey, analyze soil profiles to determine master horizons and sub-horizons and make deductions about the soil properties within a soil profile.
- Standard 7: Evaluate the importance of soils in agriculture and their role in supporting human life. Examine concerns related to soil loss and contamination of surrounding systems due to human influence in agricultural soils.
- Standard 8: Model natural climate cycles on varying time scales, including short and long term ocean currents, soils role as a significant carbon sink, and the properties of Earth's orbit and how these influence climates. Examine claims and use scientific reasoning and evidence to evaluate human caused climate change on local and global scales.

Overview

This course will examine Earth's subsystems and the interactions of soils within each system using a field-based learning approach. It is divided into three parts. Part one of the course examines an overview of Earth's four main systems including cycles of water and key nutrients and highlights the role of soils as an intermediary between these systems. Part two focuses on the living and dynamic properties of soils and covers pedogenesis, properties of soils, and soil identification. Part three studies the impacts that humans have had on our environment, soil degradation, and the impacts these issues have on larger climate scales. The course follows a project-based learning approach and requires the developments and implementation of a major project. This project takes place over the entire course and takes the place of a final exam.

Learning Outcome

At the end of this course, students will be able to describe soil as a living and dynamic system and model nutrient and water cycles through Earth's subsystems, including the role that soils play in these processes. General soil characteristics can be identified and with the use of NRCS Field books, students will be able to differentiate master horizons in soil profiles. Natural and human influenced climate change can be evaluated based on varying timescales such as ocean currents, human activities, and Earth's orbit.

Modules
Part 1 - The role of soils within Earth's subsystems
Module 1 - Earth's systems: Review of Earth's four main subsystems; lithosphere, hydrosphere, biosphere, and atmosphere.
Module 2 - Cycles of matter: Water, Carbon, Nitrogen, and Phosphorus cycles
Module 3 - The ecological role of soils: Soil interactions with each of Earth's subsystems.
Part 2 - Soil formation and soil properties
Module 4 - Soil formation: Six soil forming factors including anthropedogenesis.
Module 5 - Soil properties and classification: Physical characteristics of soils and how those properties are used to identify and classify soils.
Module 6 - Soil Horizons and soil profiles
Module 7 - Soil interactions within cycles of matter with particular focus on soil/water interactions
Part 3 - Climate, and human impacts on the environment
Module 8 - Human impacts: Nutrient use in agriculture, nutrients as soil and water pollutants, soil contaminants and soil loss due to erosion and degradation
Module 9 - Climate cycles: Focus on naturally occurring systems and how they influence short, medium, and long term climate.
Module 10 - Human caused climate change: Key concepts include deforestation and desertification, the urban island effect, and the role of greenhouse gases and large scale climate change.

Course Structure

Each module will consist of lecture notes and/or assigned readings, a class discussion, A field-based project or lab, and a summative quiz. There are three summative exams for this course at the end of part one, two, and three. There is no final exam, however a field-based project is required that will take place in sections during the entire semester.

Scoring Rubric

Assignment	Points each	Total Points	% Final Grade
Discussion Questions	20	100	10%
Labs	30	200	20%
Quizzes	20	200	20%
Exams	100	200	20%
Field-Based Project	300	300	30%
Total	N/A	1000	100%

Part Two Supplemental Materials.

Original proposal for school based field-based research

Use of Cover Crops, and Tilled, and No-Till Agriculture, to Develop a Secondary Dual Credit Science Curriculum

Sustainable agriculture practices such as no-till, reduced tillage, mulching, and cover cropping continue to gain in popularity. Current research suggests that advantages and disadvantages are present within each practice. The concept of sustainable agriculture is important today to avoid damaging the natural resources necessary for future generations to produce food. Tillage provides benefits such as temporary reduction of soil compaction, managing weeds, and releasing nutrients but also has the potential to cause long term damage to soils through hastened nutrient losses, and increased soil erosion. Sustainable agriculture seeks to address these issues (Hobbs 2007). “Soil is not just another instrument of crop production, like pesticides, fertilizers, or tractors. Rather it is a complex, living, fragile medium that must be protected and nurtured to ensure its long-term productivity and stability” (Reginold, et al, 1990).

