

Providing for the Increasing Human Population:
Soils' Sustainability and Potential Must be Maintained and Replenished
for Increased Food Production

by
Elisabeth A. Bean

A thesis presented to the Honors College of Middle Tennessee State
University in partial fulfillment of the requirements for graduation from
the University Honors College

Fall 2024

Thesis Committee:

Dr. Samuel Haruna, Thesis Director

Dr. Joan McRae, Thesis Committee Chair

Providing for the Increasing Human Population:
Soils' Sustainability and Potential Must be Maintained and Replenished
for Increased Food Production

by Elisabeth A. Bean

APPROVED:

Dr. Samuel Haruna, Thesis Director
Associate Professor, Agriculture

Joan McRae, Thesis Committee Chair
Professor, World Lang Lit & Cultures

Dedication

I dedicate this project to my community, to improve this broken world we live in so we can prosper for many, many more years to come.

Acknowledgements

Foremost I would like to thank my Lord and Savior who through I was able to complete this project.

Secondly, I would like to express my gratitude to my advisor, Dr. Samuel Haruna, for your support with my thesis project. You have continually provided me with advice, patience, motivation, and continuous help when I struggled. I could not have imagined doing this project without you and am so incredibly grateful that you were my advisor.

My sincere thanks to my thesis committee chair, Dr. Joan McRae, for your insightful comments, tough questions, and encouragement.

I thank my friends here at MTSU and back home for dealing with my craziness and my MTeach family for supporting me.

Last, but not least, I would like to thank my family. Thank you for always supporting me through my dreams and for always having my back. I am so incredibly thankful for you all. I cannot wait to see where my journey will take me, but I know you all will be with me through it all.

Abstract

To provide for the growing population, soil's sustainability and potential must be replenished and maintained for increased food production. Solutions must be implemented to increase and sustain the soil's potential, and sustainability so that plants are able to grow and produce for this increased production. A few methods that will be discussed are crop rotation, soil management practices, the introduction of healthy bacteria, and the increasing of nutrient availability. The main solution we are trying to propose is the reduction in soil erosion. With the reduction in soil erosion, soils will continue to improve and be able to continue with the production needed. Some methods of reducing soil erosion are cover cropping, crop rotation, stubble mulch, no till management, etc. Cover cropping is the practice of planting a crop to cover the soil so that soil erosion agents, water and wind, will be less severe on soils. Crop rotation is a method that many farmers implement to increase nutrients in the soil as well to provide cover. Stubble mulch is a management practice that allows for the residues of past crops to be left on the top of the soil to provide a cover for the soil, as well as a nutrient boost. No till management is the practice of using no tillage and minimal to no mechanical implements, which leads to a reduction in blow off of soils and other erosion techniques. This implementation must be done, not just by a few individuals, but by all to have effectiveness. The problems of the past were created by all, so the solutions of the future need to be implemented by all to ensure a viable world. There is only one Earth so we must take care of it and its soil or increased food production will be a dream only thought of, not realized.

Table of Contents

Dedication	iii
Acknowledgements	iv
Abstract	v
Table of Contents	vi
List of Terms	vii
1. Introduction	1
Thesis Statement	5
2. Materials and Methods	6
3. Discussion	7
4. Conclusions	17
References	20

List of Terms

Aggregate Stability: The ability of soil aggregates, soil particles that bind together, not break apart and maintain structure against disruptive forces, such as water and wind.

Bulk Density: The weight of dry soil per unit of volume.

Ecosystem Services: The direct and indirect contributions of ecosystems to human well-being and have an impact on our survival and quality of life.

Environmentally Sustainable: The ability to conserve natural resources and protect global ecosystems to support the wellbeing of current and future generations.

Erodibility: How susceptible a soil is to being eroded/lost.

Erosion: The process by which earthen material is worn away and transported by natural forces such as wind and water.

Erosivity: The strength of the agent of erosion (wind or water).

Fallow: Land that is unplanted or left unplanted for a period of time.

Food Security: The state of having reliable access to a sufficient quantity of affordable and nutritious food.

Forage: A food for animals such as grasses, grains, and other feed stuff.

Greenhouse Gases: A gas that contributes to the greenhouse effect by absorbing infrared radiation, e. g., carbon dioxide and chlorofluorocarbons.

Natural Resources: Materials or substances such as minerals, water, and fertile land that occur in nature and can be used for economic gain.

Photosynthesis: A biological process where plants convert carbon dioxide and water into oxygen and energy using energy given off by the sun.

Soil Quality: How viable soil is, especially for the purpose wanted.

Soil Sustainability: The maintaining and replenishing of the provision made by soil without damaging the soil or ecosystems.

Sustainability: Avoidance of the depletion of natural resources in order to maintain an ecological balance.

Taxation: The reduction and overuse of natural resources such as soil.

