### Thesis Prospectus 2022-23

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**Faculty Reader Approval (date):**

**MES Director Approval (date):**

1. Soil carbon levels in Southwest Washington (SW WA) pasturelands.
2. The role of soil in addressing climate change, both as a mitigating factor and as an ecosystem component, has become increasingly critical in recent years. Extreme weather events—floods, droughts, extraordinary temperature variations, changing precipitation patterns—coupled with increasing anthropogenic pressure on ecosystems and agricultural systems indicate that practices that increase resilience of those systems and contribute to long-term climate health need to be identified, expanded, incentivized, and supported. In particular, soil has the potential to store significant quantities of climate-destabilizing, anthropogenically generated excess atmospheric carbon dioxide through interactions with vegetation and soil biota (Lal, 2007). Recent research indicates that certain agricultural practices either enhance the sequestration of soil organic carbon (SOC) in soils or decrease the soil’s ability to absorb and store carbon (Lal, 2015). Other research suggests that those same practices increased soil fertility and subsequent vegetative production, as well as improved soil water absorption, storage capacity, and resistance to erosion (Hudson, 1994, Hicks Pries et al., 2017). Soil as a natural resource does not regenerate on a human timescale, and therefore is not artificially reproducible (Montgomery, 2007). The value of soil in the face of added human population pressures will continue to rise; preserving and increasing the health, quality, and capacity of soil should be a top priority of researchers, policy makers, and humans in general (Lal 2020). Understanding soil organic carbon levels, bulk density (a measure of soil mass per unit volume which has implications for soil porosity, water holding capacity, and biological populations), and their intersection with current and recent practices will provide a baseline for understanding the current health of the soil, provide the quantitative values for future measurements of soil carbon in SW WA working lands, and generate baseline data that can be used to establish effective support and incentive programs.
3. What effects do management practices have on Soil Organic Carbon (SOC) and bulk density in Southwest Washington pasturelands?
4. Globally, the potential to mitigate fossil-fuel emissions by sequestration of carbon in soil garners increasing attention (Lal, 2004, 2007; Zomer et al., 2017). Active management of soil to enhance soil carbon sequestration has proponents (Aguilera et al., 2016; Lal 2004, 2007, 2013, 2015, 2020) and skeptics with reservations about both the universal capacity of soil to successfully sequester significant amounts of carbon and the extent to which carbon sequestration will mitigate climate change effects (He et al., 2016; Six et al., 2002; Yin et al., 2022). Traditionally, the Pacific Northwest’s extensive forests are viewed as the primary carbon sink asset (Case et al., 2021). However, because of the difference in how and where carbon is stored, pasturelands have the potential to sequester larger amounts of carbon for a longer time frame than forests (Bai and Cotrufo, 2022; Dass et al., 2018; Lorenz, 2018; Fu et al., 2021). Soil carbon is an inherently dynamic component in soil, influenced by several factors including the interplay of soil physical, chemical, and biological properties (Amorim et al., 2020; Fu et al., 2021; Hudson, 1994; Naylor et al., 2020; Sakin, 2012; Taboada et al., 2011). Even more impactful are management practices that directly or indirectly influence soil properties to increase or decrease soil organic matter (and thus soil organic carbon), such as grazing intensity (Abdalla et al., 2018; Kim et al., 2023; Naidu et al., 2022), irrigation (Mudge et al., 2016), and other pasture management practices (Schabel et al., 2000; Taboada et al., 2011). I am unaware of other studies that examine pasture management practices in Southwest Washington, which has a unique combination of climate and soil features, to potentially maximize soil carbon sequestration using management practices. Therefore, combining a management survey with field observations of soil organic carbon and bulk density and knowledge of local soils from government sources (NRCS Web Soil Survey and DNR Geological Survey) will allow me to assess the level of influence of those management practices on soil carbon storage capacity.
5. Studying the SOC levels of pasturelands managed with different practices provides evidence that management practices impact the SOC levels in pasturelands. As scientists and political leaders seek solutions to mitigate anthropogenic climate changes, the knowledge accrued in this study will identify baseline SOC levels in equivalent soils in Southwest Washington. With this knowledge, policy makers will be better able to devise incentive programs to reward those agricultural producers who are contributing to climate solutions with SOC sequestration in their pasturelands. On 27 September 2022 the USDA announced its intention to support the development of a soil carbon monitoring network with an investment of $8 million dollars to “train partners on soil sampling and processing methods, conduct outreach to producers to use soil carbon monitoring practices, coordinate with NRCS national and state centers for technical support, identify and recruit specialists to help producers with soil carbon monitoring, and reach diverse producers to participate in soil carbon monitoring and other NRCS conservation practices.” This is a growing field in which my work will help establish baseline information and research protocols, as well as provide a map for future studies by MES students and others.
6. I will conduct management practice surveys with landowners during the winter season (January to February) to contextualize soil data. I will collect in-field soil samples to measure SOC and bulk density (BD) in pastures and native prairies in late winter and early spring as weather allows. The management practices, management history, and stable soil characteristics will be independent, categorical variables. The SOC and BD will be dependent, continuous variables.