There is debate among soil and agricultural scientists regarding the potential benefits of no-till agriculture (NT) when compared to conventional till agriculture (CT). The availability of plant essential elements, crop yields, and carbon sequestration are among the most widely studied areas of comparison between these two agricultural methods. Studies demonstrate that, given certain climate and soil conditions, No-till agriculture and cover cropping can increase crop yields, soil nutrients, and possibly C sequestration (Christopher, et al, 2009; Jin he, et al, 2011; Sun, et al, 2020; Thomas, et al, 2007). Climate, soil texture, and crop selection are all influential in determining any potential benefits when comparing NT and CT.

The entire soil profile must be examined when studying the effects that various agricultural practices, such as NT, CT, and cover cropping have on soil nutrients and microbial communities. Moldboard plowing (MP), and chisel plowing (CP) are two of the most commonly used commercial methods for conventional tillage. The depths of these two techniques differ with MP reaching depths of 8-12 inches (20-30 cm) and CP reaching depths of 5-10 inches (12-25 cm) (Daigh, 2018, DeJong-Hughes). Early studies demonstrated that NT presented a better means of sequestering soil organic carbon (SOC) when compared to NT (1998; Du, et al, 2015; Sherrod, et al, 2005, Smith, et al). However most early studies examined the soil profile depth to 30 cm or less. Recent analysis indicates that total SOC in a deeper profile of 60 cm in depth may not favor NT as much as previously thought. C accumulation in NT fields is often greater in the upper 0-10 cm while NT accumulations is greater at lower depths. Total accumulation from 0-60 cm varies greatly but does seem to favor one method over another. (Baker, et al, 2006; Luo, et al 2010). Other factors such as climate, soil textures, and even crop rotations may play a greater role in C sequestration than NT or CT (Luo, et al, 2010; Sun, et all 2019).

Less research exists however, regarding the effects of NT on soil microbial communities. Over the past 20 years or so, more studies regarding microbial abundance, and diversity of microbial communities have been taking place. Soil microbes provide several complex and necessary functions to soils. Nutrient cycling such as N fixation and creation of soil aggregates are a couple of the most important jobs performed by microbial communities within the soils. Soil microbes work mutualistically with other species and provide a valuable measure of soil health. (Bardgett and Shine, 1999; Edwards, 1998; Gougoulias, et al, 2014; Schmidt, et al, 2018; Visser, et al 1992; Welbaum, et al, 2004)

Effects on crop yields

Pros and cons exist with both NT and CT agriculture. This research will examine three key questions regarding outcomes of NT and CT agriculture. First, what effect do NT and CT have on crop yields? Ultimately one of the main goals of nearly all agriculture is to increase the yield of crops being produced. Commercial agriculture requires a certain yield each year to cover costs of production and see a return on investment. These costs will vary by country, crop, and production method. In 2014 the Food and Agriculture Organization of the United Nations estimated the production of corn in the United States to cost an average of $689.80 per acre. While a home gardener may not take into consideration the same number of variables in determining the cost of production, the end goal is often the same, seeing a measurable return on their labor and investment. Because of this, determining total yields between these two methods will provide value in the research.

When considering the published research, it is important to examine the growing conditions available in a particular field as well as the desired outcome of the chosen method. For instance, when comparing crop yields of NT and CT agriculture, climate tends to affect the outcome of the final yield. According to Larson et al (1970), warmer temperatures and better drainage increase crop yields in no-till systems, while cooler climates and/or poor drainage lowered production in no-till systems. Nutrients stay closer to the soil surface making them more vulnerable to runoff. In soils with good drainage these nutrients are more likely to move deeper into the soil profile.

A 25-year study of corn and soybean production in Ohio soils, found that drainage was one of the most important impacts on crop yields. Poorly drained Mollic Ochre-qualf soil had lower output with little if any benefit realized. An increase in yield was realized in well drained soils (W.A Dick et al, 1991). Jin He, et al (2011) performed a study over 11 years of wheat and maize in northern China. They found that NT produced a 3.5% overall increase in yield. Only a slight increase was noticed in the first 5 years, the following 6 years realized a greater yield. They found a similar result in maize production with a 1.4% average increase in yield. Jin He, et al attribute this result to an improvement in soil properties and nutrient status. Soil organic matter (SOM), nitrogen (N), and phosphorous (P) content, bulk density, porosity, and aggregate size improved in NT.