Tillage: The preparation of land for growing crops, which is usually done by plows or similar mechanized agricultural equipment.

CHAPTER 1

Introduction

Humans are a continuously changing species and have been for the last tens of thousands of years. From the travelling of our ancestors around the world to settling down we have continuously changed, including behaviors. “Human populations either adapted, died out, or moved on as their hunting and foraging grounds shifted around the world” (Montgomery, 2007, p. 28). With the changing of times, climate, and other circumstances the human species also had to change so as to be able to survive in those conditions. With that change, behaviors changed as well in the way humans go about agriculture.

Agriculture is the cornerstone of surviving as a species, from the way crops are harvested to the way animals are raised. Agriculture is believed to have started and helped with the building of the countries of Mesopotamia, China, Egypt, and other areas (Barker, 2006). These civilizations thrived thousands of years ago and yet they are a testament to the beginning of our relationship with agriculture. Many of the pre-historic methods current agricultural practices were based on were developed during this period. With the advancements of agriculture during these periods, there was also the development of agricultural issues, including soil degradation.

Human populations are continuously growing and with this growth, there must be adequate nutrition for these populations. Food production must rise in accordance with this increase in population, but issues arise. With this increased need for food, taxation of our natural resources occurs. When this taxation occurs, production of food decreases, which

leads to further problems. To avoid these problems, we must sustain and replenish our natural resources so that we can provide for these growing human populations.

One natural resource especially necessary for food production is viable soil. With this increased need for food production, soils will need to be able to sustain necessary production, as Amundson et al. state, “Human security has and will continue to rely on Earth’s diverse soil resources” (2015, p. 647). Soil is one of the major requirements in plant growth and development because they provide plants with nourishment, stability, and promotion of their growth. Soil provides plants with the nutrients they need to grow and develop as well as the stabilization to root and produce. Pereira et al. provide, “Soil management has important implications for the quantity and quality of the ES (ecosystem services) provided” (Pereira et al., 2018, p. 8). Ecosystem services, as the name states, are the services ecosystems provide such as soils providing support, nutriment, and environment for plants to grow and produce in.

Currently, one of the ways to improve productivity while ensuring sustainability is by changing traditional land management practices. Foremost, soil sustainability is the maintaining and replenishing of the provisions made by soil without damaging the soil or ecosystems. According to Laamrani et al., “The impacts of tillage practices and crop rotations are fundamental factors influencing changes in the soil carbon, and thus the sustainability of agricultural systems” (Laamrani et al., 2020, p. 1). For example, there is a shift from conventional tillage methods (e.g., moldboard plowing, strip tillage, disking, etc.) towards more benign and environmentally sustainable methods like no-till. No-till management practices require less equipment use. In fact, the only recommended use of equipment in no-till practice involves planting, herbicide, chemical spraying, and

harvesting. As such, there is a decrease in the environmental footprint involved in this practice. No tillage has shown its worth especially in West Tennessee with the improvement of soil quality and yields of cotton (Nouri et al., 2019, p. 1007). Further, it is economically beneficial by saving money on equipment purchase/lease as well as fuel costs. Stovall (2017) highlighted on the economic and environmental benefits of no-till and the effect it has had on Tennessee.

Looking at the at all the good sides of conservation tillage and no tillage management, why would producers not implement these practices into their plan? Some reasons producers may not implement these practices are due to the use of traditional methods, specialized equipment for no till, soil compaction, etc. Producers that are rooted in tradition and the use of traditional methods such as intensive tillage may not always change their management plans due to this continual usage of these practices for many years. Another deterrent for some producers is the need to buy specialized equipment for conservation tillage. Conservation tillage especially no till requires specialized equipment to imbed seeds into the field (“No-till farming for climate resilience”). While this equipment is beneficial for producers it is more costly in nature. One of the main reasons for the implementation of conventional (intensive, traditional) tillage is soil compaction. Soil compaction occurs when stress or soil factors leads to the decrease of air space in soils which leads to reduction of pore space. With this reduction in pore space, soils may not hold water as well as be able to hold and provide the necessary requirements for plants. Due to these factors, producers that face this soil compaction will continue to implement more intensive tillage practices to be able to produce a crop. Though intensive tillage needs

to be used in certain circumstances, in the times it is not necessary, better management such as conservation and no till tillage needs to be used as to not to further erode our soils.

Continuously looking to better land management practices for soils, there is a need to look at fertilizer usage. Fertilizer is a main part of supplying nutrients to plants, but improper or incorrect usage creates various forms of pollution. By managing fertilizer usage, there can be a decrease in pollution and greenhouse gas emissions. By combining both improved land management and fertilizer usage as stated by Deng et al. with their study in Middle Tennessee, “The alternative fertilizer sources and improved soil management could decrease N₂O emissions by reducing its moisture sensitivity. These findings are useful for better optimizing agricultural practices to maintain highly productive corn yield while reducing greenhouse gas emissions in the southeastern US.” (2015, p. 9). Knowing how important management and implementations are important to soil, the right methods must be used to replenish and maintain soil’s sustainability for increased food production, which is needed for the ever-growing population.