7. Management practices survey data AND soil data will be collected in the first three months of 2023 from a minimum of five and up to 10 pastures with similar pedology in each category of management (haying, continuous grazing, rotational grazing, native prairie) for a minimum total of 20 and maximum total of 40 pastures. A management survey for each pasture will be completed online or by phone interview prior to soil sampling. In-field sampling will follow the Washington State Department of Agriculture Standard Operating Procedures (WSDA, 2022). Samples will be collected to assess baseline soil organic carbon levels and bulk density. The soil samples will be collected from 5 random points within a pasture, then homogenized prior to testing, yielding one sample for each pasture. To collect the sample, any plant material (grass, roots, and crop residue) on the top 1-2 inches will be removed, then a one-inch diameter soil-sampling probe will be inserted at a 90-degree angle to the surface of the soil. The soil will be deposited from the probe into a clean, non-galvanized bucket. The plot sample will be homogenized by mixing in the bucket with gloved hands. The soil will be placed into a labeled and sealed ziplock bag and stored in a refrigerator before being tested. Measurements for soil organic carbon will be collected 12 inches deep. Due to the relationship between root establishment and plant growth to bulk density, bulk density will also be tested in each pasture at three random sites co-located with the five sampling points within the pasture. To collect soil for bulk density testing, a soil core cup attached to a compact slide hammer will be used. The soil cores (three total for each plot) will be placed into labeled ziplock bags and refrigerated until analyzed. The data for soil organic carbon stock will be expressed as a percentage of soil organic matter and for bulk density will be expressed in g soil/cm3. Soil organic matter, nutrients, pH, and cation exchange capacity (S1A) tests will be done by Midwest Laboratories, 13611 B Street, Omaha, NE, 68144. <https://midwestlabs.com>. Bulk density measurements will be done in the Evergreen State College Science Support Center laboratory.
8. I will group management survey responses as categorical data, using a minimum of five replicates of each management category (undisturbed/native prairie, rotationally grazed, continuously grazed, hayed). If sufficient replicates on similar soil types are not available, it may be necessary to aggregate similar practices and/or soil types if the dissimilarities are not significantly different to create adequate sample sizes. Another alternative may be to exclude soil types that have fewer than three representatives from the study. Soil organic carbon (estimated from homogenized soil organic matter percentages using the van Bemmelen Index) and bulk density will be collected from each site and recorded as continuous data. I will use ANOVA to determine the significance of management practice effects on SOC and BD. If possible, I will examine the influence of land management practices such as fertilization, pH adjustment, and irrigation on SOC within the different pasture management and soil types with an ANOVA as well.
9. My study involves both on-farm soil sampling and a land management survey. To prepare for the survey portion of this study, I took Survey Research Techniques for Social Scientists; the CITI training basic course in Social and Behavioral Research; and submitted a Human Subjects Review application to the Evergreen Institutional Review Board. My survey was approved on 20 November 2022. The impacts of this study should not be harmful to participants in the study, because their personally identifiable information will be excluded from the final published report. Analysis of the data may be used by participants to optimize their work. However, there are no requirements for the participants to change their existing practices. There are no significant risks other than foul weather or blisters in collecting samples to anyone but me.
10. I will obtain verbal permission from the landowners to enter their properties to collect soil samples when I schedule the site visits.
11. As a dedicated environmentalist and academic researcher, it is extraordinarily easy for me to advocate for climate-smart practices. My livelihood is not dependent on adopting significantly different techniques, acquiring new equipment, or adding complexity to my methods, nor is it subject to whatever is the current “hot trend” in agricultural practices. I do not have to trust a theory or risk a portion of my business to validate a theory. On the other hand, I have a tremendous amount of respect for farmers and want to find evidence that certain practices can significantly enhance their productivity. Therefore, I know I hope to find high carbon levels associated with certain practices. I will have to accept the data, whether it confirms my bias or not.
12. Most of my costs are incurred in the soil tests. Midwest Labs charge $9.30 for their basic (S1A) test. Shipping to the lab should be approximately $10/test; combining shipments may reduce costs. Maximum estimated cost of the S1A test for 40 pastures is 40 x $19.30 = $772. If I obtain more funding, I will add the Total Organic Carbon test for $25 each. The additional cost is $1000, bringing the total estimated cost to $1772. The survey will be conducted online or by phone at no cost. I will test for bulk density at Evergreen at no cost. The only other potential cost is for soil sampling equipment and travel. I will pursue borrowing or renting equipment from local sources (WSDA, NRCS, TCD). Equipment rental cost is still unknown but should be less than $200. Reimbursement for mileage in my personal vehicle to the sites will be requested at the current state rate ($0.625 per mile as of 1 July 2022); estimated distances to those sites will be determined when the final participants are finalized.
13. Introduction