This research will take place in Louisville, KY, which sits in the Ohio River Basin where soils tend to be high in clay and well drained. The moderate climate, high humidity, and warm summer temperatures could benefit the NT method, while the high clay content could prove to be either beneficial or detrimental, depending on specific characteristics. Because of these conditions it is hypothesized that crops in the no-till field will experience increased yields. The moderate climate, high annual rainfall, and lack of any soil amendments provide ample opportunity for this outcome.

Nutrient availability throughout the soil profile

Next, the proposed research will examine how NT and CT agriculture affect soil nutrients, soil organic carbon (SOC) and soil moisture content at specific depths. Different crops will have differing root depths and as a consequence, have different needs when it comes to available water and nutrient uptake. Current research in NT demonstrates that nutrient availability tends to be higher towards the surface and decreases at lower depths. CT tends to demonstrate a more consistent dispersion of nutrients throughout the soil profile (Triplett, Dick, 2008). This presents one of the concerns of NT. How are nutrients, particularly applied fertilizers in the case of commercial agriculture, incorporated into the lower depths of the soil? CT addresses this by tilling the soil, generally to a depth of 15 cm or more to distribute nutrients more evenly. Van Doren and Triplett (1973) find that in areas of sloped terrain and well drained soils, nutrients are more readily available in lower depths of NT fields. Soil moisture and retention of surface nutrients were increased due to cover cropping and mulching. They also found that clays which expand and crack benefitted NT systems by allowing nutrients to work their way down through the soil profile. This potential outcome coincides with research from Larson W.E, et al, who also found well drained soils to be more beneficial to NT because they allow leeching of surface nutrients to work their way to lower layers in the soil profile.

One of the most debated topics when comparing NT and CT is carbon sequestration. As with crop yields, studies show that climate may impact carbon sequestration when comparing NT and CT. Using data from paired studies, Sun et al (2020), state that carbon sequestration and increased crop yields using conservation (NT) agriculture are most realized in arid climates. Humid regions are more likely to only see an increase in soil organic carbon, and colder regions are just as likely to experience either a loss or gain in SOC. Louisville's humidity ranges from 35% -89% with an average of 62% according to the National Weather Service. Based on Sun's (2020) study, the expectation is to see an increase in SOC in the upper layers of the soil samples. This coincides with other findings as well. In a study done of 12 contrasting midwestern soils, Christopher et al (2009), N and C to be more prevalent in the top 5 cm of NT soils while the lower 10-30 cm of CT soils contained high levels of C.

As with carbon sequestration and crop yields, the availability of nutrients in soils varies with climate and sampling depth. A study published by Thomas et al (2007), explored three methods of agriculture, NT, CT, and reduced till (RT) in Queensland

Australia. They found that organic C increased slightly over the course of 9 years and was similar to a depth of 30 cm in all three practices. Total N stayed the same in NT while it decreased in CT and RT at 30 cm. He does state that while the total C and N in NT are higher than RT and CT, most of the concentration is in the top 10 cm and NT has a gradient concentration that decreases more rapidly at lower depths. An important consideration is the concentration of P and K. It was highest in NT but tended to gather near the surface OM layers and has the potential to reduce availability to the crops. This research will explore nutrient availability and soil moisture at different depths to compare CT and NT in side-by-side fields.

The soil being used for this study is in a region with clayey soils though there is no evidence of significant swelling or cracking upon initial inspection. The test site is a flat, well drained field with a small drainage canal that runs along one side of the field. These characteristics lead to the hypothesis that nutrient elements will be found in greater concentrations in the upper 10 cm the NT fields. The CT fields will experience a more evenly distributed concentration of nutrients through the entire profile being tested but will likely experience runoff of surface nutrients.

Soil Microorganisms

Research regarding soil microbes in NT agriculture is not as abundant as other research in this field, but this has begun to change in the past several years as conservation-based agriculture becomes more prevalent. The final question that this research will explore is, what impact does NT have on soil microbe abundance? Microorganisms are pivotal to soil health. Nutrient cycling, nitrogen fixation, and soil aggregation are a few of the benefits provided by soil microorganisms. Recent research has shown possible evidence that plants can use root exudates to physically shape the microbiome structure beneath the surface to create a more habitable zone for beneficial microbes (Jacoby et al, 2017). A 2018 Study published by Schmidt, et al examined microbial communities in NT and CT soils. They found greater microbial diversity in NT soils that tended to be slower growing and stress tolerant. CT soils contained greater numbers at lower depths. As evidenced in this study, their findings correlate with nutrients availability.