Thesis Statement

To provide for the growing population, soil's sustainability and potential must be replenished and maintained for increased food production. Calculations for the population of the world in 2050 are projected to be 9.8 billion (Fisher & Connor, 2018, p. 122). With populations predicted to continually rise, food production must also rise in accordance. This necessity for increased food production has left challenges for governments, scientists, and organizations who are the entities that must find the solutions to this global problem. With this need, methods need to be researched and then implemented to replenish and maintain our soils' sustainability and potential. For this thesis, global soil sustainability will be discussed but slightly narrowed down and focused on the state of Tennessee.

CHAPTER 2

Materials and Methods

The research is based on a literature review of scholarly agricultural articles and journals provided by the James Walker Library. Articles were gathered on the topics of soil conservation, erosion, conservation practices, outlooks for agriculture, teaching, and more. The focus area for research started globally then narrowed down to the state of Tennessee and then to the Middle Tennessee region. In addition, online research databases were used including Google Scholar, Soil and Environmental Science journal databases, and other Agricultural discipline specific journal databases to which MTSU or my advisor is subscribed. Also, these articles were used to provide more data and information to others about how the sustainability of soil is important to not only the future of agriculture but also the future of society.

CHAPTER 3

Discussion

Crop Rotation

Crop rotation is one of the many methods that can be implemented to replenish and maintain soil's sustainability and potential for increased food production. Crop rotation has been a practice that many farmers have implemented over the years to replenish nutrients, reduce erosion, provide another selling crop, and more. As the name states, crop rotation is the rotation of crops on the same land subsequently. A prime example used commonly by producers is growing corn (*Zea mays*), which is a high nitrogen needed crop, and planting soybeans (*Glycine max*) afterwards, which will recycle nitrogen in the soil. Soybeans are just one of the many crops used in crop rotation to replenish nutrients.

Replenishing nutrients is a large factor of crop rotation implementation, especially on farm operations producing crops demanding of soil nutrients like corn. Corn, also known as maize, is a highly demanding crop on soils. Researchers have found that soils used for corn production have a reduction primarily in nitrogen as well as organic matter (Biswakarma et al., 2023, p. 245). With this demand on soil health by this highly necessary crop, solutions must be found to keep soil's sustainability and potential replenished and maintained; one solution is crop rotation. Rotating soybeans after corn gives soil a less stressful crop to support, which gives time for the soil to replenish on one side (energy). Soybeans replenish and recycle nitrogen by the bacteria (Rhizobacteria) in their root nodules. This bacteria will convert nitrogen into a more absorbable form for plants to take

up. In using the rotation of crops, soils are organically being replenished by plants instead of by chemical methods, which further degrade soil potential and sustainability.

In using crop rotation, fields will actively have a crop instead of being fallow (left bare for a period of time) which can lead to reduced erosion. Implementing crops such as clover, alfalfa, perennial grasses, and more as a crop in rotation reduces erosion and replenishes the soil. As stated above, soybeans are an amazing rotation crop which replenishes soil nitrogen but also provides adequate cover for the soil which reduces erosion. Erosion is one of the leading factors of soils losing their potential and sustainability (Vanwalleghem et al., 2017, 13). When soils are left bare, with nothing to cover or hold them together, water and wind wear down, transport, and deposit sediments elsewhere. This is a major problem due to the primary station of nutrients and organic matter being on the utmost layer of the soil. When this layer is worn down and taken away, the original soil is less fertile and does not have as much sustainability. Implementing these beneficial crops in rotation will reduce erosion as well as keep producer's soils sustainable for production, especially in the increasement needed by growing populations.

In using crop rotation, producers can implement crops which benefit the soil as well as their pocket. Many producers that are farming for the money grow maize due to the necessity for the crop as well as the possibility of profit. Farming is not always a profitable adventure, with constant market changes and continuous problems, but is an essential profession due to the need for feed, fiber, and food for the human and animal populations. Implementing rotation crops such as soybeans, which are another universally used plant in food production, is beneficial for the demand for increased food production due to the ever-growing population. These crops are also greatly beneficial to the soil due

to their replenishing effect on nutrients and organic matter.