 -Description of the study (including what and where)

 -Significance of the study

 -Synopsis of the findings

 -Implications of the findings

 Literature review

 -Context for study (climate change)

 -Introduction to soils

 --Soil properties

 --Soil as an ecosystem

 --Indicators of soil health

 --Types of soil in Southwest Washington

 -Biomes in Southwest Washington

 --Native forest

 --Native prairie

 -Pasturelands

 --Role in carbon cycle

 --Management practices

 -Conclusion

 Methods

 -Management survey

 --Recruitment

 --Survey development

 --Survey coding/categorization

 -Soil sampling

 --Soil cores and bulk density

 --Soil tests

 ---Midwest: what they analyze, bona fides

 ---Bulk density: how and where

 -Site descriptions

 -Analysis

 --Variable categorization/designation

 --ANOVA

 --X2

 Results

 Discussion

 Summary

 -Primary implications of findings

 -Suggestions for further study

14) DECEMBER 2022

 2 November-20 December: Participant recruitment via TCD, SW WA Grazing Association, WCRRI, door knocking

 4 December—Thesis prospectus due to Sarah for review

 9 December—Revised (if necessary), signed thesis prospectus due to MES Director

 12 December—Science training with Jenna Nelson

 13/14 December—grant application drafts

 16 December—send survey instrument to Sarah, other pilot test subjects

 19 December—meet with Sarah (survey, grant applications, final participant list/map)

 20-30 January—contact participants to confirm location, preferred method of survey

 JANUARY 2023

 3 January—launch survey

 13 January—MES Thesis Fund Grant app due

 19 January—Climate Action & Sustainability Grant app due

 3-31 January—schedule visits with participants, ensure survey completion

 3-31 January—pre-site preparation (field/site selection, Google Earth point selection)

 3-31 January—literature review revision

 3-31 January—acquire sampling equipment (bulk density corer, slide hammer, soil probe)

 FEBRUARY 2023

 1-28 February—scrub survey data, develop code book for survey data, enter data into spreadsheet

 1-20 February—polish literature review, methods

 20 Feb-15 March—soil sampling & mailing to lab

 27 Feb-20 March—bulk density measurement in Evergreen lab

 MARCH 2023

 1-15 March—soil sampling & mailing to lab

 1-31 March—scrub soil data, enter data into spreadsheet, begin analysis if possible

 APRIL 2023

 1-30 April—data analysis and thesis draft

 14 April—complete thesis draft to Sarah (Results, discussion, introduction, and summary may be incomplete due to delays in soil sampling and reports from the lab)

 15 April—Release soil test results to participants

 MAY 2023

 1-31 May—data analysis and thesis draft

 5 May—“Request to present thesis” letter, signed by Sarah, to MES Director

 22-26 May or 29 May to 2 Jun—thesis presentations

 JUNE 2023

 2 Jun—Final thesis draft to Sarah

 9 Jun—Signed thesis to MES office

 16 Jun--Commencement

 15) The thesis process so far has involved many partners, including Thurston Conservation District, Ecostudies Institute, WSU Thurston County Extension, and all the participating landowners. Thurston CD, Ecostudies Institute, and WSU Thurston County Extension helped me recruit landowners with pastures in Southwest WA. They are interested in the results of my study and will be given copies of the final report. I also initiated contact with WSDA, NRCS, and Thurston Regional Planning Committee. I will make my final report available to them as well. I offered each participant the results of their soil tests as a thank you. Any participant who wishes to see the final report will be given access.