Welbaum et al (2004) state, “It is still unclear whether (bacterial) species diversity is, as is often proposed, critical to the integrity and long-term sustain-ability of soil ecosystems” We do know however that different species of microorganisms perform different functions and that certain plants can react differently to specific species of microorganisms. For instance, Azospirillum spp. and Bacillus sp. can positively affect growth in spring wheat. Winter wheats were positively affected by Pseudomonads (Chanway, et al, 1988). They hypothesize from their research that bacteria adapt to the genotype of the plants they coexist with. Five years was suggested as the amount of time it took for the bacterial adaptation to occur.

The role of soil microbes is fascinating and far more complex than this research can attain. Allelopathy is the harmful or beneficial effects between plants and other organisms. This can be other plants or microorganisms. Also, of note is that allelopathy can be either chemical or physical in its mechanism. Soil microbe's interaction with plants may be beneficial or harmful. Despite this it is generally agreed that an abundance of soil microbes provide an indicator of positive soil health (Bardgett and Shine, 1999; Chanway, et al, 1988; Edwards, 1998; Visser, et al, 1992; Welbaum, et al, 2004). The goal of this research is to explore microbe respiration when comparing side by side fields using NT and CT. This will provide an indicator of soil health using an affordable option for this experiment. We should expect to find a higher rate of respiration of soil microbes in the NT fields which are concentrated in the upper 10 cm of the soil. The CT fields will have lower microbial respiration which will be more evenly distributed throughout the soil profile.

Hypothesis

1. The crops in the CT fields will realize a faster initial growth due to warmer soils while crops in the no-till field will develop more slowly but should see greater yield due increased level of soil C
2. SOC, N, and other nutrient elements will be found in greater concentrations in the upper 10 cm of the NT fields; the CT fields will experience a more evenly distributed concentration of nutrients through the entire profile being tested.
3. An increase in microbial biomass will be present in the NT fields.

Study location and experimental design

Research will take place in Louisville, Kentucky at Doss High School at the coordinates: 38.09'09.9" N 85.48'41.1". The elevation at this location is 150 m. According to the National Oceanic and Atmospheric Administration the average annual rainfall in Louisville, KY is 1141 mm and average Annual temperature is 14.5 C with a summer average of 25.4 C and a winter average of 2.9 C. The field being used for this study is flat and is bordered on one side by a drainage canal. The space is 930 sq m). This location resides in an area of the city that does not contain significant commercial agriculture unlike the surrounding counties. Beef cattle, horses, tobacco, wheat, barley, and poultry are among the most produced products in Kentucky (Knopf, 2019).

The location is limited by being within the confines of a high school property. The land was developed in the mid 1950's but this portion of land was believed to have remained largely unused. The school district restricts what can and cannot be grown within the soils or school properties. Items intended for human consumption cannot be grown directly in the soil. Herbicides and pesticides are also not permitted to be used. These limitations require the use of non-edible cash crops and will require greater levels of hands-on maintenance to control unwanted organisms than methods utilizing herbicides and pesticides.

Figure 9: Aerial View of Doss High School. Captured from Google Earth: 6/6/2020.

The total plot will be divided into six equal but alternating plots. All six plots are adjacent to each other, containing the same soil type, topography, and climate factors. Three alternating plots will be monitored using no-till methods with winter rye and hairy vetch as cover crops. A roller-crimper will be used to terminate these cover crops. The three remaining alternating plots will be farmed using conventional tillage, also with the same ryegrass and hairy vetch cover crops; the cover crops and the residual plant matter from each growing season will be tilled back into the soil in the fall after the growing season. Sunflowers will be planted in both the CT and NT fields. After harvesting the last of the flowers in the fall and before the first frost, the plants will be mulched in the NT fields and tilled into the soil of the CT fields. Winter rye grass seed and hairy vetch will again be planted as cover crops and roller-crimped in early spring before going to seed. The CT field will be tilled with a rear tine gas-powered tiller. The same cash crops will be planted into the CT field as are planted in the NT field.