Soil Management Practices

Along with crop rotation, implementing better soil management practices is another method of how soil's sustainability and potential must be maintained and replenished. Over the years, management practices have improved from the methods our forebears used. Practices in the past caused more harm than benefit (e.g. during the Dustbowl of the 1930s) but thankfully scientists and farmers have learned from the past and improved upon past methods as well as implemented new ones (Smith, 2007, p. 65). The Dustbowl was a testament to what not to do to our lands when going through economic drought and environmental drought. As stated by the National Drought Mitigation Center, "reductions in soil conservation measures and the encroachment onto poorer lands made the farming community more vulnerable to wind erosion, soil moisture depletion, depleted soil nutrients, and drought." ("The dust bowl: National drought mitigation center"). Due to those intensive tillage methods and the aftermath of heavy wind erosion, governments and producers had to come together to manage and reduce these environmental tragedies. One of the major reliefs at the time was the creation of the Soil Conservation Service (SCS) which is the current National Resource Conservation Service ("The dust bowl: National drought mitigation center"). As we look from the past, we need to prepare for the future as to not repeat history, which leads to the implementation of sustainable land management practices. Some of the practices that have been implemented that improve soil sustainability and potential are conservation tillage, cover crops, conservation practices,

and more. Through these practices, soils have been able to retain what they have as well as gain.

Tillage is one of the oldest management practices pertaining to soil and is still used in modern farming. Tillage practices, especially intensive usage, have led to adverse effects on the efficient usage of resources and most of all soil's sustainability (Biswakarma et al., 2023, p. 245). Intensive tillage, while helpful in certain situations, is not a beneficial practice in being sustainable with your soil. Intensive tillage in situations that do not need to be intensively tilled or continuously over-tilled leads to a decrease in organic matter, higher susceptibility to erosion, and more hindrances to soil sustainability and potential. Due to these factors, scientists have researched and, in collaboration with farmers, implemented methods such as conservation tillage and no-till. No-till and conservation tillage are similar, with the exception of no-till is as the name states no-tillage and does not use a lot of mechanical implements in production while conservation tillage is minimally tilled and low use of mechanical agriculture on fields. As Tahat et al. summarize, "Conservation tillage practices (no tillage, reduced tillage, stubble mulch tillage, etc.) can increase soil microbial activities, soil moisture, organic matter, aggregate stability, cation exchange capacity and crop yield" (2020, p. 15). While tillage used intensively can provide more harm than benefit, using tillage minimally provides soil with more stability, energy, health, potential, and sustainability.

The use of cover crops is another practice that can be implemented to maintain and replenish soil sustainability and potential. Cover crops are used in a number of ways, but their benefits can be seen in an increase in soil moisture, reduced weeds, healthier soils, reduced erosion, and more (Clark, 2023, p. 1). Cover crops, as the name states, are a cover

for the soil which reduces the erosivity of soil erosion agents such as wind and water. Along with this reduction in erosion benefit, cover crops are also able to reduce weeds by blocking out germination requirements for weed seeds. Cover crops, especially legumes, are also an excellent way of making your soil healthier with their ability to recycle nutrients such as nitrogen. Red clover (*Trifolium pratense*) is one of the best cover crops to use to have nutrient replenishment, reduced erosion, weed suppressant, and more (Curell, 2014). Implementing cover crops reduces erosion, replenishes soil nutrients, suppresses weeds, and more which restores and maintains soil's sustainability and potential. Red clover as stated by John and Ogle, "produces a high quality forage" (2008, p. 1). With this crop being such a great food source for our livestock animals it further adds to the positives and will help in this increased food production.

Conservation practices, though broad, are one of the main ways to replenish and maintain soil's sustainability and potential. Thankfully, scientists have found and implemented many soil conservation practices such as stubble mulch, terraces, crop rotation, strip cropping, buffer strips, conservation tillage and so many more. Conservation practices protect soils from being degraded by wind and water, losing nutrients, gaining weeds, etc. Stubble mulch, also known as stubble mulch tillage, is a way to use crop residues to benefit soils. Best said by Tahat et al., "Maintaining crop residues on the topsoil surface layer...reduce soil erosion and increases soil moisture content" (2020, p. 15). Erosion is one of the main attackers on soils, especially on sustainability and potential. Reducing erosion gives soils the ability to support, nourish, and promote the growth of plants. Implementing these conservation practices replenishes and maintains soils so that

they will be able to provide for crops, especially with the intensification of production for the growing population.

Healthy Bacteria

Soils need healthy bacteria (rhizobacteria) introduced and established into the soil matrix to continue to be sustainable as well as plentiful. Rhizobacteria are beneficial to soil fertility due to their ability to recycle nutrients, remove contaminants, biocontrol, and more (Fasusi & Babalola, 2021, p. 95). Through these beneficial bacteria, soils are cleansed of contaminants which hinder plants, especially in growing, which leads to better conditions for plant growth. Beneficial rhizobacteria are also able to biocontrol, which means they are able to hinder pathogens which can sicken and possibly kill other healthy bacteria in the soil as well as plants.