 16) **My current 5 most important references are listed here with annotations. All my references are listed after these five.**

Case, M. J., Johnson, B. G., Bartowitz, K. J., & Hudiburg, T. W. (2021). Forests of the future: Climate change impacts and implications for carbon storage in the Pacific Northwest, USA. *Forest Ecology and Management*, *482*, 118886. <https://doi.org/10.1016/j.foreco.2020.118886>

Dass, P., Houlton, B. Z., Wang, Y., & Warlind, D. (2018). Grasslands may be more reliable carbon sinks than forests in California. *Environmental Research Letters*, *13*(7), 074027. <https://doi.org/10.1088/1748-9326/aacb39>

**These two studies both touch on the impacts of climate change and how to manage ecosystems to ensure best survivability. It the contrast of the two who raise questions for me about which ecosystem offers more stable long-term organic carbon storage in the face of climate change. I will compare them to help frame my discussion about the potential of soil organic carbon storage.**

Hudson, B. D. (1994). Soil organic matter and available water capacity. *Journal of Soil and Water Conservation*, *49*(2), 189.

**As I study soil organic matter and soil organic carbon in pasturelands, the knowledge gained may add to producer understanding of water availability in their pastures. In effect, if producers have observational knowledge of low production (or accrued knowledge of high seasonal high ground water), the relationships between SOM and available water capacity identified in this article will validate the producers’ observations.**

Kim, J., Ale, S., Kreuter, U. P., Richard Teague, W., DelGrosso, S. J., & Dowhower, S. L. (2023). Evaluating the impacts of alternative grazing management practices on soil carbon sequestration and soil health indicators. *Agriculture, Ecosystems & Environment*, *342*, 108234. <https://doi.org/10.1016/j.agee.2022.108234>

**Kim et al. (2023) study very similar concepts in a different climate and at a much more extensive scale than I will be able to achieve within the limits of the MES program. However, many of the techniques, analysis, and considerations from this study provide an excellent framework for my own work.**

Lal R. (2004). Soil carbon sequestration impacts on global climate change and food security. *Science*, *304*(5677), 1623–1627. <https://doi.org/10.1126/science.1097396>

Lal, R. (2006). Managing soils for feeding a global population of 10 billion. *Journal of the Science of Food and Agriculture*, *86*(14), 2273–2284. <https://doi.org/10.1002/jsfa.2626>

Lal, R. (2008). Carbon sequestration. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *363*(1492), 815–830. <https://doi.org/10.1098/rstb.2007.2185>

Lal, R. (2013). Intensive agriculture and the soil carbon pool. *Journal of Crop Improvement*, *27*. <https://doi.org/10.1080/15427528.2013.845053>

Lal, R. (2015). Restoring soil quality to mitigate soil degradation. *Sustainability*, *7*(5), 5875–5895. <https://doi.org/10.3390/su7055875>

Lal, R. (2020). Regenerative agriculture for food and climate. *Journal of Soil and Water Conservation*, jswc.2020.0620A. <https://doi.org/10.2489/jswc.2020.0620A>

**All of Lal’s works cited above demonstrate the link between climate change mitigation and soil carbon sequestration. While his work is primarily in agricultural cropping, the concepts are similar. Lal also explored the role of soil carbon sequestration in other agricultural realms, such as grazing pasturelands and other regenerative practices. As the 2020 winner of the World Food Prize, he has been well recognized for his work in climate change and soil. His work is inspirational for active, positive efforts at every level in addressing climate change.**

Lorenz, K., & Lal, R. (2018). Carbon sequestration in grassland soils. In K. Lorenz & R. Lal (Eds.), *Carbon Sequestration in Agricultural Ecosystems* (pp. 175–209). Springer International Publishing. <https://doi.org/10.1007/978-3-319-92318-5_4>

**This chapter is key for establishing baseline information about the role of grasslands or pasturelands in sequestering carbon in soils. It will help ground the purpose for my study, as well as help me identify other research in this area as I follow developing studies.**

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