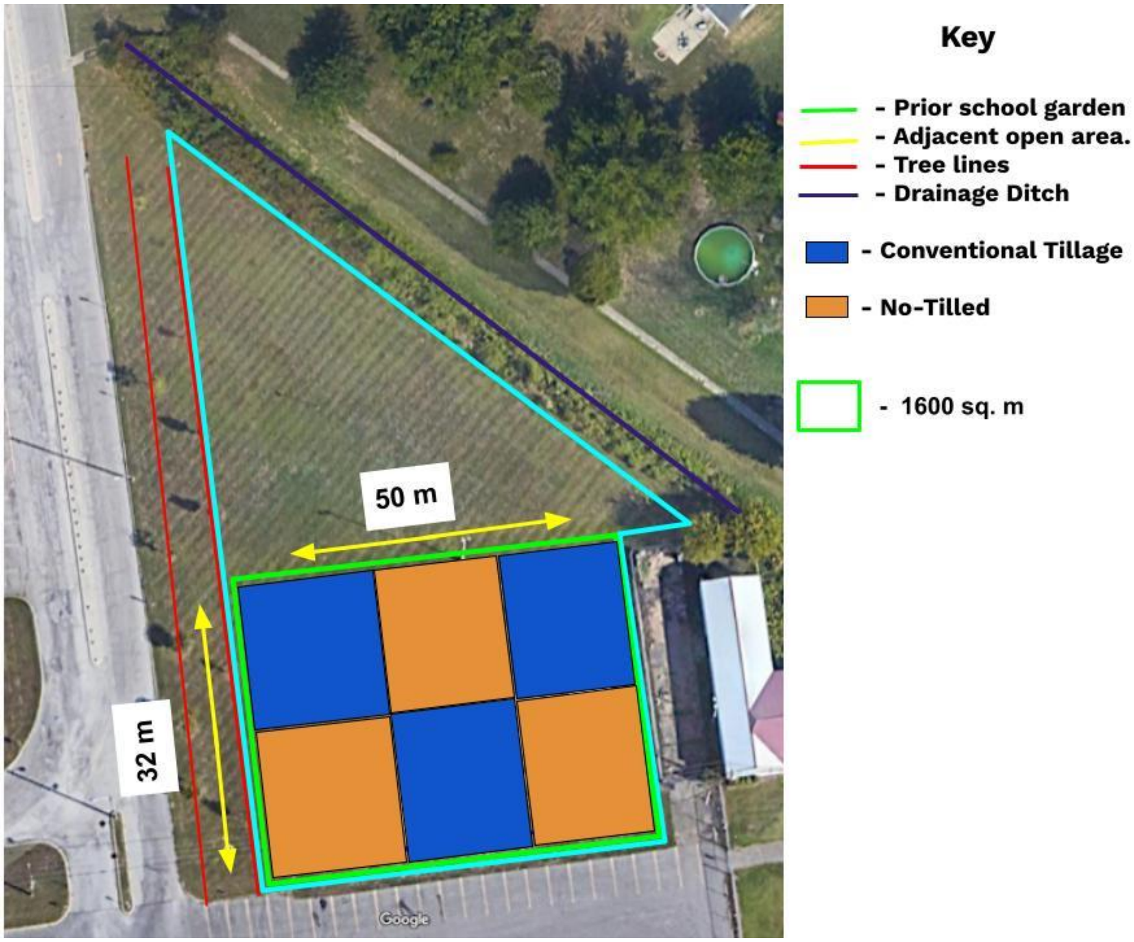

Figure 10: Aerial View of Doss High School with measurements and divided plots marked. Captured from Google Earth: 6/6/2020.

The field experiments will be conducted over the course of one growing season including the prior fall to seed ryegrass as a cover crop. Under my guidance, students will collect data at regular intervals. The research is taking place on school grounds and there are certain parameters from the school district that must be followed. Due to these restrictions, herbicides and pesticides are not permitted. Soil samples will be collected and analyzed during fall at the time the cover crops are seeded. Samples will be analyzed, and amendment recommendations will be completed.