The main reason though for introducing beneficial rhizobacteria is to replenish nutrients. Soils need to be able to provide nutrients to plants, especially in a form that plants are able to absorb. Since many soils are unable to do so, producers and scientists look for methods on how they can provide plants with the nutrients they need. Chemical fertilizers are often the road many producers turn down. The use of chemical fertilizer may provide plants with some nutrients but wreaks havoc on the environment. Chemical fertilizers do not absorb into the soil, so when they are applied, they either sink down to groundwater or runoff the soil surface into streams, which causes water pollution. This is not a sustainable method and does not replenish the soil, so scientists have turned to more organic forms such as organic fertilizers, microbes, rhizobacteria, and more. Akanmu et al. outline how these biological and organic sources enrich both plants and soil and

increase their potential (2023, p. 2). Using beneficial rhizobacteria and microbes are helpful as they both replenish and maintain soil potential and sustainability due to their ability to recycle nutrients into forms that are easier to absorb by plants than the original nutrient form in the soil. These healthy bacteria clean up soil, recycle nutrients, and make soil healthier and more productive for plant production.

Nutrient Availability

Plants need nutrients to grow and produce; soil provides these nutrients but sometimes these nutrients are unavailable or inaccessible to the plants. Due to this issue, scientists have had to find methods to increase the availability of these nutrients to plants. In finding these methods scientists must turn to more organic means so as to not further diminish soil's potential and sustainability by the use of chemicals.

Nitrogen, one of the primary nutrients plants need, must be available for plants to absorb, and use. With this need and the decreased want of chemical fertilizers, scientists and producers turn to organic means. One of these organic means is implementing plants that can perform nitrogen fixation. As stated by Jhu and Oldroyd, "Legumes are one such group of plants that form specialised root nodules, whose cells are packed full of internalised bacteria, living in an environment optimised for nitrogen fixation" (2023, p. 2). Soybeans, which are a type of legume, are able to recycle nitrogen from the soil into a more absorbable form for plants to take up. Using these biological fixations replenishes soil's potential and sustainability without further degrading the environment like chemical fertilizers do.

Potassium is one of the primary nutrients needed by plants to grow and produce (Mostofa et al., 2022, p. 279). With potassium being a necessary part of a plant's ability to grow and develop, the necessity for this nutrient to be available for plants to absorb from the soil is raised. Thankfully, there are many organic ways to add potassium into soils such as organic fertilizers/mulches, seaweed/kelp, household items such as coffee grounds, and more. Organic fertilizers/mulches provide plants and soils with the potassium they need in a healthier way than chemical fertilizers, as well as further support to plants. Coffee

grounds add potassium to soils, though in a smaller percentage, but they can be mixed directly into the soil or laid on top. Seaweed and kelp are plant products that contain potassium in larger amounts than coffee grounds and are a more organic absorbable additive. With potassium being such a necessary nutrient to plant growth, it must be accessible to plants.

Carbon, though not a plant nutrient, is necessary for soil health and sustainability. Carbon, especially soil carbon, is affected by many factors. According to Laamrani et al., “The impacts of tillage practices and crop rotations are fundamental factors influencing changes in the soil carbon, and thus the sustainability of agricultural systems” (2020, p. 1). With stubble mulch, residues of the previous crop are left behind on the soil surface, which leads to an increase in soil carbon in the decomposition. In crop rotations using oats and wheat, carbon in the soil increases (Laamrani et al., 2020, p. 10). Using these crops increases carbon in soils due to the plant's ability to absorb carbon dioxide (CO₂).

Soil Sustainability and Potential

Soil sustainability is a crucial factor that needs to be taught to not just the younger generations, but everyone. Soils must be able to provide plants with stability, nutrients, etc., which leads to plants growing and eventually being used for food production. As Fisher and Connor state, “Maintaining soil productivity is the key issue in sustainability” (2018, p. 134). If soils are unproductive, commonly known as infertile, they provide nothing for these plants which can lead to decreased yields or no yields at all, leading to shortages which will trickle down the chain. Thankfully, scientists continuously conduct

research on methods of how soil's sustainability and potential can be maintained and replenished.

Many would question why soil sustainability is so important that it needs to be taught? Soil sustainability, especially the implementation of sustainability methods, is going to be the future of not only agriculture but also industrial, residential, and habitual planning. Soils are vital to not only food production, but also the stability of housing, the use in industries, and providing for the needs of ecosystems around the globe. The need for soil sustainability is not the challenge of only a few certain people but an issue that needs to be undertaken by all.

Learning the methods of how soil sustainability and potential can be replenished and maintained will alleviate the burden as well as increase their effectiveness of them. Teaching the importance of soil sustainability informs people how they need to implement sustainable methods with soil as well as focus more on soil. Many people do not have the knowledge or the concern for soil sustainability which furthers the need for teaching the importance. As Kariuki-Githinji et al. state, "Inadequate environmental values education ... led to low awareness and action towards sustainability" (2022, p. 126). If people do not have the knowledge of the importance of soil sustainability, then they will feel no need to learn or implement methods on maintaining and replenishing the soil's sustainability and potential. Increased awareness of sustainability methods and focus on sustainable practices, through education, will help people achieve better results and further enhance and encourage soil betterment.