Six integrated soil samples will be collected from each experimental plot per year. Three samples will be collected in Fall before mowing or tilling each plot and seeding cover crops. Three more samples will be collected the following Fall after the growing season is complete and mulching and tilling takes place. Two random samples from three sampling depths will be collected. This will equate to 144 samples in total from the six experimental plots. The depths to be sampled will be 0-10 cm, 10-30 cm, and 30-60 cm. These depths are chosen based on results of previous studies, particularly more recent research suggesting that 60 cm is a more appropriate measure of the complete soil profile (Baker, et al, 2006; Luo, et al 2010). Samples will be collected with a soil sampling probe or auger and fractionated by depth.

Analytical methods

The analysis of soil nutrients including C, N, P, K, Ca, Mg, Zn, and pH and buffer pH, will be performed through the University of Kentucky School of Agriculture-Division of Regulatory Services. Samples will be submitted directly to the University of Kentucky's facility for analysis. Three different tests will be performed. The "routine soil test" will test for: P, K, Ca, Mg, Zn, pH, and buffer pH. Glass electrode in 1:1 soil: water will test pH and use of Sikora buffer for Buffer pH will be used. P, K, Ca, Mg, and Zn will be tested using Mehlich III extraction and analyzed via ICP. Soil Organic Matter and C will be tested using LECO combustion. Total Nitrogen will be tested using LECO combustion. Microbial respiration will be analyzed using soil respiration. Titration will be used to determine soil respiration. Plant growth, both height and width will be measured weekly in cm. Yield will be measured as a total of the biomass.

Time/Milestones

Early October 2021 – The first samples will be collected for each experimental plot to serve as a baseline. Soil pH will then be amended to a pH of between 6.5-7.0. The fields will then be mowed and tilled shortly before seeding with winter rye grass and hairy vetch.
April 2022 – Conventional tilled fields are mowed, and the cover crops tilled into soil. NT fields have their cover crops roller-crimped and left on the surface as mulch.
May 2022 – Spring/summer seeds are sown.
Summer/fall 2022 – Plant biomass is measured.
Fall 2022 – After the first frost, plants are tilled into the soil of the CT fields. Crops are mowed and left as mulch in NT fields. Winter ryegrass and hairy vetch are seeded. The second set of soil samples are collected for analysis.
The goal of this project is to continue this identical process with students leading the effort as part of their curriculum. However, to align with my graduate studies this is the point that data analysis will begin on the data that has been collected over this growing season.

Expected outcomes

I expect to find a greater concentration of nutrient elements to be present in the upper 10 cm of the soil profile in the NT fields. The CT fields are expected to see a more even distribution of elements due to the tillage process incorporating them into the lower soil horizon. The flat ground being used for this study should contribute to greater infiltration of surface nutrients and therefore benefit the NT field which may show higher overall concentrations of elements. Given enough time I believe that soil microbe abundance will increase in the NT soils. Though one year may be a limiting factor to see this full effect. Chanway, et al, 1988, suggest that five years is the optimal period to see soil microbes fully adapt in a soil. Plant growth and yield will be measured. The CT field will likely experience faster initial growth due to increased soil warming prior to seeding. Due to the lack of herbicides allowed for this project, the NT field could experience greater overall growth and yield as the mulch should offer a form of weed control. Though the limited time could well present a problem with identifying any change in growth and yield. Soil microbes play an important role, mutualistically assisting plants; 1 year may not be enough time to fully realize the benefits that they contribute on total yield. Despite this I believe the climate and soil type in the region are conducive to NT methods and may contribute to measurable increases.