One method of teaching the importance of soil sustainability is to include teaching it in school curriculum. Schools in Kenya are already teaching goals to their students which

pertain to concerns about the environment (Kariuki-Githinji et al., 2022, p. 129). In teaching students these goals, students are learning about environmental issues. One goal is, "the need to promote positive attitudes towards good health and environmental protection" (Kariuki- Githinji et al., 2022, p. 130). Teaching the importance of taking care of the environment, especially soil, is one of the most important lessons one can provide to another.

As a pre-service teacher, teacher in training, focusing on agriculture education I have personally seen the dire importance of teaching our future generations about soil sustainability. These upcoming students, especially agricultural programs are hungry for purpose and with this increasing problem for increased food production, they need to know all the facts. Introducing curriculum, presentations, clubs, or any other way for students that share the same opinions on needing to maintain and replenish soil's sustainability and potential for this increased food production have an opportunity to receive this education as well as share their own ideas on how to do so. By introducing these topics in our curriculum, we are reaching all students, not just those interested in the topic. Tennessee State standard 7.3 for Applied Environmental Science states "Issues and solutions: Identify current environmental issues and research the environmental and ethical implications for potential solutions, such as but not limited to ecosystem recovery, reforestation, or reclamation." (TN Department of Education, 2024, p. 6). This is just one of many of our agricultural classes have standards that relate to agricultural issues and provide students opportunities to research and create their own solutions for these problems. With these standards, teachers can teach about the seriousness of the need to maintain and replenish

our soil's sustainability for increased food production and continue the chain. We only have one world; we must take care of it, or we will not survive.

CHAPTER 4

Conclusion

Implementing methods such as crop rotation, better management practices, introducing healthy bacteria, increasing nutrient availability, and teaching the importance of soil sustainability are necessary to replenish and maintain soil's sustainability and potential. Through these methods, soils become healthier and more plentiful for plants. Plants need plentiful soils to be able to produce in abundance due to soils providing plants with stabilization, nutriment, and promoting the growth and development of plants. Replenishing and maintaining soil's sustainability and potential leads to healthier environments for plant production which leads to increased food production for the growing population.

With this increased need for food production for the growing population, scientists, organizations, and governments must find solutions. While increasing crop yields will increase food, it taxes the soil into being less fertile. As stated before, plants need fertile soil to grow in so targeting soil sustainability and potential by replenishing and maintaining them leads to increased food production. Implementing methods such as conservation tillage, introducing healthy bacteria, stubble mulch, etc. may not lead directly into producing a crop but down the line, they allow time for the soil to replenish, as well as help with replenishing and the recycling of nutrients.

List of Recommendations: Implementation of better management practices such as crop rotation, conservation tillage, no-till tillage, cover crops, terraces, strip cropping, buffer strips. Increasing the availability of nutrients to plants. Introducing healthy bacteria

to soils to increase health and nutrients. There is also the need for education on soil sustainability for all to share the dire importance of these implementations.

Implementing these methods can provide many benefits to our soils. Implementing crop rotation reduces erosion, provides a selling crop, replenishes nutrients, etc. Conservation tillage and no-till tillage increases the health, stability, sustainability, energy, and more which leads to a reduction in erosion. Introducing cover crops has shown many benefits like reduced erosion, increase in soil moisture, reduction of weeds that will all lead to healthier soils. Introducing these land management practices lead to overall healthier soils by reducing erosion, increasing plant requirements (stability, nutrients, energy), and other factors that will increase the sustainability of soils. Adding healthy bacteria such as rhizobacteria to soils can increase nutrient availability and overall soil health. Increasing the nutrient availability of soils provides plants with the necessary nutrients for plant growth and development. Educating about the importance of soil sustainability is one of the most important factors as it will increase the awareness of sustainability practices and increase effectiveness of the methods by encouraging the betterment of soils.

To provide for the growing population, soil's sustainability and potential must be replenished and maintained for increased food production. The implementation of methods that replenish and maintain soil sustainability and potential is the route, as land stewards, we must take. With the increasing human population, food production must increase but we cannot degrade our planet further in the process. We, as a society, must implement healthier methods and practices to increase and sustain our soils and their potential if we wish to have any use out of them at all. The soils we have now are the only soils we will

ever have, and if we do not take care of them there will be nothing for plants and food to be produced from.

Some limitations of this project were the inability to access academic soil samples, time limit, and narrowed focus area. Due to scheduling conflicts and family health issues, I was unable to take soil samples to include in this project. Due to this inability, research is based on literature review of scholarly agricultural articles focused on erosion, outlooks for agriculture, teaching, soil conservation, management practices, etc. The time limit of completion was also reduced compared to normal completions of theses due to status as a transfer student in junior level and set up of project. The last limitation of this project was the narrowed focus area which limited research and access to research.