Contributions

The goal of this study is to add to the growing body of research regarding no-till agriculture to better assist farmers in both commercial farms and home gardens, in determining how to best utilize their land to maintain soil health and see a return on their investment. The research proposed will examine how NT and CT compare in side-by-side fields within a single soil type. Soil nutrients, water, and microbe abundance will be analyzed to provide insight into their effects on crop yields in this region. Despite the small scale and single location, there is a need to continue exploring this topic particularly at soil depths below the 30 cm mark. Sustainable agriculture continues to gain in popularity as potential benefits are more readily realized. Improvements in tools, equipment, crop selection, and knowledge are attributable to the rise in commercial use. (Triplett and Dick) NT provides one possible method of sustainable land use and soil preservation. The goal of essentially every commercial farm is to realize a return on investment. This means increasing yields of cash crops. Ensuring nutrient and water availability, and a healthy soil microbiome are two important means of doing just that. With so many factors influencing the pros and cons of NT, it is important to continue exploring this method of sustainable agriculture in a variety of different conditions. The time scale for this project as presented is a limiting factor. Regardless of the limited time span, one uncommon aspect of this study is the starting location. This is suburban, developed land, and is not taking place in already established agricultural soil. This small plot has been planted with Bermuda grass as a cover and to the best of my knowledge has been left relatively untouched since the school opened in 1967. The anthropedogenic factors of urban development and the sudden change to agricultural land management could demonstrate an unpredictable result. As an additional note, the long-term goal is to continue this research as part of an ongoing secondary school course that continues to collect data. As such, this project creates a foundation for a long-term study that will provide more robust data sets as time goes on.

Conclusion/Discussion

The potential of the field plots as a resource for student learning was explored. When considering the potential student learning outcomes, the field-based research and project-based approach that this research and education plot provides are invaluable. Both PBL and field based learning are proven methods of increasing student academic achievement. Providing these opportunities to minority students and low income students at a Title 1 school is an invaluable opportunity.

Based on feedback from a diverse group of student volunteers that took part in the original research, this project seems to have potential to increase engagement in a positive manner for future students. This approach is laborious, as well noted by the volunteers. However, the field study and incorporation of a multi-disciplined learning experience created genuine excitement and enthusiasm despite the physical nature of the work. Student discussions regarding the physical nature of the work highlighted a need to consider how to incorporate this curriculum equitably for students that may have exceptional needs or physical impairments.

In addition to student academic achievements there is an additional contribution that arises from this first research attempt. The nature of the research plot itself has allowed a failure to fall, by happenstance, into opportunity. The discovery of buried tennis courts under nearly the entire research plot ultimately led to the failure to grow all but 12 sunflower plants. A disappointment at a time when the expectation was to grow more than 2000 plants.

The discovery of a buried M horizon in the soil certainly changes the narrative of the research, but simultaneously presents a new and potentially better opportunity.

There is of course always more to discover regarding NT agriculture, but the work itself is not necessarily unique. However, with humans ever expanding reach across the globe it is likely to necessitate future generations using land that was once developed. This site could add genuine value to the study of urban agriculture and human impacted soils.

In 1946 Hans Jenny presented the equation; s = ƒ(cl, o, r, p, t, …). Today the same 5 soil forming factors are used almost exclusively in much of the literature with “o”, organisms, originally intending to encompass humans along with all other organisms. A quick look at Jenny’s original formula shows us with his use of an ellipsis that he was leaving open the potential for other soil forming factors as our understanding of soils evolved. Anthropedogenesis is a term that has been used in recent years to discuss the distinct influence of humans, apart from other organisms, in soil formation (Bacon, 2014, Wakabayashi, et al, 2012, Lebedeva, et al, 2005, Bini, et al, 2017, Vialle, 2021). Hans Jenny himself, along with Ronald Amundson, in 1991, took the steps to update the original soil formation formula to differentiate human organisms from other organisms. The Australian soil classification system even took the important step to incorporate Anthroposols as one of the 15 soil orders (Isbell, 2016). However much of the research on anthropedogenesis focuses on the human influences across broad geographic regions and through broader timescales of the Anthropocene age which we currently exist.

This study site is unique in that it provides the basis to examine a buried M horizon over a gradient of soil depths; >10cm up to 60 cm. Updated proposals will include a request to use an adjacent field also owned by the school that was not included in the original study. This field has not been examined but from historical satellite images from Google Earth, does not appear to have had any development in the past 30 years. Together these fields provide for an adjacent control group and numerous research opportunities.

Exploring how we might better utilize such highly impacted soils will provide unique research at a key point in time. Our impact to the planet is vast to say the least, and we have contributed positively and negatively to world we inhabit. Providing new research, such as the opportunity afforded in this site, that contributes to our understanding of buried M horizons and their use as agricultural land will help us better navigate remediation of future land such as this. Combined with opportunities for students to learn directly from this research would not only contribute valuable data and academic literature but also work to develop future generations into environmentally conscience critical thinkers.

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