References

- Akanmu, A.O., Olowe, O. M., Phiri, A. T., Nirere, D., Odebode, A. J., Umuhoza, N. J. K., Asemoloye, M. D., & Babalola, O.O. (2023). Bioresources in organic farming: implications for sustainable agricultural systems. *Horticulturae*, 9(6), 1-16. Article e9060659. <https://doi-org.ezproxy.mtsu.edu/10.3390/horticulturae9060659>
- Amundson, R., Berhe, A. A., Hopmans, J. W., Olson, C., Sztein, A. E., & Sparks, D. L. (2015). Soil science: soil and human security in the 21st century. *Science*, 348(6235), 647-655. Article e1261071. <https://doi.org/10.1126/science.1261071>
- Barker, Graeme, (2006) 'Approaches to the Origins of Agriculture', *The agricultural revolution in prehistory: Why did foragers become farmers?* (Oxford, 2006; online edn, Oxford Academic, 12 Nov. 2020), <https://doi.org/10.1093/oso/9780199281091.003.0006>
- Biswakarma, N., Rai, B., Nayak, S., & Radheshyam. (2023). Conservation agriculture (ca)-based tillage practices in maize for enhancing crop yield, resource use efficiency and soil health: a review. *Agricultural Reviews*, 44(2), 245-251. <https://doiorg.ezproxy.mtsu.edu/10.18805/ag.R-218>
- Clark, A. (2023, July 21). *Cover crops for sustainable crop rotations*. SARE. <https://www.sare.org/resources/cover-crops/>
- Curell, C. (2022, January 21). *Benefits of using Red Clover as a cover crop*. MSU Extension. https://www.canr.msu.edu/news/benefits_of_using_red_clover_as_a_cover_crop

- Deng, Q., Hui, D., Wang, J., Iwuozo, S., Yu, C.-L., Jima, T., Smart, D., Reddy, C., & Dennis, S. (2015). Corn yield and soil nitrous oxide emission under different fertilizer and soil management: a three-year field experiment in middle tennessee. *PLoS ONE*, *10*(4), 1–14. <https://doi-org.ezproxy.mtsu.edu/10.1371/journal.pone.0125406>
- Fasusi, O., & Babalola, O. A. (2021). The multifaceted plant-beneficial rhizobacteria toward agricultural sustainability. *Plant Protection Science*, *57*(2), 95-111. <https://doi-org.ezproxy.mtsu.edu/10.17221/130/2020-PPS>
- Fischer, R. A., & Connor, D. J. (2018). Issues for cropping and agricultural science in the next 20 years. *Field Crops Research*, *222*(June 1), 121-142. Article e201803008. <https://doi.org/10.1016/j.fcr.2018.03.008>
- Jhu, M.-Y., & Oldroyd, G. E. D. (2023). Dancing to a different tune, can we switch from chemical to biological nitrogen fixation for sustainable food security? *PLoS Biology*, *21*(3), 1-24. Article e3001982. <https://doi-org.ezproxy.mtsu.edu/10.1371/journal.pbio.3001982>
- John, L., & Ogle, D. (2008, December 18). *Red Clover – Trifolium pratense L.* NRCS. https://plants.usda.gov/DocumentLibrary/plantguide/pdf/pg_trpr2.pdf
- Kariuki-Githinji, S., Boyo, B., Bowen, M., & Kiambi, P. (2022). School curriculum and enviromental sustainability. *Technium Social Sciences Journal*, *32*, 126-144. <https://doi-org.ezproxy.mtsu.edu/10.47577/tssj.v32i1.6604>

- Laamrani, A., Voroney, P. R., Berg, A. A., Gillespie, A. W., March, M., Deen, B., & Martin, R. C. (2020). Temporal change of soil carbon on a long-term experimental site with variable crop rotations and tillage systems. *Agronomy*, *10*(6), 1-13. Article e10060840. <https://doi-org.ezproxy.mtsu.edu/10.3390/agronomy10060840>
- Mbuthia, L. W., DeBryun, J., Schaeffer, S., Tyler, D., Odoi, E., Mpheshea, M., Walker, F., Eash, N., & Acosta-Martínez, V. (2015). Long term tillage, cover crop, and fertilization effects on microbial community structure, activity: implications for soil quality. *Soil Biology and Biochemistry*, *89*(October), 24-34. <https://doi-org.ezproxy.mtsu.edu/10.1016/j.soilbio.2015.06.016>
- Montgomery, D. R. (2007). *Dirt: The Erosion of Civilizations*. University of California Press.
- Mostofa, M. G., Rahman, M. M., Ghosh, T. K., Kabir, A. H., Abdelrahman, M., Rahman Khan, M. A., Mochida, K., & Tran, L.-S. P. (2022). Potassium in plant physiological adaptation to abiotic stresses. *Plant Physiology & Biochemistry*, *186*(September 1), 279-289. Article e202207011. <https://doi-org.ezproxy.mtsu.edu/10.1016/j.plaphy.2022.07.011>
- National Drought Mitigation Center. (n.d.). *The dust bowl: National drought mitigation center*. The Dust Bowl | National Drought Mitigation Center. <https://drought.unl.edu/dustbowl/Home.aspx>
- No-till farming for climate resilience*. USDA Climate Hubs. (n.d.). <https://www.climatehubs.usda.gov/hubs/international/topic/no-till-farming-climate-resilience>

- Nouri, A., Lee, J., Jagadamma, S., Yin, X., Tyler, D. D., & Arelli, P. (2018). Soil physical properties and soybean yield as influenced by long-term tillage systems and cover cropping in the Midsouth USA. *Sustainability (Switzerland)*, 10(12), 1-15. <https://doi-org.ezproxy.mtsu.edu/10.3390/su10124696>
- Nouri, A., Lee, J., Yin, X., Tyler, D. D., & Saxton, A. M. (2019). Thirty-four years of no-tillage and cover crops improve soil quality and increase cotton yield in alfisols, southeastern usa. *Geoderma*, 337(March 1), 998-1008. <https://doi-org.ezproxy.mtsu.edu/10.1016/j.geoderma.2018.10.016>
- Nouri, A., Yoder, D. C., Ceylan, S., Jagadamma, S., Lee, J., Walker, F. R., Raji, M., Yin, X., Fitzpatrick, J., Trexler, B., Arelli, P., & Saxton, A. M. (2021). Conservation agriculture increases the soil resilience and cotton yield stability in climate extremes of the southeast US. *Communications Earth and Environment*, 2(1), 1-12. <https://doi-org.ezproxy.mtsu.edu/10.1038/s43247-021-00223-6>
- Pereira, P., Bogunovic, I., Muñoz-Rojas, M., & Brevik, E. C. (2018). Soil ecosystem services, sustainability, valuation, and management. *Current Opinion in Environmental Science & Health*, 5(October), 7-13. [Article e201712003. https://doi-org.ezproxy.mtsu.edu/10.1016/j.coesh.2017.12.003](https://doi-org.ezproxy.mtsu.edu/10.1016/j.coesh.2017.12.003)
- Ren, X., Zou, W., Jiao, J., Jian, J., & Stewart, R. (2023). Soil properties affect crop yield changes under conservation agriculture: A systematic analysis. *European Journal of Soil Science*, 74(5), 1-19. <https://doi-org.ezproxy.mtsu.edu/10.1111/ejss.13413>
- Singh S., Jagadamma S., Yoder D., Yin X., and Walker F. (2023) A weighted soil health index approach for refined assessment of soil health in cropping systems. *Front.*

Soil Sci. 3(August), 1-11. Article 10.3389. <https://doi-org.ezproxy.mtsu.edu/10.3389/fsoil.2023.1118526>

Smith, R. (2007). Saving the Dust Bowl: “Big Hugh” Bennett’s Triumph over Tragedy. *History Teacher*, 41(1), 65–95. <https://doi.org/10.2307/30037105>

Stovall, B. (2017, March 13). *How farmers are saving the soil in Tennessee*. Farm Flavor. <https://farmflavor.com/tennessee/tennessee-environment/how-farmers-save-the-soil/>

Tahat, M. M., Alananbeh, K. M., Othman, Y. A., & Leskovar, D. I. (2020). Soil health and sustainable agriculture. *Sustainability* (2071-1050), 12(12), 1-26. Article 12124859. <https://doi-org.ezproxy.mtsu.edu/10.3390/su12124859>

TN Department of Education. (2024). *Tennessee state applied environmental science standards*. https://www.tn.gov/content/dam/tn/education/ccte/ag/cte_std_applied_environmental_science.pdf

Vanwallegem, T., Gómez, J. A., Infante Amate, J., González de Molina, M., Vanderlinden, K., Guzmán, G., Laguna, A., & Giráldez, J. V. (2017). Impact of historical land use and soil management change on soil erosion and agricultural sustainability during the anthropocene. *Anthropocene*, 17(March), 13-29. Article e201701002. <https://doi-org.ezproxy.mtsu.edu/10.1016/j.ancene.2017.01.002>

Williams, A., Jordan, N. R., Smith, R. G., Hunter, M. C., Kammerer, M., Kane, D. A., Koide, R. T., & Davis, A. S. (2018). A regionally-adapted implementation of conservation agriculture delivers rapid improvements to soil properties associated

with crop yield stability. *Scientific Reports*, 8(1), 1-8. <https://doi-org.ezproxy.mtsu.edu/10.1038/s41598-018-26896-2>